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Sangho Kim is Professor at the Department of International Trade, Honam University. Donghyun Park is Principal Economist in the Economics and Research Department, Asian Development Bank. Jong-Ho Park is Professor in the Department of Business Administration, Sunchon National University.

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Asian Development Bank
6 ADB Avenue, Mandaluyong City
1550 Metro Manila, Philippines
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Contents

Abstract

We apply a stochastic frontier production model to data from 53 countries during 1991–2003 to estimate total factor productivity growth, and decompose it into technical efficiency change and technical progress. Our empirical results indicate that world productivity growth was led by fast-growing newly emerging economies, whereas most developed countries experienced a decrease in productivity growth. Technical efficiency change significantly contributed to economic growth for many fast-growing countries, even though emerging economies still lag far behind developed countries in terms of technical efficiency.

I. Introduction

The worldwide scale of the global crisis underlines the extent of economic globalization. Although the impact of the crisis has varied between developed and developing countries, and across different regions and countries, no corner of the world has been immune. Growing trade and financial linkages mean that events in any region or country have tangible repercussions throughout the world. Of particular interest to us is the international interdependence of economic growth. The primary transmission mechanism that spread the global crisis from developed to developing countries was the trade channel. The spillover of the crisis from the financial markets to the real economies brought about a sharp recession in the European Union (EU) and the United States (US) , severely curtailing their appetite for imports. The consequent contraction of global trade had a pronounced impact on developing countries' exports and growth, especially in the fourth quarter of 2008 and first half of 2009. Likewise, the unexpectedly fast and robust recovery of developing countries, especially developing Asia, is contributing to the recovery of developed countries. Given such growing interdependence of economic growth across different groups of countries, it is worthwhile to look at economic growth across the world.

The two main sources of economic growth are accumulation of factors of production—more capital and labor—and total factor productivity (TFP) growth. TFP refers to the output produced by one unit of all factors of production, and TFP growth refers to the growth in output that cannot be explained by an increase in factors. Although poor countries often grow by deploying more capital and labor, economic growth based on productivity growth is generally viewed as more desirable and sustainable. For one, productivity-based growth is "free" in the sense that it does not require more inputs. More fundamentally, growth based on factor accumulation eventually runs into diminishing returns and therefore cannot be sustained. The distinction between productivity-led versus accumulation-based growth, along with an implicit assumption of the former's superiority, has sparked an empirical debate on the relative importance of the two in the East Asian miracle (see World Bank 1993, Young 1994 and 1995, Kim and Lau 1994, Chen 1997, Han et al. 2004, and Kim and Lee 2006). The debate has also stimulated studies that utilize a common benchmark to compare productivity between countries either by using data envelopment analysis or stochastic frontier production model (see Fare et al. 1994, Han et al. 2004, Kim and Lee 2006). These studies typically try to estimate the TFP of different countries and compare them using an estimated world production frontier as an explicit benchmark.

The central objective of our paper is to empirically examine recent trends in TFP growth and its two components—technical efficiency change (TEC) and technical progress (TP)—across 53 countries during 1991–2003. TEC refers to narrowing the gap between potential and actual output or, equivalently, moving from inside the production frontier toward the frontier. On the other hand, TP refers to shifting out of the production frontier due to technological innovation. Building on earlier studies, this paper applies a stochastic frontier production approach to estimate productivity growth. More specifically, we apply the production model developed by Cuesta (2000), which allows for firm-specific temporal variation in technical efficiency. The model is useful when different countries have different productivity trends over time, which is likely when the time series is long enough. Cuesta's model generalizes the stochastic frontier production model of Battese and Coelli (1992), which imposes a common temporal pattern in technical efficiency on all firms.

Many earlier country-level productivity studies examined the period 1960–1990 and centered on East Asian countries, namely, Japan; the newly industrializing economies (NIEs) of Hong Kong, China; the Republic of Korea; Singapore; and Taipei,China; and the Association of Southeast Asian Nations (ASEAN), in the context of the empirical debate about the sources of the East Asian miracle. Since then, however, many other developing countries have improved their economic performance significantly. The BRICs comprising Brazil, Russia, India, and the People's Republic of China (PRC) have emerged as new centers of gravity in the world economy, in particular, the PRC and India. More generally, in recent years, economic growth has spread throughout the developing world, including previously stagnant regions such as East and Central Europe, Africa, and Latin America. The drivers of superior performance include economic reform, sounder policies and stronger governance, more competitive markets, expansion of trade, and greater integration into the world economy. In short, more and more developing countries are now following in the time-proven paths to prosperity trodden earlier by East Asian countries. Therefore, it is worthwhile to broaden the scope of analysis from East Asia to a much broader group of countries. Examining trends in TFP growth can inform us about whether economic growth can be sustained in different parts of the world. This, in turn, can inform us about whether global economic growth can be sustained as the unprecedented global recedes and normalcy returns.

This paper is organized as follows. Section II presents a stochastic frontier production model with firm-specific temporal variation in technical inefficiency and gives the functional form of our estimation model. Section III describes our data, and reports and discusses our main empirical results, while Section IV concludes the paper.

II. A Model with Firm-Specific Time-Varying Technical Inefficiency

A stochastic frontier production function is defined by

$$y_{it} = f\left(x_{it}, \beta\right) + v_{it} - u_{it}, \tag{1}$$

where y_{it} is the output of the i^{th} firm (i = 1, .., N) in the t^{th} time period (t = 1, ..., T), f(·) is the production frontier, x is an input vector, β is a $k \times 1$ vector of parameters to be estimated. The efficiency error, u, represents production loss due to company-specific technical inefficiency; thus, it is always greater than or equal to zero ($u \geq 0$), and it is assumed to be independent of the statistical error, v, which is assumed to be independently and identically distributed as $N\left(0, \sigma_v^2\right)$. Note that technical inefficiency in equation (1) varies over time.

Battese and Coelli (1992) specify time-varying technical inefficiency as:

$$u_{it} = u_i \eta_t = u_i \exp\left(-\eta\left[t - T\right]\right), \tag{2}$$

where the distribution of u_i is taken to be the non-negative truncation of the normal distribution, $N\left(\mu, \sigma_u^2\right)$, and η is a parameter that represents the rate of change in technical inefficiency. A positive value (η > 0) is associated with an improvement in the technical efficiency of a firm over time. Under this specification, the temporal pattern of technical inefficiency is monotonous and common to all firms, as every firm shares the same η that determines the time path of technical inefficiency.

Cuesta (2000) generalized equation (2) by allowing for a firm-specific pattern of temporal change in the technical inefficiency term—i.e., every firm has its own unique time path of technical inefficiency. In this case, technical inefficiency can be rewritten as:

$$u_{it} = u_i \eta_{it} = u_i \exp\left(-\eta_i\left[t - T\right]\right), \tag{3}$$

where η_i is firm-specific parameters that capture the different patterns of temporal variation among firms. This model has the advantage of not imposing a common pattern of inefficiency change to all sample firms, unlike earlier models. This setting will be especially useful when the time series of the data set is long enough so that it is unrealistic to assume that every sample firm follows the same temporal variation.

Maximum-likelihood estimates can be applied for the parameters of the stochastic frontier model, defined by equations (1) and (3), in which the variance parameters are expressed in terms of $\gamma = \sigma_u^2 / \sigma_s^2$ and $\sigma_s^2 = \sigma_u^2 + \sigma_v^2$.

For estimation purposes, the production frontier can be specified in translog form as

$$\ln y_{it} = \alpha_0 + \sum_j \alpha_j \ln x_{jit} + \alpha_T t + 0.5 \sum_j \sum_l \beta_{jl} \ln x_{lit} \ln x_{jit}$$
$$+ 0.5 \beta_{TT} t^2 + \sum_j \beta_{Tj} t \ln x_{jit} + v_{it} - u_{it}, \quad \text{j, l = L, K,} \qquad (4)$$

where y_{it} is the observed output, t is the time variable, and the x variables are inputs. Subscripts j and l indicate inputs (j, l = L, K), and the efficiency error, u, is specified by equation (3).

The elasticity of output with respect to the j^{th} input is defined by

$$\varepsilon_j = \partial \ln f(x,t) / \partial \ln x_j = \alpha_j + \sum_l \beta_{jl} \ln x_l + \beta_{Tj} t, \quad \text{j, l = L, K.} \qquad (5)$$

The elasticity of scale (=RTS) is defined as $RTS = \sum_j \varepsilon_j$, and RTS decreases, is constant and increases if RTS < 1, RTS = 1 and RTS > 1, respectively.

The technical efficiency level of firm i at time t (TE_{it}) is defined as the ratio of the actual output to the potential output as follows:

$$TE_{it} = \exp(-u_{it}). \qquad (6)$$

The rate of technical progress (TP) is defined by the following:

$$TP = \partial \ln f(x,t) / \partial t = \alpha_T + \beta_{TT} t + \sum_j \beta_{Tj} \ln x_j, \quad \text{j = L, K.} \qquad (7)$$

The TFP growth rate (TFPG), which is the sum of technical progress (TP) and technical efficiency change (TEC), can be derived from equations (6) and (7) as follows:

$$TFPG = TP - (du/dt). \qquad (8)$$

Total factor productivity depends not only on technical progress but also on changes in technical inefficiency. TP is positive (negative) if exogenous technical changes shift the production frontier outward (inward). If du/dt is negative (positive), then technical efficiency improves (deteriorates) over time, and –du/dt can be interpreted as the rate at which an inefficient producer inside the production frontier moves toward the production frontier, or, equivalently, reduces the gap between potential and actual output.

III. Data and Empirical Results

In this section, we describe the data and variables used in our empirical analysis and report and discuss our main findings.

A. Data and Variables

The data set used to compare growth and TFP across the countries was derived from the Extended Penn World Tables Version 3.0 (2008), derived from Penn World Table 6.2. The sample period covered 1991–2003. Sample countries were selected based on the following three criteria: data quality of at least C level, a population of more than four million, and per capita income of more than US$3,000 in 2000. TFP growth becomes more important as a source of economic growth for middle-income and richer countries. Smaller countries were excluded since external conditions have a disproportionate impact on their economic performance. Five of the 53 sample countries are from Africa, two from North America, 13 from Central and South America, 14 from Asia, 18 from Europe, and one from Oceania.[1] For estimation, we retrieved real gross domestic product (GDP) in 2000 purchasing power parity, number of employed workers, and net fixed standardized capital stock in 2000 purchasing power parity from the Penn World Tables.[2]

B. Decomposition of Total Factor Productivity

Table 1 presents the maximum-likelihood estimates of the parameters in the translog stochastic frontier production function with country-specific technical inefficiency effects (Cuesta 2000), as defined by equations (3) and (4), along with the uniform time-varying technical inefficiency coefficient estimates of Battese and Coelli (1992). The estimates of γ are statistically significant at the 1% level for every model. For country-specific technical inefficiency, the coefficient estimates of η are statistically significantly for 37 out of 53 countries.[3] Coefficient estimates suggest the existence of country-specific temporal patterns of technical inefficiency.

1 India is omitted from the sample for low per capita GDP, and Russia for lack of time series.
2 For a detailed discussion of the data, see Heston et al. (2006) and Marquetti and Foley (2008).
3 The estimates of η are not reported here to save space but can be obtained from the authors upon request.

Table 1: Maximum-Likelihood Estimates for Parameters of the Stochastic Frontier Model with Country-Specific Time-Varying Technical Inefficiency across World Economies

	Country-Specific Time-Varying Technical Inefficiency	Uniform Time-Varying Technical Inefficiency
Const.	16.24** (3.178)	38.72** (5.256)
Log K	-0.757 (0.465)	–1.551** (0.386)
Log L	1.164** (0.450)	–0.071 (0.500)
T	0.091** (0.022)	0.135** (0.022)
log L*log K	–0. 045* (0.025)	0.119** (0.027)
t*log K	–0.002** (0.001)	–0.004** (0.001)
t*log L	–0.0006 (0.001)	–0.0003 (0.001)
$(\log K)^2$	0.038** (0.014)	–0.00001 (0.014)
$(\log L)^2$	0.016 (0.015)	–0.080** (0.017)
t^2	–0.0001 (0.0001)	–0.0004** (0.0001)
σ_s^2	0.160** (0.060)	0.663 (0.414)
γ	0.994** (0.002)	0.995** (0.002)
$\propto$	0.203 (0.145)	–0.199 (0.703)
η	n.a.	–0.009** (0.002)
LLR	1289.49	891.41

* statistically significant at the 5% level; ** statistically significant at the 1% level.

Note: Asymptotic standard errors are in parentheses. The coefficient estimates of country-specific η_i are omitted to save space.

Sources: Cuesta (2000) and Battese and Coelli (1992).

To test which model explains our data set better given the specification of stochastic frontier model, we implemented hypotheses tests using the log-likelihood test. First, the null that a country-specific time-varying technical inefficiency model is the right specification is tested against an alternative hypothesis, H_a: $\eta_1 = \eta_2 = ... = \eta_{53}$. If the null is rejected, Battese and Coelli (1992) describe the data better. Test statistic has a Chi-square distribution with degrees of freedom 52 and is –796.16, and the null is accepted at the 1% significance level. Test results suggest the country-specific time-varying technical inefficiency model explains the data better than the other model, given specifications of a frontier stochastic production model.

Table 2 shows average TE and its ranking for each country for selected periods, based on the country-specific time-varying technical inefficiency model. Estimates of TE vary considerably across both countries and periods.

Table 2: Average Technical Efficiency and its Ranking for the Sample Economies

	Group	1991–1995		1996–2000		2001–2003		1991–2003	
South Africa	Others	1.000	1	1.000	1	0.992	1	0.998	1
United Kingdom	G7	1.000	2	1.000	2	0.989	2	0.997	2
Norway	Europe	1.000	3	1.000	3	0.984	3	0.996	3
United States	G7	1.000	4	0.997	4	0.967	4	0.991	4
Belgium	Europe	0.994	5	0.976	5	0.932	6	0.973	5
Netherlands	Europe	0.965	9	0.957	6	0.951	5	0.959	6
Austria	Europe	0.950	10	0.925	7	0.896	10	0.928	7
Hong Kong, China	E. Asia	0.973	7	0.921	8	0.825	17	0.919	8
Denmark	Europe	0.946	11	0.915	10	0.880	13	0.919	9
Israel	Others	0.974	6	0.918	9	0.809	19	0.914	10
France	G7	0.906	12	0.903	11	0.901	8	0.904	11
Argentina	S. America	0.969	8	0.903	12	0.775	20	0.899	12
Italy	G7	0.897	14	0.896	13	0.895	11	0.896	13
Australia	Europe	0.901	13	0.895	14	0.890	12	0.896	14
Sweden	Europe	0.878	15	0.891	15	0.901	9	0.888	15
Canada	G7	0.844	20	0.862	16	0.875	14	0.858	16
Spain	Europe	0.860	16	0.839	19	0.822	18	0.843	17
Egypt	Others	0.789	23	0.861	17	0.903	7	0.843	18
Germany	G7	0.846	18	0.841	18	0.837	15	0.842	19
Switzerland	Europe	0.829	22	0.798	20	0.769	21	0.803	20
Chile	S. America	0.850	17	0.791	21	0.731	24	0.800	21
Portugal	Europe	0.832	21	0.775	23	0.718	25	0.784	22
Greece	Europe	0.784	24	0.770	24	0.760	22	0.773	23
Venezuela	S. America	0.845	19	0.746	26	0.635	33	0.758	24
Finland	Europe	0.694	30	0.776	22	0.829	16	0.757	25
Singapore	E. Asia	0.750	25	0.747	25	0.745	23	0.748	26
Colombia	S. America	0.737	26	0.692	29	0.653	31	0.700	27
Mexico	S. America	0.724	27	0.687	30	0.655	29	0.694	28
Malaysia	Asean	0.696	29	0.693	27	0.691	28	0.694	29
Hungary	Europe	0.691	31	0.693	28	0.694	27	0.692	30
Tunisia	Others	0.665	34	0.686	31	0.702	26	0.682	31
Guatemala	S. America	0.712	28	0.673	32	0.639	32	0.680	32
Dominican Republic	S. America	0.664	35	0.658	33	0.653	30	0.659	33
Japan	G7	0.680	33	0.654	34	0.631	35	0.659	34
El Salvador	S. America	0.682	32	0.625	36	0.575	37	0.635	35
Brazil	BRICs	0.645	37	0.632	35	0.621	36	0.634	36
Poland	Europe	0.592	40	0.616	37	0.634	34	0.611	37
Paraguay	S. America	0.657	36	0.592	38	0.536	42	0.604	38
Korea, Rep. of	E. Asia	0.598	39	0.583	39	0.571	38	0.586	39
Turkey	Others	0.633	38	0.569	40	0.514	44	0.581	40
Morocco	Others	0.590	41	0.565	41	0.543	41	0.569	41
Iran	Others	0.482	48	0.525	42	0.558	39	0.516	42
Philippines	Asean	0.525	44	0.511	43	0.499	45	0.514	43
Peru	S. America	0.527	43	0.505	45	0.487	46	0.509	44
Jordan	Others	0.525	46	0.503	46	0.486	47	0.508	45
Sri Lanka	Others	0.489	47	0.507	44	0.522	43	0.504	46
Ecuador	S. America	0.525	45	0.484	48	0.450	49	0.492	47
Nicaragua	S. America	0.537	42	0.468	50	0.410	50	0.481	48
Romania	Europe	0.421	51	0.495	47	0.552	40	0.480	49
Indonesia	Asean	0.481	49	0.472	49	0.465	48	0.474	50
Zimbabwe	Others	0.477	50	0.400	51	0.338	53	0.415	51
Thailand	Asean	0.412	52	0.396	52	0.383	52	0.400	52
PRC	BRICs	0.299	53	0.352	53	0.394	51	0.342	53

Source: Authors' estimates.

The average level of TE for the entire sample period was 0.721, and highest among the G7 countries with 87.8%, followed by European countries and East Asian countries with 82% and 75.1%, respectively during 1991–2003. The average TE level is lowest among the BRICs with 48.8%; followed by ASEAN countries with 52%. There exists a wide gap in TE between developed and developing countries, which suggests that catching up is a significant factor in the economic growth of the latter. The average level of TE deteriorated steadily in most countries.[4] The average TE for all countries was 0.735 for the period of 1991–1995, dropping to 0.720 and 0.699 for 1996–2000 and 2001–2003, respectively. The country rankings of TE are highly uniform across periods. Notable exceptions are Argentina; Hong Kong, China; Israel; and Venezuela, which saw their respective rankings plummet. Egypt, Finland, Romania, and Sweden experienced significant improvements.

Technical efficiency leaders are South Africa, the United Kingdom (UK), Norway, the US, and Belgium. The top quartile comprises four G7 countries (the UK, the US, France, Italy) and five European countries (Norway, Belgium, the Netherlands, Austria, Denmark). Four other countries (South Africa; Hong Kong, China; Israel; and Argentina) also belonged to the top quartile. Among G7 countries, the TE of Germany is relatively weak, ranked at 19 during 1991–2003, perhaps due to the impact of unification. Japan also fares poorly, reflecting its prolonged economic slump. The PRC is at the bottom of the list, despite its strong economic growth throughout the sample period. TE is also relatively low in second-tier newly industrializing Southeast Asian countries such as Indonesia, Malaysia, the Philippines, and Thailand. More specifically, Indonesia, the Philippines, and Thailand belong to the lowest quartile, with Malaysia at the lower half of the TE ranking. Despite steady and rapid economic growth, those countries still lag frontier countries by a wide margin.

Table 3 presents estimates of the averages of the rates of TP, changes in TEC, and TFPG, along with growth rates of output, labor, and capital ($\dot{Y}$, $\dot{L}$ and $\dot{K}$) for the period 1991–2003.[5] Table 3 also presents estimates of the percentage shares of contributions of $\dot{L}$, $\dot{K}$, TEC, and TP to GDP growth during 1991–2003. The contribution of factor input growth to output growth is derived by multiplying each input's share in output by factor input growth ($\varepsilon_j \times \dot{X}$, where j, X=L, K), and its relative contribution to output growth is obtained by dividing its contribution by output growth [($\varepsilon_j \times \dot{X}) / \dot{Y}$]. It should be noted that the percentage shares of contribution to output growth may not sum up to one or 100% due to random errors affecting output growth.[6]

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4 The estimated coefficient of η (i.e., country-specific temporal pattern of TE) was negative for 11 out of the 53 sample countries.

5 The by-year decomposition results are available from the authors upon request.

6 In growth accounting, the random error is included as residual productivity growth.

Table 3: Sources of Economic Growth (%) and Total Factor Productivity Growth Rankings

	$\dot{Y}$ (rank)		$\dot{L}$ (share)		$\dot{K}$ (share)		TEC (share)		TP (share)		TFPG (rank)	
PRC	9.406	1	1.022	5	10.436	59	3.106	33	0.162	2	3.268	3
Malaysia	6.394	2	2.631	19	7.315	59	−0.084	−1	1.191	19	1.107	15
Dominican Republic	5.760	3	2.494	23	7.129	49	−0.190	−3	1.808	31	1.619	9
Singapore	5.706	4	3.091	24	4.964	49	−0.089	−2	1.353	24	1.264	12
Chile	5.349	5	2.071	19	8.233	76	−1.637	−31	1.347	25	−0.291	43
Korea, Rep. of	5.133	6	1.725	15	6.984	80	−0.512	−10	0.728	14	0.216	36
Sri Lanka	4.775	7	1.801	21	3.282	27	0.712	15	1.640	34	2.352	6
Egypt	4.681	8	3.070	36	0.618	5	1.587	34	1.382	30	2.969	4
Tunisia	4.517	9	2.825	33	2.048	19	0.599	13	1.686	37	2.285	7
Jordan	4.205	10	5.326	68	1.776	17	−0.855	−20	2.018	48	1.162	14
Indonesia	4.014	11	2.645	33	3.212	39	−0.387	−10	0.762	19	0.375	31
Poland	3.973	12	0.591	7	3.214	39	0.751	19	1.109	28	1.860	8
Thailand	3.885	13	1.426	17	4.635	63	−0.814	−21	0.842	22	0.028	38
Australia	3.838	14	1.388	16	4.076	62	−0.130	−3	0.964	25	0.834	20
El Salvador	3.804	15	2.809	42	4.932	44	−1.865	−49	2.058	54	0.192	37
Peru	3.790	16	3.076	42	3.246	38	−0.885	−23	1.415	37	0.530	28
Iran	3.739	17	2.727	34	−0.146	−3	1.638	44	0.929	25	2.567	5
Israel	3.692	18	2.884	36	6.134	89	−2.065	−56	1.414	38	−0.651	48
Hong Kong, China	3.606	19	2.568	32	5.387	82	−1.841	−51	1.266	35	−0.575	47
Guatemala	3.515	20	3.492	57	2.930	29	−1.193	−34	1.928	55	0.734	21
Canada	3.398	21	1.134	14	3.167	55	0.408	12	0.802	24	1.210	13
Norway	3.299	22	0.812	11	1.683	28	−0.271	−8	1.361	41	1.090	16
United States	3.269	23	1.196	14	4.394	90	−0.471	−14	0.078	2	−0.393	45
Philippines	3.095	24	2.691	45	2.953	42	−0.568	−18	1.167	38	0.599	23
Turkey	3.083	25	2.404	39	6.211	96	−2.276	−74	1.056	34	−1.219	50
Hungary	2.931	26	0.183	3	2.204	36	0.036	1	1.423	49	1.459	11
Spain	2.810	27	1.205	19	3.942	82	−0.495	−18	0.805	29	0.310	34
Greece	2.738	28	1.112	19	2.639	50	−0.345	−13	1.324	48	0.979	18
Colombia	2.732	29	2.647	50	3.247	54	−1.340	−49	1.269	46	−0.071	39
United Kingdom	2.729	30	0.413	7	3.320	72	−0.211	−8	0.682	25	0.471	29
Mexico	2.629	31	2.723	49	3.478	70	−1.085	−41	0.831	32	−0.255	41
Finland	2.547	32	0.039	1	−0.389	−9	2.060	81	1.381	54	3.441	2
Nicaragua	2.424	33	3.206	75	4.357	61	−2.947	−122	2.138	88	−0.8100	49
Morocco	2.394	34	2.572	58	1.856	32	−0.909	−38	1.495	62	0.586	24
South Africa	2.324	35	1.504	33	1.291	24	−0.202	−9	1.280	55	1.078	17
Netherlands	2.280	36	0.557	11	2.397	60	−0.157	−7	1.037	46	0.881	19
Denmark	2.270	37	0.053	1	2.959	70	−0.786	−35	1.359	60	0.573	25
Argentina	2.161	38	2.072	46	2.482	59	−2.486	−115	1.089	50	−1.397	51
Portugal	2.094	39	0.644	14	4.657	116	−1.614	−77	1.287	61	−0.327	44
Sweden	2.049	40	0.372	8	1.249	33	0.291	14	1.227	60	1.518	10
Paraguay	2.043	41	3.201	85	1.217	24	−2.232	−109	1.943	95	−0.289	42
Austria	2.000	42	0.379	8	2.546	72	−0.642	−32	1.213	61	0.571	26
France	1.941	43	0.677	15	2.174	69	−0.055	−3	0.612	32	0.556	27
Brazil	1.923	44	1.800	44	1.022	28	−0.407	−21	0.665	35	0.258	35
Belgium	1.883	45	0.412	10	2.939	88	−0.733	−39	1.182	63	0.448	30
Ecuador	1.841	46	3.240	91	0.479	10	−1.703	−92	1.600	87	−0.103	40
Romania	1.544	47[a]	0.226	7	−5.876	−177	3.068	199	1.343	87	4.410	1
Italy	1.432	48	0.316	9	1.446	61	−0.028	−2	0.650	45	0.622	22
Germany	1.345	49	0.104	3	1.650	77	−0.119	−9	0.484	36	0.365	32
Switzerland	0.932	50	0.408	19	1.193	74	−0.833	−89	1.162	125	0.329	33
Japan	0.857	51	0.433	20	1.895	147	−0.811	−95	0.268	31	−0.543	46
Venezuela	−0.319	52	2.767	−434	0.097	−15	−3.103	974	1.348	−423	−1.754	52
Zimbabwe	−2.193	53	1.526	−39	2.518	−43	−3.783	172	1.779	−81	−2.004	53

Notes: Numbers after factor input growth, TEC, and TP represent the shares of contribution to GDP growth (in percent).
Source: Authors' estimates.

The top quartile of output growth leaders comprises the PRC; three ASEAN countries (Indonesia, Malaysia, Thailand); two NIEs (the Republic of Korea and Singapore); two African countries (Egypt and Tunisia); and the Dominican Republic, Jordan, Sri Lanka, and Poland. The growth of these countries is largely driven by factor accumulation. In particular, capital accumulation explains a large share of their growth. Specifically, factor accumulation accounts for more than 78% of the output growth of Jordan, Malaysia, and Thailand, and 95% for the Republic of Korea and Chile. However, the contribution of productivity is significant in other countries. Productivity growth accounts for at least 47% of the economic growth of Egypt, Poland, Sri Lanka, and Tunisia. In the case of the PRC, fast-improving TEC accounts for 33% of total output growth.

The average TEC for the sample period was –0.545%, suggesting a slight decrease in world output due to technical inefficiency. In contrast, the average TP is positive for every country. Average annual TP growth is highest for South American countries at 1.564% and lowest for BRICs at 0.414%. Across all countries, average TP growth was 1.195% during the sample period. The average annual TFP growth rate varies widely across countries, ranging from –2.004% to 4.41%, suggesting a wide gap between the fastest growing and slowest growing countries. Romania led TFPG at 4.41% per annum followed by the PRC, Egypt, Finland, and Iran. The top quartile comprises five EU countries (Finland, Hungary, Poland, Romania, Sweden); three small countries (Dominican Republic, Singapore, Sri Lanka); two resource-rich countries (Canada and Iran); two emerging African countries (Egypt and Tunisia); and the world's fastest-growing economy (PRC).

The PRC's world-topping growth was driven by a surge of capital accumulation that grew more than 10% throughout the sample period. The growth, however, was supported by TEC that helped the PRC catch up to the world frontier production. Large inflows of foreign direct investment have contributed substantially to TEC. However, it should be mentioned that there is a lot of scope for improving TE because it is at the world lowest level despite substantial TEC. Furthermore, the PRC needs to speed up its TP if it is to sustain its TFPG and climb up the value chain of the world economy.

Among the EU countries, Finland and Sweden entered the EU in 1995, Poland and Hungary in 2004, and Romania in 2007. This suggests that the expansion of the European market boosted TFPG of new member countries by unleashing powerful competitive pressures. The productive efficiency of the new member countries is approaching the frontier countries of the EU. The primary source of TFPG for those countries was TEC, which rose much faster than TP. This seems to support the convergence of productivity within the EU.

In Africa, Tunisia signed an Association Agreement with the EU in 1995, and became the first Mediterranean country to enter in a free trade area with the EU when it dismantled tariffs on industrial products in 2008. Tunisia is one of the EU's most well-established trading partners in the Mediterranean region, and is the most competitive economy in Africa. Egypt has enjoyed relative stability and continuous growth of 4–5% in the past quarter-century. Under comprehensive economic reforms initiated in 1991, Egypt has relaxed many price controls, reduced subsidies, brought down inflation, cut taxes, and partially liberalized trade and investment. Manufacturing became less dominated by the public sector, especially in heavy industries. A process of public sector reform and privatization has opened up new opportunities for the private sector. Economic reforms are the key factors behind the high TEC and TP of the two North African countries.

Among other countries in the top quartile of TFPG, Canada and Iran grew by an average of 3.40–3.74% on the back of higher prices for their natural resources, including petroleum, since the 1990s. However, TP was sluggish in these countries, despite their fast TEC. Therefore, these countries have to invest more in innovative activities if they are to sustain their fast rate of TFPG. The other three countries in the top quartile, the Dominican Republic, Singapore, and Sri Lanka, are small open economies that experienced fast economic growth, ranging between 4.78% and 5.76%. A combination of rapid factor accumulation and substantial TP powered Singapore's economic growth; rapid capital accumulation and TP drove the Dominican Republic's growth; whereas TEC and TP drove Sri Lanka's growth.

All G7 countries except Canada experienced low TFPG of less than 1% per annum. In particular, the US and Japan are ranked low at 45th and 46th, respectively. France, the UK, and Germany are also ranked in the lower half of the sample at 27th, 29th, and 32nd, respectively. All these countries experienced a combination of negative TEC and slow TP of less than 1% per annum. Among East Asian tigers, the Republic of Korea's TFPG contracted and Hong Kong, China's barely grew, despite their healthy GDP growth. On the other hand, Singapore experienced much higher TFPG than the other two NIEs. Among the ASEAN countries, the economic growth of Malaysia and the Philippines are in line with their productivity growth, whereas the growth of Indonesia and Thailand are driven more by factor accumulation.

Table 4 presents the average annual growth rates of various components of output growth in 13 of the world's 15 largest economies for selected time periods (1991–1995, 1996–2000, 2001–2003). The table shows that all developed countries experienced a drop in TFPG over time. This decrease in TFPG resulted from a continuous drop in both TE and TP. The Republic of Korea, Japan, Mexico, the UK, and the US all suffered a contraction of TFPG in 2001–2003. Some promising signs of productivity growth are observable only in the PRC and Canada.

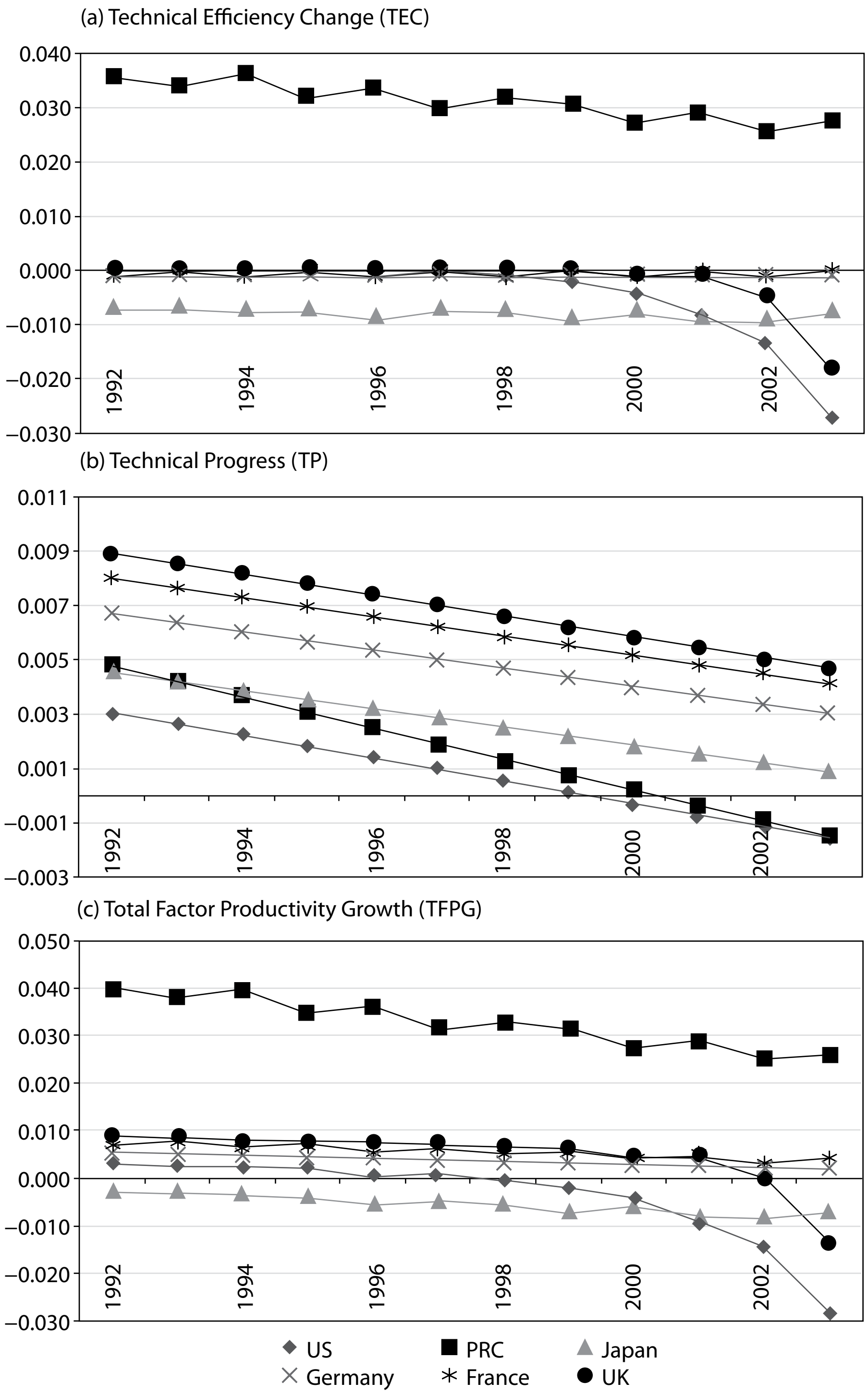
Table 4: Output, Input, and Productivity Growth (%) for Largest Economies by Subperiods

	Year	$\dot{Y}$	$\dot{L}$	$\dot{K}$	TEC	TP	TFPG
United States	1991–95	3.388	1.204	3.123	0.000	0.249	0.249
	1996–00	4.354	1.254	6.013	−0.176	0.035	−0.141
	2001–03	2.000	1.072	3.493	−2.022	−0.134	−2.156
Japan	1991–95	0.887	0.880	2.986	−0.735	0.408	−0.327
	1996–00	0.664	0.372	1.875	−0.803	0.229	−0.575
	2001–03	0.327	−0.081	−0.392	−0.871	0.105	−0.766
PRC	1991–95	11.354	1.287	10.708	3.428	0.393	3.820
	1996–00	8.741	0.962	10.073	2.987	0.101	3.087
	2001–03	8.126	0.711	10.513	2.662	−0.118	2.545
Germany	1991–95	1.374	0.409	2.264	−0.118	0.620	0.502
	1996–00	2.153	−0.161	2.108	−0.119	0.448	0.329
	2001–03	−0.240	0.076	−0.267	−0.119	0.320	0.201
France	1991–95	1.200	0.990	1.516	−0.055	0.752	0.696
	1996–00	3.435	0.667	2.745	−0.055	0.580	0.524
	2001–03	0.984	0.265	2.273	−0.055	0.432	0.376
United Kingdom	1991–95	2.566	0.418	2.335	0.000	0.837	0.837
	1996–00	3.511	0.429	4.377	−0.025	0.643	0.618
	2001–03	1.987	0.379	2.899	−1.166	0.487	−0.679
Italy	1991–95	1.305	0.570	0.649	−0.028	0.782	0.754
	1996–00	2.210	0.309	1.952	−0.028	0.618	0.590
	2001–03	0.377	−0.022	2.032	0.000	0.480	0.480
Brazil	1991–95	2.075	2.103	−0.182	−0.427	0.805	0.379
	1996–00	2.284	1.839	2.545	−0.396	0.626	0.230
	2001–03	1.946	1.260	0.000	−0.402	0.498	0.095
Spain	1991–95	1.179	1.162	2.864	−0.436	0.965	0.528
	1996–00	4.426	1.196	4.854	−0.506	0.768	0.261
	2001–03	2.716	1.417	4.351	−0.548	0.598	0.050
Canada	1991–95	3.049	1.181	1.819	0.445	0.957	1.401
	1996–00	5.030	1.188	4.308	0.406	0.763	1.169
	2001–03	2.681	0.977	3.681	0.343	0.605	0.948
Mexico	1991–95	0.814	3.040	1.423	−0.933	0.986	0.053
	1996–00	5.317	2.559	5.516	−1.092	0.797	−0.295
	2001–03	1.099	2.492	3.638	−1.297	0.622	−0.675
Australia	1991–95	3.926	1.425	2.630	−0.111	1.128	1.017
	1996–00	3.888	1.513	4.736	−0.140	0.924	0.785
	2001–03	3.580	1.113	5.579	−0.168	0.756	0.588
Korea, Rep. of	1991–95	7.053	2.292	10.572	−0.502	0.923	0.422
	1996–00	3.343	1.671	4.805	−0.515	0.670	0.155
	2001–03	4.706	0.967	4.043	−0.525	0.509	−0.017

Note: The economies are taken from a World Bank's list of world's 15 largest GDP countries in 2008.
Source: Authors' estimates.

Figure 1 maps out annual movements in TEC, TP, and TFPG for the PRC, France, Germany, Japan, the UK, and the US. The PRC led TEC throughout the sample period, and a wide gap separated the PRC from the other five countries. In fact, TEC was negative throughout for the other five countries, and deteriorated sharply for the UK and the US after 2000. The UK led TP, followed by France, Germany, Japan, the PRC, and the US, respectively. TEC in France, Germany, and the UK ranged from 0.003% to 0.009%. The pattern of TP over time was very similar for every country, i.e., a secular decline. TP turned negative in the PRC and the US after 2000. The PRC led TFPG, followed by the UK and France. Japan was the worst TFPG performer for most of the sample period, but the US assumed that position after 2000. TFPG trends were dominated by TEC, with countries that experienced faster TEC generally experiencing faster TFPG.

Figure 1: TEC, TP, and TFPG for Great 6 Economies (percent)



Source: Authors' estimates.

IV. Concluding Observations

Beyond the short run, the world economy faces the perennial challenge of achieving rapid yet sustainable economic growth. This challenge is all the more urgent for developing countries since sustained growth is the only proven means of making a significant dent on poverty. As the global crisis recedes, the fundamental ingredients of long-term growth—macroeconomic stability, good governance, sound policies, openness to trade, competitive markets, and so forth—will reassert their central significance for growth. Those ingredients are captured by total factor productivity growth, which consists of technical efficiency change and technical progress. This paper examined TFPG and its two components across 53 countries across the world during 1991–2003. Doing so can inform us about the sustainability of growth in different parts of the world.

The empirical results show that developing countries still lag developed countries by a wide margin in terms of TE even though they are steadily catching up. Most TE leaders are developed countries whereas the laggards are predominantly developing countries. It is interesting to note that the PRC, despite its astonishing growth over the last three decades, still had the lowest TE among the sample countries. This suggests that there is plenty of scope for the PRC to improve its TE in the future, and such improvements will contribute to productivity and output growth. More generally, in light of the large TE gap that still separates developed and developing countries, a major avenue for growth in developing countries is to narrow the distance between potential and actual output. Narrowing the distance requires a more efficient allocation of resources given the level of technology through structural reform and macroeconomic stability. Efficient financial and labor markets allow an economy to produce more with the same inputs without any technological innovation.

For the whole sample, the average TEC was –0.545%. The negative average hides considerable heterogeneity across countries. For example, the PRC experienced substantial positive TEC, which contributed a lot to the country's output growth. In fact, the PRC's TFPG has been driven mostly by TEC rather than TP. However, the overall pattern of TEC across the world, which includes negative TEC in many globally significant large economies such as Japan and the US, suggests that TEC has subtracted from, rather than added to, global output. In striking contrast, the average TP is positive for every country in the sample period. TP has thus made a positive contribution to TFPG and hence output growth across the world. As with TEC, the countries in the sample showed considerable diversity in terms of their TP performance. The same can be said for TFPG; furthermore, there is a big gap in TFPG between the fastest-growing and slowest-growing economies. Most economies in the sample experienced positive TFPG but some larger, mature, industrialized economies suffered a deterioration of TFP. In particular, Japan, the UK, and the US suffered a pronounced decline in TFPG. This indicates that global productivity growth was led by productivity growth in fast-growing developing countries. Going forward, this implies that global output growth will increasingly be determined by the output growth of developing countries.

The results of our empirical analysis of the sources of economic growth show that factor accumulation continued to play a much bigger role than productivity growth in many fast-growing developing countries. This was especially true in Chile, Jordan, the Republic of Korea, Malaysia, and Thailand where much of economic growth was driven by factor accumulation. Since these economies are at income levels where the source of growth has shifted from factor accumulation to productivity growth, policymakers must take measures to facilitate and accelerate the transition from accumulation-based growth to productivity-led growth. However, productivity growth had a much larger effect on the economic growth of other fast-growing developing countries. This is true in the PRC as well as some other countries such as Egypt, Poland, Sri Lanka, and Tunisia. Regardless of their TFPG, the fact that developing countries substantially lag developed countries in TE suggests that productivity growth will depend as much on promoting TEC as TP. That is, in order for developing countries to achieve sustainable economic growth, they will not only have to achieve higher technological levels but also make better use of existing technologies and factor endowments. Their success in meeting this challenge will impinge heavily upon future global economic growth.

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About the Paper

Sangho Kim, Donghyun Park, and Jong-Ho Park apply a stochastic frontier production model to data from 53 countries during 1991–2003 to estimate total factor productivity growth, and decompose it into technical efficiency change and technical progress. The empirical results indicate that world productivity growth was led by fast-growing newly emerging economies, whereas most developed countries experienced a decrease in productivity growth. The results also show that technical efficiency change significantly contributed to economic growth for many fast-growing countries, even though emerging economies still lag far behind developed countries in terms of technical efficiency.

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