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Working Paper

Efficient Technology and the Conservation of Natural Forests: Evidence from Sri Lanka

ERD Working Paper Series, No. 105

Provided in Cooperation with:
Asian Development Bank (ADB), Manila

ADB

ECONOMICS AND RESEARCH DEPARTMENT

ERD WORKING PAPER SERIES NO. 105

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Asian Development Bank

Asian Development Bank
6 ADB Avenue, Mandaluyong City
1550 Metro Manila, Philippines
www.adb.org/economics

October 2007
ISSN 1655-5252

FOREWORD

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ABSTRACT

Existing policy instruments for conserving tropical forests have shown limited success. This paper investigates the feasibility of improving the technical efficiency of the wood processing industry as an alternative approach to forest conservation, using sawmills in Sri Lanka as a case study. Improved wood processing efficiency decreases the volume of raw material (logs) required to produce a given quantity of processed wood products and, therefore, decreases the pressure on natural forests. A stochastic frontier production function was estimated to assess the technical efficiency of sawmilling in Sri Lanka. Given the considerable inefficiency found in sawmilling operations, current sawn wood output can be obtained with 28% less inputs. Compared with other policy measures, technical efficiency improvement has a potential to play a noteworthy role in conserving natural forests. Technological improvements, as a tool for conservation, deserve the attention of researchers and policymakers.

I. INTRODUCTION

The rapid decline in the world's forest cover is a tangible measure of a number of critical global environmental policy interests: (i) the decline in natural habitat and biodiversity; (ii) carbon sequestration to mitigate climate change; (iii) watershed management and erosion control; (iv) livelihoods of indigenous people and the rural poor; and (v) general protection of aesthetic values. Policy dialogue for each of these concerns has focused primarily on: (i) direct legislative instruments to control forest destruction such as restrictions on timber harvest levels and/or total logging ban, (ii) replanting and improving forest management, (iii) certification of good management, (iv) incentives for good management, (v) taxes on forest products, and (vi) improvements in property rights of forest lands.

The success of these instruments in protecting remaining tropical natural forests has been limited and policymakers continue to search for alternative means. This paper examines the feasibility of technical efficiency improvement in the wood processing industry as a means to conserve natural forests. The forest-conserving effect of technical efficiency improvement could be substantial in many cases. This paper uses inefficiency in sawmills in Sri Lanka to illustrate the impact of technological improvements on forest conservation. Sri Lanka has a land area of 6.56 million hectares, of which 80% was covered by closed-canopy natural forests in the beginning of the last century. This forest cover has dwindled to about 18% by 1992 (MFE 1995).

Economics examines two measures of efficiency: allocative and technical efficiency. Improvements in allocative efficiency require the firm to change the combination of inputs in order to align with input price changes. Hyde (1980) shows that improved allocative efficiency in timber management in the Pacific Northwest of the United States (US) would sharply increase production or, alternatively, maintain timber production while sufficiently reducing land input to triple the area of protected natural forests. The global or regional impact of similar allocative efficiency improvements is unknown. However, examples of policies that create uncertainty and thereby limit forest production or constrain capital investment in forestry and wood processing are widespread. Yin and Newman (1996) as well as Liu et al. (2001), and Hyde et al. (1997) discuss such policies in force in the People's Republic of China, and the Philippines, respectively. Deacon (1994) analyzes the effect of a more general event of widespread social disruption on forestry. Policies that restrict harvests and shipment are just as common (Sedjo and Wiseman 1983, Boyd and Krutilla 1987, Zhang et al. 1998).

Improvements in technical efficiency refer to increased output from the same level of inputs or obtaining the same output from fewer inputs. Hyde (1997) suggests that improved technical efficiency in the US wood processing industry would also have a forest-conserving effect. Industrial research and support from agencies such as the US Forest Product Laboratory have led to useful technological innovations,[1] which increased the ratio of lumber to roundwood from 33% in 1970 to

[1] These innovations include (i) best open face technology, which optimizes the initial line for sawing; (ii) edge-glue and rip method, which reduces the wood lost in edging; (iii) saw-dry-rip method, which increases the defect-free lumber available from hardwoods; and (iv) use of sharper and more stable blades, which can increase lumber recovery from logs by 5% to 10%.

42% in 1993 (Grantham and Howard 1980 and Ince 1994, as cited by Wernick et al. 1997). Victor and Ausubel (2000) similarly contend that further improvements in management and technology will generate higher value out of products and save more virgin forests. For example, re-engineering wooden I-beams for floor systems to use less fiber than traditional construction, and making oriented strand board as a substitute for plywood, could help curb demand for wood. Together with lifting crop yields and concentrating forestry in fast-growing wood farms, technological improvements are estimated to increase the area left for nature to 3 billion hectares. This paper systematically measures technical efficiency of wood processing and assesses the possibility of using technical efficiency improvements as a tool for forest conservation in Sri Lanka.

The general objectives of this paper are to trace the effect of efficiency improvement on natural forests in terms of reduction of harvest of logs, and to assess the relative merits of this approach in comparison to other policy instruments. The rest of the paper is organized as follows. Section II describes the forestry situation in Sri Lanka. Section III presents the theory in relation to the estimation of technical efficiency using the stochastic frontier production functions. Section IV describes the sample, data, and hypotheses, followed by an analysis of the research findings. The final section discusses the policy implications.

II. BACKGROUND

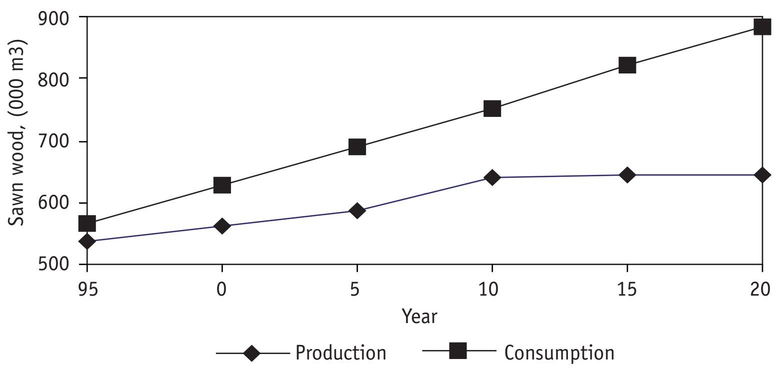
Sri Lanka's contribution to the global wealth of genetic materials and biodiversity is noteworthy (Kotagama et al. 1997). Hence, the deforestation in the country—more than 40,000 hectares from 1956 to 2000—is alarming, given the average annual replanting during the same period of only 2,000 hectares. The factors that contributed to deforestation and forest degradation in Sri Lanka are extensive and complex; some are even outside the forestry sector. These factors include large agricultural and human settlement projects such as the Mahaweli development project, shifting cultivation, excessive harvesting of timber, and sometimes, harvesting nontimber forest products.

There is a strong link between population growth and deforestation in many developing countries. More food is needed to feed/support the increasing population. Over the years, agricultural production has increased in Sri Lanka mainly by expanding the area under cultivation (MFE 1995). In addition to the demand for food, demand for fuel-wood, construction wood, and other wood-based products such as paper, pulp, etc. are also increasing with population growth. The resource base that supplies forest products in Sri Lanka has declined remarkably; per capita forest area has declined from about 1.3 in 1900 to less than 0.1 hectare in 2000. The remaining natural forests face mounting pressure as the population keeps increasing; population in Sri Lanka is still growing at a rate of 1.16% (Central Bank 2006).

From a conservation point of view, this situation has been aggravated due to unequal distribution of the existing types of natural forests. Of the remaining natural high canopy forests, about 85% are dry-zone forest types. Ecologically more important lowland rainforests and montagne forests are confined to small patches (Gunatilleke and Gunatilleke 1991). Rich biological diversity and higher level of endemism found in the latter category of forests have made their protection a priority. Having recognized the importance of these forests for biodiversity protection, the government of Sri Lanka has declared most of the remaining lowland rainforests and montagne forests as protected areas.

Since natural forests supply a range of multiple products and environmental services, the consequences of rapid deforestation can be far reaching. According to the MFE (1995), annual sawn wood consumption per 1,000 persons in Sri Lanka in 1993 was estimated at 31 cubic meters (m^3), which is comparatively less than in other countries: Malaysia 216.9m^3, Thailand 67.4m^3, Republic of Korea 112m^3, India 20.5m^3, and US 485m^3. Sawn wood demand in Sri Lanka is projected to grow from 0.544 million cubic meters (m^3) in 1993 to 0.885 million cubic meters in 2020, at a rate of 12,600m^3/year. Demand for plywood and other wood-based panels, respectively, are predicted to increase at rates of 2.8% and 3.5% per year (MFE 1995). Predicted supply and demand for sawn wood is depicted in Figure 1. If current trends continue unchecked and wood imports are not promoted, there would be a shortage of sawn wood in the country.

FIGURE 1
PREDICTED SAWN WOOD PRODUCTION AND CONSUMPTION FOR SRI LANKA



Source: MFE (1995).

Before the 1970s, the country's timber requirement was harvested from natural forests. Excessive harvesting of timber and clearing forests for agricultural expansion left only a small proportion of natural forests, which were also highly degraded. Having recognized the need for conservation of the remaining forests, the government declared some of the natural forests as protected areas. Harvesting timber from unprotected natural forests was also banned. As a result of the ban, people started to substitute less preferred tree species that grow in home gardens and other private lands, in place of the high-value tropical timber species. Private lands were supplying the timber requirement of the country for some time while very restrictive regulations for felling and transport of timber were enacted (Senaviratne and Gunatilake 2001). These regulations created an artificial scarcity of timber. However, due to the uncertainty of getting timber transport permits to sell timber, private sector investments in the forestry sector has been lacking. This further aggravated timber scarcity in the country and raised timber prices (Senaviratne and Gunatilake 2001).

The higher prices of timber unfortunately provide incentives for illegal logging from natural forests. For example, if a rural daily wageworker can harvest a mature satin tree (a high-quality tropical hardwood tree) from a natural forest, he can make more money than from working the whole year. Given such incentives, illegal logging has become widespread; the number of forest offences recorded in 1997 increased by 3% to 5,158 against 5,014 in 1996, while the value of illegal timber confiscated was Rupees 35.7 million in 1997 (Central Bank 1997). These records represent only a fraction of the illegal activities. Given the tedious procedures and tough regulations, obtaining a timber permit has become an extremely difficult task without "special" support from government officers. Having realized the potential mutual benefits, timber traders and government officers involved in issuing timber permits have formed a cartel, which facilitates issuance of permits to timber traders. Since tree owners know that they are unable to get permits easily, timber traders in the cartel have excessive bargaining power against timber owners in deciding stumpage prices. Thus, the prevailing situation has provided opportunities for timber traders to make excessive profits. For example, Senaviratne and Gunatilake (2001) show that the profit margin in timber trading is about 60%. Tree owners only get about 22% of the total value. In return for the support of government officials, timber traders pay them bribes. Thus, a part of the value of timber ends up as income for government officials. Very low prices received by tree owners and lack of clear property rights (existing regulations take part of the ownership rights away from tree owners) discourage cultivation of trees by smallholders.

Initially, this cooperative arrangement between timber traders and government officers worked in harvesting timber from private lands. Since there were minimum efforts by private landowners to grow timber trees, most of the multipurpose trees available in home gardens were harvested without proper regeneration. Therefore, timber scarcity worsened during the last two decades. As timber became scarce, the cartel of timber traders and government officers extended their activities to natural forests. Currently, it seems that with the connivance of government officers, timber illegally harvested from natural forests is sent to the market as if they were harvested from private lands. Because of this involvement of corrupt government officers in the cartel, it is nearly impossible to stop illegal logging. Given the above background, one of the major challenges Sri Lanka would be facing in the immediate future is supplying forest-based products, especially timber, without compromising the felt need of conserving remaining natural forests with high biodiversity value.

Conventionally, steps taken to resolve this type of situation include: (i) establishment of forest plantations by the government; (ii) enactment of more stringent regulations; and (iii) timber trade liberalization. However, establishment of forest plantations by the government is prohibitive, costly, and inefficient in Sri Lanka (MFE 1995). The forestry sector master plan has therefore ruled out this possibility as a solution to the problem. On the other hand, more legislation may not yield positive results as existing restrictive regulation itself has failed to do so. The private sector’s involvement in timber cultivation is critical to augment timber supply in the country. However, as described, private timber production has been severely discouraged by existing heavy regulatory measures. Timber trade liberalization is a possibility, which is dealt with by Weerahewa and Gunatilake (2007). Apart from the possibility of increasing wood production and trade liberalization, efficient utilization of logs produced in the country may be an alternative means to relieve the pressure on natural forests.

There seems to be a significant wastage in the sawmilling industry at present. The forest/wood industry in Sri Lanka is dominated by sawmills producing sawn timber for domestic markets and for subsequent processing such as conversion into furniture and other wood products. Previous records of the sawmilling sector consisted of more than 4,000 sawmills, including pit-sawing units. This study, however, finds that pit-sawing units are no longer in operation due to higher labor costs. Sawmills in Sri Lanka are, in general, small and labor-intensive. They have old and mostly worn-out machinery. Total output of sawn wood in 1993 is estimated at 515,000m^3. The capacity of sawmills ranges from a few cubic meters a year to 7,000m^3/year. The average output of the major sawmills[2] is about 750m^3/year. Sawmills in Sri Lanka are old, with the average age of surveyed mills at about 18 years (MFE 1995). The oldest mills were established in the early 1950s and many have not gone through any major improvements. The old mills employ simple and labor-intensive technology and still use originally imported equipment, while some of the new mills have locally made replicas of the old imported machinery (MFE 1995). Primary cutting machines are dominated by circular saws, and some larger mills have band saws (with horizontal reciprocating head rings) that allow for higher recovery of wood due to their relatively narrow saw blades. Small size, labor intensiveness, old and mostly worn-out machinery, poor layout, and poor saw-doctoring and feeding systems have resulted in heavy losses during milling. The average recovery rate is only about 40% (compared to 55% and 50% in Malaysia and Indonesia, respectively).

This picture of the sawmilling industry in Sri Lanka implies an ongoing wastage and lack of efficiency. There may be possibilities for improving efficiency in this sector to make sawmilling more profitable. Consumers may be able to purchase sawn timber at a lower price if efficiency is improved. More importantly, improving the efficiency of this sector may play a vital role in the conservation of natural forests. Reduction of wastage in sawmilling would relieve extra pressure on tree harvesting and reduce the ongoing destruction of natural forests in Sri Lanka. This will have a significant positive impact on forest conservation in Sri Lanka, in addition to direct producer and consumer benefits.

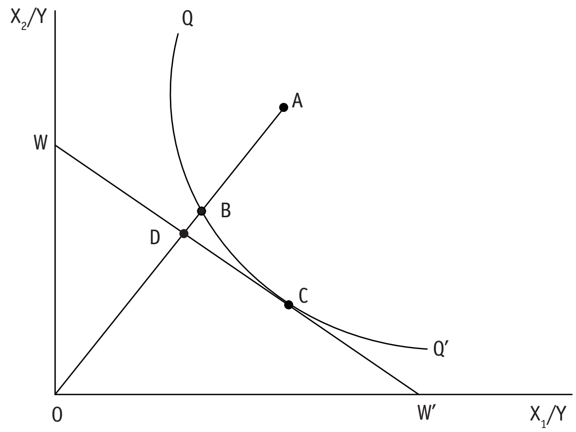
III. METHODOLOGY FOR CALCULATING TECHNICAL EFFICIENCY

Traditionally, economic efficiency at the firm level is measured by single factor productivity. This approach is, however, not very accurate as other factors should be held constant in measuring factor productivity. Farrell (1957) developed better and simple two measures of efficiency: technical efficiency and allocative efficiency. Of these, technical efficiency reflects the ability of a firm to obtain maximum output from a given set of inputs, or to obtain a given level of output from a minimum level of inputs. Allocative efficiency reflects the ability of a firm to use inputs in optimal proportions, given their prices (Coelli 1995). These two efficiency measures are combined to estimate economic efficiency.

Farrell's technical, allocative, and economic efficiency can be further elaborated on using the concept of unit isoquants (Figure 2). Consider a firm producing output Y from inputs X1 and X2 with the production function, $Y=f(X1,X2)$. Assuming constant return to scale, the frontier technology can be represented by the unit isoquant, $1=f(X1/Y,X2/Y)$, QQ'. Let WW' represent the ratio of input prices. Farrell defines a firm producing at point A as technically inefficient and the ratio OB/OA gives Farrell's measure of technical efficiency. If the firm is operating at point B, it is considered technically efficient but allocatively inefficient; the ratio OD/OB gives Farrell's measure of allocative efficiency. Finally, the ratio OD/OA measures total efficiency. Economic efficiency is measured by combining both ratios and is equal to the product of technical and allocative efficiencies.

[2] In Thailand, the average is 7,000m^3/year and in Indonesia it is 30,000 m^3/year. Thus, the average output of a sawmill in Sri Lanka is lower than that of other Asian countries.

FIGURE 2
EFFICIENCY MEASUREMENTS



Source: Gunatilake and Gunaratne (2002).

Often, firm level input–output relationships are examined with production functions estimated using regression analysis. Since the regression line is fitted through the means of the data set, such analysis provides only an average relationship (Alauddin et al. 1993). In contrast, the frontier production function corresponds to the formal definition of a production function, which refers to the maximum output obtainable from a given set of inputs and technology. The basic difference of a stochastic frontier, compared to an average production function, lies in the formulation of the residual term of the regression equation. Here the error term is separated into symmetric and asymmetric components. The symmetric component represents the usual random variations, measurement errors, and statistical noise. The asymmetric (one-sided) term captures the technical inefficiency of the firm (Kumbhakar et al. 1991, Bravo-Ureta and Pinheiro 1993, Coelli 1995). The major weaknesses of the stochastic frontier method include arbitrary specification of the distributional form of the one-sided error term, selection of the functional form, and difficulties involved when multiple outputs are present.[3]

Following the standard assumption of Zellner et al. (1966), the above theory can be used to specify a frontier production function for sawmills. Assuming that mill owners maximize expected profits, the single equation Cobb-Douglas stochastic production model (Aigner et al. 1977, Meeusen and van den Broeck 1977) can be specified as:

$$Lny_i = Ln\beta_0 + \sum_{k=1}^{5} \beta_{ik} Lnx_{ik} + v_i - u_i$$

where

y_i is the index of sawn wood output, cubic feet/month

x_1 is the index of log inputs, cubic feet/month

x_2 is units of energy used, kilowatt hours/month

[3] Technical efficiency of a multiple product firm can be measured using the mathematical programming method known as data envelopment analysis.

x_3 is capital expenditure of the mill

x_4 is skilled labor, person days/month

x_5 is unskilled labor, person days/month

βk (k =1,2,...5) are the parameters

v_i is a random variable, iid ~N(0, σ^2_v)

u_i is a non-negative random variable that represents technical inefficiency

The two error terms make the difference between an average production function and a frontier production function. Using Battese and Coelli's (1992) parametric specification, the maximum likelihood estimation of the equation provides estimators for β, $\sigma^2 = \sigma^2{}_v + \sigma^2{}_u$ and $\gamma = \sigma^2{}_u + \sigma^2$. Prediction of technical efficiency of a firm is based on conditional expectation of u_i (exp($-u_i$)), given the value of random variable $\varepsilon_i = v_i - u_i$. Subtracting exp($-v_i$) from both sides of the above equation:

$$Lny_i^* = Lny_i - u_i$$

where y_i^* = is the ith firm's observed output, adjusted for statistical noise. The above equation forms the basis for the measurement of the technical efficiency of the firm.

IV. SAMPLE, DATA, AND HYPOTHESES

Primary data for estimating the above production function was collected using a structured questionnaire. A stratified random sample was drawn from the population, based on the geographic zones in Sri Lanka. From each zone, a number of mills to be included in the sample were decided based on the proportion of the mills in the zone. Then random number tables were used to select the predetermined number of mills. The original sampling framework and the distribution of the final sample are given in the Appendix (Table A1). The survey was conducted in two stages. In the first stage of the survey, information on general aspects of the sawmills was collected and an input–output sheet was given to the mill manager. At the first stage, most of the managers agreed to fill out the input–output sheet. However, at the time of collection, almost all managers did not fill out the input–output sheets. With this disappointing experience, a second visit to the mills was arranged to fill the forms using person-to-person interviews. The data gathered are based on the memory of the mill manager in most cases, as they do not keep proper records. Data would have been more accurate had the mill managers filled out the form as inputs came in and soon after milling the logs.

In the original sampling framework, the sample size was 180 mills. Thirteen mills were allocated for Ampara and Batticaloa districts. Due to security reasons, the research assistants were not able to make the second visit to these 13 mills. About eight questionnaires were excluded from the sample from different districts due to inconsistencies found in the answers. Another 11 mills were excluded from the sample due to mill owners' reluctance to provide information on log inputs and outputs. Thus, a complete set of data was available for only 148 sawmills.

Another problem encountered in estimating the equation was the presence of a number of different outputs. As mentioned earlier, the stochastic frontier technique can be used only for single-output firms. Therefore, the different outputs were aggregated to a single output index using the following formula:

$$y_j = \frac{\sum_{r=1}^{s} p_{rj} q_{rj}}{\sum_{j=1}^{n} \bar{P}_j \big/ n}$$

where y_j is the normalized output for the jth firm, s denotes the number of differentiated products, p_{rj} denotes the price of the rth product for the jth firm, q_{rj} denotes the amount of rth product for the jth firm and, n is the number of firms. The average price in the denominator is defined as:

$$\bar{p}_j = \sum_{r=1}^{s} p_{rj} q_{rj} / q_j, q_j = \sum_{r=1}^{s} q_{rj}$$

A similar problem was encountered in measuring log inputs. The log inputs were broadly categorized into softwood and hardwood, disregarding the species, and were also aggregated using the above formula. The number of units of energy used during the month under consideration was obtained from the monthly electricity bills. An attempt was made to get accurate information on capital expenditure of the sawmills. However, during the pre-testing stage it was felt that mill owners/managers were not willing to reveal true information on capital expenditures, probably due to tax evasive strategies. Therefore, a proxy—mill capacity—was used in place of capital expenditure.

Many technical efficiency studies have estimated a second regression equation[4] to identify the determinants of technical efficiency. The study followed this approach to identify the determinants of technical efficiency of sawmilling. Since there are no previous studies on the technical efficiency of sawmilling, the variables were identified based on the survey findings, informal discussions with the mill managers, and scatter plots of efficiency scores and related variables. The variables and the postulated hypotheses are given in Table 1.

4 The first regression equation estimates the production function to calculate efficiency scores.

Table 1
Determinants of Technical Efficiency

Variable	Description	Hypothesized Relationship to Technical Efficiency
X1	Age of the manager/owner	Positive
X2	Quality of log inputs	Positive
X3	Charges based on log input =1, Others = 0	Negative
X4	Owner-managed mills = 1, Others = 0	Positive
X5	Education of the manager/owner	Positive
X6	Entrepreneurship	Positive
X7	Capacity of the mill	Negative
X8	Source of energy, only public electricity =1, public electricity and other = 0	Negative
X9	Age of the machines	Negative

As to age of the manager/owner, age is assumed to influence technical efficiency positively, since age reflects the experience of the manager in the sawmilling industry.

Regarding quality of log inputs, given the scarcity of wood, many immature trees are harvested, resulting in very low recovery rates. Moreover, since the logs are not supplied by well-managed forestlands, many logs are not straight. High-quality logs (mature straight logs) are assumed to provide higher technical efficiency. For charges based on log input, certain mills only lease their machines for milling, with charges based on log inputs. The other mills purchase logs, mill them, and sell the sawn wood. Since the former type of mills have no incentives to improve technical efficiency, it was assumed that such mills are technically inefficient.

For the variable mill ownership, the survey revealed that when hired managers manage the mills, they are paid a fixed monthly salary. There are no incentive payments based on profits or any other measure of performance (Gunatilake and Gunaratne 2002). Therefore, owner-managed mills are assumed to be more efficient. For the issue on education of the manager/owner, formal education may enhance the management ability of managers. Therefore, it is assumed that a higher level of formal education positively affects technical efficiency. Meanwhile, on the variable entrepreneurship, managers with higher entrepreneurship ability may consciously take steps to increase technical efficiency to increase profits. Therefore entrepreneurship is assumed to affect technical efficiency positively.

On mill capacity, given log shortages, large mills may not be able to fully utilize their fixed production factors. Therefore, it is assumed that mill capacity negatively affects technical efficiency.

As to source of energy, Sri Lanka has a very irregular supply of power because the country depends mainly on hydropower. Power cuts are frequent and, as mill owners explain, these power cuts may be one reason for lower efficiency. Therefore, it is assumed that mills with only public electricity supply are inefficient compared to those with public as well as their own means of power supply (generators).

Finally, on age of machines, old and worn-out machines lead to low recovery and are therefore assumed to affect technical efficiency negatively.

The age of the owner (X1) was considered when the owner himself managed the mill. Otherwise, the manager's age was considered. Log quality (X2) was ranked from 1 to 5; 1 representing the poorest quality and 5 representing the best quality. The type of milling (X3) variable was measured as a dummy: 1 for the mills that leased their machines, 0 otherwise. Owner-managed mills (X4) were assigned 1 while the mills managed by hired managers were given 0. Education (X5) was ranked 1 through 6 for no schooling, up to grade 5, up to grade 10, first government examination passed, university entrance passed, and degree or diploma, respectively. Six entrepreneurship characteristics were qualitatively assessed to rank the entrepreneurship (X6) of the mill manager. These characteristics include risk perception, employee welfare technology adoption, plura-activity or diversification, development of contacts and networks, and sustainability/environmental awareness. Managers/mill owners were asked a few questions on each of these aspects. Based on the answers, they were assigned a rank from 1 through 5, 1 representing very poor entrepreneurship and 5 representing very good entrepreneurship. Capacity of the mill (X7) was measured as potential to produce sawn wood per month if the mill operated for eight hours at full capacity for 22 days. If the source of energy (X8) in a mill is only electricity, that mill was assigned 1, and mills with diesel-operated machines or combination of electricity and diesel were assigned 0.

In early studies of technical efficiency, a two-stage procedure was followed in analyzing the determinants of technical efficiency. In the first stage, technical efficiency scores were estimated, and then a second-stage regression was estimated to find the determinants of technical efficiency. As shown by Kumbhakar et al. (1991), this procedure has two problems. First, technical efficiency may be correlated with inputs causing inconsistent estimates of the parameters and technical efficiency scores. Second, the standard ordinary least squares estimators are inappropriate because the technical efficiency scores—the dependent variable in the second stage regression—are one-sided. Kumbhakar et al (1991) suggest a one-step formulation in order to overcome these problems. The present study used this one-step procedure to obtain technical efficiency scores and their determinants simultaneously using the Frontier econometric software (Version 4.1) program.

V. RESULTS

Appendix Table A2 shows the descriptive statistics of the variables used in the estimation of the frontier production function. Only the log input is significant in the production function. Energy inputs and both labor inputs are insignificant (see Appendix Table 3). The results reveal that the log input is the limiting factor of production in sawmilling. Most of the mills are operating under capacity due to a severe shortage of logs. The poor results of the production function analysis may be due to measurement errors. Had the input–output sheets been filled out soon after milling was undertaken, as originally planned, better results would have been obtained.

The distribution of the technical efficiency scores is given in Table 2. The average technical efficiency is 0.7219. From an input perspective, this indicates that on average the sawmills can save about 28% of all inputs while producing the same output if the production process is reorganized in an appropriate manner. From an output perspective, the results suggest that on average 28% more sawn wood can be produced with the current level of inputs. Thus, the overall results indicate that there is considerable inefficiency in the sawmilling industry.

TABLE 2
DISTRIBUTION OF TECHNICAL EFFICIENCY SCORES

EFFICIENCY SCORE (PERCENT)	NUMBER OF MILLS	PERCENTAGE OF MILLS
< 10	1	0.68
11 – 20	1	0.68
21 – 30	8	5.41
31 – 40	10	6.76
41 – 50	12	8.11
51 – 60	3	2.03
61 – 70	6	4.05
71 – 80	23	15.54
81 – 90	41	27.70
91 – 100	43	29.05
Average efficiency score	0.7219	
Standard deviation	0.229	

Table 3 shows the factors influencing technical efficiency in the sawmilling industry. As mentioned earlier, the equation to analyze the determinants of technical efficiency was estimated using the maximum likelihood method, which does not estimate coefficient of determination (R^2). Nevertheless, the correlation between actual and predicted values is 0.68, and seven of the nine variables used are statistically significant. The age of the manager/owner and the source of energy do not show a statistically significant impact on technical efficiency. Since there are frequent power cuts, it was hypothesized that mills that completely depend on public power supply are technically inefficient. However, results indicate that there is no statistically significant relationship between source of energy and technical efficiency.

TABLE 3
FACTORS AFFECTING TECHNICAL EFFICIENCY

VARIABLE	COEFFICIENT	STANDARD ERROR	T- RATIO
Intercept	–0.40366	1.58370	–0.2549
Age (X1)	0.03787	0.05036	0.7518
Quality of logs (X2)	0.35137	0.03369	10.4302**
Type of mill (X3)	–0.47824	0.06415	–7.4540**
Owner management (X4)	0.20986	0.02942	7.1326**
Education (X5)	–0.22210	0.02816	–7.8855**
Entrepreneurship (X6)	0.10627	0.02891	3.6756**
Capacity (X7)	–0.08626	0.01516	–5.6894**
Source of energy (X8)	0.16516	0.11648	1.4179
Age of machine (X9)	–0.28842	0.07388	–3.9040**

** Significant at 0.05 level.

Quality of the log input shows a statistically significant positive impact on technical efficiency, as expected. The mills that are only milling and charging based on the log input are inefficient because there is no incentive for such mills to improve technical efficiency. As discussed earlier, mill managers are not provided any incentives based on the performance of the mill. Therefore, it is expected that owner-managed mills are technically more efficient. The expected relationship was observed with statistical significance. Education of the owner/manager was expected to positively affect technical efficiency. This relationship was not observed, which may be due to lack of focus of formal education in business management. Entrepreneurship was expected to positively affect technical efficiency. The results show the expected impact with statistical significance. As expected, there is a negative relationship between capacity of the mill and technical efficiency. As indicated earlier, most of the machinery in the sawmilling industry are old, and as machines get older their performance becomes poor, leading to technical inefficiency. As hypothesized, the age of the machine negatively influences technical efficiency.

A. Efficiency Improvements and Forest Conservation

Technical efficiency measures the maximum rate at which the use of all inputs can be reduced without reducing outputs. It can also be measured as the rate at which the outputs can be increased with the same level of inputs (Kumbhakar 1996 and Seiford 1996). As the results show, there is significant inefficiency in the sawmilling industry in Sri Lanka. A data envelopment analysis was also carried out with the same data and it was found that efficiency scores were similar to those described above (Gunatilake and Gunaratne 2002). The results thus suggest that the current sawn wood output can be obtained with about a 28% cut in all inputs. Such an improvement will relieve pressure on the overall wood supply sector. However, protected forests will receive the greatest impact from the log inputs savings. As basic forest economics suggests, there is a cost gradient for illegal harvesting from different types of forests (Clarke et al. 1993). The least-cost types will always be harvested first and the highest-cost types will be harvested last. Private lands such as home gardens are the least-cost wood sources while protected forests are the highest-cost sources.[5] Unprotected natural forests may be in between these two categories. If current trends continue, scarcity will raise prices, providing the incentive for illegal timber extraction even from highest-cost protected forests.

In order to highlight the magnitude of forest savings due to efficiency improvements, saved logs can be converted to an area of natural forests with some plausible assumptions, as follows. The data used in this calculation were taken from MFE (1995).

(i) On average the different types of mature natural forests provide the following wood volumes:

Lowland rain forests – 126 m^3/ha

Dry monsoon forests – 21 m^3/ha

Moist monsoon forests – 39 m^3/ha

Of these forest types, lowland rainforests are confined to a few patches. Wood harvest from this type is not possible because they are protected. Moist monsoon forests are

[5] In general, protected natural forests are the least disturbed forests and historically remained intact due to high cost of timber extraction. In addition to the location and related high cost of harvesting protected forests, there are additional costs of being caught and punished for illegal logging. Such costs are highest for the protected forests.

also limited to small areas. Only dry monsoon forests remain in large areas. Therefore, the saved forests are calculated, assuming a weighted average of 25.5 m^3 of wood can be harvested from one hectare of forests. In calculating the weights, the dry monsoon forests were assigned a weight of 3 and the moist monsoon forests were assigned 1 based on the available forest areas.

(ii) As technical efficiency improves, the timber supply curve shifts to the right. Assuming that the demand curve does not shift, the shift in the supply curve results in a lower price and a higher equilibrium quantity of sawn wood. Thus, the technical efficiency improvement allows production of the extra quantity without extra log inputs. This has two effects. First, the price decrease improves social welfare because lower prices increase consumer surplus. Lower prices also reduce the incentives for illegal logging. Second, producing the extra sawn wood output with the same inputs leads to saving the source of logs—and consequently the forest lands.

(iii) Total round wood consumption in Sri Lanka is 1,396,000m^3 in 2000. Of this volume of logs, it was assumed that 28% could be saved annually if technical inefficiency is completely eliminated. However, complete elimination of technical inefficiency is an unrealistic assumption. Therefore, the avoided deforestation was calculated assuming that technical efficiency improvement are 25%, 50% and 75% of the existing inefficiency of 28%.

TABLE 5
EFFICIENCY IMPROVEMENTS AND PREVENTED DEFORESTATION

EFFICIENCY IMPROVEMENT (PERCENT)	PREVENTED ANNUAL DEFORESTATION (HECTARES)
25	3,695.29
50	7,390.58
75	1,1085.88

Table 5 shows the extent of prevented deforestation under different levels of technical efficiency improvements. The assessment of the determinants of technical efficiency provides some avenues for technical efficiency improvements. Enhancing the supply of quality logs, investing in new machinery, providing hired managers incentives that are linked to efficiency improvements, and improving entrepreneurship abilities can be used to improve technical efficiency.

This study analyzed technical efficiency improvements only at one stage of forestry—sawmilling. The analysis shows that technical efficiency improvement only at the milling stage has a potential role in preventing deforestation in Sri Lanka. Technical efficiency improvements over the entire forestry life cycle (starting from tree planting up to end uses such as construction/furniture industries) may provide much higher conservation impacts. If such technical efficiency improvements can be realized at the regional or global levels, there would be profound positive impacts on forest conservation. The value of the findings of this study is limited by the small sample size and quality of data. Moreover, technical efficiency in this type of studies is defined taking the best mills in the sample as the benchmark. If the sample is cross-country, including countries with better milling technology, much bigger inefficiency may be discovered. Therefore, more cross-country research on technological improvements on forestry covering the entire life cycle could provide more valuable policy directions.

B. Efficiency Improvement versus Other Policies

The results show that technical improvement in the sawmilling industry has a potential role to play in protecting natural forests in Sri Lanka. However, to better appreciate its value, comparison with other policy tools is needed. Such an analysis should answer the following questions: (i) How effective is the policy to achieve conservation objectives? (ii) How long will the policy take to be effective?[6] (iii) Is the policy measure politically feasible? (iv) Does the policy achieve the conservation objective without compromising economic efficiency? Gunatilake and Gunaratne (2002) undertook such a comparative analysis considering timber trade liberalization, and removal of timber permit system in comparison to technical efficiency improvement. The following provides a summary of their findings.

The effect of timber market liberalization on forest protection was analyzed using a static market simulation model (see Weerahewa and Gunatilake 2007 for details). Lack of estimated demand elasticity for timber products in Sri Lanka was a constraint in this analysis. The analysis was undertaken with plausible assumption on price elasticity. Removal of existing distortions such as tariff, goods and service tax, defense levy, and other border charges can cut down the local supply of sawn logs significantly. The supply would be reduced due to the impact of sawn wood prices: removal of all border charges reduce timber price by about 25%. The decline in timber price reduces the incentives for illegal logging and enhances forest conservation in Sri Lanka. The price reduction also results in an increase in consumer surplus of about US$40 million per year. Timber trade liberalization reduces local supply by about 12% to 31% depending on the elasticity of supply and demand. Timber market liberalization is a short-run measure that can effectively reduce sawn wood prices and consequently decrease the incentives for illegal logging. Also, it will reduce the local sawn log supply and effectively lessen the pressure on natural forests. Similar to the analysis on the elimination of technical inefficiency, the annual savings of equivalent natural forest were estimated using plausible assumptions. With the more conservative assumption of inelastic demand, timber market liberalization can save about 6,985 hectares of forest annually. If the demand is elastic, these savings can increase up to 17,469 hectares per annum.

Compared to the technical efficiency improvement, timber market liberalization seems to have a quicker effect on natural forests. As shown in the analysis, timber market liberalization improves overall social welfare, and thus economic efficiency. Generally, open market policies benefit certain groups in the society and adversely affect certain other groups. In this case, the consumers are gainers and the producers are losers. One unique characteristic of the current forestry sector in Sri Lanka is that there is no organized timber supply sector. Part of the timber is supplied from home gardens and other nonforest lands as a by-product. The rest is illegally extracted from natural forests. Timber traders and government officers, in both cases, appropriate most of the rents. Therefore, the actual producer surplus losses can be very low and there are no true losers in the case of timber market liberalization. However, political feasibility of timber trade liberalization is moderate. More importantly, depending on the forest management practices of the timber exporters, this policy may lead to destruction of forests elsewhere. In particular, if the timber is exported from an unsustainable source, there would be no conservation impact at the global or regional level. This seems to be the major drawback[7] of the timber trade liberalization policy as a tool for conservation.

[6] This requirement is unique in forestry because forestry cycles are long and the results of many policy changes are realized after 20–40 years depending on the forest species. For example, the effect of any incentive program for smallholder tree growers will be observed only after 20–40 years.

[7] Timber certification system can be implemented to prevent deforestation in the exporting country. However, costs and

TABLE 6
SUMMARY OF POLICY ALTERNATIVES

POLICY	EFFECT		EFFECTIVENESS	POLITICAL FEASIBILITY	ECONOMIC EFFICIENCY
	SHORT RUN	LONG RUN			
Removal of permit system	Low sawn wood price		High	Moderate	Economically efficient
	Incentives for tree growing	Supply of high-quality logs			No losers
	Conducive business environment for milling	Incentives for investment in mills			
Technical efficiency improvement:			Moderate	Moderate	Technical efficiency improvement measures should be subject to cost–benefit analysis
1) Investment on machinery	Saw logs savings	Saw logs savings			
2) Supply of quality logs	Saw logs savings	Saw logs savings			
3) Mill level measures	Saw logs savings	Saw logs savings			
Timber market liberalization	Low sawn wood prices	Potential deforestation in exporting countries	High	Moderate	Economically efficient
	Reduction of local supply				No losers

Source: Adapted from Gunatilake and Gunaratne (2002).

As discussed in the background section, the existing timber permit system provides perverse incentives for conservation. It keeps timber prices higher and provides incentives for illegal logging. On the other hand, the value of timber is largely extracted by timber traders and government officials so that there are hardly any incentives for smallholders to grow timber trees. Removal of the timber permit system for tree species grown in private lands such as jack, teak, and mahogany will reduce timber prices and consequently reduce incentives for illegal logging. In addition, it will provide a conducive business environment for milling and may promote investments in the sawmilling industry. This measure will also provide incentives for the private sector and smallholders to grow timber trees. Thus, it will enhance the long-term supply of quality saw logs, which is necessary for technical

benefits and existing institutional capacity will determine the success of the certification system.

efficiency improvement. This policy will be highly effective as shown by the case studies presented in Gunatilake and Gunaratne (2002). However, its political feasibility is ranked low because the beneficiaries of the existing system are politically powerful. The donor community has been trying to implement this policy for some years without success. This incident clearly shows the strength of the groups backing the status quo. Because the unnecessary interventions are removed and the market is allowed to play its role, this policy is potentially economically efficient. There are no true losers in this case because currently a small group of timber traders and government officers appropriate most of the rents in the timber sector.

Technical efficiency improvement will have both short- and long-term effects. Replacing old with new machinery is a measure that can be taken in the short term, subject to capital availability. Uninterrupted supply of quality logs is required to improve technical efficiency. This is, however, a long-term measure that can be achieved through removal of restrictive regulations and provision of necessary incentives. In addition, certain changes can be made at the mill level to improve efficiency. These measures include converting the hiring-type mills to milling businesses, providing performance-based incentives for mill managers, and making the mill managers aware of their own technical efficiency levels and the possible ways to improve technical efficiency. The effectiveness of improvement of technical efficiency is ranked as moderate because changing the determinants to improve technical efficiency is not easy. Developing entrepreneurial ability of mill managers or provision of low-interest loans to purchase new machines is not expected to generate opposition from society, unlike in the case of trade liberalization. Therefore, technical efficiency measures are politically more feasible in comparison to trade liberalization. The effects of technical efficiency improvement on social welfare are not very clear as most of the efficiency improvement interventions incur costs. Therefore, the measures should be subjected to cost–benefit analysis.

Since certain effects are realized in the long run, the above-described three major policy measures should be considered for simultaneous implementation. In applying a number of policy measures, the adverse impact of one measure vis-à-vis the others needs further consideration. For example, timber market liberalization will reduce local timber supply and may negatively affect the sawmilling sector. Consequently, it may negatively affect certain restructuring required to improve technical efficiency in the sawmilling industry. In the face of declining local production due to market liberalization, mill owners may hesitate to invest in new machines, etc.

VI. CONCLUDING COMMENTS

Policymakers continue to look for alternative policy instruments to conserve tropical natural forests, since available instruments have shown limited success. This study examined the feasibility of a new approach to forest conservation through improvement of technical efficiency in sawmilling. The paper illustrates the merits of this approach based on sawmilling operations in Sri Lanka.

Analyses show that there is considerable inefficiency in sawmilling in Sri Lanka. With technical efficiency improvements, the current sawn wood output can be produced with 28% less inputs. Conversion of the log input savings to natural forest area saved shows reasonably high conservation impacts.

The findings of the study are, however, preliminary in nature. The study analyzes technical efficiency only at one stage in the life cycle of forest products, sawmilling. Moreover, technical efficiency in this type of studies is defined by taking the best mills in the sample as the benchmark. If the sample is cross-country, much bigger opportunities may be found for technical efficiency improvements. Such improvements may provide better alternative means for natural forest conservation. Therefore, more cross-country research on the effect of technological improvements on forestry covering the entire life cycle of forest products is recommended. This will strengthen the basis for using technological improvement as a tool for conservation of natural forests, and therefore deserves the attention of policymakers.

APPENDIX
DISTRIBUTION OF THE SAMPLE AND DESCRIPTIVE STATISTICS OF THE DATA

Appendix Table 1
Sampling Framework

	Climatic Zones			Geographical Zones			District			
	Climatic Zones	Number of Millers	Sample Size	Geographical Zones	Number of Millers	Sample Size	District	Number of Millers	Sample Size	Actual Sample
Total Sample Size = 200	Wet Zone	846	100	North Wet Zone Lowland	366	37	Gampaha	209	16	14
							Kegalle	23	5	5
							Kuruneagale	113	11	9
							Matale	21	5	4
				South Wet Zone Lowland	353	33	Kalutara	117	11	10
							Galle	164	15	14
							Matara	39	4	4
							Ratnapura	33	3	3
				Upland	127	30	Kandy	117	23	20
							N. Eliya	4	3	2
							Badulla	6	4	4
	Dry Zone	203	50	South Eastern Dry Zone	110	29	Hambantota	32	14	12
							Moneragala	4	2	2
							Ampara	51	11	-
							Batticaloa	23	2	-
				Central Dry Zone	93	21	Anuradhapura	13	11	9
							Trincomalee	8	-	-
							Puttalam	72	10	10
	Highly Urban	198	50	Colombo	198	50	Colombo	198	50	47

APPENDIX TABLE 2
DESCRIPTIVE STATISTICS OF THE VARIABLES

	OUTPUT INDEX	INDEX INPUT	ENERGY (kWh)	MILL CAPACITY (ft3/MONTH)	LABOR 1, PERSON-DAYS/ MONTH	LABOR 2, PERSON-DAYS/ MONTH
Mean	2832.761	4031.898	1581.446	3626.689	90.081	61.986
Median	1104.939	1806.832	1165	2875	88	44
Mode	2626.441	2427.381	1000	1500	88	44
Standard Deviation	6650.399	8814.211	1427.866	3838.604	53.047	35.653
Range	43771.11	60544.83	8820	29775	264	154
Minimum	2.8974	139.6878	180	225	22	22
Maximum	43774.01	60684.52	9000	30000	286	176
Count	148	148	148	148	148	148

APPENDIX TABLE 3
ESTIMATED PRODUCTION FUNCTION FOR THE SAWMILLING INDUSTRY

VARIABLE	COEFFICIENT	STANDARD ERROR	T-RATIO
Intercept	–0.4988	0.2254	–2.2135**
Log input	1.0191	0.0259	39.4843**
Energy	0.0099	0.0289	0.3445
Capacity of the mill	0.0204	0.0208	0.9846
Unskilled labor	0.0347	0.0323	1.0780
Skilled labor	–0.0473	0.0293	–1.6142

** Significant at 0.05 level.

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About the Paper

Herath Gunatilake examines the feasibility of technical efficiency improvement as an approach for forest conservation using a case study of saw milling in Sri Lanka. The paper shows that reduction of existing inefficiency helps prevent deforestation. Having compared the merits of this approach with other policy options, the paper asserts that technological improvements as a means of forest conservation deserve the attention of policymakers.

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6 ADB Avenue, Mandaluyong City
1550 Metro Manila, Philippines
www.adb.org/economics
ISSN: 1655-5252
Publication Stock No.

Printed in the Philippines