Decomposing Total Factor Productivity Growth in Manufacturing and Services

NEIL FOSTER-MCGREGOR AND BART VERSPAGEN*

Using the World Input–Output Database, this paper calculates total factor productivity (TFP) growth for a sample of 40 economies during the period 1995–2009 to show that TFP growth in Asian economies has been relatively strong. In a number of Asian economies, TFP growth in services has outpaced that in manufacturing. This paper presents a novel structural decomposition of TFP growth and shows that the main drivers of aggregate productivity growth, as well as differences in productivity growth between services and manufacturing, have been changing factor requirements. These effects tend to offset the negative productivity effect of a declining ratio of value added to gross output.

Keywords: manufacturing and services, structural decomposition, total factor productivity
JEL codes: O40, O57

I. Introduction

A great deal of effort has been expended in trying to understand why differences in the dynamics of productivity persist across both economies and time (see, for example, Temple 1999). The reason for such an interest is clear: relatively minor differences in productivity growth between economies, when sustained over time, can lead to large differences in standards of living. One particular strand of this literature highlights and attempts to explain the relatively strong performance of Asian economies in terms of productivity growth in the recent past (see, for example, Young 1992, Krugman 1994, Felipe 1997).

In this paper, we update the discussion of the relative performance of Asian economies vis-à-vis the rest of the world. Using data from the World Input–Output Database (WIOD), the paper confirms the relatively strong performance of Asian economies in terms of total factor productivity (TFP) growth over the period 1995–2009. The paper further shows that while for most economies in the sample, TFP growth in manufacturing has outpaced that of TFP growth in services—which

*Neil Foster-McGregor (corresponding author): Research Fellow, United Nations University–Maastricht Economic and Social Research Institute on Innovation and Technology. E-mail: foster@merit.unu.edu. Bart Verspagen: Director, United Nations University–Maastricht Economic and Social Research Institute on Innovation and Technology. E-mail: verspagen@merit.unu.edu. The authors would like to thank the participants at the Asian Development Outlook–Asian Development Review Conference held in Seoul in November 2015, the managing editor, and an anonymous referee for helpful comments. The usual disclaimer applies.

Asian Development Review, vol. 34, no. 1, pp. 88–115

is consistent with the view that productivity in services is in general lower than in manufacturing (see, for example, Baumol 1967)—in a number of economies, particularly Asian economies, TFP growth in services has been faster than in manufacturing, lending some support to the concept of an "Asian services model" (Park and Noland 2013).

In search of an explanation for the relatively strong performance of Asian economies and of the different dynamics of productivity in manufacturing and services, this paper presents a novel structural decomposition of TFP growth by building upon the work of Dietzenbacher, Hoen, and Los (2000). Our approach decomposes the growth of TFP into changes in factor requirements, changes in the value-added content of output, and changes in the structure and composition of intermediate and final demand.

The approach adopted is related to recent contributions, such as McMillan, Rodrik, and Verduzco-Gallo (2014) and Timmer, de Vries, and de Vries (2015), who use sectoral-level productivity data to decompose aggregate productivity changes into effects of within-industry changes in productivity and effects of sectoral labor reallocations, with the results tending to suggest that within-sector productivity changes often drive aggregate productivity changes. This paper is also interested in decomposing productivity changes but moves away from the traditional shift-share analysis of McMillan, Rodrik, and Verduzco-Gallo (2014) and Timmer, de Vries, and de Vries (2015). Instead, the current paper builds upon the approach of Chenery, Shishido, and Watanabe (1962); Feldman, McClain, and Palmer (1987); Wolff (1985); and Dietzenbacher, Hoen, and Los (2000) who use structural decomposition methods to decompose productivity growth into the growth of its constituent parts (e.g., value added and labor requirements).[1] Adopting a structural decomposition approach to decompose productivity has a number of advantages, most notably by acknowledging that industries are interdependent (both within and across economies) and through input–output linkages allowing one to capture the productivity effects of these interactions. With the rise of global value chains (GVCs) (see Amador and Cabral [2016] for a recent survey), understanding and identifying the impacts of these input–output relations on productivity growth is a timely and worthwhile exercise.

Using the developed structural decomposition of TFP growth, this paper decomposes overall TFP growth rates as well as differences in TFP growth between the manufacturing and service sectors. The results suggest that declining factor requirements are the main determinant of TFP growth in the sample of WIOD economies, with a declining domestic value-added content of gross output serving to reduce TFP growth in most economies. The role of input–output linkages tends to be limited, though some evidence of a role for the changing structure and composition of intermediate and final goods demand is found in some economies. When considering

[1] See chapter 13 in Miller and Blair (2009) for more details on structural decomposition analysis.

differences in the relative performance of manufacturing and services, declining factor requirements again tend to dominate, though a role for input–output linkages is also evident for a number of economies. In general, the services productivity advantage that is witnessed in many Asian economies has no simple or single explanation, with changing factor requirements and changing input–output structure and composition being either more or less important in different economies.

The remainder of the paper is organized as follows. Section II discusses and describes the data. Section III describes the decomposition methodology. Section IV presents the main results and section V concludes.

II. Data and Descriptive Analysis

Data are drawn from the WIOD (Timmer 2015).[2] The WIOD reports data on socioeconomic accounts, international input–output tables, and bilateral trade across 35 industries and 40 economies (plus the rest of the world) over the period 1995–2009.[3] Data on value added, gross output, and intermediate purchases needed for the decomposition described in the following section are taken from the world input–output tables and are expressed in millions of United States dollars. Two sets of tables are given, one reporting values in current prices and a second reporting values in previous year prices.

We construct TFP growth and undertake the structural decomposition on a year-on-year basis, thus allowing us to consider growth in real TFP ($\hat{g}_t^{\phi}$) as

$$\hat{g}_t^{\phi} = \ln \frac{\phi_t^{t-1}}{\phi_{t-1}^{t-1}} = \ln \frac{v_t^{t-1}}{v_{t-1}^{t-1}} - \bar{\alpha}_t \ln \frac{l_t}{l_{t-1}} - \bar{\beta}_t \ln \frac{k_t}{k_{t-1}}$$

where the superscript refers to the year in which prices are measured; that is, v_t^{t-1} is the value added in period t using previous year $(t-1)$ prices. The factor inputs labor (l) and capital (k) are taken from the socioeconomic accounts and expressed in real terms (hours worked in the case of labor; in 1995 prices and domestic currencies in the case of capital stocks).[4] The labor share (α) is calculated as the share of labor compensation in value added, with the capital share being calculated as the residual ($\beta = 1 - \alpha$). We use a Tornqvist approximation for the labor and capital shares, thus allowing for these shares to be time-varying ($\bar{\alpha}_t = \frac{1}{2}(\alpha_{t-1} + \alpha_t)$ and $\bar{\beta}_t = \frac{1}{2}(\beta_{t-1} + \beta_t)$). Some existing evidence suggests that these shares are not constant over time, with a declining labor share often observed (see, for example, Elsby, Hobijn, and Sahin 2013).

[2] See www.wiod.org for more details.

[3] See Table A.1 in the Appendix for a list of economies and sectors.

[4] We converted the capital stocks from 1995 domestic currencies to United States dollars using the 1995 nominal exchange rates provided in the WIOD.

Our main interest is in considering longer-term changes in TFP (the growth rate between 1995 and 2009), with the growth of real TFP between 1995 and 2009 calculated as

$$\hat{g}^{\phi}_{1995:2009} = \sum_{t=1996}^{2009} \ln \frac{\phi_t^{t-1}}{\phi_{t-1}^{t-1}}$$

Table 1 reports for each of the 40 WIOD economies the initial (1995) level and the cumulative growth rate of TFP over the period 1995–2009, along with unweighted averages for four economy groups: Asia, non-Asian developed, European Union (EU) new member states (NMS), and non-Asian developing. Results are reported for an economy's total TFP and for manufacturing and services TFP separately.[5] The data confirm previous studies and our expectations that TFP growth has been stronger in Asia than in other regions, with cumulative TFP growth of 35.5% in Asia over the period 1995–2009. The TFP growth rate during the review period was also strong in EU NMS at 26.8% and (to a lesser extent) in non-Asian developing economies at 22%, while TFP growth in developed economies was relatively low at 8.8%. These averages hide a great deal of heterogeneity within each group, with TFP growth in the People's Republic of China (PRC) as high as 89%, compared with growth rates of 17.5% for Japan; 15.4% for Taipei,China; and (perhaps most surprisingly) 15.2% for Indonesia.

When considering manufacturing and services separately, we find that TFP growth in manufacturing outpaced TFP growth in services in EU NMS and non-Asian developed economies, with the difference being more than 15 percentage points in the case of non-Asian developed economies and more than 20 percentage points in the case of EU NMS. Such results are consistent with the view of Baumol (1967) that productivity growth in services tends to be lower than in manufacturing. In the cases of Asia and non-Asian developing economies, however, we observe that TFP growth is higher in services than in manufacturing. Again, there is a great deal of heterogeneity within economy groups. For example, in Asia, services TFP growth outstrips manufacturing TFP growth by more than 40 percentage points in India, while TFP growth in manufacturing is more than 55 percentage points higher than services TFP growth in the Republic of Korea.

Even in the PRC and the Republic of Korea, where TFP growth in manufacturing exceeds that in services, the growth rate of TFP in services was still higher than the average rate for the full sample of economies. In all six Asian economies (and three of the four non-Asian developing economies), services TFP growth over the period 1995–2009 was above 15%, with growth of TFP in manufacturing exceeding 15% in just three Asian economies (and two non-Asian

[5]See Table A.2 in the Appendix for details of which individual industries are considered to comprise manufacturing and services.

Table 1. **Descriptive Statistics for Total Factor Productivity Growth**

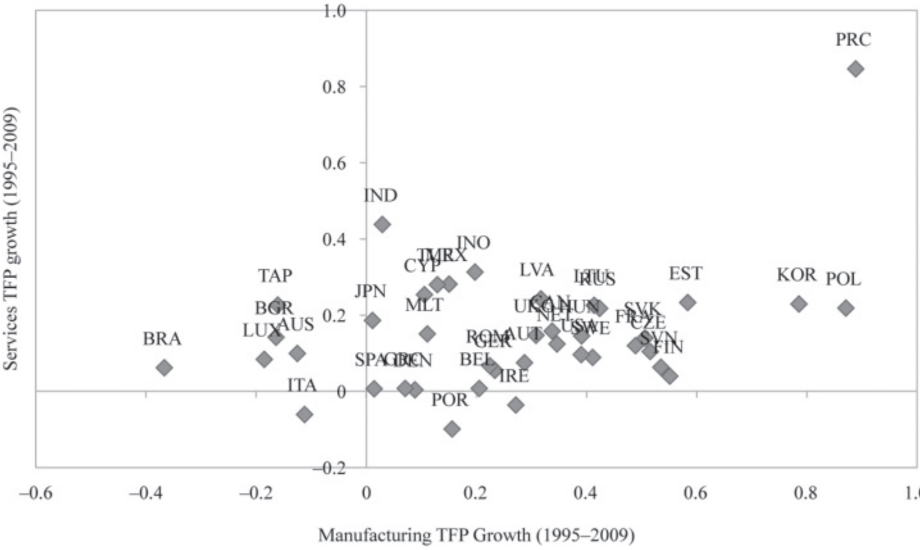
	All Sectors		Manufacturing		Services	
	ϕ_{1995}	$\hat{g}^{\phi}_{1995:2009}$	ϕ_{1995}	$\hat{g}^{\phi}_{1995:2009}$	ϕ_{1995}	$\hat{g}^{\phi}_{1995:2009}$
Asia		**35.46%**		**29.16%**		**37.33%**
People's Republic of China	0.467	89.03%	0.682	88.85%	0.409	84.65%
Indonesia	0.913	15.24%	1.564	19.72%	0.832	31.33%
India	0.388	32.24%	0.433	2.84%	0.524	43.77%
Japan	5.383	17.45%	6.616	1.08%	5.480	18.63%
Republic of Korea	4.802	43.40%	3.726	78.57%	5.075	22.95%
Taipei,China	4.021	15.41%	3.660	−16.11%	4.190	22.66%
Non-Asian Developed		**8.83%**		**20.73%**		**5.11%**
Australia	4.162	5.31%	6.048	−12.56%	4.291	9.93%
Austria	7.829	14.74%	10.588	28.68%	6.972	7.49%
Belgium	8.914	3.96%	11.721	20.50%	8.555	0.75%
Canada	3.817	16.52%	5.492	33.70%	4.019	15.79%
Germany	8.105	9.19%	17.909	23.32%	6.179	5.52%
Denmark	6.758	1.89%	11.812	8.82%	6.492	0.40%
Spain	4.875	2.82%	6.492	1.40%	4.979	0.66%
Finland	6.493	19.60%	7.608	55.12%	6.493	3.96%
France	5.926	17.94%	10.218	48.84%	5.483	12.02%
United Kingdom	6.061	13.16%	10.007	30.78%	5.877	14.73%
Greece	2.216	3.67%	3.928	7.03%	2.128	0.78%
Ireland	4.869	7.00%	4.451	27.15%	6.215	−3.58%
Italy	5.473	−5.40%	7.411	−11.24%	5.105	−6.05%
Luxembourg	5.122	6.01%	9.334	−18.54%	4.597	8.41%
The Netherlands	7.150	13.95%	9.124	34.57%	7.455	12.42%
Portugal	3.487	−1.59%	3.442	15.55%	3.513	−9.88%
Sweden	6.929	16.98%	7.872	41.09%	6.868	8.94%
United States	5.396	13.13%	7.139	39.00%	5.373	9.66%
EU New Member States		**26.80%**		**36.73%**		**16.55%**
Bulgaria	0.715	7.69%	1.331	−16.40%	0.519	14.19%
Cyprus	3.155	24.49%	4.213	10.55%	3.252	25.34%
Czech Republic	0.810	23.99%	1.168	51.57%	0.724	10.44%
Estonia	1.129	34.14%	1.370	58.32%	1.090	23.30%
Hungary	1.405	30.20%	1.865	39.05%	1.297	14.57%
Lithuania	0.738	29.36%	1.102	41.32%	0.705	22.56%
Latvia	1.039	31.52%	1.319	31.72%	0.942	24.27%
Malta	2.504	12.25%	4.157	11.03%	2.309	15.06%
Poland	4.265	52.30%	2.203	87.05%	1.738	21.83%
Romania	0.899	19.32%	1.127	22.42%	0.700	6.73%
Slovakia	0.757	27.10%	1.120	50.60%	0.663	13.97%
Slovenia	6.183	29.24%	5.766	53.48%	4.589	6.35%
Non-Asian Developing		**22.02%**		**8.38%**		**21.03%**
Brazil	1.149	−0.22%	1.798	−36.72%	1.228	6.16%
Mexico	0.630	28.91%	1.085	15.01%	0.630	28.13%
Russian Federation	1.118	26.62%	1.049	42.35%	1.346	21.80%
Turkey	0.924	32.78%	1.064	12.88%	0.781	28.02%

EU = European Union.

Notes: This table reports the initial (1995) level of total factor productivity (TFP) by economy for (i) all World Input–Output Database sectors, (ii) the manufacturing sector only, and (iii) the service sector only, as well as the (cumulative) growth rate of TFP over the period 1995–2009. TFP growth rates for the four economy groups are unweighted averages.

Source: Authors' calculations using the World Input–Output Database. www.wiod.org

Figure 1. **Scatterplot of Manufacturing and Services Total Factor Productivity Growth, 1995–2009**



AUS = Australia; AUT = Austria; BEL = Belgium; BGR = Bulgaria; BRA = Brazil; CAN = Canada; CYP = Cyprus; CZE = Czech Republic; DEN = Denmark; EST = Estonia; FIN = Finland; FRA = France; GER = Germany; GRC = Greece; HUN = Hungary; IND = India; INO = Indonesia; IRE = Ireland; ITA = Italy; JPN = Japan; KOR = Republic of Korea; LTU = Lithuania; LUX = Luxembourg; LVA = Latvia; MEX = Mexico; MLT = Malta; NET = The Netherlands; POL = Poland; POR = Portugal; PRC = People's Republic of China; ROM = Romania; RUS = Russian Federation; SVK = Slovakia; SVN = Slovenia; SPA = Spain; SWE = Sweden; TAP = Taipei,China; TFP = total factor productivity; TUR = Turkey; UKG = United Kingdom; USA = United States.
Source: Authors' calculations using World Input–Output Database. www.wiod.org

developing economies). This outcome suggests that services production need not imply low overall TFP growth and may further point to the possibility of an "Asian services model" (Park and Noland 2013).

These differences between TFP growth in manufacturing and services can be further observed in Figure 1, which plots TFP growth in manufacturing against that in services for the period 1995–2009. This figure further shows that there is only a weak correlation between services and manufacturing TFP growth. When considering all observations, the correlation coefficient is 0.35. It falls to 0.14 when the major outlier, the PRC, is excluded from the calculation.[6] There are also numerous individual cases where services TFP growth outperforms that of manufacturing. In a number of these cases, the difference partly reflects poor—and often negative—TFP growth in manufacturing (e.g., Australia; Bulgaria; Brazil; India; Italy; Luxembourg; and

[6]A simple regression of manufacturing TFP growth on a constant and services TFP growth results in a coefficient of 0.64 (significant at the 5% level) when the PRC is included and 0.36 (not significant) when the PRC is excluded.

Taipei,China). In other cases—most notably Indonesia and Japan in Asia as well as Cyprus, Malta, Mexico, and Turkey—higher TFP growth rates for services arise despite positive TFP growth rates for manufacturing.

To understand further these differences in TFP growth, both across economies and between manufacturing and services, we now proceed to decompose TFP growth using structural decomposition methods in the following section.

III. Methodology

The decomposition method employed in this paper builds upon that developed by Dietzenbacher, Hoen, and Los (2000) for labor productivity, with the current paper decomposing TFP growth rather than the growth of labor productivity. The decomposition of labor productivity changes undertaken by Dietzenbacher, Hoen, and Los (2000) results in six components: two reflect changing labor productivity levels for each industry in each economy, two reflect changing industry output shares across economies, and two reflect changing trade relationships between economies. In their analysis, Dietzenbacher, Hoen, and Los (2000) show that changes in labor requirements per unit of gross output are the biggest determinant of labor productivity changes for six European economies, with part of this positive impact being offset by the productivity-decreasing effect of a smaller share of value added in gross output.

We begin by defining a number of variables used by Dietzenbacher, Hoen, and Los (2000), where N represents the number of industries per economy (35) and C the number of economies (40 plus the rest of the world):[7]

v: aggregate value added (scalar);

l: aggregate labor inputs (scalar);

π: aggregate labor productivity, v/l (scalar);

A: matrix of input coefficients ($NC \times NC$), with typical element a_{ij}^{rs} denoting the input of product i from economy r per unit of output in industry j in economy s;

L: Leontief inverse ($NC \times NC$), $\mathbf{L} \equiv (\mathbf{I} - \mathbf{A})^{-1}$;

F: matrix of final demands ($NC \times C$), with typical element f_i^{rs} giving the final demand for product i produced in economy r by economy s;

[7] WIOD reports for the rest of the world aggregate all variables that we need for our analysis other than data on labor and capital use and compensation. We therefore include the rest of the world as a 41st economy in our analysis, setting the labor and capital variables to some arbitrary values. Doing this allows us to easily include intermediate and final demand from the rest of the world in our calculations while not affecting the measured values of labor productivity and TFP for our 40 economies of interest.

f: vector with element f_i^r giving the final demand for output of industry i in economy r $(NC \times 1)$; $\mathbf{f} = \mathbf{Fe}$ where $\mathbf{e}$ is the $C \times 1$ summation vector consisting of ones;

λ: vector with elements λ_i^r giving the use of labor per unit of gross output in industry i in economy r $(NC \times 1)$; and

μ: vector with elements μ_i^r giving the value added per unit of gross output in industry i in economy r $(NC \times 1)$.

In order to extend the analysis to a decomposition of TFP growth, we further define the following additional variables:

k: aggregate capital inputs (scalar),[8]

τ: vector with elements τ_i^r giving the use of capital per unit of gross output in industry i in economy r $(NC \times 1)$,

α: labor share in total compensation of capital and labor (scalar), and

β: capital share in total compensation of capital and labor (scalar).

Given the above definitions we can further define

$$v = \mu' \mathbf{x}$$

$$l = \lambda' \mathbf{Lf} \text{ and}$$

$$k = \tau' \mathbf{Lf}$$

where $\mathbf{x}$ is the $NC \times 1$ vector of gross output levels x_i^r of industry i in economy r:

$$\mathbf{x} = \mathbf{Ax} + \mathbf{f} = (\mathbf{I} - \mathbf{A})^{-1}\,\mathbf{f} = \mathbf{Lf}$$

To decompose TFP growth, we start with a general form of the production function:

$$v_t = F(\phi_t, l_t, k_t)$$

with ϕ being TFP. Taking logs and derivatives with respect to time we get

$$\frac{\dot{v}}{v} = \frac{F_\phi \phi}{v}\frac{\dot{\phi}}{\phi} + \frac{F_l l}{v}\frac{\dot{l}}{l} + \frac{F_k k}{v}\frac{\dot{k}}{k}$$

[8]We assume that capital is a primary factor of production rather than a produced input to production. In his analysis, Wolff (1985) assumes the latter by introducing an additional sector capturing the production of capital goods.

Assuming that technology is Hicks neutral, the growth rate of TFP $g^{\phi} = \frac{F\phi}{v}\frac{\dot{\phi}}{\phi}$ becomes $g^{\phi} = \frac{\dot{\phi}}{\phi}$, while assuming competitive markets implies that factors are paid their social marginal products; that is, $F_k = r$ and $F_l = w$. We can then write

$$g^{\phi} = \frac{\dot{v}}{v} - \frac{wl}{v}\frac{\dot{l}}{l} - \frac{rk}{v}\frac{\dot{k}}{k}$$

The capital and labor shares are written as $\beta = \frac{rk}{v}$ and $\alpha = \frac{wl}{v}$, and under the assumption of constant returns to scale we have $\beta + \alpha = 1$.

Using the discrete time approximation, we then have

$$\hat{g}^{\phi} = \ln\frac{v_t}{v_{t-1}} - \bar{\alpha}_t \ln\frac{l_t}{l_{t-1}} - \bar{\beta}_t \ln\frac{k_t}{k_{t-1}}$$

with

$$\hat{g}^{\phi} = \ln\frac{\phi_t}{\phi_{t-1}}$$

Using $v = \mu'\mathbf{Lf}$, $l = \lambda'\mathbf{Lf}$, and $k = \tau'\mathbf{Lf}$, we can write aggregate TFP growth as

$$\hat{g}^{\phi} = \ln\left(\frac{\mu_1'\mathbf{L_1f_1}}{\mu_0'\mathbf{L_0f_0}}\right) - \bar{\alpha}_t \ln\left(\frac{\lambda_1'\mathbf{L_1f_1}}{\lambda_0'\mathbf{L_0f_0}}\right) - \bar{\beta}_t \ln\left(\frac{\tau_1'\mathbf{L_1f_1}}{\tau_0'\mathbf{L_0f_0}}\right) \tag{1}$$

The first two terms on the right-hand side of equation (1) can be written as

$$\ln\frac{\mu_1'\mathbf{L_1f_1}}{\mu_0'\mathbf{L_1f_1}} + \ln\frac{\mu_0'\mathbf{L_1f_1}}{\mu_0'\mathbf{L_0f_1}} + \ln\frac{\mu_0'\mathbf{L_0f_1}}{\mu_0'\mathbf{L_0f_0}}$$

and

$$\bar{\alpha}_t\ln\frac{\lambda_1'\mathbf{L_1f_1}}{\lambda_0'\mathbf{L_1f_1}} + \bar{\alpha}_t\ln\frac{\lambda_0'\mathbf{L_1f_1}}{\lambda_0'\mathbf{L_0f_1}} + \bar{\alpha}_t\ln\frac{\lambda_0'\mathbf{L_0f_1}}{\lambda_0'\mathbf{L_0f_0}}$$

The third term can be written as

$$\bar{\beta}_t\ln\frac{\tau_1'\mathbf{L_1f_1}}{\tau_0'\mathbf{L_1f_1}} + \bar{\beta}_t\ln\frac{\tau_0'\mathbf{L_1f_1}}{\tau_0'\mathbf{L_0f_1}} + \bar{\beta}_t\ln\frac{\tau_0'\mathbf{L_0f_1}}{\tau_0'\mathbf{L_0f_0}}$$

Combining and rearranging these terms gives

$$\hat{g}^{\phi} = \ln\frac{\mu_1'\mathbf{L_1f_1}}{\mu_0'\mathbf{L_1f_1}} - \bar{\alpha}_t\ln\frac{\lambda_1'\mathbf{L_1f_1}}{\lambda_0'\mathbf{L_1f_1}} - \bar{\beta}_t\ln\frac{\tau_1'\mathbf{L_1f_1}}{\tau_0'\mathbf{L_1f_1}} + \left(\ln\frac{\mu_0'\mathbf{L_1f_1}}{\mu_0'\mathbf{L_0f_1}} - \bar{\alpha}_t\ln\frac{\lambda_0'\mathbf{L_1f_1}}{\lambda_0'\mathbf{L_0f_1}} - \bar{\beta}_t\ln\frac{\tau_0'\mathbf{L_1f_1}}{\tau_0'\mathbf{L_0f_1}}\right) + \left(\ln\frac{\mu_0'\mathbf{L_0f_1}}{\mu_0'\mathbf{L_0f_0}} - \bar{\alpha}_t\ln\frac{\lambda_0'\mathbf{L_0f_1}}{\lambda_0'\mathbf{L_0f_0}} - \bar{\beta}_t\ln\frac{\tau_0'\mathbf{L_0f_1}}{\tau_0'\mathbf{L_0f_0}}\right) \quad (2)$$

Dietzenbacher, Hoen, and Los (2000) note that equation (2) can be further decomposed to incorporate the distinction between the effects of aggregate production structure changes and aggregate final demand changes, and the effects of changing international trade (with respect to both intermediate inputs and final demand deliveries). To achieve this, the following matrices are defined:

$\mathbf{A}^*$: a matrix constructed by stacking C identical $N \times NC$ matrices of aggregate intermediate inputs per unit of gross output by industry and economy ($NC \times NC$ matrix), $\forall r. [a^*]_{ij}^{rs} = \sum_{r=1}^{C} a_{ij}^{rs}$;

$\mathbf{T^A}$: a matrix of intermediate trade coefficients, representing the shares of each economy in aggregate inputs by input, industry, and economy ($NC \times NC$ matrix), $[t^A]_{ij}^{rs} = a_{ij}^{rs} / [a^*]_{ij}^{rs}$, and $\sum_r [t^A]_{ij}^{rs} = 1$;

$\mathbf{F}^*$: a matrix constructed by stacking C identical $N \times C$ matrices of final demand for product i in economy s ($NC \times C$ matrix). $\forall r. [f^*]_i^{rs} = \sum_{r=1}^{C} f_i^{rs}1$; and

$\mathbf{T^F}$: a matrix of final demand trade coefficients, representing the shares of economy r in aggregate final demand for product i in economy s ($NC \times C$ matrix). $\left[t^F\right]_i^{rs} = f_i^{rs} / [f^*]_i^{rs}$, and $\sum_r \left[t^F\right]_i^{rs} = 1$.

We can then write the Leontief inverse as $\mathbf{L} = \left[\mathbf{I} - \mathbf{A}^* \circ \mathbf{T^A}\right]^{-1}$ and $\mathbf{f} = \left[\mathbf{F}^* \circ \mathbf{T^F}\right]\mathbf{e}$, where $\circ$ denotes the Hadamard product (of elementwise multiplication). Using these, we can decompose TFP growth further as

$$\hat{g}^{\phi} = [\theta_1] - [\theta_2] - [\theta_3] + [\theta_4] + [\theta_5] + [\theta_6] + [\theta_7] \quad (3)$$

with

$$\theta_1 = \ln\frac{\mu_1'\mathbf{L_1f_1}}{\mu_0'\mathbf{L_1f_1}}$$

representing the productivity effects of changes in the value added per unit of gross output by industry;

$$\theta_2 = \bar{\alpha}_t\ln\frac{\lambda_1'\mathbf{L_1f_1}}{\lambda_0'\mathbf{L_1f_1}}$$

representing the productivity effects of changes in labor requirements per unit of gross output by industry;

$$\theta_3 = \bar{\beta}_t \ln \frac{\tau_1' \mathbf{L_1 f_1}}{\tau_0' \mathbf{L_1 f_1}}$$

representing the productivity effects of changes in capital requirements per unit of gross output by industry;

$$\theta_4 = \left[\ln \frac{\mu_0' \left[\mathbf{I} - \left(\mathbf{A}_1^* \circ \mathbf{T}_1^{\mathrm{A}} \right) \right]^{-1} \mathbf{f}_1}{\mu_0' \left[\mathbf{I} - \left(\mathbf{A}_0^* \circ \mathbf{T}_1^{\mathrm{A}} \right) \right]^{-1} \mathbf{f}_1} - \bar{\alpha}_t \ln \frac{\lambda_0' \left[\mathbf{I} - \left(\mathbf{A}_1^* \circ \mathbf{T}_1^{\mathrm{A}} \right) \right]^{-1} \mathbf{f}_1}{\lambda_0' \left[\mathbf{I} - \left(\mathbf{A}_0^* \circ \mathbf{T}_1^{\mathrm{A}} \right) \right]^{-1} \mathbf{f}_1} \right.$$
$$\left. - \bar{\beta}_t \ln \frac{\tau_0' \left[\mathbf{I} - \left(\mathbf{A}_1^* \circ \mathbf{T}_1^{\mathrm{A}} \right) \right]^{-1} \mathbf{f}_1}{\tau_0' \left[\mathbf{I} - \left(\mathbf{A}_0^* \circ \mathbf{T}_1^{\mathrm{A}} \right) \right]^{-1} \mathbf{f}_1} \right]$$

representing the productivity effects of changes in the interindustry structure (e.g., due to technological change, factor substitution, and changing output compositions within industries);

$$\theta_5 = \left[\ln \frac{\mu_0' \left[\mathbf{I} - \left(\mathbf{A}_0^* \circ \mathbf{T}_1^{\mathrm{A}} \right) \right]^{-1} \mathbf{f}_1}{\mu_0' \left[\mathbf{I} - \left(\mathbf{A}_0^* \circ \mathbf{T}_0^{\mathrm{A}} \right) \right]^{-1} \mathbf{f}_1} - \bar{\alpha}_t \ln \frac{\lambda_0' \left[\mathbf{I} - \left(\mathbf{A}_0^* \circ \mathbf{T}_1^{\mathrm{A}} \right) \right]^{-1} \mathbf{f}_1}{\lambda_0' \left[\mathbf{I} - \left(\mathbf{A}_0^* \circ \mathbf{T}_0^{\mathrm{A}} \right) \right]^{-1} \mathbf{f}_1} \right.$$
$$\left. - \bar{\beta}_t \ln \frac{\tau_0' \left[\mathbf{I} - \left(\mathbf{A}_0^* \circ \mathbf{T}_1^{\mathrm{A}} \right) \right]^{-1} \mathbf{f}_1}{\tau_0' \left[\mathbf{I} - \left(\mathbf{A}_0^* \circ \mathbf{T}_0^{\mathrm{A}} \right) \right]^{-1} \mathbf{f}_1} \right]$$

representing the productivity effects of changes in trade structure with respect to commodities and services used as intermediate inputs (e.g., due to changes in sourcing patterns associated with GVCs);

$$\theta_6 = \left[\ln \frac{\mu_0' \mathbf{L_0} \left(\mathbf{F}_1^* \circ \mathbf{T}_1^{\mathbf{F}} \right) \mathbf{e}}{\mu_0' \mathbf{L_0} \left(\mathbf{F}_0^* \circ \mathbf{T}_1^{\mathbf{F}} \right) \mathbf{e}} - \bar{\alpha}_t \ln \frac{\lambda_0' \mathbf{L_0} \left(\mathbf{F}_1^* \circ \mathbf{T}_1^{\mathbf{F}} \right) \mathbf{e}}{\lambda_0' \mathbf{L_0} \left(\mathbf{F}_0^* \circ \mathbf{T}_1^{\mathbf{F}} \right) \mathbf{e}} - \bar{\beta}_t \ln \frac{\tau_0' \mathbf{L_0} \left(\mathbf{F}_1^* \circ \mathbf{T}_1^{\mathbf{F}} \right) \mathbf{e}}{\tau_0' \mathbf{L_0} \left(\mathbf{F}_0^* \circ \mathbf{T}_1^{\mathbf{F}} \right) \mathbf{e}} \right]$$

representing the productivity effects of changes in final demand composition (e.g., due to substitution by consumers, investors, or third economies following relative price changes or changing preference structures); and

$$\theta_7 = \left[\ln \frac{\mu_0' \mathbf{L_0} \left(\mathbf{F}_0^* \circ \mathbf{T}_1^{\mathbf{F}} \right) \mathbf{e}}{\mu_0' \mathbf{L_0} \left(\mathbf{F}_0^* \circ \mathbf{T}_0^{\mathbf{F}} \right) \mathbf{e}} - \bar{\alpha}_t \ln \frac{\lambda_0' \mathbf{L_0} \left(\mathbf{F}_0^* \circ \mathbf{T}_1^{\mathbf{F}} \right) \mathbf{e}}{\lambda_0' \mathbf{L_0} \left(\mathbf{F}_0^* \circ \mathbf{T}_0^{\mathbf{F}} \right) \mathbf{e}} - \bar{\beta}_t \ln \frac{\tau_0' \mathbf{L_0} \left(\mathbf{F}_0^* \circ \mathbf{T}_1^{\mathbf{F}} \right) \mathbf{e}}{\tau_0' \mathbf{L_0} \left(\mathbf{F}_1^* \circ \mathbf{T}_0^{\mathbf{F}} \right) \mathbf{e}} \right]$$

representing the productivity effects of changes in the trade structure as regards commodities and services used for final demand purposes.

Dietzenbacher, Hoen, and Los (2000) note that structural change decompositions are not unique and that the sensitivity of decomposition results can be very large. In the additive case, Dietzenbacher and Los (1998) find that reversing the weights and taking the average of the two types of decompositions generates results that are generally close to the average of all decomposition forms, with the variance of the results being much smaller. We follow Dietzenbacher, Hoen, and Los (2000) and undertake both decompositions, reporting the average of the two decompositions in the analysis below.

The above equations provide estimates of the various partial effects on TFP growth for the entire sample of 41 WIOD economies (including the rest of the world) aggregated across economies and industries. To obtain estimates for single economies (across industries) or single industries (across economies), we replace the vectors μ, λ, and τ with diagonal matrices with the same elements along the main diagonal and zeroes elsewhere, further premultiplying all numerators and denominators with $(1 \times NC)$ aggregation vectors.

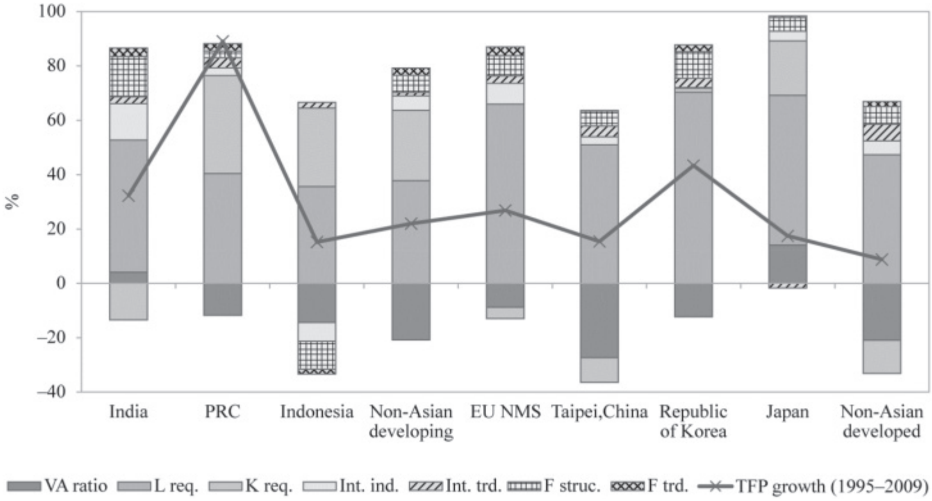
IV. Decomposition of Aggregate Total Factor Productivity Growth

This section reports results for the decomposition of TFP growth using the method described above. We begin by undertaking the decomposition of TFP growth for the aggregate (all 35 WIOD sectors) of each of our economies. Adopting the same approach as discussed in section II, we decompose aggregate real TFP growth by summing up year-on-year real TFP growth and year-on-year real changes in the components of TFP growth, calculated using previous year price data. As such, the Leontief inverse and the final demand vector are calculated in both current and previous year prices. After undertaking the decomposition of aggregate TFP growth, we then undertake the decomposition for manufacturing and services separately, calculating the contributions of the different components to the difference in TFP growth between manufacturing and services. When presenting the results, we report results for the full sample of 40 economies in the Appendix, with results for the six Asian economies and a comparison to (unweighted) average values for the other economy groups (EU NMS, non-Asian developing economies, and non-Asian developed economies) reported in the main text.

Figure 2 reports the results of the TFP decomposition for the six Asian economies and the three economy aggregates, with economies and regions listed in ascending order of initial TFP levels. Table A.3 in the Appendix reports results for the full sample of economies. The line in Figure 2 represents the growth rate of TFP between 1995 and 2009, while the bars decompose TFP growth into its constituent parts.[9] As we have already seen in section II, the growth rate of TFP between 1995

[9]Since some elements of the decompositions are negative (they work against the direction of the change in TFP), only the absolute value of the sum of the different terms equals 100%.

Figure 2. **Structural Decomposition of Total Factor Productivity Growth, 1995–2009**



EU NMS = European Union new member states, F struc. = final demand structure, F trd. = final demand composition, Int. ind. = intermediate input structure, Int. trd. = intermediate input composition, K req. = capital requirements, L req. = labor requirements, PRC = People's Republic of China, TFP = total factor productivity, VA ratio = value-added ratio.
Source: Authors' calculations.

and 2009 was found to be highest for the PRC at about 89%. The TFP growth rate was also above the sample average in India at about 32% and it exceeded the average in Indonesia and the Republic of Korea as well. In Japan and Taipei,China, TFP growth was lower than the sample average.

In terms of the decomposition, we observe positive values for the contribution of the growth of labor requirements for all economies, with the values being relatively large for all Asian economies except Japan and (to a lesser extent) Indonesia. These values were particularly large for the PRC. The values for this component tend to be large relative to the contributions of most other components, including capital requirements, which suggest that labor-saving process innovation and the substitution of direct labor played an important role in enhancing TFP in most economies, particularly in Asia. In the case of Asian economies, we find that the decline in labor input per unit of gross output would have increased TFP by between a low of 9 percentage points in Japan to a high of 47 percentage points in the PRC, assuming that no other factors changed. Relatively large effects of changes in labor requirements were also found for the Republic of Korea (43 percentage points) and Taipei,China (29 percentage points), which is perhaps surprising given its relatively poor TFP growth during the review period. Such outcomes are consistent with the results of Dietzenbacher, Hoen, and Los (2000) for European economies, who also found in their decomposition of labor productivity that the factor with the largest positive impact was the change in labor input per unit of gross output.

Also consistent with the results of Dietzenbacher, Hoen, and Los (2000) is the result that a smaller share of value added in gross output tends to have a productivity-decreasing effect. A potential explanation for such a development relates to the increasing role of GVCs in production that have led to more intermediate deliveries across borders, raising the intermediate content (and lowering the value added) of local gross production. However, there are a number of exceptions to this general conclusion as 11 economies in the full sample reported positive contributions from the change in value added to gross output, including a number of EU transition economies (e.g., Estonia, Latvia, Lithuania, Slovakia, Slovenia) as well as both Japan and India. In the case of Asian economies, the results suggest that the decline in value added to gross output would have decreased TFP by about 14 percentage points in the PRC had no other factors changed, with declines of about 15 percentage points observed for Taipei,China and about 7 percentage points for both Indonesia and the Republic of Korea. Even these smaller numbers for Indonesia and the Republic of Korea tend to be large relative to the other economy groups: declines of 5.4 percentage points, 3.1 percentage points, and 7.8 percentage points, respectively, were observed for non-Asian developed economies, EU NMS, and non-Asian developing economies.

The effects of changes in capital inputs per unit of gross output are mixed across economies, with declines in capital inputs per unit of gross output found to have lowered TFP in 22 economies and increased it in 18 economies. Among all economies, positive effects were the largest in the PRC (42 percentage points) by a wide margin. In Asia, the effects of declining capital usage per unit of gross output were also positive in Indonesia (13 percentage points), Japan (4 percentage points), and the Republic of Korea (1 percentage point), but had a negative impact in India (6 percentage points) and Taipei,China (5 percentage points).

In terms of the remaining four factors, our findings are again consistent with Dietzenbacher, Hoen, and Los (2000) in that there is little evidence of a large productivity growth effect in most economies. However, intermediate composition and intermediate trade structure play an important role in enhancing TFP growth in a number of economies, most notably in non-Asian developed economies, EU NMS, and India. Such results suggest that by changing their sourcing patterns and intermediate trade structure, these economies were able to increase TFP growth, a finding that may be related to the expanding role of GVCs and the increased fragmentation of production. In the case of India, the composition of intermediates is the stronger of the two effects, while for EU NMS and non-Asian developed economies the intermediate trade structure plays the more dominant role. This would suggest that among these two groups a realignment of economy sourcing patterns rather than shifts in intermediate composition due to technological change is the more important source of TFP growth.

Final demand composition and trade structure are also found to make a relatively large contribution to TFP growth for India, EU NMS, and non-Asian developed economies, with the final demand trade structure dominating the two effects. Final demand composition and trade structure together account for more than 10% of overall TFP growth in all other economies except the PRC, Indonesia, and Japan. In the case of Indonesia, the effects of final demand trade structure as well as the trade structure of intermediate demand are found to be negative.

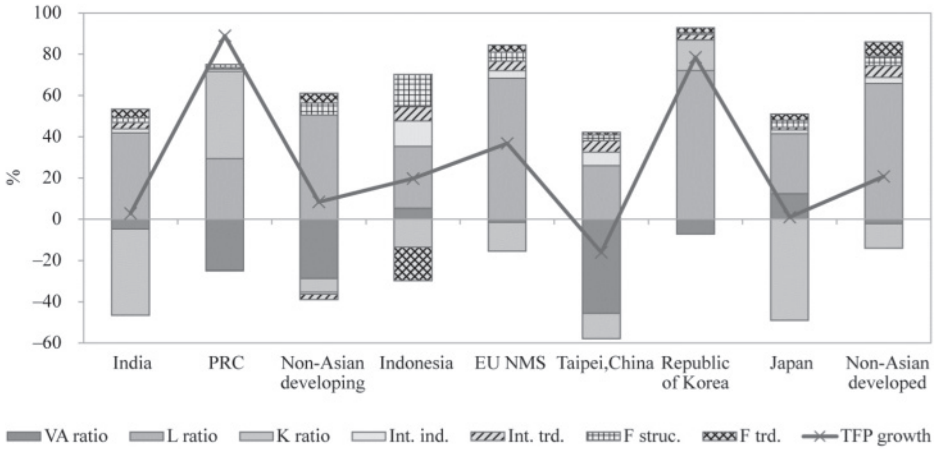
Overall, the results suggest that declining labor and capital requirements per unit of gross output are the main contributors to TFP growth, more than offsetting the negative effect of a smaller share of value added in gross output. The more successful Asian economies during the period tended to minimize their decline in the share of value added in gross output while significantly reducing the labor and capital requirements per unit of gross output. At the same time, there appears to be no single recipe for success, with the PRC benefiting significantly from a drop in capital requirements per unit of gross output, the Republic of Korea benefiting almost exclusively from a drop in labor requirements per unit of gross output, and India benefitting significantly from changes in the structure of intermediate and final demand.

We now turn to the discussion of the structural decomposition of TFP growth for manufacturing and services, examining whether the decomposition can shed any light on the differences in the evolution of TFP in manufacturing and services across economies. In Tables A.4 and A.5 in the Appendix, we report the full decomposition for all 40 economies for both manufacturing and services. In the main text, we concentrate on the comparison between the sample of Asian economies and the other three economy groups, reporting the decomposition of manufacturing and services TFP growth in Figures 3 and 4, respectively, and the results of the decomposition of the difference in the (cumulative) growth rate of TFP for manufacturing and services in Figure 5.[10]

Figures 3 and 4 reveal that declines in the ratio of labor and (to a lesser extent) capital requirements tend to explain the largest part of TFP growth in both manufacturing and services. While the importance of labor requirements is fairly consistent across economies and economy groups, the results for capital requirements are mixed. A declining ratio of capital to gross output spurred TFP growth in both manufacturing and services in the PRC; in manufacturing in the Republic of Korea; and in services in Indonesia, Japan, and non-Asian developing economies. In the case of manufacturing, however, an increasing ratio of capital to gross output negatively impacted TFP growth in many economies, most notably India; Indonesia; Japan; and Taipei,China. Reductions in TFP growth in services due to increasing ratios of capital to gross output are observed for Taipei,China and non-Asian developed economies.

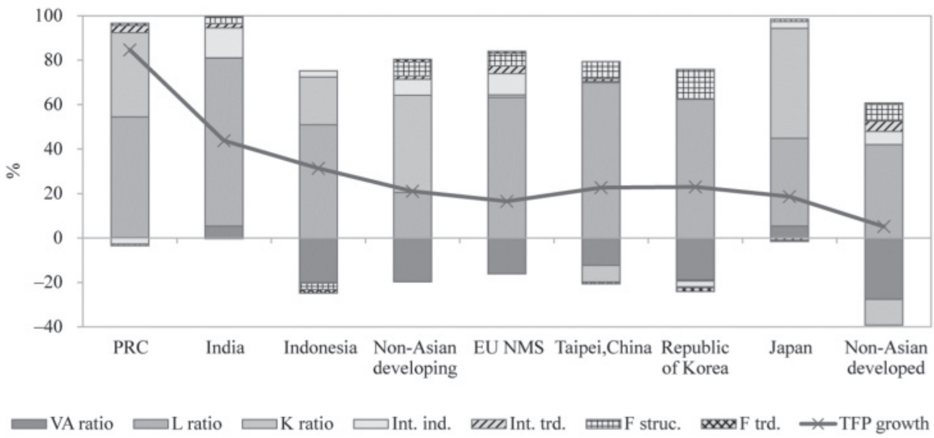
[10]These contributions are calculated simply as the difference in the values of the contributions to manufacturing and services TFP growth.

Figure 3. **Structural Decomposition of Manufacturing Total Factor Productivity Growth, 1995–2009**



EU NMS = European Union new member states, F struc. = final demand structure, F trd. = final demand composition, Int. ind. = intermediate input structure, Int. trd. = intermediate input composition, K ratio = capital ratio, L ratio = labor ratio, PRC = People's Republic of China, TFP = total factor productivity, VA ratio = value-added ratio.
Source: Authors' calculations.

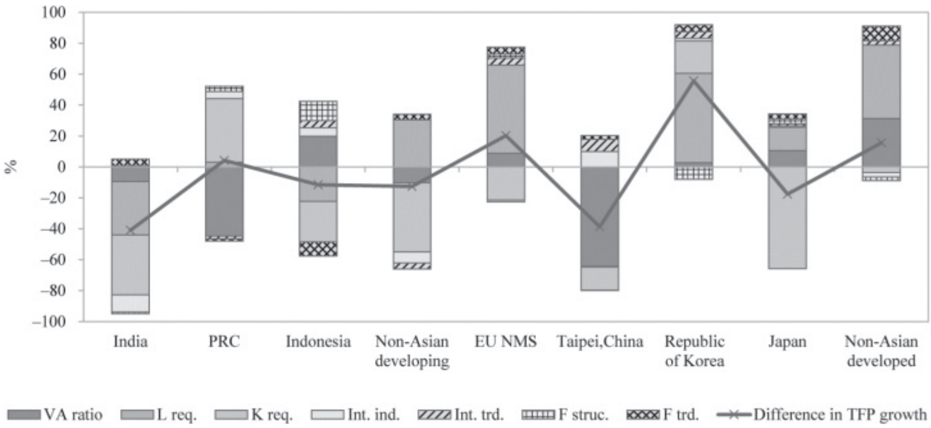
Figure 4. **Structural Decomposition of Services Total Factor Productivity Growth, 1995–2009**



EU NMS = European Union new member states, F struc. = final demand structure, F trd. = final demand composition, Int. ind. = intermediate input structure, Int. trd. = intermediate input composition, K ratio = capital ratio, L ratio = labor ratio, PRC = People's Republic of China, TFP = total factor productivity, VA ratio = value-added ratio.
Source: Authors' calculations.

The results in Figures 3 and 4 further show that changes in intermediate and final demand structure and trade play an important role in some economies. Changes in intermediate and final demand structure account for a relatively large

Figure 5. **Structural Decomposition of Differences in Manufacturing and Services Total Factor Productivity Growth, 1995–2009**



EU NMS = European Union new member states, F struc. = final demand structure, F trd. = final demand composition, Int. ind. = intermediate input structure, Int. trd. = intermediate input composition, K req. = capital requirements, L req. = labor requirements, PRC = People's Republic of China, TFP = total factor productivity, VA ratio = value-added ratio.
Source: Authors' calculations.

proportion of the TFP growth in manufacturing in Indonesia. These two terms are also relatively important for services TFP growth in India; the Republic of Korea; and Taipei,China; as well as in non-Asian developed economies and non-Asian developing economies.

Given the discussion in section II, an explanation is desired for the varying performance of manufacturing and services TFP growth across economies, including whether there is a single explanation for the relatively faster growth of TFP for services in many Asian economies. Figure 5 plots the difference in growth between manufacturing and services (solid line) for select economies and economy groups, with a negative value indicating that TFP grew faster in services than in manufacturing. While in many cases, the difference in TFP growth between manufacturing and services during the review period was relatively small, in other cases, the differences were large. For example, TFP growth in manufacturing exceeded that in services by more than 50 percentage points in the Republic of Korea, while TFP growth in services exceeded that in manufacturing by about 40 percentage points in India and Taipei,China.

Figure 5 reports the contributions of the different decomposition terms to the difference in TFP growth between manufacturing and services. For most economies, the majority of the difference in TFP growth between manufacturing and services is due to differences in the ratios of labor and capital to gross output, highlighting the role of capital requirements. There are some exceptions, however, with Japan being an interesting example. The decline in capital requirements in Japan was strong in services, explaining all of the difference in TFP growth between manufacturing and services; but the decline in labor requirements favored the manufacturing sector, thus dampening the difference between TFP growth in services and manufacturing. A similar outcome was found for non-Asian developing economies, while TFP growth was higher in manufacturing in EU NMS. Declines in the ratio of value added to gross output tended to be larger in the sector that performed relatively poorly, which can also help explain differences in TFP growth between manufacturing and services. There are exceptions, however, with the changes in value added to gross output dampening the productivity advantage of manufacturing in the PRC and the productivity advantage of services in Indonesia and Japan. While smaller, there is also a significant effect from structural change (changing structure of intermediate and final demand) for many economies, with changes in intermediate trade patterns also being relevant for a number of economies, most notably India; Indonesia; and Taipei,China.

Considering the economies in which we observe a higher TFP growth rate in services, there is no pattern that clearly stands out in terms of the factors driving the services advantage. Among Asian economies, India stands out in terms of its high contribution of the structure of intermediates to the services advantage, suggesting that structural change has been relatively important there. This term also plays a relatively important role in the case of non-Asian developing economies. In the cases of Taipei,China and Indonesia, the structure of intermediates also plays an important role by dampening the differences in TFP growth between services and manufacturing. In Indonesia, final demand trade is an important contributor to the TFP growth advantage of services relative to manufacturing, with the structure of intermediates and the structure of final demand and intermediate trade dampening this advantage. Taipei,China represents another interesting example, with relatively strong declines in the ratio of capital to gross output in services and in the ratio of value added to gross output in manufacturing explaining the TFP growth advantage for services. The relatively strong decline in value added in gross output for manufacturing in Taipei,China can be contrasted with the relatively strong decline in value added to gross output for services in the PRC. In Japan, changes in all factors other than the ratio of capital to gross output favor the manufacturing sector, emphasizing the relatively strong decline in the ratio of capital to gross output in services that enabled services TFP growth to be higher than manufacturing TFP growth during the review period.

V. Conclusion

This paper examined differences in TFP growth among a sample of 40 economies, including six Asian economies, and further distinguished between TFP growth in the manufacturing and service sectors. Over the period 1995–2009, Asian economies tended to perform relatively well in terms of TFP growth, partially reflecting a convergence in TFP levels. Consistent with existing evidence, TFP growth in manufacturing tended to outpace that in services for most economies. There are exceptions, however, particularly among Asian economies, suggesting that productivity growth in services need not always be lower than that in manufacturing.

To shed light on these productivity growth differentials across economies and between manufacturing and services, this paper introduced a novel structural decomposition of TFP growth into effects due to changes in factor requirements per unit of gross output, changes in value added per unit of gross output, and changes in the structure and composition of intermediate and final goods. The results suggest that, for most economies, declines in factor requirements—labor in particular—per unit of gross output can explain a large proportion of TFP growth over the period 1995–2009. Furthermore, declines in factor usage offset the negative contribution to TFP growth of a declining ratio of value added to gross output. Changes in the structure and composition of intermediate and final goods tended to contribute less to TFP growth, though they remain important for some economies, particularly changes in the structure of intermediate and final goods, which may partly reflect the role of GVCs in changing sourcing patterns.

The relatively strong performance of services in Asian economies during the review period does not appear to have a single explanation in terms of our decomposition calculations, which show interesting differences among Asian economies. While factor requirements, particularly capital requirements, per unit of gross output remain important for most economies, changes in the structure of intermediates and in final demand composition are also important factors for some economies in explaining the services advantage.

Our findings suggest that although factors such as trade, structural change, and demand dynamics can play a significant role in some economies, they are not the factors that have driven the rise of the service sector in Asia. Rather, changing labor requirements have driven productivity growth in services in Asia. Thus, the idea of services as a traditional sector in which (labor) productivity cannot grow at high rates is subject to revision, particularly with regard to Asia.

References*

Amador, João, and Sónia Cabral. 2016. "Global Value Chains: Surveying Drivers, Measures, and Impacts." *Journal of Economic Surveys* 30 (2): 278–301.

Baumol, William. 1967. "Macroeconomics of Unbalanced Growth: The Anatomy of Urban Crisis." *American Economic Review* 57 (3): 415–26.

Chenery, Hollis, Shuntaro Shishido, and Tsunehiko Watanabe. 1962. "The Pattern of Japanese Growth, 1914–1954." *Econometrica* 30 (1): 98–139.

*ADB recognizes "Hong Kong" as Hong Kong, China.

Dietzenbacher, Erik, Alex Hoen, and Bart Los. 2000. "Labor Productivity in Western Europe 1975–1985: An Intereconomy Interindustry Analysis." *Journal of Regional Science* 40 (3): 425–52.

Dietzenbacher, Erik, and Bart Los. 1998. "Structural Decomposition Techniques: Sense and Sensitivity." *Economic Systems Research* 10 (4): 307–23.

Elsby, Michael, Bart Hobijn, and Aysegül Sahin. 2013. "The Decline of the US Labor Share." *Brookings Papers on Economic Activity* 2013 (2): 1–63.

Feldman, Stanley, David McClain, and Karen Palmer. 1987. "Sources of Structural Change in the United States." *Review of Economics and Statistics* 69 (3): 503–10.

Felipe, Jesus. 1997. "Total Factor Productivity Growth in East Asia: A Critical Survey." EDRC Report Series No. 5. Manila: Asian Development Bank.

Krugman, Paul. 1994. "The Myth of Asia's Miracle." *Foreign Affairs* 73 (6): 62–78.

McMillan, Margaret, Dani Rodrik, and Íñigo Verduzco-Gallo. 2014. "Globalization, Structural Change, and Productivity Growth, with an Update on Africa." *World Development* 63 (Special Issue): 11–32.

Miller, Ronald, and Peter Blair. 2009. *Input–Output Analysis: Foundations and Extensions (Second Edition)*. Cambridge: Cambridge University Press.

Timmer, Marcel. 2015. "An Illustrated User Guide to the World Input–Output Database: The Case of Global Automotive Production." *Review of International Economics* 23 (3): 575–605.

Timmer, Marcel, Gaaitzen de Vries, and Klaas de Vries. 2015. "Structural Transformation in Africa: Static Gains, Dynamic Losses." *Journal of Development Studies* 51 (6): 674–88.

Park, Donghyun, and Marcus Noland, eds. 2013. *Developing the Service Sector as an Engine of Growth for Asia*. Manila: Asian Development Bank.

Temple, Jonathan. 1999. "The New Growth Evidence." *Journal of Economic Literature* 37 (1): 112–56.

Wolff, Edward. 1985. "Industrial Composition, Interindustry Effects, and the US Productivity Slowdown." *Review of Economics and Statistics* 67 (2): 268–77.

Young, Alwyn. 1992. "A Tale of Two Cities: Factor Accumulation and Technical Change in Hong Kong and Singapore." *NBER Macroeconomics Annual* 7 (1992): 13–64.

Appendix

Table A.1. **List of Economies**

Code	Economy	Region
PRC	People's Republic of China	Asia
TAP	Taipei,China	
IND	India	
INO	Indonesia	
JPN	Japan	
KOR	Republic of Korea	
AUT	Austria	EU15
BEL	Belgium	
DEN	Denmark	
FIN	Finland	
FRA	France	
GER	Germany	
GRC	Greece	
IRE	Ireland	
ITA	Italy	
LUX	Luxembourg	
NET	The Netherlands	
POR	Portugal	
SPA	Spain	
SWE	Sweden	
UKG	United Kingdom	
BGR	Bulgaria	EU12
CYP	Cyprus	
CZE	Czech Republic	
EST	Estonia	
HUN	Hungary	
LVA	Latvia	
LTU	Lithuania	
MLT	Malta	
POL	Poland	
ROU	Romania	
SVK	Slovakia	
SVN	Slovenia	
BRA	Brazil	Americas
CAN	Canada	
MEX	Mexico	
USA	United States	
AUS	Australia	Other
RUS	Russian Federation	
TUR	Turkey	

EU = European Union.
Source: World Input–Output Database. www.wiod.org

Table A.2. **Industries and Industry Classification**

Code	Industry	Sector
AtB	Agriculture, Hunting, Forestry, and Fishing	Primary
C	Mining and Quarrying	
15t16	Food, Beverages, and Tobacco	Manufacturing
17t18	Textiles and Textile Products	
19	Leather, Leather and Footwear	
20	Wood and Products of Wood and Cork	
21t22	Pulp, Paper, and Printing and Publishing	
23	Coke, Refined Petroleum, and Nuclear Fuel	
24	Chemicals and Chemical Products	
25	Rubber and Plastics	
26	Other Non-Metallic Mineral	
27t28	Basic Metals and Fabricated Metal	
29	Machinery, not elsewhere classified	
30t33	Electrical and Optical Equipment	
34t35	Transport Equipment	
36t37	Manufacturing, not elsewhere classified; Recycling	
E	Electricity, Gas, and Water Supply	Services
F	Construction	
50	Sale, Maintenance, and Repair of Motor Vehicles and Motorcycles; Retail Sale of Fuel	
51	Wholesale Trade and Commission Trade, Except of Motor Vehicles and Motorcycles	
52	Retail Trade, Except of Motor Vehicles and Motorcycles; Repair of Household Goods	
H	Hotels and Restaurants	
60	Inland Transport	
61	Water Transport	
62	Air Transport	
63	Other Supporting and Auxiliary Transport Activities; Activities of Travel Agencies	
64	Post and Telecommunications	
J	Financial Intermediation	
70	Real Estate Activities	
71t74	Renting of Machinery and Equipment and Other Business Activities	
L	Public Administration and Defense; Compulsory Social Security	
M	Education	
N	Health and Social Work	
O	Other Community, Social and Personal Services	
P	Private Households with Employed Persons	

Source: World Input–Output Database. www.wiod.org

Table A.3. **Total Factor Productivity Growth Decomposition, 1995–2009**

			Due to changes in						
Economy	ϕ_{1995}	$\hat{g}^{\phi}$	θ_1	θ_2	θ_3	θ_4	θ_5	θ_6	θ_7
Asia									
People's Republic of China	0.467	0.890	−0.137	0.471	0.419	0.033	0.044	0.029	0.032
Taipei,China	4.021	0.154	−0.154	0.288	−0.051	0.017	0.022	0.031	0.001
India	0.388	0.322	0.018	0.214	−0.059	0.059	0.011	0.065	0.014
Indonesia	0.913	0.152	−0.066	0.163	0.132	−0.031	0.010	−0.047	−0.008
Japan	5.383	0.175	0.025	0.100	0.036	0.006	−0.003	0.009	0.001
Republic of Korea	4.802	0.434	−0.071	0.405	0.008	0.001	0.019	0.057	0.014
Non-Asian Developed									
Australia	4.1621	0.0531	−0.0043	0.0782	−0.0370	0.0163	−0.0056	0.0040	0.0014
Austria	7.8286	0.1474	−0.0828	0.1541	0.0141	0.0116	0.0150	0.0321	0.0033
Belgium	8.9137	0.0396	−0.0517	0.1038	−0.0452	0.0058	−0.0022	0.0276	0.0015
Canada	3.8174	0.1652	−0.0461	0.1940	−0.0124	0.0029	0.0146	0.0110	0.0012
Denmark	6.7582	0.0189	−0.1026	0.1081	−0.0203	0.0067	0.0038	0.0228	0.0004
Finland	6.4933	0.1960	−0.0435	0.1699	0.0110	0.0014	0.0255	0.0261	0.0055
France	5.9256	0.1794	−0.0232	0.1521	0.0250	0.0170	0.0025	0.0026	0.0034
Germany	8.1046	0.0919	−0.0442	0.1223	−0.0162	0.0049	−0.0002	0.0277	−0.0023
Greece	2.2155	0.0367	0.0308	0.0871	−0.1452	0.0384	0.0148	0.0119	−0.0012
Ireland	4.8688	0.0700	−0.1150	0.1333	−0.0783	0.0230	0.1177	−0.0722	0.0616
Italy	5.4731	−0.0540	−0.0870	0.0476	0.0045	−0.0266	0.0060	−0.0003	0.0016
Luxembourg	5.1222	0.0601	−0.2815	0.0626	0.0797	0.0348	0.0956	0.0581	0.0108
The Netherlands	7.1505	0.1395	−0.0047	0.1289	−0.0081	0.0057	0.0004	0.0195	−0.0022
Portugal	3.4868	−0.0159	−0.0263	0.0628	−0.1363	0.0317	0.0013	0.0430	0.0081
Spain	4.8753	0.0282	−0.0641	0.0959	−0.0386	0.0141	−0.0014	0.0220	0.0004
Sweden	6.9286	0.1698	0.0217	0.1554	−0.0562	0.0045	0.0092	0.0290	0.0063
United Kingdom	6.0607	0.1316	−0.0718	0.2190	−0.0439	0.0249	−0.0102	0.0238	−0.0102
United States	5.3957	0.1313	0.0164	0.1516	−0.0721	0.0217	−0.0023	0.0171	−0.0012

Continued.

Table A.3. *Continued.*

			Due to changes in						
Economy	ϕ_{1995}	$\hat{g}^{\phi}$	θ_1	θ_2	θ_3	θ_4	θ_5	θ_6	θ_7
European Union New Member States									
Bulgaria	0.7151	0.0769	−0.1387	0.1376	0.0301	0.0261	−0.0304	0.0422	0.0099
Cyprus	3.1554	0.2449	−0.1360	0.1441	0.1465	0.0329	0.0260	0.0073	0.0242
Czech Republic	0.8095	0.2399	−0.1433	0.2927	0.0376	0.0185	0.0086	0.0099	0.0160
Estonia	1.1291	0.3414	0.0959	0.3010	−0.1815	0.0511	0.0266	0.0463	0.0021
Hungary	1.4047	0.3020	−0.0367	0.2055	0.0597	0.0013	0.0033	0.0306	0.0383
Latvia	1.0395	0.3152	0.0799	0.2874	−0.0851	−0.0028	0.0272	0.0067	0.0047
Lithuania	0.7382	0.2936	0.1278	0.1691	−0.0495	0.0293	0.0210	−0.0132	0.0092
Malta	2.5036	0.1225	−0.0885	0.1863	0.0399	0.0277	0.0005	−0.0244	−0.0191
Poland	4.2647	0.5230	−0.0511	0.4125	0.0561	0.0570	0.0086	0.0352	0.0047
Romania	0.8988	0.1932	−0.1873	0.2875	−0.0052	0.0378	−0.0001	0.0572	0.0033
Slovakia	0.7569	0.2710	0.0844	0.2011	−0.1819	0.0228	0.0266	0.0859	0.0321
Slovenia	6.1826	0.2924	0.0157	0.2424	−0.0531	0.0297	0.0008	0.0408	0.0161
Non-Asian Developing									
Brazil	1.1488	−0.0022	0.0126	0.0562	−0.0741	0.0094	−0.0123	0.0082	−0.0022
Mexico	0.6300	0.2891	−0.0513	0.0041	0.2796	0.0116	0.0089	0.0340	0.0023
Russian Federation	1.1176	0.2662	−0.1233	0.2548	0.0606	0.0227	0.0085	0.0112	0.0318
Turkey	0.9241	0.3278	−0.1515	0.2551	0.1241	0.0359	0.0132	0.0424	0.0086

Note: The figures for the different decompositions are the averages of the original and alternative decomposition.
Source: Authors' calculations.

Table A.4. **Total Factor Productivity Growth Decomposition for Manufacturing, 1995–2009**

			Due to changes in						
Economy	ϕ_{1995}	$\hat{g}^{\phi}$	θ_1	θ_2	θ_3	θ_4	θ_5	θ_6	θ_7
Asia									
People's Republic of China	0.6819	0.8885	−0.4410	0.5227	0.7533	0.0199	0.0113	0.0269	−0.0046
Taipei,China	3.6599	−0.1611	−0.4669	0.2669	−0.1263	0.0666	0.0569	0.0293	0.0124
India	0.4328	0.0284	−0.0195	0.1750	−0.1753	0.0083	0.0127	0.0094	0.0177
Indonesia	1.5638	0.1972	0.0261	0.1467	−0.0663	0.0599	0.0337	0.0763	−0.0792
Japan	6.6165	0.0108	0.0683	0.1606	−0.2708	0.0105	0.0064	0.0197	0.0161
Republic of Korea	3.7263	0.7857	−0.0654	0.6603	0.1364	0.0002	0.0255	0.0064	0.0222
Non-Asian Developed									
Australia	6.0484	−0.1256	0.0029	0.1063	−0.2778	0.0296	−0.0075	0.0085	0.0124
Austria	10.5885	0.2868	−0.0874	0.2698	0.0769	0.0072	−0.0038	0.0193	0.0049
Belgium	11.7211	0.2050	0.0082	0.2063	−0.0499	0.0036	0.0123	0.0104	0.0139
Canada	5.4917	0.3370	−0.0745	0.2620	0.1364	0.0082	−0.0007	0.0040	0.0016
Denmark	11.8119	0.0882	−0.0576	0.1739	−0.0804	0.0043	0.0132	0.0127	0.0221
Finland	7.6082	0.5512	0.1438	0.2124	0.0320	0.0433	0.0591	0.0292	0.0313
France	10.2178	0.4884	−0.2497	0.5577	0.1346	0.0056	0.0109	0.0170	0.0123
Germany	17.9087	0.2332	−0.1023	0.2933	0.0010	0.0122	−0.0017	0.0303	0.0004
Greece	3.9284	0.0703	0.1676	−0.0338	−0.1018	−0.0015	0.0156	0.0237	0.0005
Ireland	4.4514	0.2715	−0.1803	0.2188	0.0071	−0.0061	0.1237	−0.0066	0.1148
Italy	7.4108	−0.1124	−0.0977	0.0634	−0.0793	−0.0010	−0.0037	0.0049	0.0010
Luxembourg	9.3344	−0.1854	−0.1323	−0.0710	−0.0309	−0.0003	0.0084	−0.0048	0.0454
The Netherlands	9.1235	0.1555	0.0342	0.1535	−0.1143	0.0057	0.0169	0.0234	0.0361
Portugal	3.4419	0.3457	0.1371	0.1672	0.0103	0.0023	0.0116	0.0079	0.0092
Spain	6.4917	0.0140	−0.1467	0.1646	−0.0380	0.0039	0.0033	0.0144	0.0124
Sweden	7.8720	0.4109	0.2108	0.2038	−0.1056	0.0188	0.0308	0.0248	0.0274
United Kingdom	10.0075	0.3078	0.0920	0.2609	−0.0485	−0.0023	0.0030	0.0007	0.0020
United States	7.1393	0.3900	0.2247	0.2089	−0.0930	0.0183	0.0028	0.0164	0.0120

Continued.

Table A.4. *Continued.*

			Due to changes in						
Economy	ϕ_{1995}	$\hat{g}^{\phi}$	θ_1	θ_2	θ_3	θ_4	θ_5	θ_6	θ_7
European Union New Member States									
Bulgaria	1.3308	−0.1640	−0.1778	0.0871	−0.1473	0.0573	0.0193	0.0307	−0.0334
Cyprus	4.2131	0.1055	−0.1429	0.1270	0.0007	0.0434	0.0043	0.0147	0.0583
Czech Republic	1.1684	0.5157	−0.0273	0.4615	0.0344	0.0054	0.0179	0.0118	0.0119
Estonia	1.3701	0.5832	0.0708	0.5982	−0.1985	0.0235	0.0387	0.0489	0.0015
Hungary	1.8649	0.3905	−0.0618	0.2568	−0.0798	0.0391	0.0569	0.0688	0.1105
Latvia	1.3189	0.3172	0.1029	0.4245	−0.2411	−0.0003	0.0249	0.0089	−0.0026
Lithuania	1.1018	0.4132	0.1512	0.4045	−0.2244	0.0019	0.0357	0.0123	0.0320
Malta	4.1571	0.1103	0.2359	0.1129	−0.2093	−0.0062	0.0357	−0.0580	−0.0006
Poland	2.2029	0.8705	−0.1086	0.7175	0.2036	0.0244	0.0064	0.0295	−0.0023
Romania	1.1270	0.2242	−0.1383	0.3295	−0.0467	0.0211	0.0032	0.0713	−0.0158
Slovakia	1.1204	0.5060	−0.0705	0.4122	0.0426	0.0237	0.0485	0.0187	0.0308
Slovenia	5.7655	0.5348	0.0739	0.4334	−0.0317	−0.0014	0.0099	0.0209	0.0299
Non-Asian Developing									
Brazil	1.7980	−0.3672	0.2195	−0.0654	−0.5347	0.0113	−0.0203	0.0295	−0.0071
Mexico	1.0849	0.1501	−0.1517	0.0888	0.1653	0.0064	0.0028	0.0282	0.0103
Russian Federation	1.0494	0.4235	−0.0463	0.3664	0.0257	0.0002	0.0071	−0.0305	0.1010
Turkey	1.0638	0.1288	−0.4546	0.3743	0.2415	−0.0309	−0.0298	0.0618	−0.0335

Note: The figures for the different decompositions are the averages of the original and alternative decomposition.
Source: Authors' calculations.

Table A.5. **Total Factor Productivity Growth Decomposition for Services, 1995–2009**

			Due to changes in						
Economy	ϕ_{1995}	$\hat{g}^{\phi}$	θ_1	θ_2	θ_3	θ_4	θ_5	θ_6	θ_7
Asia									
People's Republic of China	0.4088	0.8465	0.0020	0.4933	0.3436	−0.0246	0.0299	−0.0064	0.0087
Taipei,China	4.1901	0.2266	−0.0475	0.2697	−0.0289	0.0019	0.0050	0.0297	−0.0033
India	0.5239	0.4377	0.0234	0.3326	0.0010	0.0589	0.0086	0.0144	−0.0011
Indonesia	0.8318	0.3133	−0.1244	0.3162	0.1333	0.0174	−0.0012	−0.0185	−0.0096
Japan	5.4801	0.1863	0.0103	0.0759	0.0951	0.0057	−0.0017	0.0021	−0.0012
Republic of Korea	5.0751	0.2295	−0.0833	0.2768	−0.0024	−0.0116	−0.0016	0.0597	−0.0081
Non-Asian Developed									
Australia	4.2907	0.0993	−0.0073	0.0721	0.0127	0.0136	0.0003	0.0070	0.0010
Austria	6.9717	0.0749	−0.0854	0.1084	0.0094	0.0103	0.0115	0.0197	0.0009
Belgium	8.5545	0.0075	−0.0683	0.0849	−0.0452	0.0084	−0.0019	0.0285	0.0009
Canada	4.0187	0.1579	−0.0362	0.1938	−0.0222	0.0072	0.0030	0.0119	0.0005
Denmark	6.4917	0.0040	−0.1159	0.0898	−0.0128	0.0155	0.0014	0.0268	−0.0008
Finland	6.4934	0.0396	−0.1216	0.1356	0.0126	0.0004	0.0029	0.0092	0.0006
France	5.4831	0.1202	0.0169	0.0731	0.0146	0.0174	0.0004	−0.0039	0.0017
Germany	6.1790	0.0552	−0.0293	0.0725	−0.0205	0.0076	0.0038	0.0201	0.0011
Greece	2.1278	0.0078	0.0089	0.0997	−0.1470	0.0259	0.0098	0.0101	0.0004
Ireland	6.2150	−0.0358	−0.0845	0.0711	−0.0698	0.0151	0.0551	−0.0389	0.0161
Italy	5.1054	−0.0605	−0.0886	0.0309	0.0252	−0.0394	0.0118	−0.0051	0.0047
Luxembourg	4.5966	0.0841	−0.3011	0.0716	0.1032	0.0374	0.1038	0.0623	0.0069
The Netherlands	7.4554	0.1242	−0.0294	0.1235	−0.0084	0.0127	−0.0012	0.0271	−0.0001
Portugal	3.5133	−0.0988	−0.0302	0.0074	−0.1560	0.0347	−0.0023	0.0478	−0.0001
Spain	4.9791	0.0066	−0.0453	0.0557	−0.0399	0.0148	−0.0021	0.0230	0.0005
Sweden	6.8677	0.0894	−0.0311	0.1345	−0.0474	0.0050	0.0059	0.0215	0.0010
United Kingdom	5.8772	0.1473	−0.1080	0.2235	−0.0367	0.0407	0.0009	0.0305	−0.0036
United States	5.3727	0.0966	−0.0189	0.1463	−0.0705	0.0253	−0.0027	0.0184	−0.0014

Continued.

Table A.5. *Continued.*

			Due to changes in						
Economy	ϕ_{1995}	$\hat{g}^{\phi}$	θ_1	θ_2	θ_3	θ_4	θ_5	θ_6	θ_7
European Union New Member States									
Bulgaria	0.5193	0.1419	−0.1345	0.1531	0.1146	−0.0118	−0.0049	0.0368	−0.0114
Cyprus	3.2515	0.2534	−0.1391	0.1699	0.1641	0.0293	0.0287	−0.0066	0.0072
Czech Republic	0.7240	0.1044	−0.1887	0.2139	0.0478	0.0218	−0.0016	0.0073	0.0039
Estonia	1.0897	0.2330	0.0911	0.1927	−0.1733	0.0584	0.0153	0.0474	0.0014
Hungary	1.2971	0.1457	−0.0201	0.0963	0.0661	−0.0064	−0.0039	0.0128	0.0009
Latvia	0.9416	0.2427	0.0712	0.2126	−0.0423	0.0100	0.0323	−0.0118	−0.0005
Lithuania	0.7045	0.2256	0.1236	0.0820	−0.0124	0.0200	0.0220	−0.0126	0.0031
Malta	2.3092	0.1506	−0.1522	0.2074	0.0823	0.0371	0.0028	−0.0169	−0.0100
Poland	1.7385	0.2183	−0.0432	0.1521	0.0289	0.0771	0.0026	−0.0068	0.0076
Romania	0.6998	0.0673	−0.2031	0.1872	0.0703	0.0109	−0.0027	0.0022	0.0025
Slovakia	0.6631	0.1397	0.1227	0.1081	−0.2260	0.0115	0.0115	0.0914	0.0206
Slovenia	4.5893	0.0635	−0.0042	0.1022	−0.0846	0.0248	0.0009	0.0241	0.0003
Non-Asian Developing									
Brazil	1.2283	0.0616	−0.0318	−0.0058	0.0795	0.0111	0.0006	0.0062	0.0018
Mexico	0.6301	0.2813	−0.0254	−0.0443	0.2919	0.0181	−0.0002	0.0403	0.0008
Russian Federation	1.3459	0.2180	−0.1452	0.2050	0.0943	0.0249	0.0066	0.0333	−0.0008
Turkey	0.7807	0.2802	−0.0689	0.1282	0.1398	0.0461	0.0134	0.0078	0.0139

Note: The figures for the different decompositions are the averages of the original and alternative decomposition.
Source: Authors' calculations.