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## Total Factor Productivity Growth in Singapore: Methodology and Trends

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# TOTAL FACTOR PRODUCTIVITY GROWTH IN SINGAPORE: METHODOLOGY AND TRENDS

## Introduction

1. This paper presents the methodology used to estimate multi-factor productivity or total factor productivity (TFP) growth in Singapore. It also examines the trend of TFP growth for the period 1975 to 1995. Lastly, the sensitivity of TFP growth to changes in the assumed service lives of fixed assets is examined.

## Description of Methodology

2. TFP growth is the difference between the growth of output and the growth of a combination of all factor inputs, usually labour and capital. In general, improvements in TFP reflect the contribution to output as a result of the more efficient use of resources or the adoption of new production technologies.

3. In Singapore, the approach used to estimate TFP growth is to employ a production function to first decompose growth in output (or real GDP) into the contributions of primary resources (labour and capital). A weighting scheme is employed that allows the contributions of primary factors to be aggregated. The difference between real GDP growth and the portion accounted for by the factors of production is then taken to be a measure of TFP growth.

4. Like most studies in the literature, the methodology used in Singapore assumes a transcendental logarithmic (translog) production function, whereby, under the assumptions of constant returns to scale and competitive markets for factor inputs, TFP growth is estimated from the following relationship:

$$\ln\left(\frac{Y(t)}{Y(t-1)}\right) = \bar{\theta}_K \ln\left(\frac{K(t)}{K(t-1)}\right) + \bar{\theta}_L \ln\left(\frac{L(t)}{L(t-1)}\right) + TFP_{t-1,t} \quad (1)$$

where

$$\bar{\theta}_i = [\theta_i(t) + \theta_i(t-1)]/2, \quad \text{for } i = K, L$$

5. In Equation (1), Y, L and K denote output and the input of labour and capital services respectively, while  $\bar{\theta}_K$  and  $\bar{\theta}_L$  represent the respective shares of capital and labour input in total factor payments averaged over time periods t and t-1. The assumption of competitive markets implies the share of each factor input in total factor payments is equal to the value of its marginal contribution to output. The translog index of TFP growth ( $TFP_{t-1,t}$ ) is a residual that registers those changes in output which are not due to changes in labour and capital inputs.

### a. Measure of Output and Factor Shares

The economy-wide TFP growth is estimated using GDP measured at 1990 market prices as a measure of output. On the other hand, the computation of the share of labour input in total factor payments is derived by expressing national accounts estimates of wage compensation as a fraction of GDP at current factor cost, with the share of capital input taken to be the complement of the share of labour.

Computing factor shares on the basis of market prices distorts the relative contributions of labour and capital. For instance, the share of wages as a proportion of GDP at market prices is lower than the corresponding share of GDP at factor cost. To avoid the distortion of indirect taxes (taxes on production) on factor shares, it is preferable to use nominal GDP at factor cost to compute factor shares. On the other hand, to estimate output growth, real GDP at market prices is used on the basis that these prices better reflect the relative scarcities and values of the components of national output.

b. Measure of Labour Input

Labour input is defined as the total number of employed persons in the economy. Such data are obtained from administrative records. Labour input is not distinguished by categories such as experience, age, or gender, and no quality differentiation is assumed.

c. Measure of Capital Input

Capital input or the service provided by capital is assumed to be proportional to the net capital stock at 1990 market prices. Net capital stock is estimated by applying the perpetual inventory method (PIM) on the fixed assets in Table 1 with their respective assumed service lives. The computation of the capital stock series in Singapore assumes that the assets of a given type and vintage are retired simultaneously the moment they reach the average service life of the type of asset concerned and a straight-line depreciation. Like labour input, no adjustments are made for changes in the quality of capital input.<sup>1</sup>

**Table 1**  
**Assumed Average Service Lives of Fixed Assets**

Type of Asset	Average Service Life (Years)
Buildings	
Residential	80
Non-Residential	40
Other Construction	40
Transport Equipment	
Ships & Boats	20
Aircraft	15
Road Vehicles	10
Machinery and Equipment	15

**Analysis of Results**

6. Appendix 1 shows the annual growth rates of real GDP, factor inputs (capital and labour),

estimates of contributions to real GDP growth of factor inputs and TFP growth.<sup>2</sup> Annual estimates as well as estimates for the entire 1975 to 1995 period and four sub-periods (1975 to 1980, 1980 to 1985, 1985 to 1990 and 1990 to 1995) are presented. Table 2 below shows the percentage contribution to real GDP growth of each input and TFP growth.

**Table 2**  
**Percentage Contributions to Growth of Real GDP**

Period	Capital	Labour	TFP Growth
1975 to 1995	61.1	19.4	19.5
1975 to 1980	69.9	24.0	6.1
1980 to 1985	98.6	11.8	- 10.3
1985 to 1990	37.3	16.2	46.5
1990 to 1995	48.3	23.7	28.0

7. During the entire 1975 to 1995 period, capital input was the dominant factor behind real GDP growth. It contributed 4.6 percentage points, or about 61 per cent, to the average real GDP growth of 7.6 per cent. The share of capital input in real GDP growth was especially phenomenal in the first half of the 1980s, with its contribution averaging 99 per cent. This reflects the heavy investment in buildings, especially residential apartments, during that period. However, the latter part of the 1980s saw a sharp deterioration in the contribution of capital input to output growth, though in the 1990-95 period, its contribution rebounded to around 48 per cent per annum.

8. Labour input contributed an average of 1.5 percentage points, or about 19 per cent, to real GDP growth between 1975 and 1995. While the contribution of labour input fell to a low of 12 per cent in the 1980 to 1985 period, it has since increased progressively over the remaining sub-periods.

9. The contribution of TFP growth to real GDP growth over the entire 1975 to 1995 period was similar to the contribution of labour. However, unlike labour, the contribution of TFP growth has been more volatile. In the 1975 to 1980 period, TFP growth accounted for around 6 per cent of real

<sup>1</sup> This means that the measure of TFP growth obtained includes the effects of improvements in the quality of productive factors.

<sup>2</sup> All growth rates reported in this paper are log growth rates.

GDP growth, while in the early 1980s, the contribution of TFP growth was negative. However, TFP growth has since recovered strongly, contributing 47 and 28 per cent of real GDP growth in the 1985 to 1990 and 1990 to 1995 sub-periods respectively. This could be attributed to the larger number of polytechnic diploma-holders and university graduates joining the labour force as well as the effects of skills upgrading of the existing labour force.

10. Year-to-year variations in TFP growth also closely parallels real GDP growth (Chart 1). Chart 1 shows TFP growth hitting a trough in the 1985 recession and a peak in 1988, when real economic growth was especially strong. A similar trough and peak can be observed in 1992 (a year of relatively slow growth) and 1993 (when real GDP growth rebounded strongly)

### **Sensitivity Analysis**

11. The accuracy of TFP growth is heavily dependent on the precision with which the measures of labour and capital inputs are obtained. While labour inputs can be measured with a relatively high degree of accuracy since they are usually readily available from administrative sources, the same cannot be said of capital input. Capital input in Singapore, like most TFP studies, is computed from the net capital stock estimates which are obtained using the PIM. A central assumption of the PIM is the average service lives associated with the various fixed assets. Thus, changing the assumed service lives of fixed assets may have an impact on the estimates of TFP growth. This section examines the effects of changing the assumed service lives of fixed assets on TFP growth.

12. Appendix 2 shows three alternative assumptions of asset service lives, besides the ones used to compute TFP growth earlier. In general, the service lives of assets in the alternative assumptions are lower relative to those in the original assumptions. The capital stock obtained using the three alternative assumptions are used to estimate alternative measures of TFP growth for the 1976 to 1995 period, with the results obtained plotted in Chart 2. Chart 2 shows that the overall trend of TFP growth is maintained under the various assumptions of asset service lives. Moreover, there does not appear to be any significant differences in the year-to-year variations in TFP growth. This sensitivity test seems to indicate that estimates of TFP growth in Singapore are relatively robust to changes in the assumed service lives of fixed assets.

### **Conclusion**

13. This paper has outlined the methodology used in Singapore to estimate TFP growth. In principle, the methodology is based on the growth-accounting approach. Our results show that TFP growth (which includes improvements in the quality of factor inputs), while relatively weak in the late 1970s and early 1980s, has since rebounded. This could be attributed to the improvements in the educational attainment of the labour force as well as the impact of skills upgrading. In addition, the pattern of TFP growth in Singapore tends to track the business cycle quite closely, while estimates of TFP growth appear to be quite robust to changes in the assumed service lives of fixed assets.

14. The estimates of TFP growth in this paper were computed without any adjustments in the quality of factor inputs. In future, the Department of Statistics (DOS) will attempt to estimate TFP growth for Singapore by removing the effects of changes in factor input quality. Such quality changes are quite significant in the case of Singapore, given, for instance, the rapidly rising educational attainment of the labour force.

# Appendix 1

## CONTRIBUTIONS TO GROWTH IN REAL GDP

Year	Growth of:			Average Share of Capital Input (in per cent)	Average Share of Labour Input (in per cent)	Contribution to Growth in Real GDP of:		
	Real GDP	Capital Input	Labour Input			Capital Input	Labour Input	TFP Growth
1976	0.069	0.100	0.043	0.600	0.400	0.060	0.017	-0.008
1977	0.075	0.090	0.038	0.598	0.402	0.054	0.015	0.006
1978	0.082	0.092	0.059	0.594	0.406	0.054	0.024	0.004
1979	0.089	0.094	0.062	0.585	0.415	0.055	0.026	0.008
1980	0.093	0.106	0.038	0.584	0.416	0.062	0.016	0.015
1981	0.092	0.111	0.041	0.580	0.420	0.065	0.017	0.010
1982	0.066	0.124	0.050	0.549	0.451	0.068	0.023	-0.024
1983	0.079	0.123	0.027	0.518	0.482	0.064	0.013	0.002
1984	0.080	0.119	0.013	0.500	0.500	0.059	0.007	0.014
1985	-0.016	0.084	-0.047	0.481	0.519	0.040	-0.024	-0.033
1986	0.023	0.059	-0.042	0.498	0.502	0.029	-0.021	0.015
1987	0.093	0.052	0.043	0.538	0.462	0.028	0.020	0.045
1988	0.110	0.050	0.061	0.556	0.444	0.028	0.027	0.055
1989	0.092	0.058	0.042	0.554	0.446	0.032	0.019	0.041
1990	0.086	0.062	0.046	0.543	0.457	0.034	0.021	0.031
1991	0.071	0.068	0.050	0.534	0.466	0.036	0.023	0.011
1992	0.060	0.074	0.032	0.521	0.479	0.038	0.015	0.007
1993	0.099	0.078	0.032	0.520	0.480	0.041	0.015	0.044
1994	0.096	0.078	0.044	0.529	0.471	0.041	0.021	0.034
1995	0.084	0.078	0.049	0.532	0.468	0.042	0.023	0.020
Average (1975-95)	0.076	0.085	0.034	0.546	0.454	0.046	0.015	0.015
Average (1975-80)	0.082	0.096	0.048	0.592	0.408	0.057	0.020	0.005
Average (1980-85)	0.060	0.112	0.017	0.525	0.475	0.059	0.007	-0.006
Average (1985-90)	0.081	0.056	0.030	0.538	0.462	0.030	0.013	0.038
Average (1990-95)	0.082	0.075	0.041	0.527	0.473	0.040	0.019	0.023

## Assumed Service Lives of Fixed Assets

Description	Original (STK002A )	Variation I (STK002B)	Variation II (STK002C)	Variation III (STK002D )
<b>Building</b>				
Residential	80 yrs	40 yrs	30 yrs	60 yrs
Non-residential	40 yrs	25 yrs	25 yrs	40 yrs
<b>Other Construction</b>	40 yrs	20 yrs	20 yrs	20 yrs
<b>Transport Equipment</b>				
Ships and Boats	20 yrs	20 yrs	20 yrs	16 yrs
Aircraft	15 yrs	15 yrs	15 yrs	13 yrs
Road Vehicles	10 yrs	10 yrs	10 yrs	6 yrs
<b>Machinery and Equipment</b>	15 yrs	10 yrs	10 yrs	8 yrs

