Environment and Development Economics 7 (2002): 107–122

The impacts of economic reform on the efficiency of silviculture: a non-parametric approach

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ABSTRACT Institutions and organizations are regarded as being important in determining the efficiency of economic agents and public units. This study first reviews the economic reforms in silvicultural activities in China's state-owned forestry bureaux, then empirically examines the impact of economic reforms. Panel data from 40 forestry bureaux in Heilongjiang Province, and two different economic regimes: from the pre-reform and economic transition periods, are analyzed by Data Envelopment Analysis (DEA). The technical efficiency has been decomposed into pure technical efficiency and scale efficiency and then examined. Our results show that the economic reforms have increased efficiency on average by about 25 per cent. Moreover, the study qualitatively analyses the sources of improvement and argues that the efficiency gain is a result of reductions in labour shirking and administration costs.

Key words: DEA, economic reforms, silviculture, efficiency, forestry, China

1 Introduction

The impact of institutions and organizations on economic efficiency is of primary interest in economics and management sciences. Issues associated with institutions and organizations have received greater attention in recent years particularly because of economic transitions in the former Eastern European countries and China. Privatization of forest tenure is becoming an important theme not only in developing countries and countries in transition, but also in the developed world (Bass and Hearne, 1997; Landell-Mills and Ford, 1999; Fisher, 1999; and Grebner and Amacher, 2000). However, empirical quantitative and even qualitative studies are still very few.

Mr Ren Qingshan of the Northeast Forestry University (China) and Mrs. Chao Renjie of the General Forest Resources Bureau of Heilongjiang (China) provided assistance in data collection. I am also grateful to Douglas Allen, Jari Kuuluvainen, Jussi Uusivuori, Esa-Jussi Viitala and three anonymous reviewers for their helpful comments. The data collection was carried out with the aid of a grant from the International Development Research Centre's (IDRC) Economy and Environment Program for Southeast Asia (EEPSEA).

This study uses the economic reforms in China's state-owned forestry[1] to empirically test the impact of different economic regimes on the efficiency of silvicultural activities. Since the mid 1980s, the state-owned forestry bureaux (SOFBs) in China have been carrying out various reforms in institutions and organizations. The old economic regime represented a more centralized and planned economy, while the new one is becoming more a decentralized and market-oriented one.[2]

The impacts of the economic reforms on the SOFBs are still controversial. On the one hand, the general state of the economy of most SOFBs seems little better, perhaps even worse after two decades of persistent reforms. On the other hand, there is some evidence of improvement in forest management. It is difficult to form a clear judgement because different bureaux and periods cannot be compared. As we know, the economy of SOFBs, like the mining industry to some extent, greatly depends on internal environment, such as the endowment of resources, and external environment, such as timber price, market competition, and government policies. In addition, it is still too early to draw a clear conclusion on a decade-long experiment because both time and costs are needed for the transition from a planned economy to a market-oriented one.

When comparing the efficiency of the two economic regimes, a good indicator could be the change in efficiency of silvicultural activities. We choose areas successfully planted and tended as the outputs rather than using the growth of forests, which is much more difficult to measure and is greatly dependent on the state and location of the forests (for example, age and species, soil and climate). Total expense is used as the input. We hypothesize that the adoption of economic reforms has affected efficiency. The purpose of this study is to test this hypothesis, measure quantitative impacts, and find at least some qualitative explanations.

2 Economic reforms in silviculture of SOFBs

Silvicultural activities, even after separation from the logging section,[3]

[1] China has 40 million ha of state-owned forest land with 3 billion cubic metres of standing forest stock, accounting for 15 per cent and 25 per cent of the total, respectively. These forests were managed by State-Owned Forestry Bureaux (SOFBs). From the 1950s to the 1980s, the SOFBs had cumulatively provided 1 billion cubic metres of industrial timber, accounting for 50 per cent of the total supply for the whole country, and nearly 1.5 billion Chinese Yuan of revenue for the central government, which is 1.3 times the total public investment in SOFBs. Presently there are 135 bureaux across the country with more than 80 located in the northeast, about 40 in the southwest, and the rest in the northwest. The SOFBs employ a total of 1.5 million people, accounting for 30 per cent of the 5 million residents within these administrative regions.

[2] Of course, the current mode is clearly still not a market economy. In principle, it is only a transition period and the old legacy of the planned economy still greatly remains (Zhang 2000a).

[3] Silviculture in SOFBs used to be vertically integrated with logging as well as wood-processing in forest management. The first most distinguishable reform has been the division between silviculture, logging and wood processing. It was first conducted as an experiment in some SOFBs, and then was extended to others.

used to be conducted by big forest farms or the whole bureau as one unit under soft budgets. The economic reforms have divided the old forest farms (or units) into smaller silvicultural units, which are either smaller forest farms, groups of households, or just individual households. Based on previous experiments, the total costs of forest management are calculated and used as standards in contracting silvicultural activities.

According to Hong, Li, and Wei (1992), small group and household contracting in silviculture was first introduced in the Taoshan Forestry Bureau in 1983. At first, the contracting time was short and the jobs were small. According to Tan and Zhao (1996), the current contracting period is ten years in the Mulin Forestry Bureau in Heilongjiang Province, but the costs are adjusted every year. The experiment in Mulin covers eight forest farms and involves 428 households. Each farm and household is quite independent in their management, but technically they still must follow the plan made by the SOFBs.

There are several kinds of contracting systems. The simplest one to use is piece-salary: payment is based on the amount of work accomplished, for example, the number of trees planted, rather than the time involved. This in fact is a kind of privatization of labour, although general planning, materials, and machinery are still provided by the forest farms. Another similar system is to assign a certain amount of work to a small team or individuals; the contractors are responsible for their own time management.

Gross cost component contracting is a further step in the process. The contractors are responsible for organizing labour and materials, site preparation, planting, and tending for the first few years. The cost savings belong to the contractors. Total budget contracting is also widely applied to administration spending, including public security, procuratorial, judicial, and legislative units (keep in mind that the SOFBs are still local governments to some degree).

Another different system is designed to partly transfer state-owned property rights to internal employees (often called *employee buy out*). In this case, the individuals and the SOFBs share the potential profits and risks. This system has already been widely implemented in the state-owned enterprises outside the forestry sector in China. In the SOFBs, it has still been limited to some small sawmills and wood-processing units and has proved very successful in most cases (Guo, Wang, and Gui, 1995). Its success has also promoted its popularity in silviculture. As an example, the Qingshan Forest Farm (in the Weihe Forestry Bureau), a share-holding farm, was established with a total share fund of 140,000 Yuan. Of the total share, a share of 80,000 is owned by the internal farm staff. This system may help internal monitoring, reduce monitoring costs, and labour shirking. After two years of operations the output value of the farm was reported to be 350,000 Yuan, with a profit of 50,000 Yuan (Xu and Guo, 1996).

A further step in reforms has been carried out by either renting-out or transferring land-use rights. However, the land is usually limited to internal employees, while forest resources are still limited to internal buyers, and the prices are not completely determined by the market. This

is similar to the reform in agriculture. It has proved successful for small firms, like small sawmills and wood-processing firms, machinery repair shops and some service units (Guo, Wang, and Gui, 1995), but the system has only been adopted in a few cases in silviculture. There are other new, continuing experiments, but they are limited to wasteland afforestation. The most common approach is to auction land-use rights to groups of households or individuals. The SOFBs charge land rent while the contractors are able to use the lands subject to constraints.[4] Usually a deposit for the land rent is required, so, if the contractors are unable to meet the requirements of the agreement, the land-use right is revoked and the deposit is not returned.

Regardless of what kind of specific reform is chosen, the intention is to link efforts and rewards, and create incentives. This study examines whether the new approaches, generally termed as household responsibility system (HRS) in agriculture, are more effective than the old regimes as instruments for promoting silviculture.

3 Empirical method of analysis

This study focuses on changes in technical efficiency during the transition from the old economic regime to the current one. Measuring efficiency in principle is to compare the inputs and outputs. Since the outputs and inputs have no market prices, we have an aggregation problem. Data Envelopment Analysis (DEA), originally developed by Farrell (1957), is a solution to this problem. DEA uses technical efficiency, that is, the actual outputs in respect to actual inputs. DEA has become popular in analysing the efficiency of the organizations of the public sector because it does not require that the inputs and outputs have market value. In forestry, a small number of studies, for example, Kao and Yang (1991, 1992), Kao, Chuang, and Hwang (1993) and Viitala and Hanninen (1998), have been carried out using the DEA approach.

Since Shephard (1953), production frontier and distance functions have been widely used to measure efficiency. The method is illustrated in figure 1. Every point in the figure is named as one decision-making unit (DMU). In this study, each forestry bureau is treated as one DMU. All DMUs along the frontier are assumed to be efficient. The relative distance to the frontier, by either horizontal or vertical dimension, is used as a measurement of the efficiency: for example, for DMU B in figure 1, the relative efficiency is y'/y'' if we use the output-oriented model; or x'/x'' if we use the input-oriented model.

An iso-cost curve can be used as a production frontier for multiple outputs and single input cases (see figure 2). The relative efficiency of DMU B is the ratio of OB′ to OB, meaning that if DMU B is managed with

[4] During recent years a growing number of SOFBs have been unable to pay salaries. Some arable land is allocated as payment for salary, pension for the retired staff, and compensation for workers who have been dismissed. It is called 'salary land', 'pension land', and 'employment land', respectively. In Heilongjiang Province alone the three kinds of land, 'salary land', 'pension land', and 'employment land', respectively, amounted to 4,500 ha, 2,100 ha and 1,850 ha (CAFLU 1997).

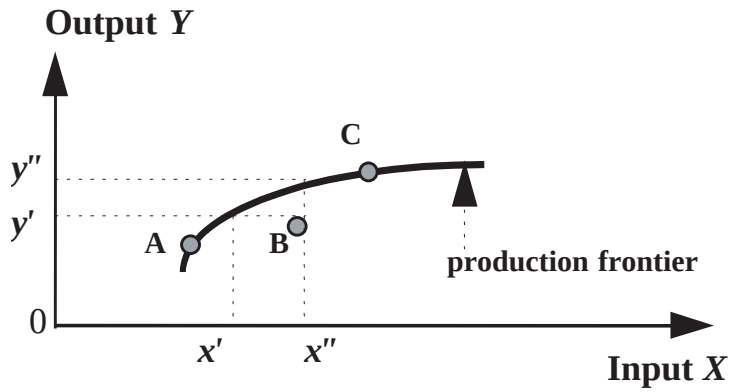

Figure 1. *Measuring technical efficiency based on production frontier*

efficiency (referring to the frontier), a share of cost BB′/B′O should be saved. Similarly, an isoquant can be used as the production frontier.

Charnes, Cooper and Rhodes (1978) extended and generalized the single-output/input ratio for a DMU in terms of rational linear-programming formulations that transform the multiple output/input characterization of each DMU into a single 'virtual' output, for example, a weighted sum of outputs, and 'virtual' inputs, for example, a weighted sum of inputs. Therefore, relative efficiency can be obtained from the ratio of the weighted sums. The contribution of DEA is an approach to formulating the production frontier surface, that is, a piecewise, empirical, external production surface.

Mathematically, the efficiency of the DMU under examination is obtained by maximizing the ratio of the weighted outputs to the weighted inputs, on condition that the similar ratios for every DMU are less than or

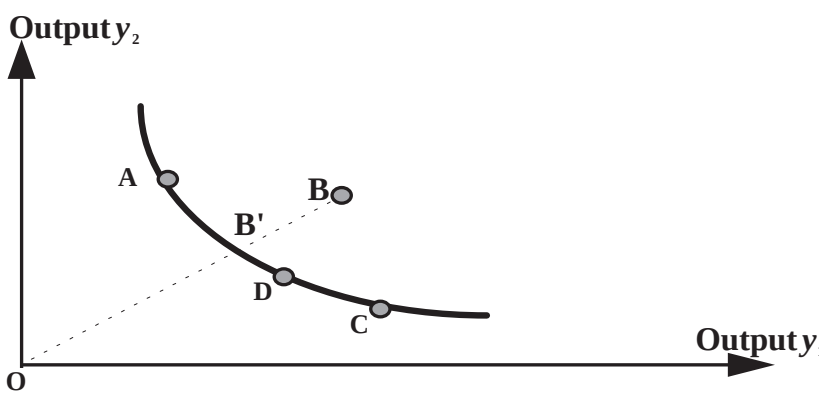

Figure 2. *Measuring efficiency based on isocost*

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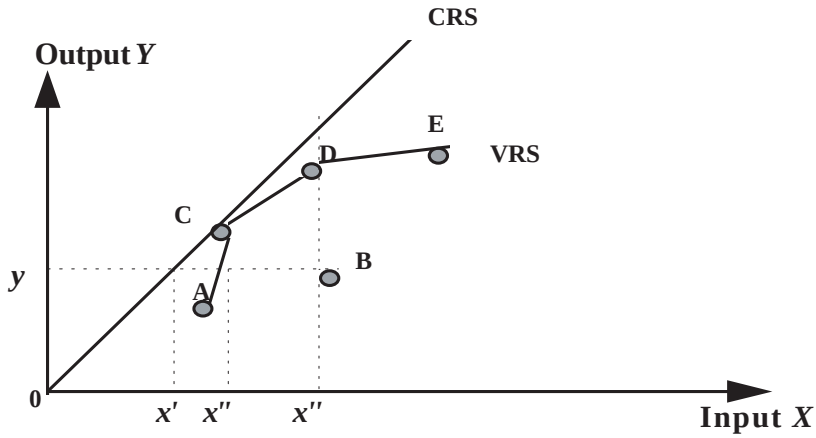

Figure 3. *Technical efficiency based on DEA*

equal to 1. A graphical explanation of the calculation of efficiency is illustrated in figure 3.

Referring to figure 3, the frontier (efficiency) is different for the assumption of constant returns to scale (CRS) and variable returns to scale (VRS). The efficiency of VRS is often decomposed into 'pure technical efficiency' and 'scale efficiency'. The scale efficiency is the ratio of CRS to VRS efficiency scores, that is the ratio of x′/x″. Both the CRS model, sometimes termed as the CCR model for Charnes, Cooper and Rhodes (1978), and the VRS model, sometimes termed as the BCC model for Banker, Charnes and Cooper (1984), can be either input or output oriented.

Based on the characteristics of our study, minimization of input for given outputs (input orientation) was used in our analysis to test the efficiency of cost savings in the economic transition period. Each forestry bureau was one DMU. We analyzed the difference across time as well as across units. However, the shift across time was our primary interest.

4 Data

We chose Heilongjiang Province, the most important province for state-owned forests, as our case study. Silvicultural activities by areas of afforestation, reforestation, and junior-forest tending are recorded in the annual statistical reports of the Heilongjiang Forestry General Bureau. The data sources for this study are mainly from HPFGB (1985–1987 and 1995–1997). These three activities are identified as major silvicultural outputs. Other activities, such as roads and facilities for silviculture purposes, are not included. The nursery establishment and seedlings activities may fluctuate greatly from year to year, but should be proportional to the forest plantation area in the long term. Hence, they are also excluded in the outputs.

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However, on the basis of our data sources, it is very difficult to identify the individual costs associated with each activity. We were usually able to obtain only the total amount of expenses in silviculture. Some protection costs for preventing disease and animal damage are embodied in those costs. Administration costs associated with silviculture cannot be separately categorized, and even the total administration costs for silviculture are only available for 1986. The expenses on silvicultural infrastructure are often separated in the documentation. Because these costs are not directly related to silviculture, they are deducted from the total silvicultural investment. Afforestation and reforestation are not limited by land area in the mid 1980s and the mid 1990s since almost all forestry bureaux still had some land available for plantation. Therefore, we have not treated land area (or bare land and logged-over land) as an input variable. Labour input in silviculture is available for some years and for some forestry bureaux prior to the 1990s. Since then, it has been impossible to know the labour input in silviculture because most of the work has been contracted out to individuals and does not need to be documented. The forestry bureaux only need to check the results and do not need to organize labour. Thus only the total expense is used as an input, and generally reflects well the combination of all input variables. Since the cost of labour is a major cost of silviculture and consumer goods is the major cost of labour, the consumer price index is used as a deflator. All prices are based on 1985 prices, the base year of this study. The consumer price indexes are from the provincial statistical yearbooks.

The efficiency measured by the inputs and outputs described above should be greatly dependent on the environment, such as distance from inhabitants, soil, landscapes, and the condition of the sites, as well as the intensity of silvicultural activities, such as planting density and the intensity of site preparation. However, the environment (which can be viewed as inputs), and silviculture intensity (which can be viewed as outputs), are difficult to measure. Therefore, we have limited our observations to the same province and a ten-year period. On average, the environment and silviculture intensity are generally comparable during this period. More importantly, we are interested in measuring the change in efficiency at each forest bureau throughout the different economic regimes. Thus, the difference across units may not be a big problem.

The economic reforms have been adopted gradually and differ from bureau to bureau. There is no systematic documentation of the change and it is difficult to note progress in more detail. However, it is clear that the old system was still dominant in all bureaux in the mid 1980s, while great progress was made from the mid 1980s to the mid 1990s. These two point observations, the mid 1980s and the mid 1990s, should reflect the impacts of economic reforms on efficiency.

In summary, we have three outputs: afforestation area, reforestation area, and junior-forest tending area, and one input: total expense in silviculture. As silvicultural activities often cover more than one year (for instance, site preparation is often undertaken in the previous year of planting), and there is variation from year to year, we used the average for 1985–1987 as the old economic regime, and 1995–1997 as the new econ-

Table 1. *Data summary for two periods of silviculture at 40 forestry bureaux*

	Total expense (1000 yuan)		*Afforestation (ha)*		*Reforestation (ha)*		*Junior forest tending (ha)*	
	Period 1	Period 2	Period 1	Period 2	Period 1	Period 2	Period 1	Period 2
Mean	772	568	766	831	1,059	926	5,650	4,425
Min	931	778	33	33	60	88	3,215	5,689
Max	4,687	4,405	6,050	4,299	6,436	4,957	39,412	34,603
SD	947	802	1,192	1,054	1,371	1,196	7,615	5,651

omic regime. Since there are 40 forestry bureaux in the Heilongjiang Province, we have a panel data of 80 observations. The input and output data for the 40 forestry bureaux are summarized in table 1.

5 Empirical results and analysis

Empirically, we use an input-oriented radial model. The efficiency value for both CRS and VRS are calculated. Efficiency is measured by the relative gain or loss compared with the frontier. Scale efficiency is derived from the ratio of CRS efficiency to VRS efficiency. The results, which are presented in table 2 and figures 4a and 4b, show that the relative efficiency on average improved by 27 per cent and 24 per cent for CRS and VRS, respectively. Only a very small numbers of forestry bureaux (three of 40 by CRS and eight of 40 bureaux by VRS) show some loss in efficiency. The scale efficiency change is relatively small, probably because the sizes of the forestry bureaux have remained the same despite economic reforms.

It would be interesting to know what contributed to the gains in efficiency. Owing to data limitations, we are not able to conduct such a regression. However, some theoretical arguments and empirical observations may help us formulate some preliminary conclusions and policy implications.

The relationship between institutions, organizational forms and economic performance is best elaborated by the transaction cost theory. This theory defines total costs of production as consisting of the resource inputs of land, labour, and capital, which are involved in both transforming the physical attributes of goods and in transacting, including defining, protecting, and enforcing property rights (Allen, 1991). As an example, the SOFBs incur significant administration costs (such as organizing, accounting, and monitoring) when carrying out silvicultural activities. Even so, moral hazard is still unavoidable because of the nature of silvicultural activities (Zhang, 2001c). Allen and Lueck (1998) argued that the seasonal and random nature of farming and the interplay of these qualities generates moral hazard, limits the gains from specialization, and causes timing problems between stages of production. Consequently, farming has generally not been converted from small, family-based firms into large, factory-style corporate firms. Silviculture, like farming, is also seasonal and random, providing the conditions that generate moral hazard.

It seems likely that reductions in labour shirking and administration costs are two major reasons for the efficiency gains. The privatization of

Table 2. *Efficiency values for the 40 forestry bureaux at two observation points*

Forestry Bureau	*CRS (CCR Model)*			*VRS (BCC model)*			*Scale efficiency*		
	Period 1	*Period 2*	*Change (per cent)*	*Period 1*	*Period 2*	*Change (per cent)*	*Period 1*	*Period 2*	*Change (per cent)*
B01	0,63	0,69	10	0,65	0,70	8	0,97	0,99	2
B02	0,80	0,82	3	1,00	0,87	−13	0,80	0,95	18
B03	0,84	0,85	1	1,00	0,85	−15	0,84	1,00	19
B04	0,88	0,91	4	0,99	1,00	1	0,89	0,91	2
B05	0,75	0,77	3	1,00	0,77	−23	0,75	1,00	34
B06	0,67	0,96	42	0,70	1,00	43	0,96	0,96	0
B07	0,62	0,74	19	0,64	0,80	24	0,97	0,93	−4
B08	0,74	0,84	14	0,77	0,85	11	0,96	0,99	3
B09	0,82	0,84	3	0,84	0,84	1	0,98	1,00	2
B10	0,81	1,00	23	0,88	1,00	14	0,92	1,00	8
B11	0,58	0,65	12	0,70	0,75	7	0,84	0,87	4
B12	0,51	0,66	29	0,82	0,77	−6	0,62	0,85	37
B13	0,50	0,73	46	0,79	0,74	−6	0,63	0,98	56
B14	0,92	0,86	−6	0,95	0,86	−9	0,97	0,99	3
B15	0,67	0,80	19	0,84	0,80	−4	0,80	1,00	24
B16	0,64	0,80	26	0,64	0,81	26	0,99	0,99	0
B17	0,60	0,94	57	0,69	0,95	37	0,87	0,99	14
B18	0,59	1,00	70	0,77	1,00	29	0,76	1,00	32
B19	0,53	0,68	29	0,55	0,72	31	0,96	0,94	−2
B20	0,50	0,99	97	0,51	1,00	97	0,99	0,99	0
B21	0,69	1,00	45	0,93	1,00	8	0,74	1,00	34
B22	0,47	0,66	38	0,49	0,67	38	0,97	0,97	0
B23	0,62	0,91	48	1,00	1,00	0	0,62	0,91	48
B24	0,34	0,63	87	0,34	0,64	89	1,00	0,99	−1
B25	0,38	0,54	42	0,39	0,54	39	0,97	1,00	2
B26	0,28	0,43	55	0,28	0,43	55	0,99	0,99	0
B27	0,50	0,54	8	0,50	0,54	8	1,00	1,00	0
B28	0,38	0,73	96	0,39	0,75	94	0,97	0,98	1
B29	0,48	0,49	3	0,51	0,51	−2	0,93	0,97	5
B30	0,45	0,44	−3	0,45	0,51	14	1,00	0,85	−15
B31	0,49	0,64	29	0,53	0,87	64	0,93	0,73	−21
B32	0,74	1,00	35	0,77	1,00	30	0,96	1,00	4
B33	0,74	0,93	25	0,86	0,95	10	0,86	0,98	14
B34	0,52	0,64	24	0,53	0,66	25	0,98	0,97	−1
B35	0,54	0,61	14	0,54	0,84	56	1,00	0,73	−27
B36	0,79	0,93	18	0,89	1,00	13	0,89	0,93	5
B37	0,88	1,00	14	0,88	1,00	14	1,00	1,00	0
B38	0,51	0,45	−12	0,52	0,87	69	0,99	0,52	−48
B39	0,54	0,69	27	0,55	1,00	83	0,99	0,69	−31
B40	0,38	0,40	5	0,51	0,47	−7	0,75	0,85	13
Max	**0,92**	**1,00**	**97**	**1,00**	**1,00**	**97**	**1,00**	**1,00**	**20**
Min	**0,28**	**0,40**	**−12**	**0,28**	**0,43**	**−23**	**0,62**	**0,52**	**−48**
Median	**0,59**	**0,75**	**23**	**0,69**	**0,84**	**14**	**0,96**	**0,98**	**2**
Mean	**0,61**	**0,75**	**27**	**0,69**	**0,81**	**24**	**0,90**	**0,93**	**6**
SD	**0,16**	**0,18**	**27**	**0,21**	**0,17**	**32**	**0,11**	**0,10**	**20**

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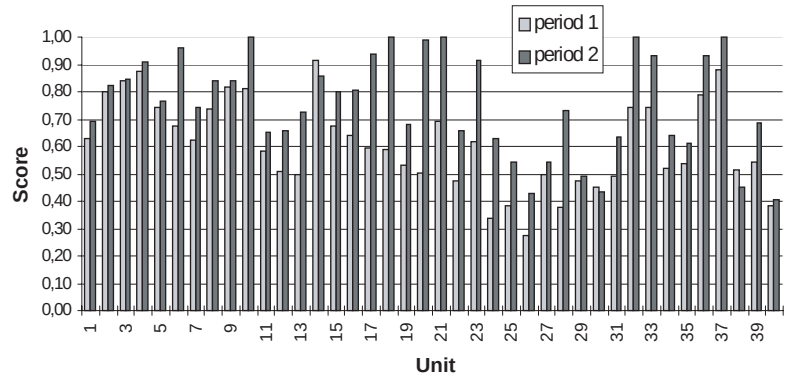

Figure 4a. *Technical efficiency score for the 40 SOFBs (by CRS)*

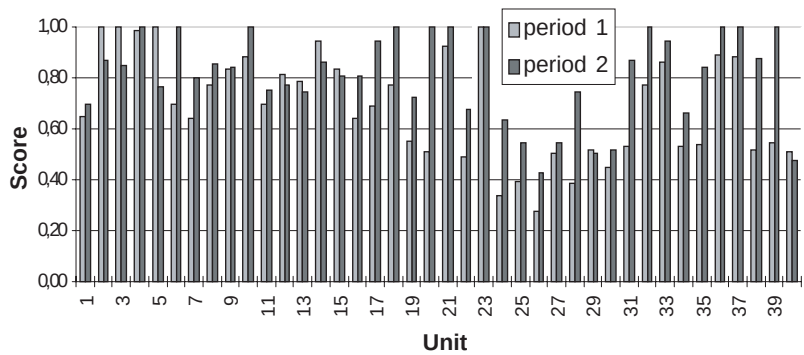

Figure 4b. *Technical efficiency score for the 40 SOFBs (by VRS)*

the labour factor is effective against labour shirking. One of the most important reasons for the slow advance of afforestation and reforestation is the low survival rate in China. According to a survey conducted by the Heilongjiang Rural Development Research Centre (1988), the survival rate of trees planted in SOFBs was only 31.9 per cent between 1951 and 1957, 13.7 per cent between 1958 and 1961, 44.6 per cent between 1962 and 1969, 31.8 per cent between 1970 and 1978, and 53.2 between 1979 and 1985. Hu (1985) argued that the deteriorated status of the forest is not due to less investment, but to less effectiveness in silviculture. The lowest survival rate occurred between 1958 and 1961, the period with the most centralized economy. Such a low survival rate was greatly due to carelessness in planting and tending after planting, resulting from the poor linkage between effort (or output) and reward (Ross, 1988; Zhang, 2000b).

In the old regime, the wage system was inflexible and did not follow the rules of competition. As a consequence, moral hazard, or labour shirking,

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was very serious. Moral hazard is basically a result of information problems and the inflexible labour market (see, for example, Holmstrom, 1982). The 'iron bowel' system of the Chinese labour market in the planned economic regime facilitated the moral hazard. Dong and Dow (1993) claimed that mutual monitoring in an egalitarian production team takes 10–20 per cent of the labour time, while McMillan, Whalley, and Zhu (1989) concluded that the effective labour supply per worker nearly doubled as a result of the shift to household contracting. Here we must note that teamwork in rural agriculture was easier to cross-monitor than silvicultural activities in the state-owned forestry bureaux, and it is likely that labour shirking in silviculture is more serious than in agriculture.

A survey by Shan *et al*. (1993) in table 3 shows more clearly how effective economic reforms are for the increase in survival rate. In the old regime, budget allocation was based on the planning of forestation activities, which were organized by teamwork. In the new economic regime, workers, who work individually, can receive only 60–80 per cent of the total budget when contracting for forestation with a forest farm. The households organize the activities and the rest of the payment is only given if the quality of tree planting, including the survival rate for the current year and the following three years, reaches certain standards agreed upon. Shan *et al*. (1993) further analyzed the significant improvements after the reforms. Based on planting and tending success, it was found that about one third of the budget can be saved using the new method. This investigation provides many concrete examples of repeat planting due to failure and the great waste associated with the centrally planned regimes. Many other studies (for example, Hu, 1985; Teng and Xie, 1991; Hong, Li, and Wei, 1992, Zhang, 1994, Zhang, Li, and Du, 1994) have similar results; silviculture activities organized in a decentralized system are less costly and achieve better outcomes.

High administration costs are probably another important reason for low efficiency. Administration means co-ordination of various inputs. Most administration costs, if not all, are transaction costs. Economic reforms reduce the administration costs because less administration work is required and hard budgeting is applied to administrative spending. On

Table 3. *A comparison of survival rate during different economic regimes on the Jile Forest Farm*

Year	*Planted area (ha)*	*Survival rate at current year (per cent)*	*Survival rate after three year*
1985	27	75	32
1986	101	70	30
1987	103	70	50
Average	77	71	39
1988	42	92	83
1989	60	89	84
1990	51	89	94
Average	51	90	87

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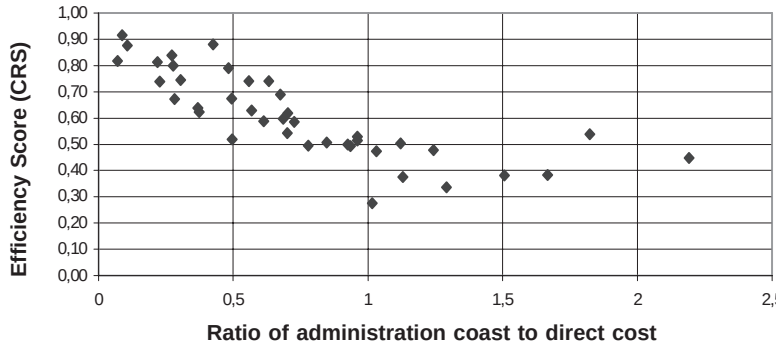

Figure 5. *The relationship between administration costs and technical efficiency (1986)*

average, the administration staff has gradually been reduced by one third through reorganization and forced early retirement. This hypothesis is preliminarily supported by figure 5, which shows a high correlation between the ratio of administration costs to direct costs in silviculture in 1986 and the efficiency score (column 1 in table 2).[5]

Li, Yi, and Wang (1993) found that the economic reforms not only improved the survival rate of planted trees from 80 per cent in the mid 1980s to 90 per cent in the early 1990s, but also significantly reduced the administrative costs. For instance, administrative staff were reduced by 20 per cent and 50 per cent in the Beishishan Forestry Bureau and Bamiangtong Forestry Bureau respectively. Other studies (for example, Zhang 2000a) have similar results.

The sign-off administrative staffs (named 'cadre', meaning office jobs) either retire or become a 'worker' (meaning field jobs). The sign-off workers are usually encouraged by government with favourable policies to transfer to other sectors, such as industry, agriculture, transportation and other business and services. It was reported that by the end of 1995 about half a million of employees were transferred to the diversified economy, such as small wood processing, restaurants, tourism, and other services in the Heilongjiang Forestry Bureau (CAFLU, 1997). The economic structural changes have eased the pressure on natural forests and indirectly promoted forest development and the private sector of the economy. How to resettle the redundant work forces is another theme resulting from the economic reforms.

6 Discussion

Our results show that economic reforms have resulted in a substantial

[5] Because we do not have separate administration cost in other years and we are not able to obtain the administration cost from the total expenses, only the figure of 1986 is used.

https://doi.org/10.1017/S1355770X02000062 Published online by Cambridge University Press

improvement in efficiency. However, a large number of SOFBs are still far below the frontier in terms of both CRS and VRS. This implies that there is still great potential for improvement through further economic reforms and reorganization of the scale of SOFBs. Various contracting systems for organizing silvicultural activities, that aim to overcome shirking of labour and to further reduce administration costs through streamlining the bureaucratic system, could be important in future reforms.

The costs of silvicultural activities have been significantly reduced by the economic reforms. However, unlike agriculture, in which the outputs are usually freely traded on the market or easily measured, the economic reforms in forestry in the Heilongjiang and other state-owned forestry regions have not as yet reached complete privatization of outputs (payment is based on the contracted work and examined reports by the administrative staff). The fairness and objectivity of the contracting standards and examination process are still a big question. If the contracting standards and examinations are problematic, they undermine incentive. Probably, the best solution is to develop stumpage and junior tree markets in the long run. If junior tree markets can function well, the government may not even need to check outputs of silviculture because markets might work more effectively and efficiently to test their results. In addition, the market will help farmers easily liquidate the output and greatly ease the risk of long-term investment and the uncertainty associated with silviculture.

Several limitations of this study should be emphasized here. From a methodological point of view, DEA offers new ways of organizing and analysing data and can result in new managerial and theoretical insights. It relaxes the imposition of a specific functional form, distribution of the error term, and many other restrictions of the parametric approach. However, the method has two major limitations. First, the frontier is very sensitive to extremes (extreme efficiency), particularly in CRS.[6] As we know, the extreme cases may come from incorrect data, random noises, or problems in variable selection. Second, efficiency is only a relative measurement, the so-called production frontier is only obtained from our sample and this does not mean it is most efficient (or that there is no room for improvement).

Due to data limitation, our results are still very preliminary. The changes in wages and worker skills,[7] technology development in silviculture, tree species, seedlings, and even the natural environment can all contribute to efficiency gains. However, our study is not able to identify these contributions and thus all gains are assumed to be the result of institutional innovation. Therefore, analysis of the factors affecting efficiency across SOFBs as well as between these two economic regimes has not been

[6] The stochastic estimation of distance functions is still being developed. It is not applied in this study considering our limited observation points.

[7] After deflation, the average wage has still increased moderately since the mid-1980s. The increase means that more efficiency was gained than suggested by the results obtained from this study. However, improvements in worker skills might explain some of the efficiency gain.

explored rigorously. Interpretation of the results should be conducted very carefully.

The efficiency gains seem significant if we consider silviculture alone. However, forest management has a much broader scope. Forest fires, insect, and disease prevention may become serious concerns due to the fragmentation of forest management. Some of the gains from decentralization and privatization of silviculture have been lost by new emerging problems. Therefore, this result may not reflect the real change in total economic performance. How to co-ordinate and organize these contracting silvicultural units has become an important theme.

In addition, this study does not analyse the impact of economic reforms on the change in investment behaviour in silviculture. For instance, it is quite uncertain whether households would invest more in silviculture if the land were allocated to them for a long term and if the government did not provide the capital. Jin (1996) opposed the HRS in forestland because he found little incentive for investment in household-owned bare land. A comparison of the various approaches of the economic reforms has not been conducted in this study. The interaction between economic reforms and the characteristics of forest land has also not been considered. All these questions are important for future studies and have great implications for policy. More studies are needed.

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