Evaluating the Performance of Privatization on Regional Transit Services: Case Study

Hsun-Jung Cho[1] and Chih-Ku Fan, Ph.D.[2]

Abstract: In this study, we propose three categories of productivity measures of changes in production, service, and consumption following privatization of the Taiwan Motor Transport Company. The results indicate that privatization had a striking impact in terms of total factor productivity on various productivity growths. The results also demonstrate that technical change was the most important factor in the progress in productivity of the new owner, the Guo Gwang Bus Company, while change in efficiency or effectiveness contributed little to this growth. However, results further suggest that the insignificant increase in efficiency and effectiveness in the newly privatized firm may be attributed either to incorrect selection of input combinations or inappropriate returns to scale, or to both.

DOI: 10.1061/(ASCE)0733-9488(2007)133:2(119)

CE Database subject headings: Privatization; Case reports; Buses; Performance characteristics; Evaluation; Productivity.

Introduction

The Taiwan Motor Transportation Company (TMTC) was privatized on July 1, 2001, as the first case of an employee buyout (EBO) (Wright and Mulley 1989) in Taiwan. TMTC's privatization is of particular interest in several respects. First, it is especially unfortunate that few studies have focused on the effects of privatization and regulatory changes on the public transport industry (De Borger et al. 2002). Second, TMTC had been facing long-term financial difficulties due mainly to its inefficiency since 1988. The most notable studies have focused on the aftereffects of transferring ownership to the private sector, that is, whether the privatized firm, the Guo Gwang Bus Company (GGBC), is capable of improving this situation or is quickly driven out of the market. Third, the economic literature that deals with employee-owned firms has paid little attention to EBOs (Bonin and Putterman 1987; Bonin et al. 1993). Hence, as an important case study, the comparison of TMTC's performance before and after privatization offers a unique opportunity to analyze the effects on the performance of its kind.

According to Wright and Mulley (1989), case study interviews with 20 of the employees who took part in the National Bus Company (NBC) buyout, undertaken in the first year after the TMTC buyout, found clear evidence that the breakup (of NBC) had given the employees a great deal of freedom to introduce more appropriate organizational structures, purchase appropriate fleet vehicles, reduce cost bases, and obtain fuel at a lower cost than had been available through central purchasing. Wright et al. (1992) indicate that most of the cost savings of the EBO appear to have come about through productivity improvements, particularly among nonplatform staff, and reduced pay and wages. Apart from reducing the number of employees, there is evidence that working practices have changed following the breakdown of national bargaining, resulting in increased flexibility. In addition, a number of publications [see for example Gomez-Ibanez and Meyer (1990), Mackie et al. (1995), White (1997), Karlaftis and McCarthy (1999)] using a variety of data and methodologies found the results of privatization to be positive for the efficiency and productivity of bus transit systems.

A comprehensive survey of methodologies and empirical results for public transit has been presented by De Borger et al. (2002). The existing studies measuring urban transit performance have also been systematically summarized and critically assessed. However, it appears that most of their performance measurements focused on efficiency instead of productivity [see for example Chang and Kao (1992), Chu and Fielding (1992), Cowie and Asenova (1999), Kerstens (1999), Nolan et al. (2002)]. Here, efficiency is measured by using the services produced as outputs and resources consumed as inputs.

A framework for transit performance concepts was presented by Fielding (1987), where cost efficiency, service effectiveness, and cost effectiveness were the terms used to describe the three dimensions of transit performance. Several studies, such as Hensher and Daniels (1995) and Hooper and Hensher (1997), applied this framework for performance evaluation. On the other hand, Chu and Fielding (1992) extended the DEA technique to develop separate DEA models for relative efficiency and effectiveness. DEA can measure effectiveness by using consumed service as the output and produced services along with selected exogenous environmental variables as inputs. Furthermore, Chang et al. (1995) extended the model for measuring the relative effectiveness of an organization to become a model for measuring the change in effectiveness of an organization by merging it with the Malmquist productivity approach, as expressed by Färe et al. (1985). However, relative to the static concept of efficiency or effectiveness,

[1]Professor, Dept. of Transportation Technology and Management, National Chiao-Tung Univ., 1001 Tahsueh Rd., Hsinchu 300, Taiwan, R.O.C. E-mail: hjcho@cc.nctu.edu.tw

[2]Chairman, Board of Directors, Taiwan Motor Transport Co., 4F, 17, Hsuchang St., Taipei 100, Taiwan, R.O.C.; and, Dept. of Transportation, Technology, and Management, National Chiao-Tung Univ., Taiwan R.O.C. E-mail: frank.tem84g@nctu.edu.tw

Note. Discussion open until November 1, 2007. Separate discussions must be submitted for individual papers. To extend the closing date by one month, a written request must be filed with the ASCE Managing Editor. The manuscript for this paper was submitted for review and possible publication on November 19, 2003; approved on April 15, 2004. This paper is part of the ***Journal of Urban Planning and Development***, Vol. 133, No. 2, June 1, 2007. ©ASCE, ISSN 0733-9488/2007/2-119–127/$25.00.

productivity is also regarded as a dynamic concept due to its time-related characteristics (Coelli et al. 1998).

Following Chang et al. (1995), the purpose of this article is therefore to extend further the models for measuring the cost efficiency, service effectiveness, and cost effectiveness of TMTC by merging them with the Malmquist productivity approach in the DEA framework to estimate the changes of productivity in production, service, and consumption following TMTC'S privatization.

Privatization of Taiwan Motor Transport Company

The TMTC was set up in 1980, before which time the Taiwanese regional transit services had been provided by the nationwide TMTC in a monopoly. Subsequently, during the mid-90s, partial deregulation of the public transit sector led to a major structural change in the Taiwanese regional bus transit industry. Several influences occurred within TMTC itself. First, public management was exceedingly inefficient. Under the operation of TMTC's 50 subsidiaries (stations) in 1990, there were 207 operating lines with a total of 3,070 vehicles. The number of TMTC employees by then was 13,000, and the number of employees per vehicle was more than 4, approximately double the average of privately owned local bus operators. The financial losses of the system were enormous. Second, TMTC's quality of service severely deteriorated. Its fleet, where more than half the number of vehicles are over 10 years old, was the least maintained part of the system. Complaints about its poor service began to increase. Part of its operational inefficiency should be attributed to TMTC's management and its employees and the government and politicians' intervention in controlling the transportation industry. For example, without government approval (usually time consuming), TMTC could not determine its budget for new services (such as renewing rolling stock). These aforementioned factors combined either to increase the cost or reduce the productivity. Subsequently, since TMTC's financial crisis pushed it to the verge of bankruptcy at the end of 2000, this served as a further impetus for accelerating the privatization of TMTC.

The privatization has produced major structural changes in the regional bus transit industry in Taiwan. Some of the important changes characterizing its privatization can be summarized in two ways. First, TMTC was fully privatized, with the aim of improving its efficiency and performance, on July 1, 2001. By transferring hundreds of vehicles, fewer than 100 operating lines, together with all the 15 stations and depots (by lease) to some 1,100 voluntary investing employees, the resultant privately owned enterprise became organized as GGBC. Second, under the operations of GGBC's 15 stations by 2002, there were 86 operating lines with a total of 804 vehicles, and the number of employees was, 1,682. Today, GGBC is a good example of the privatized enterprise operating in a similar, partially deregulated transportation market, but almost entirely free from government restrictions as a state-owned enterprise.

One of GGBC's stated missions is to become a competitive organization with a strong emphasis on productive efficiency and effectiveness in the field of public transit. In terms of organizational reform, GGBC has introduced a more appropriate organizational structure by cutting 59 operating lines, about 1,400 employees, and 700 vehicles, as compared to TMTC following privatization. With regard to management policy, GGBC has created a cost structure capable of competing properly in the transportation market against the other low-cost independent operators immediately after privatization. This has resulted in a decline of real wage rates by up to 74% and fuel costs to 90% that for TMTC on average, respectively. By purchasing a new fleet as well as being more flexible in the scheduling and dispatch of vehicles and drivers to meet travel demand, hence GGBC has raised the level of service and the resulting load factor.

Methodology

As mentioned in the previous section, the performance measurement for transit firms restricts its analysis to the use of either efficiency and effectiveness or of Fielding's (1987) concept of three dimensions of transit performance: cost efficiency, service effectiveness, and cost effectiveness. The cost efficiency of a transit firm represents the manner in which the physical inputs of labor, energy, maintenance materials, capital, and overhead are used to produce the physical (intermediate) services such as vehicle miles and frequency of service. Cost efficiency is concerned with the supply-side relationships. Effectiveness has two essential components: (1) service effectiveness—the relationship between produced services (e.g., vehicle miles) and consumed (final) services (e.g., passenger miles); and (2) cost effectiveness—the relationship between input and consumed (final) services (e.g., passenger miles or passengers). Cost effectiveness is concerned with the demand side of relationships (Hensher and Daniels 1995).

According to Färe et al. (1994), a nonparametric programming method (activity analysis) was used to compute Malmquist productivity indexes (MPIs), which were decomposed into two mutually exclusive and exhaustive components: changes in technical efficiency over time (EFFCH), and shifts in technology over time (TECHCH). These components lend themselves in a natural way to the identification of catching up and the identification of innovation, respectively. Furthermore, technical efficiency change was decomposed into pure technical efficiency (PEEFCH) and scale efficiency (SCH) components.

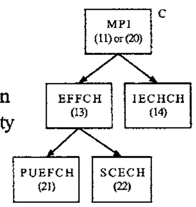
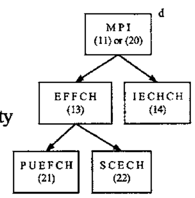
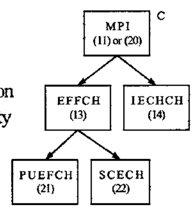
Following Chang et al. (1995) we further apply the above three dimensions of transit performance to a broader extent with productivity. More specifically, combining MPI and its components into three dimensions—cost efficiency, service effectiveness, and cost effectiveness—productivity can be measured in three ways, as depicted in Table 1, which constitutes the framework of the proposed performance evaluation in this study. (1) The production productivity measure relates to cost efficiency and is considered an input-oriented measure, that is, it measures by how much input quantities can be proportionally reduced without changing the output quantities produced; (2) the service productivity measure concerns service effectiveness and considered an output-oriented measure, that is, it measures by how much output quantities can be proportionally expanded without altering the input quantities used; and (3) the consumption productivity measure is connected with cost effectiveness and is considered an input-oriented measure.

Malmquist Total Factor Productivity Index

The Malmquist productivity index identifies productivity growth with respect to two time periods through a quantitative ratio index of distance functions (Malmquist 1953). The original derivation of the MPI can be found in Caves et al. (1982), whose definition makes use of the Shephard (1953) concept of distance function.

J. Urban Plann. Dev. 2007.133:119-127.

Table 1. Relationship among Indicators, Measures, and Equations Employed

I/O	Performance indicators	Dimensions of transit performance	Productivity measures	Employed equation (number)
Input	Fleet (x_1)			
	Drivers(x_2)			
	Fuel (x_3)	Cost efficiency	Production productivity	
	Service area population[a] (e)			
Output	Vehicle-km[b](y_1)			
Input	Vehicle-km[b] (y_1)			
		Service effectiveness	Service productivity	
Output	Passenger-km (y_2)			
Input	Fleet (x_1)			
	Drivers(x_2)			
	Fuel (x_3)	Cost effectiveness	Consumption productivity	
	Service area population[a] (e)			
Output	Passenger-km (y_2)			

[a]Environmental (input) variable measure.

[b]Vehicle-km is used as for the measure of output for both production productivity and input for service productivity.

[c]Input-oriented measure.

[d]Output-oriented measure.

Applications of these techniques include Forsund (1993), Färe et al. (1994), Chang et al. (1995), Viton (1998), and McMullen and Okuyama (2000).

The basic intuition is to define an efficient production frontier, constructed using observed data points. This frontier then stands for efficient production given existing technology. Efficiency in any year is measured as each firm's (here referred to as station's) distance from the production frontier.

The actual calculation of the frontier is achieved using linear programming, mainly DEA techniques introduced by Charnes et al. (1978). For a theoretical discussion of DEA, see Sieford and Thrall (1990), Lovell (1993), Grosskopf (1993), and Färe et al. (1997). DEA techniques produce Farrell (1957) efficiency measures, which are identical to the distance functions required for the MPI (Forsund 1993).

To derive the MPI, it is assumed that there is a production technology $\mathbf{S}^t=\{(\mathbf{x}^t,\mathbf{y}^t):\mathbf{x}^t \text{ can produce } \mathbf{y}^t\}$, which describes all possible sets of input-output vectors ($\mathbf{x}^t$ denotes the input vector and $\mathbf{y}^t$ denotes the output vector) for each time period, $t=1,\ldots,T$. The model used here imposes constant returns to scale (CRS) technology to estimate distance functions for the calculation of the MPI, as failure to do so may result in biased productivity measurement (Coelli et al. 1998).

The input and output distance functions at time t are defined as

Output Distance Function

$$d_0^t(\mathbf{x}^t,\mathbf{y}^t)=\inf[\lambda:(\mathbf{x}^t,\mathbf{y}^t/\lambda)\in\mathbf{S}^t] \quad (1)$$

Input Distance Function

$$d_0^t(\mathbf{x}^t,\mathbf{y}^t)=\inf[\theta:(\theta\mathbf{x}^t,\mathbf{y}^t)\in\mathbf{S}^t] \quad (2)$$

where λ denotes output efficiency or effectiveness, and θ denotes input efficiency or effectiveness. These functions describes the technology in that $(\mathbf{x}^t,\mathbf{y}^t)$ belongs to $\mathbf{S}^t$ only if $d_0^t(\mathbf{x}^t,\mathbf{y}^t)$ or $d_i^t(\mathbf{x}^t,\mathbf{y}^t)$ is less than or equal to one.

Caves et al. (1982) introduced the MPI, which involves time-distance functions using information from both periods, t and $t+1$:

Output Orientation

$$d_0^{t+1}(\mathbf{x}^t,\mathbf{y}^t)=\inf[\lambda:(\mathbf{x}^t,\mathbf{y}^t/\lambda)\in\mathbf{S}^{t+1}] \quad (3)$$

$$d_0^{t}(\mathbf{x}^{t+1},\mathbf{y}^{t+1})=\inf[\lambda:(\mathbf{x}^{t+1},\mathbf{y}^{t+1}/\lambda)\in\mathbf{S}^{t}] \quad (4)$$

$$d_0^{t+1}(\mathbf{x}^{t+1},\mathbf{y}^{t+1})=\inf[\lambda:(\mathbf{x}^{t},\mathbf{y}^{t+1}/\lambda)\in\mathbf{S}^{t+1}] \quad (5)$$

$$d_0^{t}(\mathbf{x}^{t},\mathbf{y}^{t})=\inf[\lambda:(\mathbf{x}^{t},\mathbf{y}^{t}/\lambda)\in\mathbf{S}^{t}] \quad (6)$$

Input Orientation

$$d_i^{t+1}(\mathbf{x}^t,\mathbf{y}^t)=\inf[\theta:(\theta\mathbf{x}^t,\mathbf{y}^t)\in\mathbf{S}^{t+1}] \quad (7)$$

$$d_i^{t}(\mathbf{x}^{t+1},\mathbf{y}^{t+1})=\inf[\theta:(\theta\mathbf{x}^{t+1},\mathbf{y}^{t+1})\in\mathbf{S}^{t}] \quad (8)$$

$$d_i^{t+1}(\mathbf{x}^{t+1},\mathbf{y}^{t+1})=\inf[\theta:(\theta\mathbf{x}^{t},\mathbf{y}^{t+1})\in\mathbf{S}^{t+1}] \quad (9)$$

$$d_i^{t}(\mathbf{x}^{t},\mathbf{y}^{t})=\inf[\theta:(\theta\mathbf{x}^{t},\mathbf{y}^{t})\in\mathbf{S}^{t}] \quad (10)$$

The MPI can be written as the geometric mean of two mixed-period distance functions (Färe et al. 1985)

$$m_0(\mathbf{y}^{t+1},\mathbf{x}^{t+1},\mathbf{y}^t,\mathbf{x}^t)=\{[d_0^t(\mathbf{x}^{t+1},\mathbf{y}^{t+1})/d_0^t(\mathbf{x}^t,\mathbf{y}^t)] \times [d_0^{t+1}(\mathbf{x}^{t+1},\mathbf{y}^{t+1})/d_0^t(\mathbf{x}^t,\mathbf{y}^t)]\}^{1/2} \quad (11)$$

Following Coelli et al. (1998), an equivalent way of writing this index is

$$m_0(\mathbf{y}^{t+1},\mathbf{x}^{t+1},\mathbf{y}^t,\mathbf{x}^t)=d_0^{t+1}(\mathbf{x}^{t+1},\mathbf{y}^{t+1})/d_0^t(\mathbf{x}^t,\mathbf{y}^t) \times [d_0^t(\mathbf{x}^{t+1},\mathbf{y}^{t+1})/d_0^{t+1}(\mathbf{x}^{t+1},\mathbf{y}^{t+1}) \times d_0^t(\mathbf{x}^t,\mathbf{y}^t)/d_0^{t+1}(\mathbf{x}^t,\mathbf{y}^t)]^{1/2} \quad (12)$$

where the ratio outside the square brackets measures the change in the output-oriented measure of technical efficiency or effectiveness between periods t and $t+1$. The remaining part of the index in Eq. (12) is a measure of technical change. It is the geometric mean of the shift in technology between the two periods, evaluated at $\mathbf{x}^{t+1}$ and also at $\mathbf{x}^t$. Thus the two terms in Eq. (12) are

$$\text{Efficiency or effectiveness change (EFFCH)} = d_0^{t+1}(\mathbf{x}^{t+1},\mathbf{y}^{t+1})/d_0^t(\mathbf{x}^t,\mathbf{y}^t) \quad (13)$$

and

$$\text{Technical change (TECHCH)} = [d_0^t(\mathbf{x}^{t+1},\mathbf{y}^{t+1})/d_0^{t+1}(\mathbf{x}^{t+1},\mathbf{y}^{t+1}) \times d_0^t(x^t,y^t)/d_0^{t+1}(x^t,y^t)]^{1/2} \quad (14)$$

We only show as an output-oriented measure here, however, that are input-oriented measure can be defined and used in a similar way. Following Färe et al. (1994), and given that suitable

J. Urban Plann. Dev. 2007.133:119-127.

panel data are available, we can calculate the required distances using DEA-like linear programs. For each observation, the distance functions in the Malmquist index are computed as the solutions to a mathematical programming problem. For example, for station k' (representing a decision making unit, DMU)

Output Orientation

$$d_0^t(x_k^t, y_k^t) = \min \lambda^{k'} \tag{15}$$

subject to

$$y_{k',m}/\lambda^{k'} \leq \sum_{k=1}^{K} z_k^t y_{k,m}^t \quad m = 1, \ldots, M,$$

$$\sum_{k=1}^{K} z_{k,n}^t x_{k,n}^t \leq x_{k',n}^t \quad n = 1, \ldots, N,$$

$$\sum_{k=1}^{K} z_k^t e_{k,p}^t \leq e_{k',p}^t \quad p = 1, \ldots, P,$$

$$z_k^t \geq 0 \quad k = 1, \ldots, K, \tag{16}$$

Input Orientation

$$d_i^t(x_k^t, y_k^t) = \min \theta^{k'} \tag{17}$$

subject to

$$y_{k',m} \leq \sum_{k=1}^{K} z_k^t y_{k,m}^t \quad m = 1, \ldots, M,$$

$$\sum_{k=1}^{K} z_k^t x_k^t \leq \theta^{k'} x_{k',n}^t \quad n = 1, \ldots, N,$$

$$\sum_{k=1}^{K} z_k^t e_{k,p}^t \leq e_{k',p}^t \quad p = 1, \ldots, P,$$

$$z_k^t \geq 0 \quad k = 1, \ldots, K, \tag{18}$$

where $x_{k,n}^t$ denotes the quantity of the nth input of the kth observation in period t; $y_{k,m}^t$ denotes the quantity of the mth output of the kth observation in period t; and z denotes the intensity variable.

Furthermore, following Afriat (1972), the assumption of CRS may be relaxed to variable returns to scale (VRS) by adding the following restriction:

$$\sum_{k=1}^{k} z_k^t = 1 \tag{19}$$

To measure changes in scale efficiency or effectiveness, the distance functions under the VRS technology (denoted by V) are also calculated by adding Eq. (19) into the constraints in Eqs. (16) and (18). Technical change (TECHCH) is calculated relative to the CRS technology, and scale efficiency or effectiveness change (SCECH) in each time period is constructed as a ratio of the distance function satisfying CRS to the distance function under VRS, while the pure efficiency or effectiveness change (PUEFCH) is defined as a ratio of the own-period distance functions in each period under VRS. With these two distance functions with respect to VRS technology, the decomposition of Eq. (12) becomes

$$\begin{aligned} m_0(\mathbf{y}^{t+1}, \mathbf{x}^{t+1}, \mathbf{y}^t, \mathbf{x}^t) = {} & [d_0^t(\mathbf{x}^{t+1}, \mathbf{y}^{t+1})/d_0^{t+1}(\mathbf{x}^{t+1}, \mathbf{y}^{t+1}) \\ & \times d_0^t(\mathbf{x}^t, \mathbf{y}^t)/d_0^{t+1}(\mathbf{x}^t, \mathbf{y}^t)]^{1/2} \\ & \times [d_0^{t+1}(\mathbf{x}^{t+1}, \mathbf{y}^{t+1}|V)/d_0^t(\mathbf{x}^t, \mathbf{y}^t|V)] \\ & \times [d_0^t(\mathbf{x}^t, \mathbf{y}^t|V)/d_0^{t+1}(\mathbf{x}^{t+1}, \mathbf{y}^{t+1}|V)] \\ & \times [d_0^{t+1}(\mathbf{x}^{t+1}, \mathbf{y}^{t+1})/d_0^t(\mathbf{x}^t, \mathbf{y}^t)] \end{aligned} \tag{20}$$

The last two terms in Eq. (20) are

$$\text{Pure efficiency or effectiveness change (PUEFCH)} = [d_0^{t+1}(\mathbf{x}^{t+1}, \mathbf{y}^{t+1}|V)/d_0^t(\mathbf{x}^t, \mathbf{y}^t|V)] \tag{21}$$

and

$$\text{Scale efficiency or effectiveness change (SCECH)} = [d_0^t(\mathbf{x}^t, \mathbf{y}^t|V)/d_0^{t+1}(\mathbf{x}^{t+1}, \mathbf{y}^{t+1}|V)] \times [d_0^{t+1}(\mathbf{x}^{t+1}, \mathbf{y}^{t+1})d_0^t(\mathbf{x}^t, \mathbf{y}^t)] \tag{22}$$

Data

Data on inputs and outputs were drawn from both TMTC and GGBC's annual statistical reports, and accounts and were supplemented by further data requested from both operators. The available data span from 1997 to 2002 only because an organizational reform had occurred before 1997 in TMTC, so early data were not very consistent with those of later years. The dataset is divided into two test periods: the last four calendar years of the preprivatization period, 1997–2000, and the first calendar year of postprivatization period, 2002. Since both TMTC and GGBC were undoubtedly undergoing a degree of "privatization turmoil," characterized by a fundamental shakeup, changing business or working practices, and employees entering and leaving the firms, the data for the year of privatization (2001) were excluded to avoid any possible bias. In addition, no significant reforms appear to have been taken after the year of structural changes in GGBC. Therefore we use the TMTC station-level panel data from the period of 1997 to 2000 and the GGBC data from the period of 2002.

The wild variability in the use of inputs and outputs in urban transit technology specifications has been reviewed by De Borger et al. (2002), who indicate that this variability simply suggests that generally there is no accepted set of relevant variables in the bus industry. In this study, for each DMU in the sample, we therefore use three traditional inputs to assess production and consumption productivities, which are measured in physical units: the fleet sizes (x_1), which we take to be the total number of vehicles operated in maximum service, the drivers (x_2), and the number of liters of fuel (x_3). And we take as the measure of output the quantity of vehicle-kms (y_1) for the measurement of production productivity, as well as the measure of output the quantity of passenger-kilometers (y_2) for that of consumption productivity.

As for the assessment of service productivity, vehicle-kilometers (y_1) are used as the measure of input and passenger-kilometers (y_2) as the measure of output. A further series, differences in service area population (e) of each DMU (station), was added to these three productivity measures as an environmental (input) variable to reflect the differences in potential demand

J. Urban Plann. Dev. 2007.133:119-127.

Table 2. Input and Output Characteristics of TMTC and GGBC

I/O	Item	Unit	Maximum–minimum		Mean	Standard deviation
		(a) TMTC (mean of 1997–2000)				
Input	Fleet (x_1)	Vehicle	157	20	64	43
	Drivers (x_2)	Person	253	20	81	63
	Fuel (x_3)	Liter (10^3)	9,247	694	2,965	2,190
	Service area population [a](e)	Person (10^3)	4,977	245	1,434	1,175
Output	Vehicle-kilometers (y_1)	Vehicle-kilometers(10^3)	24,527	2,000	7,635	5,688
	Passenger-kilometers (y_2)	Passenger-kilometers(10^3)	493,855	21,533	135,550	109,911
		(b) GGBC (2002)				
Input	Fleets (x_1)	Vehicle	133	14	54	36
	Drivers (x_2)	Person	200	15	70	52
	Fuel (x_3)	Literal (10^3)	8,722	533	2,770	2,147
	Service area population [a](e)	Person (10^3)	5,020	244	1,467	1,232
Output	Vehicle-kilometers (y_1)	Vehicle-kilometers (10^3)	23,791	1,474	7,485	5,775
	Passenger-kilometers (y_2)	Passenger-kilometers (10^3)	385,964	13,536	122,805	98,791
		(c) Percent change				
Input	Fleet (x_1)		−15.3	−30.0	−15.6	−16.3
	Drivers (x_2)		−20.9	−25.0	−13.6	−17.5
	Fuel (x_3)		−5.7	−23.2	−6.6	−2.0
	Service area population [a](e)		0.9	−0.4	2.3	4.9
Output	Vehicle-kilometers (y_1)		−3.0	−26.3	−2.0	1.5
	Passenger-kilometers (y_2)		−21.8	−37.1	−9.4	−10.1

[a]Environmental variable measure.

impacting on transit service outputs but outside the control of management. The intention was to prevent DMUs in remote areas from being disadvantaged in an assessment of relative productivity over time. All these input and output data constitute the terms x_m, y_n, and e_p of the previous section. The relationship among indicators, various measures, and employed equations mentioned above is summarized in Table 1, and Table 2 summarizes the inputs and outputs provided by the 15 stations of both companies. These three sets of input and output indicators represent a basic approach to performance evaluation for the study transit systems; for each measure we show the sample maximum, minimum, mean, and standard deviation.

It is worth noting that there are wide variations in both the minimum and maximum samples, which is one of the reasons why an environmental variable was added to these three productivity measures. Moreover, a preliminary examination of summary data before and after privatization reveals the organizational and operational changes that have been instituted at TMTC and GGBC, as well as the markets' response to their service offers. In terms of resources, GGBC has cut the fleet size by 15.6%, the number of drivers by 13.6%, and the liters of fuel used by 6.6% as compared to TMTC over the study period. Although the size of the service area population has a slight increase of 2.3%, the amount of desired outputs of vehicle-kilometers and passenger-kilometers have deceased by 9.4 and 10.1%, respectively.

Results and Discussions

Our primary concern in this study is the impact of privatization on TMTC's performance. Instead of presenting disaggregated results for each station and year, a series of summary descriptions of the average productivity changes of all stations over the entire period (but divided into pre- and postprivatization periods for comparison) were utilized. Moreover, since the Malmquist productivity index and its components themselves are multiplicative, we can calculate the cumulated Malmquist productivity index and its components such as the cumulated technical change index and the cumulated efficiency or effectiveness change index for each station as the sequential multiplicative sums of the annual indexes. The cumulated Malmquist indexes can give more perspective than the average annual Malmquist indexes on the growth pattern of productivity. It is noteworthy that, while the cumulative index has the long-run indication, it has the indication of the short-run change when two adjacent indexes are compared. Hence it is appropriate to compare the performance changes of TMTC before and after privatization. Note that if the value of the (cumulated) Malmquist index or any of its components is less than 1, it denotes regression or deterioration in performance between any two adjacent years, whereas values greater than 1 denote improvements in the relevant performance.

Furthermore, in order to provide statistically robust findings concerning the station's productivities and performance improvement before and after privatization, a Mann-Whitney statistical test is applied (see appendix). The significance of the Z-values is set as one-tailed tests at the 0.05 acceptance level.

Production Productivity

Looking at the first column in the top left corner of Table 3, it is seen that the (input-oriented) cumulative Malmquist TFP index exhibited an average regress rate of −5.1% during the entire 1997–2000 period. As for the components of the TFP, we find that, on average, the technical change index (TECHCH) and efficiency change index (EFFCH) declined by −1.7 and −3.3%, respectively. This suggests that the regression in TFP can be attributed to both efficiency change and technical change. The results of further analysis indicate that both the decrease in mean

J. Urban Plann. Dev. 2007.133:119-127.

Table 3. Results of Changes in Various Productivities before and after Privatization

Measures	Mean		Test of significance	
	Before	After	Statistics	Before versus after
(a) Production productivity				
MPI	0.949	1.111	Z-value	4.2500[a]
			P-value	0.0002
TECHCH	0.983	1.123	Z-value	4.2900[a]
			P-value	0.0002
EFFCH	0.967	0.991	Z-value	0.85
			P-value	0.1977
PUEFCH	0.978	0.971	Z-value	0.87
			P-value	0.1922
SCECH	0.99	1.021	Z-value	1.7200[a]
			P-value	0.0427
(b) Service productivity				
MPI	0.849	0.992	Z-value	3.1300[a]
			P-value	0.0009
TECHCH	0.86	0.948	Z-value	3.0500[a]
			P-value	0.0011
EFFCH	10.986	1.056	Z-value	1.16
			P-value	0.123
PUEFCH	0.94	1.09	Z-value	2.3400[a]
			P-value	0.0096
SCECH	1.061	0.978	Z-value	1.58
			P-value	0.0571
(c) Consumption productivity				
MPI	0.807	1.105	Z-value	4.2500[a]
			P-value	0.0002
TECHCH	0.874	1.081	Z-value	4.0000[a]
			P-value	0.0002
EFFCH	0.947	1.023	Z-value	0.97
			P-value	0.166
PUEFCH	0.957	0.998	Z-value	0.31
			P-value	0.3783
SCECH	0.99	1.025	Z-value	0.52
			P-value	0.3015

[a]Significant at 5% level of significance.

pure technical efficiency change (PUEFCH, −2.2%) and mean scale efficiency change (SCECH, −1.0%) resulted in the decline in mean efficiency. The above finding denotes that, in terms of the cumulated TFP, production productivity had been on a downward trend before privatization.

Turning to the results of average changes of production productivity for the sample stations during 2000–2002 (excluding 2001) of the postprivatization period, as shown in the second column, it is worth noting that the average TFP increased significantly over this period: the change in the TFP was 11.1% for our sample as a whole. On the other hand, the test of significance before and after privatization yielded a Z-value of 4.25, which shows a statistically significant increase in TFP (top right corner of Table 3).

This may suggest that, in terms of total factor productivity, the newly privatized GGBC has made a striking improvement in production productivity following privatization. The decomposition of the Malmquist TFP index helps to guide the search for an explanation for the measured productivity change. In analyzing the components of the MPI, we find that the mean technical score (TECHCH) increased 12.3%, while the mean efficiency score (EFFCH) slightly decreased 0.9%. The statistical test confirms that the former is a significant change (a Z-value of 4.29), while the latter is not (a Z-value of 0.85).

Moreover, the results of further decomposition suggest that the slight increase in the mean scale efficiency change index (SCECH) number (+2%) and the slight regress in the mean pure technical efficiency change index (PUEFCH) number (−2.9%) resulted in the slight decrease in mean efficiency change. Their corresponding Z-values were 0.87 (PUEFCH) and 1.72 (SCECH), which show an insignificant increase in PUEFCH and a significant increase in SCECH, respectively. The slight regress in pure technical efficiency may suggest that GGBC did not really change its working practices concerning production. However, the significant increase in scale efficiency (SCECH) implies that GGBC gained more appropriate returns to scale following privatization. In contrast to TMTC's regression trend during the preprivatization period, a noteworthy productivity gain was achieved by GGBC, which may suggest that privatization greatly enhanced the production productivity of the sample stations as a whole.

Service Productivity

The (output-oriented) cumulative Malmquist TFP change index of service productivity for the whole sample of stations from 1997 to 2000 of the preprivatization period were shown in the first column of second from the top of Table 3. The average cumulative TFP index presented a decline rate of −15.1% during the entire 1997–2000 period for the stations as a whole. On average, that deterioration was ascribed to a technology regression (−14.0%) and an effectiveness decline (−1.4%). Growth in mean scale effectiveness score (+6.1%) and decline in mean pure technical effectiveness score (−6.0%) resulted in the deterioration in effectiveness change. In terms of the cumulated TFP, the above finding indicates that a regressive service productivity trend was already in place before privatization.

We now turn to an analysis of changes of service productivity for the whole sample of stations during 2000–2002 (excluding 2001) of the postprivatization period, as shown in the second column. Although the average TFP slightly decreased (−0.8%), the test of significance yielded a Z-value of 3.13, which shows a statistically significant increase in TFP. This may suggest that, in terms of TFP, the newly privatized firm still made progress in service productivity following privatization. As for the source of TFP, we find that although the mean technology score was 0.948 (TECHCH) and the mean effectiveness score (EFFCH) was 1.056, the test of significance yielded Z-values were 3.05 (TECHCH) and 1.16 (EFFCH), respectively. This confirms that TECHCH yielded a significant increase, while EFFCH did not. Moreover, the mean effectiveness change came from the mean pure technical effectiveness progress (PUEFCH, 1.09) and the mean scale effectiveness decline (SCECH, −2.2%). These were confirmed by a statistical test with Z-values of 2.34 (PUEFCH) and 1.58 (SCECH), respectively, which may imply that service technique of GGBC clearly improved to satisfy its customers' needs.

Consumption Productivity

Table 3 reports the average (input-oriented) cumulative Malmquist TFP index of consumption productivity for the sample units over the entire 1997–2000 preprivatization period. It is seen that the cumulated TFP index reported, on average, a regression rate of −19.3% during the whole 1997–2000 period. As regards the components of the TFP, we find that the mean technology score (TECHCH) and mean technical effectiveness score (EFFCH) decreased by −12.6 and −5.3%, respectively, which suggests that the regress in TFP was attributable more to technology change than to effectiveness change. The results of further decomposition indicate that both the decrease in mean pure technical effectiveness score (PUEFCH, −4.3%) and the mean scale effectiveness score (SCECH, −1.0%) resulted in the decline in effectiveness change. The above finding indicates that, in terms of the cumulated TFP, consumption productivity had been on a downward trend before privatization.

Turning to the results of the average changes in consumption productivity for each station over 2000–2002 (excluding 2001) of the postprivatization period (Table 3), it is noteworthy that the average TFP clearly increased over this period for the stations in our sample: the change in the TFP was 10.5% for the stations as a whole, and TFP had a statistically significant increase, with a Z-value of 4.25. This may imply that, in terms of TFP, the newly privatized firm GGBC has caused a substantial improvement in consumption productivity following privatization. As to the components of the TFP, it is seen that both the mean technology score (TECHCH) and the mean technical effectiveness score (EFFCH) increased 8.1 and 2.3%, respectively. The statistical test for technology change shows a significant increase, while the effectiveness change was insignificant. This indicates that the productivity growth rose mainly due to technology change rather than to effectiveness change. Furthermore, decomposing results indicates that the near stability in effectiveness change stemmed from scale effectiveness change (SCECH, 2.5%) and pure effectiveness change (PUEFCH, −0.2%). These were confirmed by statistical tests with Z-values of 0.31 (PUEFCH) and 0.52 (SCECH). In contrast to TMTC's regression tendency during the preprivatization period, a remarkable productivity improvement was reached by GGBC, which may imply that the impact of privatization on the performance of the newly privatized firm was positive.

Conclusions

The purpose of this article is to use the proposed three categories of productivity measures to empirically investigate the effects of privatization on TMTC's performance. Particular contributions are (1) a description of a holistic framework for performance measures that enables mapping of the impact of privatization on TMTC's performance; (2) an extension of DEA beyond its usual cross-sectional analysis to a time-series application, which can be tracked over time as a measure of continuous improvement; and (3) a Malmquist decomposition to identify the impact of a shift in technology, separated from changes in productive efficiency or effectiveness. This paper, therefore, makes contributions in both methodology and application.

The results obtained from this study have important implications for TMTC's privatization. First, various productivities have adversely increased after privatization, although the decreasing trends of various productivities were already in place before privatization. Among the three cases, the production productivity had the relatively highest increase in TFP after privatization, followed by consumption productivity, and service productivity had the relatively least growth. Second, all three measures exhibited statistically significant increases in TFP after privatization, and the improvement was mostly ascribed to technology change rather than efficiency or effectiveness change. This appears to be mainly because privatization had given a great deal of freedom to the newly privatized GGBC, such as freedom from government's political intervention to introduce more appropriate organizational structures, purchase advanced fleet vehicles, reduce cost bases, and obtain fuel at lower cost than before. Third, further decomposition shows different results among the three productivity measures.

Since the efficiency or effectiveness score (EFFCH) is the product of the pure technical efficiency or effectiveness score (PUEFCH) and the scale efficiency or effectiveness score (SCECH), the relative sizes of those scores provide evidence as to the source of inefficiencies or ineffectiveness. We find that the statistical test confirms that the scale efficiency (SCECH) improved significantly after decomposing from the production productivity. This may suggest that the pure technical efficiency factor has more importance than the scale factor as a source of inefficiency among all stations following privatization. That is to say, insignificant increase in the efficiency of GGBC may be attributed either to incorrect selection of input combinations or inappropriate returns to scale. However, the source of insignificant effectiveness of service productivity in this firm may be ascribed to inappropriate returns to scale, while the source of insignificant effectiveness of consumption productivity may come from both aforementioned factors.

One advantage of the Malmquist methodology is that it does not require information on input prices, only quantities. Another is the ease with which multiple outputs can be considered a necessity in an industry such as bus service where there is a great deal of heterogeneity in output. Finally, this nonparametric technique does not impose any behavioral assumptions, nor does it specify any particular functional form for either the cost or production function, or for the error terms associated with frontier function estimation. On the other hand, the main limitation of nonparametric techniques is that they do not make any assumption regarding the stochastic properties of the data, rendering statistical confidence interval testing of the results impossible.

The remaining issue to be resolved in the future has two aspects. First, incorporating the service area population as an environmental variable may not be enough, since transit performance is thought to be sensitive to the environment in which the system operates (Giuliano 1981). Some other appropriate economic environmental variables accounting for the changes in productivity over the study period need to be identified further and thus taken into account. Second, DEA is deterministic and so is plagued by measurement errors in the included variables. Therefore, developing a stochastic model to describe the impact also calls for future work.

Acknowledgments

This research was partially supported by the Ministry of Education, Taiwan, R.O.C., under Grant No. EX-91-E-FA06-4-4 and was partially supported by the National Science Council, Taiwan, R.O.C., under Grant No. NSC-92-2415-H-009-004.

Appendix

The details of the Mann-Whitney test are described as follows:

The null hypothesis is that the scores of the various productivities and their components of the sample stations after privati-

J. Urban Plann. Dev. 2007.133:119-127.

zation are larger than those of the cumulated productivities and their components of the sample stations before privatization. The alternative hypothesis is that the scores of the various productivities and their components of the sample stations after privatization are not larger than those of the cumulated productivities and their components of the stations before privatization.

Z -value is calculated by

$$Z = u - E(u)/\sqrt{V(u)} \tag{23}$$

where u is the lower figure between U_1 and U_2

$$U_1 = n_1 n_2 [n_1(n_1+1)/2] - W_1, \quad U_2 = n_1 n_2 + [n_2(n_2+1)/2] - W_2 \tag{24}$$

where W_1 and W_2 are the rank sums of each selected sample. In our case, each of n has the same sample size ($n=15$). We can generate a Z-value and refer to the standardized normal distribution to test the null hypothesis.

Notation

The following symbols are used in this paper:

d_o = output distance function;
d_i = input distance function;
E = expected value;
$\mathbf{e}$ = environmental variable;
P = probability;
m_o = output-oriented Malmquist productivity index;
n = sample size;
$\mathbf{S}$ = production technology or feasible production set;
U = Mann-Whitney U statistic;
u = lower value of U_1 and U_2;
V = variable returns to scale;
V = variance;
W = rank sums of each selected sample;
$\mathbf{x}$ = input vector;
$x_{k,n}^t$ = quantity of *n*th input of *k*th observation in period *t*;
$\mathbf{y}$ = output vector;
$y_{k,m}^t$ = quantity of *m*th input of *k*th observation in period *t*;
Z = standardized normal variable;
$\mathbf{z}$ = intensity variable;
λ = output-oriented efficiency or effectiveness; and
θ = input-oriented efficiency or effectiveness.

Subscripts

k = station number;
m = output number;
n = input number;
P = number of environmental variables; and
t = time period.

References

Afriat, S. (1972). “Efficiency estimation of production functions.” *Int. Econom. Rev.*, 13, 568–598.

Bonin, J. P., Jones, D. C., and Putterman, L. (1993). “Theoretical and empirical studies of producer cooperatives: Will ever the Twain meet?” *J. Econom. Lit.*, 31(3), 1290–1320.

Bonin, J. P., and Putterman, L. (1987). *Economics of cooperation and the labor-managed economy*, Harwood Academic Publishers.

Caves, D. W., Christensen, L. R., and Diewert, W. E. (1982). “The economic theory of index numbers and the measurement of input, output and productivity.” *Econometrica*, 50, 1393–1414.

Chang, K. P., and Kao, P. H. (1992). “The relative efficiency of public versus private municipal bus firms: An application of data envelopment analysis.” *J. Productivity Analysis*, 3, 67–84.

Chang, P. L., Hwang, S. N., and Cheng, W. Y. (1995). “Using data envelopment analysis to measure the achievement and change of regional development in Taiwan.” *J. Environ. Manage.*, 43, 49–66.

Charnes, A., Cooper, W. W., and Rhodes, E. (1978). “Measuring the efficiency of decision making units.” *Eur. J. Oper. Res.*, 2, 429–444.

Chu, X., and Fielding, G. J. (1992). “Measuring transit performance using data envelopment analysis.” *Transportation Research*, 26A(3), 223–230.

Coelli, T., Rao, D. S. P., and Battese, G. E. (1998). *An introduction to efficiency and productivity analysis*, Kluwer Academic, Norwell, Mass., 222–228.

Cowie, J., and Asenova, D. (1999). “Organisation form, scale effects and efficiency in the British bus industry.” *Transportation*, 26, 231–248.

De Borger, B., Kerstens, K., and Costa, A. (2002). “Public transit performance: What does one learn from frontier studies?” *Transport Rev.*, 22, 1–38.

Färe, R., Grosskopf, S., and Lovell, C. A. K. (1985). *The measurement of efficiency of production*, Kluwer Academic, Boston.

Färe, R., Grosskopf, S., Norris, M., and Zhang, Z. (1994). “Productivity growth, technical progress, and efficiency changes in industrialised countries.” *Am. Econ. Rev.*, 84, 66–83.

Färe, R., Grosskopf, S., and Weber, W. (1997). “The effect of risk-based capital requirements on profit efficiency in banking.” *Discussion paper series no. 97–112*, Dept. of Economics, Southern Illinois Univ. at Carbondale, Ill.

Farrell, M. J. (1957). “The measurement of productive efficiency.” *J. R. Stat. Soc. Ser. A (Gen.)*, CXX(3), 253–290.

Fielding, G. J. (1987). *Managing public transit strategically*, Jossey-Bass, San Francisco.

Forsund, E. R. (1993). “Productivity growth in Norwegian ferries.” *The measurement of productive efficiency: Techniques and applications*, H. O. Fried, C. A. K. Lovell, and S. Schmidt, eds., Oxford University Press, Oxford, U.K., 353–673.

Giuliano, G. (1981). “Effect of environmental factors on the efficiency of public transit service.” *Transportation Research Record. 797*, Transportation Research Board, Washington, D.C., 11–16.

Gomez-Ibanez, J. A., and Meyer, J. R. (1990). “Privatizing and deregulating local public services: Lessons from Britain’s buses.” *J. Am. Plan. Assn.*, 56(1), 9–21.

Grosskopf, S. (1993). “Efficiency and productivity.” *The measurement of productive efficiency: Techniques and applications*, H. O. Fried, C. A. K. Lovell, and S. Schmidt, eds., Oxford University Press, Oxford, U.K., 160–194.

Hensher, D. A., and Daniels, R. (1995). “Productivity measurement in the urban bus sector.” *Transp. Policy*, 2(3), 179–194.

Hooper, P. G., and Hensher, D. A. (1997). “Measuring total factor productivity of airports—An index number approach.” *Transp. Res. Part E*, 33(4), 249–259.

Karlaftis, M. G., and McCarthy, P. S. (1999). “The effect of privatization on public transit costs.” *J. Regulatory Economics*, 16, 27–43.

Kerstens, K. (1999). “Decomposing technical efficiency and effectiveness of French urban transport.” *Annales d’Economie et de Statistique*, 54, 129–155.

Lovell, C. A. K. (1993). “Production functions and productive efficiency.” *The measurement of productive efficiency: Techniques and applications*, H. O. Fried, C. A. K. Lovell, and S. Schmid, eds., Oxford University Press, Oxford, U.K., 271–283.

Mackie, P., Preston, J., and Nash, C. (1995). “Bus deregulation: Ten years on.” *Transport Rev.*, 15(3), 229–251.

Malmquist, S. (1953). “Index numbers and indifference surfaces.” *Trabajos de Estatistica*, 4, 209–242.

McMullen, B. S., and Okuyama, K. (2000). “Productivity changes in the U.S. motor carrier industry following deregulation: A Malmquist

index approach." *Int. J. Transport Economics*, XXVII(3), 335–454.
Nolan, J. F., Ritchie, P. C., and Rowcroft, J. E. (2002). "Identifying and measuring public policy goals: ISTEA and the U.S. bus transit industry." *J. Econ. Behav. Organ.*, 48(3), 291–304.
Shephard, R. W. (1953). *Cost and production functions*, Princeton University Press, Princeton, N.J.
Sieford, L. M., and Thrall, R. M. (1990). "Recent developments in DEA: The mathematical programming approach to frontier analysis." *J. Econometrics*, 46, 7–38.
Viton, P. (1998). "Changes in multimode bus transit efficiency, 1988–1992." *Transportation*, 25, 1–21.
White, P. (1997). "The experience of bus and coach deregulation in Britain and in other countries." *Int. J. Transport Economics*, XXIV(1), 35–52.
Wright, M., Dobson, P., Thompson, S., and Robbie, K. (1992). "How well does privatization achieve government objectives? The case of bus buy-outs." *Int. J. Transport Economics*, XIX(3), 258–285.
Wright, M., and Mulley, C. (1989). "Early experiences from the privatisation of national bus." *Annual Conf., Transport Research Group*, Univ. of Newcastle upon Tyne, U.K.

J. Urban Plann. Dev. 2007.133:119-127.