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Productivity analysis in Asia−Pacific Economic Cooperation region: A multi−country translog comparative analysis, 1965−97

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Abstract

We employ the total factor productivity (TFP) index in growth accounting as a proxy for productivity growth to compare patterns and sources of output growth for a group of proximate countries in Asia−Pacific Economic Cooperation region. The estimates indicate that output growth has benefited from both TFP and factor input contributions albeit with differing magnitudes. Whereas TFP and capital are the dominant contributors to output growth in Japan and the tiger economies, capital and labour emerge as the dominant contributors in the baby tiger economies. In addition, Japanese productivity has on the average been growing over the past decade. It also emerges that foreign direct investment may be playing a prominent role of promoting the contribution of TFP.

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1 Introduction and literature review

The term total factor productivity (TFP) refers to how output would change if all the factor inputs were maintained constant. TFP is thus, a catch-all for those things that increase the joint efficiency of labour and capital. This concept was introduced by Tibergen (1942) (Christensen, Cummings and Jorgenson (1980)). Several economists (Denison (1962), Christensen, Cummings and Jorgenson (1980), Krugman (1994), Kim and Lau (1992), and Osaka (1996)) have since made international comparison of post-war patterns of aggregate economic growth. Their common underlying theme is that growth should be driven by efficiency gains rather by the rapid growth of factor inputs which, are subject to diminishing returns. Kim and Lau's (1992) results revealed that even with the inclusion of human capital in the aggregate production function, technical progress remains the most important source of growth for the G-5. Krugman (1994) made similar observations for the G-5 (except Japan). However, regarding the Asian newly industrialising countries' (NICs) growth, he concluded that nothing is left over after the factor contributions of capital and labour to growth are deducted from GDP growth so that there is no productivity growth in the NICs.

This paper compares pre-Asian Financial crisis sources and patterns of aggregate economic growth for a group of five Asia-Pacific Economic Cooperation (APEC) countries (Hong Kong, Japan, the Philippines, Taiwan and Thailand) - in the same region but at different levels of economic development. To achieve this, we employ the TFP index in growth accounting as our proxy for productivity growth. Furthermore, we disaggregate the estimates into sub-periods concomitant with certain renown global economic shocks, i.e. the period up to the first oil shock, the second oil shock, the Plaza Accord and the Japanese stock market slump (1965-74, 1975-79, 1980-85, 1986-89, and 1990-97).

The rest of the paper is therefore organised as follows. Section 2 discusses the model. The empirical analysis is presented in section 3 while concluding remarks are the focus of section 4.

2 The model

The analysis utilises a model that transforms an aggregate production function into a production function in which output is an exponential function of the logarithms, i.e. the *translog production function*, which is presented as: [1]

$$
\begin{aligned}
Y = \exp[a_0 + a_L InL + a_K InK + a_T T + \frac{1}{2} b_{KK} (InK)^2 + b_{KL} InKInL \\
+ b_{KT} T * InK + \frac{1}{2} b_{LL} (InL)^2 + b_{LT} InL * T + \frac{1}{2} b_{TT} T^2]
\end{aligned}
\qquad (1)
$$

where Y = output, K = capital, L = labour and T = time. Expression (1) can be viewed as a second order approximation of a production function and provides a *theoretical justification* for the use of *average factor shares* and *log differences* as a means of the extension of the Divisia analysis[2] of productivity growth for data between two discrete time periods. The expression for the average rate of technical change v'_T (TFP) over two discrete periods T and $T-1$ can then be defined as:

[1] For a detailed derivation, conditions and assumptions regarding this function see Appendix 1.
[2] The Divisia indices technique (quantity and analogous price indices) was initiated by Divisia (1925) and later used by Christensen *et al* (1980) in estimating TFP.

$$TFP = [InY(T) - InY(T-1)] - v'_K\,[InK(T) - InK(T-1)]$$
$$- v'_L\,[InL(T) - InL(T-1)] \qquad (2)$$

where v'_K and v'_L denote the mean aggregate factor in total factor payments between two discrete time periods.

3 Empirical results

The results summarised in Table I,[3] demonstrate that the aggregate picture for all the countries (except Hong Kong) over the entire period (1965-97) is in agreement with Krugman's (1994) observation, i.e. output growth was derived mainly from the contribution of capital stock. However, on disaggregating the results, it becomes evident that the contribution of TFP to Japanese output growth has increased consistently since after the first oil crisis, and certainly TFP has generally dominated contribution to output growth since 1986 (see Figure 1). Similarly, between 1985-97, TFP's contribution to Taiwanese output growth has been no less than 20% in any year and has averaged 43%. Furthermore, although TFP's contribution to Hong Kong's output growth has been declining, it remains the dominant contributor. For the baby tigers (the Philippines and Thailand), however, capital remains the major contributor. It thus, emerges that capital and TFP are dominant in Japan and the NICs, while capital and labour are the dominant factors in the Asian baby tiger economies. This is concomitant with the factor endowments. According to our estimates then, Krugman's (1994) assertion now relates to the Asian baby tiger economies. However, when it comes to the Asian NICs, the conclusion now changes to '*nothing is left over after the contributions of capital and TFP to growth are deducted from GDP growth so that there is no contribution by labour*'.

Another interesting observation is that concerning the role of FDI. The period following the Plaza Accord, i.e. 1986-89 relates to a surge in FDI flows into the less capital-intensive countries, and a consolidation of high tech- and capital-intensive production strategy in the more capital-intensive countries. The results demonstrate that the contribution of TFP exceeded that of capital and labour for all the countries indicating a simultaneous surge in productivity. The implication for the developing countries is that FDI transfers new technology (in the form of capital machinery, product innovation, process innovation and technical and managerial knowledge) which promotes the efficiency of production.[4] Thus, FDI is a potential channel through which developing economies can increase their productivity.

4 Conclusion

Our disggregated TFP estimates for the Asian NICs fail to concur with Krugman's (1994) conclusion. Instead, it is the Asian baby tigers, which can now be related to his observation. FDI's role cannot be ignored since it presents a potential channel through which productivity can be enhanced. In relation to productivity and FDI is the quality of human capital. The NICs have invested extensively in the development of human capital, which may have been complementary to FDI and productivity growth. By contrast, the baby tiger's enrolment ratios drop significantly at the post-primary levels limiting their capability to accept, adopt and diffuse new technologies and knowledge and hence, to stimulate productivity. Hence, the

[3] An annual breakdown of the growth rates plus the estimates for capital stock, labour and TFP contributions are available upon request. See Appendix 2 for measurement of variables.
[4] On the importance of this in this context see for instance Chudnovsky (1993).

need to invest extensively in human capital. Turning to the Asian NICs, if they are to continue sustaining productivity (that in Hong Kong is declining), they have to devote more resources to investment in R&D.

Appendices

Appendix 1 The derivation of the formula

We design a model which separates growth in real factor input from growth in total factor productivity in accounting for growth in real product, i.e. one that identifies individual contributions. To achieve this, we consider a specific aggregate production function of the form:[5]

$$Y = F(K, L, T) \tag{1}$$

where Y = output, K = capital, L = labour and T = time.
Here time is included in the production function for purposes of measuring changes in the pattern of production, i.e. rate of technical change or put in other words, the rate of output growth, holding all inputs constant.

If the production function F gives output Y as a function of aggregate inputs, say X, the function is of the form,

$$Y = G[X(K, L), T] \tag{2}$$

where G is homogeneous of degree one in aggregate input X, and aggregate input is homogeneous of degree one in capital input K and labour input L, so that technical change is *Hicks-neutral*:

$$Y = A(T)X(K, L) \tag{3}$$

This can be transformed into a production function in which output is transcendental or, more specifically, an exponential function of the logarithms of inputs. This is referred to as *transcendental logarithmic production function* or simply, the *translog production function*. It enables the inclusion of data at discrete time periods.

$$\begin{aligned} Y = \exp[&a_0 + a_L InL + a_K InK + a_T T + \frac{1}{2} b_{KK}(InK)^2 + b_{KL} InKInL \\ &+ b_{KT} T * InK + \frac{1}{2} b_{LL}(InL)^2 + b_{LT} InL * T + \frac{1}{2} b_{TT} T^2] \end{aligned} \tag{4}$$

Expression *(4)* can be viewed as a second order approximation of a production function and provides a theoretical justification for the use of average factor shares and log differences as a means of the extension of the Divisia analysis of productivity growth for data between two discrete time periods. The conditions for satisfying the assumption of constant returns to scale are:

$$a_K + a_L = 1$$
$$b_{KK} + b_{KL} = 0$$
$$b_{KL} + b_{LL} = 0$$

Moreover, the value shares of capital, labour and technical change can be expressed as:

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[5] This section draws extensively from Christensen *et al* (1980).

$$
\begin{aligned}
v_K &= a_K + b_{KK} InK + b_{KL} InL + b_{KT} InT \\
v_L &= a_L + b_{KL} InK + b_{LL} InL + b_{LT} InT \\
v_T &= a_T + b_{KT} InK + b_{LT} InL + b_{TT} InT
\end{aligned} \tag{5}
$$

The average rate of change of output between two discrete time points *T* and *T-1* can now be expressed as:

$$
\begin{aligned}
& InY(T) - InY(T-1) = v'_K [InK(T) - InK(T-1)] \\
& + v'_L [InL(T) - InL(T-1)] + v'_T
\end{aligned} \tag{6}
$$

$$v'_K = \frac{1}{2}[v_K(T) + v_K(T-1)]$$

where $v'_L = \frac{1}{2}[v_L(T) + v_L(T-1)]$

$$v'_T = \frac{1}{2}[v_T(T) + v_T(T-1)]$$

The expression for the average rate of technical change v'_T is referred to as the *translog index of technical change*. Defining v'_T as Total Factor Productivity (TFP) – (ratio between real product and real factor input) over two discrete periods *T* and *T-1* gives:

$$
\begin{aligned}
& TFP = [InY(T) - InY(T-1)] - v'_K [InK(T) - InK(T-1)] \\
& - v'_L [InL(T) - InL(T-1)]
\end{aligned} \tag{7}
$$

where v'_K and v'_L denote the mean aggregate factor in total factor payments between two discrete time periods.

Appendix 2 Measurement of variables and data sources

Output = log GDP (international prices), computed from Penn World Tables.
Capital stock = log capital stock (international prices), computed from Penn World Tables.
Employment = log number employed, computed from Penn World Tables.
Labour hours = log labour hours. A product of number employed and average hours worked.
Hours worked = Average annual hours worked, from Labour Statistical Yearbook.
FDI = (100 billion U.S $), from Balance of Payments Statistical Yearbook.
*Factor shar*es - For simplicity, our labour income share in output comprises compensation of employees drawn from the National Accounts Statistics Yearbook.

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Table I Aggregate estimates and percentage shares for TFP, and for capital and labour contributions

Period	Hong Kong	Japan	Philippines	Taiwan	Thailand
TFP					
1965-74	.035 (43.3)	.011 (15.5)	.009 (15.5)	-.001 (-1.3)	-.032 (-55.6)
1975-79	.042 (43.0)	-.004 (-8.6)	.021 (37.8)	.008 (8.2)	.001 (1.9)
1980-85	.048 (75.5)	.015 (39.4)	-.042 (686)	.002 (5.2)	-.015 (-35.8)
1986-89	.063 (74.5)	.019 (45.3)	.040 (75.6)	.055 (56.7)	.051 (59.1)
1990-97	.013 (26.3)	.013 (61.0)	.015 (39.9)	.026 (41.8)	-.025 (-36.6)
1965-97	.037 (49.9)	.011 (24.2)	.006 (16.3)	.014 (18.2)	-.012 (-20.9)
Capital					
1965-74	.031 (38.6)	.062 (81.0)	.037 (66.5)	.081 (87.7)	.095 (146)
1975-79	.035 (35.4)	.023 (53.4)	.025 (45.1)	.071 (80.0)	.071 (89.4)
1980-85	.014 (22.0)	.018 (45.8)	.030 (-481)	.049 (84.2)	.051 (118)
1986-89	.019 (22.5)	.017 (38.9)	.001 (2.8)	.036 (36.4)	.038 (43.3)
1990-97	.032 (63.9)	.011 (51.3)	.012 (31.2)	.034 (54.3)	.088 (130)
1965-97	.027 (37.2)	.030 (64.1)	.023 (59.1)	.057 (71.8)	.075 (113)
Labour					
1965-74	.014 (18.2)	.003 (3.5)	.010 (18.0)	.013 (13.6)	.007 (10.5)
1975-79	.021 (21.7)	.023 (54.8)	.009 (17.2)	.010 (11.8)	.007 (8.7)
1980-85	.002 (2.5)	.006 (14.7)	.007 (-106)	.006 (10.6)	.008 (17.6)
1986-89	.003 (3.1)	.007 (15.8)	.011 (21.6)	.007 (6.9)	-.002 (-2.4)
1990-97	.005 (9.8)	-.003 (-12.4)	.011 (29.6)	.002 (3.8)	.005 (7.0)
1965-97	.009 (12.9)	.006 (11.7)	.010 (24.6)	.008 (10.0)	.006 (8.2)

Notes: Figures may not tally due to rounding off. Percentage shares in parentheses.

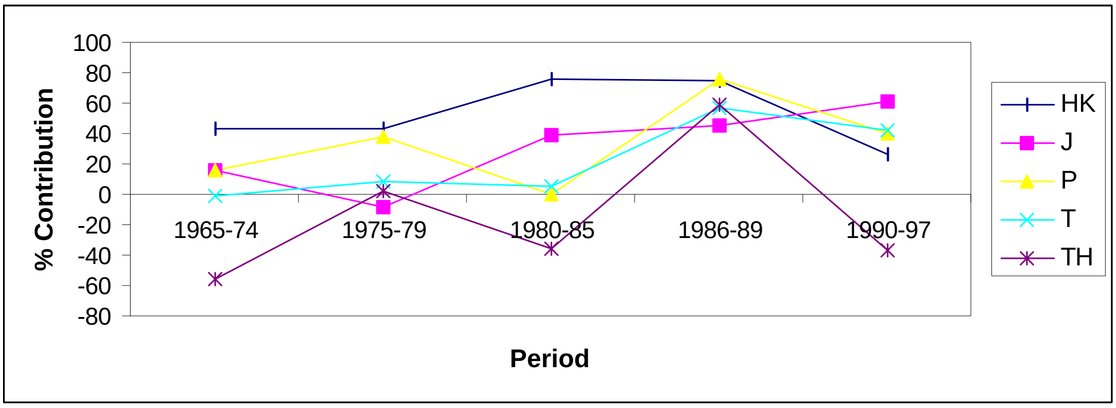

Figure 1 Average aggregate percentage contribution of TFP to output growth.

Notes: HK – Hong Kong, J – Japan, P – Philippines, T – Taiwan and TH – Thailand. The figure for the Philippines for 1980-85 has been set to zero since average aggregate output growth was negative.