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A frontier approach to measuring total factor productivity growth in Singapore's services sector

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Keywords *Productivity, Growth, Technology, Innovation, Efficiency*

Abstract *Although an East Asian miracle, Singapore has been singled out for experiencing insignificant total factor productivity (TFP) growth, thereby reflecting limited potential for long-term growth. Examines the validity of this statement for the services sector, which is an important engine of growth for Singapore. This is done using panel data with a stochastic frontier model, which, unlike the conventional growth accounting model used by previous studies, not only decomposes output growth into input growth and TFP growth but further decomposes TFP growth into technological progress and changes in technical efficiency. In addition, the stochastic frontier model incorporates the more realistic non-neutral shifting production frontier, as opposed to the commonly assumed Hicks-neutral production technology underlying a production function.*

Introduction

Singapore has often been cited as "the most successful of the four Asian dragons" (Giordano and Kato, 1993) and was also the first among the newly industrializing economies (NIEs) to be graduated to the advanced developing country status by the OECD since January 1996. Despite having a per capita GDP of US$20, 400 by 1994, enjoying full employment since 1973 and maintaining low inflation rates, various studies (Tsao, 1985; Young, 1992; Krugman, 1994; Leung, 1997) have shown that the aggregate economy as well as the manufacturing sector of Singapore has suffered from insignificant total factor productivity (TFP) growth. This study examines the TFP growth issue for the services sector by measuring its contribution to output growth.

After the 1984/85 recession, the services sector whose GDP contribution has been about 70 per cent of the Singapore economy's GDP since 1985, was identified as an important engine of growth for Singapore. Singapore is also a large exporter of services and in 1993 was ranked 11th largest in the world using the *Balance of Payments Statistics Yearbook 1994* (Statistics Department, 1994). The value of service export has averaged about 45 per cent of its GDP since 1986. Given the importance of services in Singapore, an attempt is made to study the sources of output growth as well as TFP growth in the service industries.

To date, only two studies have estimated the TFP growth in Singapore's services sector and both studies found service output growth to be input-driven. While Rao and Lee (1995) found that TFP growth increased from 0.9 per

Journal of Economic Studies, Vol. 29 No. 1, 2002, pp. 48-58.
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DOI 10.1108/01443580210414111

cent between 1976-1984 to 2.2 per cent between 1987-1994, Tan and Virabhak (1998) on the other hand, found that TFP growth in the service industries hovered about 0 per cent. A point to note is that Rao and Lee (1995) considered services as a residual (a concept long overdue), where all data for services were obtained by subtracting data on the manufacturing sector from that of the aggregate economy, thereby including utilities and construction as services.

The stochastic frontier approach

A frontier approach is adopted in this study to measure TFP growth as both the above-mentioned studies suffer from major flaws in their estimation methodology. These studies used the conventional growth accounting approach to estimate TFP growth without distinguishing between the two components of TFP growth, technological progress (TP) and changes in technical efficiency (TE). In fact, the growth accounting approach unrealistically assumes that resources are used efficiently and that TFP growth can only emanate from technological progress. The stochastic frontier approach, on the other hand, relaxes this assumption and decomposes output growth into not just input growth and TFP growth (which the conventional approach does) but further decomposes TFP growth into TP and changes in TE. The embodied technology in the more advanced capital enables technological progress to increase output, while technical efficiency, which is disembodied technological change, would result in increased output if resources and given technology are efficiently used.

The word “frontier” emphasizes the idea of maximality and represents the “best practice” approach to production. Unlike the growth accounting approach, which provides a picture of the shape of an average industry, the estimation of a frontier function is heavily influenced by the best performing industry. Most stochastic frontier models assume that the Hicks-neutral technology underlies the production frontiers, resulting in parallel shifts of the frontier. These models also require the imposition of *ad hoc* assumptions on the distribution of technical efficiency, based purely on the attractiveness of the statistical properties of the assumed distributions without any theoretical justification. Often, technical efficiency in the conventional frontier approach is implicitly assumed to be monotone throughout time and this is a rigid parametrisation.

The stochastic frontier model adopted in this study is an improvement over the conventional frontier approach in the following ways. First, it allows for non-neutral shifts such that the marginal rate of technical substitution at any input combination changes over time. This follows from Kalirajan and Shand’s (1994) argument that, with the same level of inputs, different levels of output are obtained by following different methods of applications. This implies that different methods of applying various inputs will influence output differently and this means that the diversity of individual decision industry leads to parameter variation across industries. Second, there is no need to impose any distributional assumption on technical efficiency, resulting in a non-rigid parametrisation. Thus, there is no strong theoretical reason to believe in the conventional parallel shifting production frontier approach of measuring potential output, as it is not consistent with the concept of technical efficiency.

Model specification

The stochastic production function can then be written as:

$$\ln Y_{it} = \beta_{1i} + \sum_{j=1}^{2} \beta_{ij} \ln X_{ijt} \tag{1}$$

where

$i = 1, 2, \ldots 17$ (no. of service industries).

$j = K, L$ (no. of inputs used).

$t = 1, 2, \ldots 20$ (no. of years, from 1975 to 1994).

Y = value added output in 1985 constant prices

X_K = capital expenditure measured in 1985 prices.

X_L = number of workers employed

β_{1i} = intercept term of the ith industry.

β_{ij} = actual response of output to the method of application of the jth input used by the ith industry.

Kalirajan and Shand (1994, p. 167) explain that the efficient use of each input due to various industry-specific characteristics contributes individually to technical efficiency and the contribution can be measured by the magnitudes of the random slope coefficients and all other production characteristics are captured by the varying random intercept term.

Since intercepts and slope coefficients can vary across industries, we can write:

$$\begin{aligned} \beta_{ij} &= \bar{\beta}_j + u_{ij} \\ \beta_{1i} &= \bar{\beta}_1 + \nu_{1i} \quad \text{if } j = t \text{ and zero otherwise} \end{aligned} \tag{2}$$

where $\bar{\beta}_j$ is the mean response coefficient of output with respect to the jth input, and u_{ij} and ν_{1i} are random disturbance terms.

Combining Equations (1) and (2):

$$\ln Y_{it} = \bar{\beta}_1 + \sum_{j=1}^{2} \bar{\beta}_j \ln X_{ijt} + \sum_{j=1}^{2} u_{ij} \ln X_{ijt} + \nu_{1i}.$$

Following the Aitken's generalised least squares method suggested by Hildreth and Houck (1968) and the estimation procedure by Griffiths (1972), the industry-specific and input-specific response coefficient estimates of the above model can be obtained. The highest magnitude of each response coefficient and intercept form the frontier coefficient of the potential production function. If β^* are the parameter estimates of the frontier production, then

$$\beta_j^* = \max\{\beta_{ij}\}$$

where $i = 1, 2, \dots 17$ and $j = 1, 2$.

The potential output of the industry can be realized when the "best practice" techniques are used and this is given by

$$\ln Y_{it}^* = \beta_1^* + \sum_{j=1}^{2} \beta_j^* \ln X_{ijt}.$$

The industry-specific technical efficiency is given by the ratio of the industry's actual realized output to that of its potential output,

$$TE_{it} = \frac{Y_{it}}{\exp(\ln Y_{it}^*)}. \quad (3)$$

The decomposition of output growth and TFP growth

The relationship of TFP growth to output growth in the stochastic frontier approach has been demonstrated by Mahaderan and Kalirajan (1999) (see Figure 1).

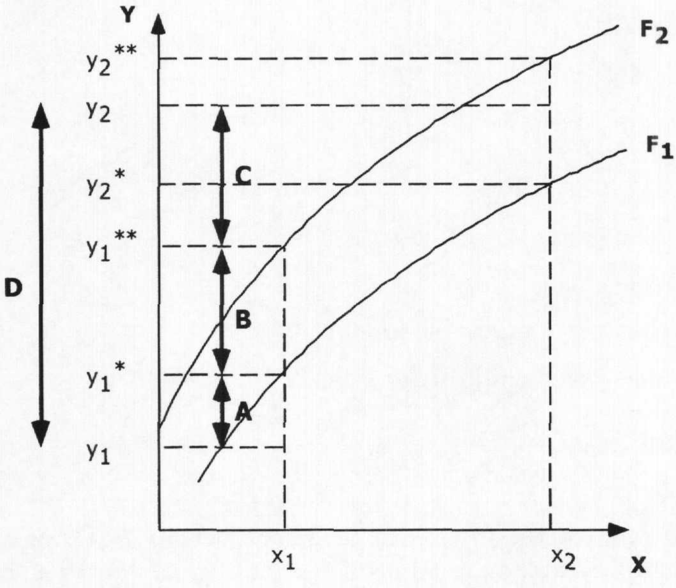

Figure 1. Decomposition of output growth

Assume that the industry faces production frontiers F_1 and F_2 in period 1 and period 2 respectively. If the industry is technically efficient, output would be on the frontier, that is, industry would be able to produce output y_1^* in period 1, using x_1 input level and output y_2^{**} in period 2, using x_2 input level. However, in periods 1 and 2, industry may be producing output y_1 and y_2 respectively, due to technical inefficiency in production. Technical inefficiency in terms of output forgone is represented by the distance between the frontier output and actual output of a given industry in the Figure. The industry in period 1 is said to experience TE1 in period 1, if it is able to increase production from y_1 to y_1^* and TE2 in period 2 if it is able to increase production from y_2 to y_2^{**}. Thus, change in technical efficiency over time is the difference between TE1 and TE2 and technological progress is measured by the distance between frontier 2 and frontier 1 given by $y_1^{**} - y_1^*$ evaluated at x_1 input level. The input growth between the two periods denoted by Δy_x causes output growth of $y_2^{**} - y_1^{**}$. This output growth can be decomposed into three components, i.e. input growth, technological progress, and improvements in technical efficiency; the sum of the latter two constitutes total factor productivity growth.

The decomposition can be mathematically expressed as follows:

$$\begin{aligned}
D &= y_2 - y_1 \\
&= A + B + C \\
&= [y_1^* - y_1] + [y_1^{**} - y_1^*] + [y_2 - y_1^{**}] \\
&= [y_1^* - y_1] + [y_1^{**} - y_1^*] + [y_2 - y_1^{**}] + [y_2^{**} - y_2^{**}] \\
&= [y_1^* - y_1] + [y_1^{**} - y_1^*] - [y_2^{**} - y_2] + [y_2^{**} - y_1^{**}] \\
&= \{(y_1^* - y_1) - (y_2^{**} - y_2)\} + (y_1^{**} - y_1^*) + (y_2^{**} - y_1^{**}) \\
&= \dot{TE} + \dot{TP} + \dot{y}_x^* \\
&= \dot{TFP} + \dot{y}_x^*
\end{aligned} \tag{4}$$

where

$y_2 - y_1$ = output growth between two periods.

$\dot{TE}$ = change in technical efficiency

$\dot{TP}$ = technological progress.

$\dot{y}_x^*$ = change in output due to input growth.

$\dot{TFP}$ = total factor productivity growth.

Data and empirical results

Most of the data were obtained from the *Report on Survey of Services* (Department of Statistics, 1974-1989) for various years, *The Service Sector* (Department of Statistics, 1990-1993), *Census of Services 1994* (Department of Statistics, 1994) as well as separate Economics Survey Series published on

Wholesale and Retail, Transport and Communication, Financial and Business Services (Department of Statistics, n.d.). The industrial classification used in this study is that of the Singapore Standard Industrial Classification and the industrial disaggregation is at the two- and three-digit level. With labor, data on workers employed were obtained from the *Singapore Yearbook of Labour Statistics* (Ministry of Labour, various issues) and the *Report on the Labour Force Survey of Singapore* (Ministry of Labour, various issues). The Appendix gives details on the construction of variables used.

A Fortran program, TERAN, which was developed at the Australian National University, was used to obtain the frontier coefficients and technical efficiencies. To estimate the production function, first, a nested hypothesis testing was done, in which a translog functional form was estimated and tested for the Cobb-Douglas functional form with the null hypothesis that the coefficients of the second-order terms are zero. The null hypothesis was accepted at the 5 per cent level of significance by an F-test, which implies that the Cobb-Douglas production function is appropriate for the present data[1]. Using Equation (4) and the estimates from the TERAN program, the sources of output growth and TFP growth are shown in Tables I and II.

	1976-1984			1987-1994		
Service industries	Output growth	Input growth	TFP growth	Output growth	Input growth	TFP growth
Wholesale trade	1.373	3.791	–2.419	3.291	5.761	–2.470
Retail trade	1.028	4.288	–3.260	5.200	5.506	–0.306
Hotels and catering	2.555	16.480	–13.925	2.403	5.492	–3.089
Land transport	1.610	4.620	–3.010	1.805	5.126	–3.321
Water transport	1.053	2.309	–1.256	1.609	3.960	–2.351
Air transport	1.846	4.714	–2.868	0.967	2.708	–1.741
Services allied to transport	2.928	12.383	–9.455	2.434	4.409	–1.975
Storage and warehousing	3.021	7.680	–4.659	3.053	7.768	–4.715
Communications	2.529	4.442	–1.914	2.030	1.345	0.685
Financial services	6.780	4.763	2.017	2.748	3.105	–0.358
Insurance services	2.027	2.442	–0.415	3.073	1.711	1.361
Real estate	8.989	10.046	–1.056	3.783	4.379	–0.596
Legal services	4.700	5.236	–0.536	3.339	2.031	1.308
Accounting, auditing and bookkeeping	2.908	2.173	0.735	2.188	1.673	0.515
Information technology	11.488	16.554	–5.066	8.185	13.906	–5.721
Engineering, architectural and technical	3.919	3.908	0.010	5.497	6.623	–1.126
Other business services	5.158	10.999	–5.841	5.916	8.591	–2.675

Notes: Since 1985/1986 is a recession year, it was excluded from the above estimation. However, when 1985/1986 was included, only the magnitudes of the above calculations were different but the trends were similar. Output growth = $(Y_2 - Y_1)/Y_1$

Table I. Sources of output growth in service industries

Table II. Sources of total factor productivity growth in service industries

Service industries	1976-1984 TFP growth	1976-1984 Change in TE	1976-1984 TP	1987-1994 TFP growth	1987-1994 Change in TE	1987-1994 TP
Wholesale trade	–2.419	–3.775	1.356	–2.470	–4.980	2.510
Retail trade	–3.260	–5.735	2.475	–0.306	–4.242	3.936
Hotels and catering	–13.925	–19.004	5.079	–3.089	–10.280	7.191
Land transport	–3.010	–5.603	2.593	–3.321	–5.750	2.428
Water transport	–1.256	–4.066	2.809	–2.351	–4.869	2.518
Air transport	–2.868	–4.238	1.370	–1.741	–3.210	1.469
Services allied to transport	–9.455	–10.995	1.541	–1.975	–10.409	8.435
Storage and warehousing	–4.659	–5.831	1.172	–4.715	–6.821	2.106
Communications	–1.914	–3.649	1.735	0.685	–1.143	1.828
Financial services	2.017	0.322	1.695	–0.358	–2.661	2.303
Insurance services	–0.415	–1.836	1.421	1.361	–1.726	3.088
Real estate	–1.056	–5.966	4.909	–0.596	–2.988	2.391
Legal services	–0.536	–1.428	0.892	1.308	0.131	1.177
Accounting, auditing and bookkeeping	0.735	–0.384	1.119	0.515	–0.372	0.887
Information technology	–5.066	–7.172	2.105	–5.721	–7.427	1.706
Engineering, architectural and technical	0.010	–1.356	1.367	–1.126	–3.290	2.164
Other business services	–5.841	–7.593	1.752	–2.675	–5.738	3.063

Sources of output growth and TFP growth in service industries

Table I shows that during 1976-1984 and 1987-1994, output growth was fuelled by the increase in input use for all of the service industries. Although the contribution of input growth to output growth decreased in the second period, TFP growth was negative for most industries in both periods, except for accounting, auditing and bookkeeping services. The communications, insurance services and legal services, however, improved their TFP growth performance in the later period. With telecommunications, rising demand from other industries of the economy as well as increasing international demand has exposed this industry to very high levels of competition, which led to improvements in its TFP growth performance. Insurance and legal services also saw improvements brought about by competition among the increased number of firms in the market and the need to satisfy consumers of an increasingly sophisticated society. As for the wholesale and retail trade, rise in tourism clearly boosted output growth but this did not come from any TFP growth. Somewhat puzzling is the poor performance of water and air transport services, although Singapore's port and airport services have reached world-class status.

For the financial sector, TFP growth was positive in 1976-1984, reflecting the government's initial successful efforts in establishing a major international financial centre through the rapid expansion of financial intermediation, introduction of financial innovations and attracting international financial institutions. Although broadening and deepening of financial services have taken place over time, the financial sector's negative TFP growth in 1987-1994 is worrying, given Singapore's aim of becoming the "financial supermarket" of Southeast Asia. Perhaps the deregulation measures mapped out in the first half of 1998 would result in some future growth for the financial sector by exposing the sector to greater competition.

Given the negative productivity growth performance of the service industries over time, contrary to Tan and Virabhak's (1998) conclusion, we say that the government's efforts at economic restructuring, which commenced in early 1979 and after the 1985/1986 recession, did not bear fruit for the services sector, although the government's restructuring efforts and the various incentives it offered were aimed to benefit all the sectors. As evidence from Wong and Tok (1994) and Rao and Lee (1995) shows that the government's restructuring efforts had a positive effect on the TFP growth of the manufacturing sector, it can be deduced that such benefits were not passed on to services.

The results obtained here are very different from that of Tan and Virabhak's (1998) evidence, where all of the service industries experienced not only positive but increased TFP growth over time. This is not surprising, as TFP growth is synonymous with technological progress in the growth accounting approach, resulting from the assumption that all industries are technically efficient. From Table II it can be seen that the service industries did enjoy technological progress, which increased over time. This means that the industries are able to benefit from the embodied technology in the new and more advanced capital which they are investing over time. However, this is significantly overshadowed by the deterioration in TE (the inefficient use of resources and technology), causing negative TFP growth for all but one service industry in both periods. Thus, the assumption of technical efficiency in the growth accounting approach clearly does not hold.

It is likely that industries such as the financial and transport services have invested in capital intensive and more advanced technology without fully exploiting its potential and thus see no improvements in technical efficiency to attain maximum output. With capital equipment being easily accessible in the world market, there was less incentive to use it efficiently. A negative correlation was also seen between the two components of TFP growth for most of the service industries. This shows that little improvement in TE co-existed with TP, while high rates of TP typically co-existed with deteriorating TE. Nishimizu and Page (1982) explain that this is possible due to failures in achieving technological mastery or due to short-run cost-minimizing behavior in the face of quasi-fixed vintage of capital.

Technical efficiency estimates

The concern raised by the deterioration in technical efficiency in Table III is closely examined for all service industries below. This is done using Equation (3) to calculate the technical efficiency estimates of service industries over time.

Service industries	Mean technical efficiency	Standard deviation	1976	1982	1988	1994
Wholesale trade	0.722	0.182	0.994	0.498	0.650	0.737
Retail trade	0.391	0.138	0.485	0.264	0.362	0.717
Hotels and catering	0.238	0.064	0.261	0.164	0.214	0.286
Land transport	0.354	0.097	0.406	0.196	0.418	0.367
Water transport	0.508	0.116	0.525	0.379	0.624	0.519
Air transport	0.744	0.147	0.968	0.583	0.642	0.781
Services allied to transport	0.355	0.202	0.676	0.344	0.177	0.248
Storage and warehousing	0.451	0.128	0.753	0.291	0.480	0.383
Communications	0.647	0.245	0.707	0.448	0.707	0.869
Financial services	0.756	0.212	0.796	0.702	0.711	0.813
Insurance services	0.448	0.126	0.679	0.495	0.265	0.441
Real estate	0.450	0.014	0.319	0.404	0.538	0.540
Legal services	0.671	0.171	0.750	0.497	0.586	0.873
Accounting, auditing and bookkeeping	0.583	0.144	0.610	0.362	0.603	0.712
Information technology	0.389	0.111	0.331	0.264	0.379	0.557
Engineering, architectural and technical services	0.565	0.090	0.667	0.530	0.456	0.663
Other business services	0.455	0.115	0.553	0.315	0.396	0.637

Table III. Technical efficiency estimates of service industries

The mean TE is computed as an average of the TE levels obtained over 1975-1994.

All of the TE estimates are below one, indicating that the service industries are not operating at full capacity. Of the 17 service industries, 13, on average, are operating at only 65 per cent or below their potential output level, that is to say, they are 35 per cent or more short of the maximum possible output level. In particular, the retail trade, hotels and catering, and land transport services performed poorly, as these industries are not exposed to international competition and are domestically oriented, thereby not being able to operate on the production frontier. The information technology (IT) services too have low TE estimates, as most of the benefits of the IT sector often accrue to other firms using IT. Some service industries, like air transport, financial services, wholesale and communications services, have relatively higher average TE measures, reflecting their role as important producer services, and hence the need for efficiency to keep up with the demands of other industries. There was, however, no evident pattern in the TE estimates of the service industries over time, although there is variation in the technical efficiency measures of the service industries given by their standard deviation.

Conclusion

Singapore's services sector's output growth was found to be input-driven with negative total factor productivity growth over 1975-1994. The empirical results from the stochastic frontier model adopted here showed that the poor TFP growth was caused by significant deterioration in technical efficiency, although the service industries enjoyed positive and increasing technological progress over time. However, it must be cautioned that there are limits to newer and more advanced technology and thus improving technical efficiency holds the key to improved TFP growth. Young's (1992) postulation of Singapore having pushed itself into technologies too far ahead of itself to benefit from learning from doing is empirically proven for the services sector in Singapore. The empirical results also showed that the assumption of service industries being technically efficient in the growth accounting approach cannot hold, thereby raising serious doubts on previous TFP studies on Singapore's services sector.

Although this study does not closely examine the causes for the poor TFP growth and hence did not suggest measures that can be taken to improve the growth potential in the services sector, the results clearly suggest the urgency for formulating appropriate policies to address the issue. This requires an empirical investigation of the determinants of technological progress and technical efficiency to sustain TFP growth for services in the long run. It must be noted that the slowing-down of TFP growth due to increased technical inefficiency (resulting from institutional barriers or structural bottle-necks) calls for different policies from TFP slow-down due to lack of technological progress (directed towards innovation and diffusion of new technology). Both types of policies need to work hand in hand and opting for new technology without fully utilizing the resources and given technology is a suboptimal strategy.

Note

1. One limitation of the Cobb-Douglas random coefficient frontier approach is that, under special cases of the production process in which the constant returns to scale are imposed on the β coefficients, the estimation of β^* would be complicated and intractable. Even when the condition of constant returns to scale is imposed on the mean of βs, the problem still exists. Such a problem does not occur if the production processes do not have to hold constant returns to scale.

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Appendix. Construction of variables

The value added for each service industry was obtained from published data and was deflated using the GDP deflator for the services sector.

Capital assets are composed of land, buildings and structures, machinery equipment, office equipment and transport equipment. Gross investment is first obtained by subtracting the value of fixed assets sold from capital expenditure and then deflated using the gross domestic fixed capital formation price deflators for machinery equipment, office equipment and transport equipment, and the property price index as a deflator for land, buildings and structures. These were then depreciated using Jorgenson's (1990) depreciation rates for the various types of capital. The capital stock series was finally calculated using the perpetual inventory method with the net value of fixed assets of 1974 as the initial capital stock.

For labor, the number of workers employed was adjusted according to average weekly hours worked using 1974 as a base index. Skill level was also accounted for in the labor variable by considering three occupational groups:

(1) professional, administration, management, and related workers;

(2) production, transport, and other related workers;

(3) clerical, sales, service and related workers.

Labor was adjusted using the method by Tan and Virabhak (1998).