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Information Technology and the World Economy*

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Abstract

This paper addresses the impact of investment in information technology (IT) on the recent resurgence of world economic growth. We describe the growth of the world economy, seven regions and 14 major economies during the period 1989–2003. We allocate the growth of world output between input growth and productivity and find, surprisingly, that input growth greatly predominates! The contributions of IT investment have increased in all regions, but especially in industrialized economies and Developing Asia. Differences in per capita output are explained by differences in per capita input, rather than by variations in productivity.

Keywords: Growth; investment; productivity; information technology

JEL classification: *O*47

I. Introduction

The purpose of this paper is to analyze the impact of investment in information technology (IT) equipment and software on the recent resurgence in world economic growth. The crucial role of IT investment in the growth of the U.S. economy has been thoroughly documented and widely discussed.[1] Jorgenson (2001) has shown that the remarkable behavior of IT prices is the

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[1] See Jorgenson and Stiroh (2000) and Oliner and Daniel Sichel (2000). The growth accounting methodology employed in this literature is discussed by Jorgenson, Ho and Stiroh (2005) and summarized by Jorgenson (2005).

key to understanding the resurgence of American economic growth. This behavior can be traced to developments in semiconductor technology that are widely understood by technologists and economists.

Jorgenson (2003) has shown that the growth of IT investment jumped to double-digit levels after 1995 in all the G7 economies—Canada, France, Germany, Italy, Japan and the United Kingdom, as well as the United States.[2] These economies account for nearly half of world output and a much larger share of world IT investment. The surge of IT investment after 1995 resulted from a sharp acceleration in the rate of decline in prices of IT equipment and software. Jorgenson (2001) has traced this to a drastic shortening of the product cycle for semiconductors from three years to two years, beginning in 1995.

In Section II we describe the growth of the world economy, seven economic regions and 14 major economies given in Table 1 during the period 1989–2003.[3] The world economy is divided among the G7 and non-G7 industrialized economies, Developing Asia, Latin America, Eastern Europe and the former Soviet Union, North Africa and the Middle East, and Sub-Saharan Africa. The 14 major economies include the G7 economies listed above and the developing and transition economies of Brazil, China, India, Indonesia, Mexico, Russia and South Korea.

We have subdivided the period in 1995 in order to focus on the response of IT investment to the accelerated decline in IT prices. As shown in Table 1, world economic growth has undergone a powerful revival since 1995. The per capita growth rate jumped nearly a full percentage point from 2.50 percent during 1989–1995 to 3.45 percent in 1995–2003. We can underline the significance of this difference by pointing out that per capita growth of 3.45 percent doubles world output per capita in a little over two decades, while slower growth of 2.50 percent doubles per capita output in slightly less than three decades.

In Section III we allocate the growth of world output between input growth and productivity. Our most astonishing finding is that input growth greatly predominated! Productivity growth accounted for only one-fifth of the total during 1989–1995, while input growth accounted for almost

[2] Ahmad, Schreyer and Wolfl (2004) have analyzed the impact of IT investment in OECD countries. Van Ark, Melka, Mulder, Timmer and Ypma (2003, updated 2005) and Daveri (2002) have presented comparisons among European economies. Piatkowski and van Ark (2005) have compared the impact of IT investment on the economies of Eastern Europe and the former Soviet Union.

[3] We include 110 economies with more than 1 million in population and a complete set of national accounts for the period 1989–2003 from Penn World Table (Heston, Summers and Aten, 2002) and World Bank Development Indicators Online (2004). These economies account for more than 96 percent of world output.

Table 1. *The world economy: shares in size and growth by group, region and major economies*

Group/Region	Period 1989–1995			Period 1995–2003		
		Average share			Average share	
	GDP growth	GDP	Growth	GDP growth	GDP	Growth
World (110 economies)	**2.50**	**100.00**	**100.00**	**3.45**	**100.00**	**100.00**
G7 (7 economies)	2.18	47.44	41.33	2.56	45.26	33.62
Developing Asia (16)	7.35	20.76	61.13	5.62	26.05	42.56
Non-G7 (15)	2.03	8.38	6.77	3.01	8.13	7.10
Latin America (19)	3.06	8.35	10.20	2.11	8.07	4.94
Eastern Europe (14)	−7.05	9.32	−26.76	2.87	6.57	5.47
Sub-Saharan Africa (28)	1.21	2.13	1.03	2.88	2.01	1.68
N. Africa & M. East (11)	4.36	3.61	6.29	4.08	3.91	4.64

Economy	Period 1989–1995					Period 1995–2003				
		Avg. GDP share		Growth share			Avg. GDP share		Growth share	
	GDP growth	Group	World	Group	World	GDP growth	Group	World	Group	World
Seven world major economies (G7)										
Canada	1.39	4.90	2.32	3.12	1.29	2.51	4.78	2.17	4.69	1.58
France	1.30	7.10	3.37	4.23	1.75	1.92	6.76	3.06	5.05	1.70
Germany	2.34	10.80	5.12	11.58	4.79	0.86	10.20	4.63	3.41	1.15
Italy	1.52	7.42	3.52	5.17	2.14	1.48	6.99	3.17	4.05	1.36
Japan	2.56	16.23	7.70	19.03	7.88	1.39	15.73	7.13	8.54	2.88
United Kingdom	1.62	7.45	3.54	5.53	2.29	2.55	7.37	3.34	7.32	2.46
United States	2.43	46.11	21.87	51.34	21.26	3.56	48.16	21.76	66.92	22.46
All G7	**2.18**	**100.0**	**47.4**	**100.0**	**41.4**	**2.56**	**100.0**	**45.3**	**100.0**	**33.6**

Table 1. *(Continued)*

	Period 1989–1995					Period 1995–2003				
		Avg. GDP share		Growth share			Avg. GDP share		Growth share	
Economy	GDP growth	Group	World	Group	World	GDP growth	Group	World	Group	World
Seven major developing and transition economies (GD7)										
Brazil	1.97	12.10	3.16	6.89	2.48	1.94	10.16	2.93	3.80	1.65
China	9.94	29.26	7.64	84.23	30.36	7.13	37.79	10.91	51.99	22.55
India	5.03	18.98	4.95	27.65	9.97	6.15	20.69	5.97	24.54	10.65
Indonesia	6.82	7.12	1.86	14.07	5.07	2.41	6.98	2.02	3.25	1.41
Mexico	2.19	7.48	1.95	4.74	1.71	3.56	6.74	1.95	4.63	2.01
Russian Federation	−8.44	19.92	5.20	−48.71	−17.56	3.18	12.17	3.52	7.46	3.24
South Korea	7.48	5.14	1.34	11.13	4.01	4.09	5.47	1.58	4.32	1.87
All GD7	**3.45**	**100.0**	**26.1**	**100.0**	**36.0**	**5.18**	**100.0**	**28.9**	**100.0**	**43.4**

Note: The measures for groups and the world are averages weighted by GDP (in PPP$) share.

four-fifths. Similarly, input growth contributed more than 70 percent of growth after 1995, while productivity accounted for less than 30 percent. The only important departure from this worldwide trend is the Asian Miracle prior to 1995, when the rate of economic growth in Developing Asia far outstripped the rest of the world and productivity growth predominated.

In Section III we also distribute the growth of input per capita between investments in tangible assets, especially IT equipment and software, and investments in human capital. The world economy, all seven regions and the 14 major economies, except Indonesia and Mexico, experienced a surge in investment in IT after 1995. The soaring level of U.S. IT investment after 1995 was paralleled by jumps in IT investment throughout the industrialized world. The contributions of IT investment in Developing Asia, Latin America, Eastern Europe, North Africa and the Middle East, and Sub-Saharan Africa more than doubled after 1995, beginning from much lower levels. By far the most dramatic increase took place in Developing Asia.

In Section IV we report levels of output per capita, input per capita and productivity for the world economy, the seven economic regions and the 14 major economies. We find that differences in per capita output levels are primarily explained by differences in per capita input, rather than variations in productivity. Taking U.S. output per capita in 2000 as 100.0, world output per capita was a relatively modest 23.9 in 2003. Using similar scales for input and productivity, world input per capita in 2003 was a substantial 42.4 and world productivity a robust 56.3. Section V concludes the paper.

II. World Economic Growth, 1989–2003

In order to set the stage for analyzing the impact of IT investment on the growth of the world economy, we first consider the shares of world product and growth for each of the seven regions and the 14 major economies in Table 1. Following Jorgenson (2001), we have chosen GDP as a measure of output. We used the Penn World Table, generated by Heston, Summers and Aten (2002), as the primary data source on GDP and purchasing power parities for economies outside the G7 and the European Union, as it existed prior to enlargement in May 2004.[4]

We have revised and updated the U.S. data in Jorgenson (2001) through 2003. Comparable data for Canada have been constructed by Statistics Canada.[5] Data for France, Germany, Italy and the U.K. and the economies of the European Union before enlargement have been developed for the

[4] In his magisterial volume, Maddison (2001) provides estimates of national product and population for 134 countries for varying periods between 1820 and 1998.
[5] See Baldwin and Harchaoui (2003).

European Commission by van Ark *et al*.[6] Finally, data for Japan have been assembled by Jorgenson and Motohashi for the Research Institute on Economy, Trade and Industry.[7] We have linked these data by means of the OECD's purchasing power parities for 1999.[8]

The G7 economies accounted for slightly under half of world product during the period 1989–2003. The per capita growth rates of these economies—2.18 percent before 1995 and 2.56 percent afterward—were considerably below world growth rates. The growth acceleration of 0.60 percent for the G7 economies lagged behind the jump in world economic growth. The G7 shares in world growth were 41.3 percent during 1989–1995 and 33.6 percent in 1995–2003, well below the G7 shares in world product of 47.4 percent and 45.3 percent, respectively.

During 1995–2003, the U.S. accounted for 21.8 percent of world product and 48.2 percent of G7 output. After 1995, Japan fell from its ranking as the world's second largest economy to third largest after China. Germany dropped from fourth place before 1995, following the U.S., China and Japan, to fifth place during 1995–2003, ranking behind India as well. Japan remained the second largest of the G7 economies, while Germany retained its position as the leading European economy. France, Italy and the U.K. were similar in size, but less than half the size of Japan. Canada was the smallest of the G7 economies.

The U.S. growth rate jumped from 2.43 percent during 1989–1995 to 3.56 percent in 1995–2003. The period 1995–2003 includes the shallow U.S. recession of 2001 and the ensuing recovery, as well as the IT-generated investment boom of the last half of the 1990s. The U.S. share in world growth fell below its share in world product before 1995, but rose above the U.S. product share after 1995. By contrast, Japan's share in world economic growth before 1995 exceeded its share in world product, but fell short of the product share after 1995. The remaining G7 economies had lower shares of world growth than world product before and after 1995.

The 16 economies of Developing Asia generated slightly more than a fifth of world output before 1995 and more than a quarter afterward. The burgeoning economies of China and India accounted for more than 60 percent of Asian output in both periods.[9] The economies of Developing Asia grew at 7.35 percent before 1995 and 5.62 percent afterward. These economies were responsible for an astounding 61 percent of world growth during 1989–1995!

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[6] See van Ark *et al*. (2003, updated 2005).
[7] See Jorgenson and Motohashi (2005).
[8] See OECD (2002).
[9] Our data for China are taken from the Penn World Table (2002). Young (2003) offers persuasive evidence that the official estimates given, for example, by the World Development Indicators (2004) exaggerate the growth of output and productivity in China.

Slightly less than half of this took place in China, while slightly less than a third occurred in India. Developing Asia's share in world growth declined to 43 percent during 1995–2003, remaining well above the region's share of 26.1 percent of world product. China accounted for more than half of this growth and India about a quarter.

The 15 non-G7 industrialized economies generated more than 8 percent of world output during 1989–2003. These economies were responsible for lower shares in world growth than world product before and after 1995. Prior to the fall of the Berlin Wall and the collapse of the Soviet Union, the 14 economies of Eastern Europe and the former Soviet Union were larger in size than the non-G7, generating 9.3 percent of world product. All of the economies of Eastern Europe experienced a decline in output during 1989–1995. Collectively, these economies subtracted 26.8 percent from world growth during 1989–1995, dragging their share of world product down to 6.6 percent. During 1989–1995, Russia's economy was comparable in size to Germany's, but from 1995 to 2003 the Russian economy was only slightly larger than the U.K. economy.

During 1989–1995, the 10 percent share of the Latin American economies in world growth exceeded their 8.5 percent share in world product. After 1995, these economies had a substantially smaller 6 percent share in world growth, while retaining close to an 8.5 percent share in world product, with Brazil and Mexico responsible for more than 60 percent of this amount. Brazil's share in world growth was below its 3 percent share in world product before and after 1995, while Mexico's growth was lower than its product share before 1995 and higher afterward.

The 11 economies of North Africa and the Middle East, taken together, were comparable in size to France, Italy or the U.K., while the 30 economies of Sub-Saharan Africa, as a group, ranked with Canada. The economies of North Africa and the Middle East had a share in world growth of 6.3 percent during 1989–1995, well above their 3.6 percent share in world product. After 1995, their share in world growth fell to 4.6 percent, still above the share in world product of 3.9 percent. Growth in the economies of Sub-Saharan Africa lagged behind their shares in world product during both periods.

III. Sources of World Economic Growth

Next, we allocate the sources of world economic growth during the period 1989–2003 between the contributions of capital and labor inputs and the growth of productivity. We find that productivity, frequently touted as the primary engine of economic growth, accounted for only 20–30 percent of world growth. Nearly half of this growth can be attributed to the accumulation and deployment of capital and another quarter to a third to the more

effective use of labor. Our second objective is to explore the determinants of the growth of capital and labor inputs, emphasizing the role of investment in information technology equipment and software as well as the importance of investment in human capital.

After having derived estimates of capital input and property income from national accounting data for the G7 economies, we constructed estimates of hours worked and labor compensation from labor force surveys for each of these economies. We measure the contribution of labor inputs, classified by age, sex, educational attainment and employment status, by weighting the growth rate of each type of labor input by its share in the value of output. We use purchasing power parities for capital and labor inputs constructed by Jorgenson (2003).[10] We have extended these estimates of capital and labor inputs to the 103 non-G7 countries using data sources and methods described in the Appendix to the electronic version of the paper.[11]

We have distinguished investments in information technology equipment and software from investments in other assets for all 110 economies in our study. We have derived estimates of IT investment from national accounting data for the G7 economies and those of the European Union before enlargement. We measure the contribution of IT investment to economic growth by weighting the growth rate of IT capital inputs by the shares of these inputs in the value of output. Similarly, the contribution of non-IT investment is a share-weighted growth rate of non-IT capital inputs. The contribution of capital input is the sum of these two components.

We have revised and updated the U.S. data in Jorgenson (2001) on investment in information technology and equipment.[12] Data on IT investment for Canada have been constructed by Statistics Canada.[13] Data for the countries of the European Union have been developed for the European Commission by van Ark *et al*.[14] Data for Japan have been compiled by Jorgenson and Motohashi.[15] We have relied on the WITSA *Digital Planet*

[10] Purchasing power parities for inputs follow the methodology described in detail by Jorgenson and Yip (2000).

[11] We use data on educational attainment from Barro and Lee (2001) and governance indicators constructed by Kaufmann, Kraay and Mastruzzi (2004) for the World Bank; for further details, see the electronic version of the paper: http://www.post.economics.harvard.edu/faculty/jorgenson/papers/papers.html.

[12] U.S. data on investment in IT equipment and software, provided by the Bureau of Economic Analysis (BEA), are the most comprehensive and detailed. The BEA data are described by Grimm, Moulton and Wasshausen (2005).

[13] See Baldwin and Harchaoui (2003).

[14] See van Ark *et al*. (2003, updated 2005).

[15] See Jorgenson and Motohashi (2005).

Report (2002, 2004), as the starting point for estimates of IT investment for the remaining economies.[16]

We have divided labor input growth between the growth of hours worked and labor quality, where quality is defined as the ratio of labor input to hours worked. This reflects changes in the composition of labor input, for example, through increases in the education and experience of the labor force. The contribution of labor input is the rate of growth of this input, weighted by the share of labor in the value of output. Productivity growth is the difference between the rate of growth of output and the contributions of capital and labor inputs.

The contribution of capital input to world economic growth before 1995 was 1.18 percent, slightly more than 47 percent of the growth rate of 2.50 percent. Labor input contributed 0.79 percent or slightly less than 32 percent, while productivity growth contributed 0.53 percent or just over 21 percent. After 1995 the contribution of capital input climbed to 1.56 percent, around 45 percent of output growth, while the contribution of labor input rose to 0.89 percent, around 26 percent. Productivity increased to 0.99 percent or nearly 29 percent of growth. We arrive at the astonishing conclusion that the contributions of capital and labor inputs greatly predominated over productivity as sources of world economic growth before and after 1995!

We have divided the contribution of capital input to world economic growth between IT equipment and software and non-IT capital input. The contribution of IT almost doubled after 1995, less than a quarter to more than a third of the contribution of capital input. However, non-IT was more important before and after 1995. We have divided the contribution of labor input between hours worked and labor quality. Hours rose from 0.39 percent before 1995 to 0.62 percent after 1995, while labor quality declined from 0.40 percent to 0.27 percent. Labor quality and hours worked were almost equal in importance before 1995, but hours worked became the major source of labor input growth after 1995.

The acceleration in the world growth rate after 1995 was 0.95 percent, almost a full percentage point. The contribution of capital input explained 0.38 percent of this increase, while productivity accounted for 0.46 percent. Labor input contributed a relatively modest 0.10 percent. The jump in IT investment of 0.26 percent was the most important source of the increase in capital input. This can be traced to the stepped-up rate of decline in IT prices after 1995 analyzed by Jorgenson (2001). The substantial increase of 0.23

[16] WITSA stands for the World Information Technology and Services Alliance. Other important sources of data include the International Telecommunication Union (ITU) telecommunications indicators, the UNDP *Human Development* reports, and the Business Software Alliance (2003). Additional details are given in the Appendix to the electronic version of this paper: http://www.post.economics.harvard.edu/faculty/jorgenson/papers/papers.html.

percent in the contribution of hours worked was the most important component of labor input growth.

Table 2 reports the contribution of capital input to economic growth for the G7 economies, divided between IT and non-IT. Capital input was the most important source of growth before and after 1995. The contribution of capital input before 1995 was 1.28 or almost three-fifths of the G7 growth rate of 2.18 percent, while the contribution of 1.43 percent after 1995 was 55 percent of the higher growth rate of 2.56 percent. Labor input growth contributed 0.49 percent before 1995 and 0.46 percent afterward, about 22 percent and 18 percent of growth, respectively. Productivity accounted for 0.42 percent before 1995 and 0.67 percent after 1995 or less than a fifth and slightly more than a quarter of G7 growth, respectively.

The powerful surge of IT investment in the U.S. after 1995 is mirrored in jumps in the growth rates of IT capital through the G7. The contribution of IT capital input for the G7 increased from 0.38 during the period 1989–1995 to 0.69 percent during 1995–2003, rising from 30 percent of the contribution of capital input to more than 48 percent. The contribution of non-IT capital input predominated in both periods, but receded slightly from 0.90 percent before 1995 to 0.74 percent afterward. This reflected more rapid substitution of IT capital input for non-IT capital input in response to swiftly declining prices of IT equipment and software after 1995.

The modest acceleration of 0.38 percent in G7 output growth after 1995 was powered by investment in IT equipment and software, accounting for 0.31 percent, while the contribution of non-IT investment slipped by 0.16 percent. Before 1995, the contribution of labor quality of 0.42 percent accounted for more than 80 percent of the contribution of G7 labor input, while the contribution of hours worked of 0.28 percent explained more than 60 percent after 1995. The rising contribution of hours worked was offset by the declining contribution of labor quality, while productivity growth rose by 0.25 percent.

In Developing Asia the contribution of capital input increased from 1.88 percent before 1995 to 2.70 percent after 1995, while the contribution of labor input fell from 1.61 percent to 1.19 percent. These opposing trends had a slightly positive impact on growth. The significant slowdown in the Asian growth rate from 7.35 percent to 5.62 percent can be traced entirely to a sharp decline in productivity growth from 3.86 to 1.72 percent. Productivity explained slightly more than half of Asian growth before 1995, but only 30 percent after 1995.

The first half of the 1990s witnessed a continuation of the Asian Miracle, analyzed by Krugman (1994), Lau (1999) and Young (1995). This period was dominated by the spectacular rise of China and India and the continuing emergence of the Gang of Four—Hong Kong, Singapore, South Korea and Taiwan. However, all the Asian economies had growth rates considerably in

Table 2. *Sources of output growth: 1995–2003 vs. 1989–1995*

	Period 1989–1995						Period 1995–2003					
		Sources of growth (% points per annum)						Sources of growth (% points per annum)				
		Capital		Labor				Capital		Labor		
Economy	GDP growth	ICT	Non-ICT	Hours	Quality	TFP	GDP growth	ICT	Non-ICT	Hours	Quality	TFP
World (110 economies)	**2.50**	**0.27**	**0.91**	**0.39**	**0.40**	**0.53**	**3.45**	**0.53**	**1.03**	**0.62**	**0.27**	**0.99**
G7 (7 economies)	2.18	0.38	0.90	0.07	0.42	0.42	2.56	0.69	0.74	0.28	0.18	0.67
Developing Asia (16)	7.35	0.15	1.73	1.19	0.42	3.86	5.62	0.43	2.27	0.81	0.38	1.72
Non-G7 (15)	2.03	0.32	0.68	0.21	0.21	0.61	3.01	0.49	0.77	1.06	0.20	0.49
Latin America (19)	3.06	0.16	0.58	1.20	0.37	0.75	2.11	0.39	0.61	1.10	0.34	−0.32
Eastern Europe (14)	−7.05	0.10	−0.15	−0.86	0.36	−6.50	2.87	0.23	−0.81	0.01	0.39	3.06
Sub-Saharan Africa (28)	1.21	0.13	0.24	1.66	0.56	−1.39	2.88	0.29	0.68	1.18	0.42	0.32
N. Africa & M. East (11)	4.36	0.15	0.72	1.43	0.56	1.50	4.08	0.40	0.88	2.02	0.49	0.30
Seven world major economies (G7)												
Canada	1.39	0.49	0.27	0.07	0.55	0.01	2.51	0.65	0.61	0.68	0.16	0.42
France	1.30	0.19	0.93	−0.17	0.61	−0.26	1.92	0.36	0.75	0.22	0.07	0.52
Germany	2.34	0.26	1.05	−0.42	0.33	1.12	0.86	0.40	0.50	−0.24	0.09	0.11
Italy	1.52	0.26	0.86	−0.35	0.38	0.37	1.48	0.46	0.96	0.61	0.27	−0.82
Japan	2.56	0.31	1.16	−0.39	0.54	0.94	1.39	0.56	0.26	−0.32	0.22	0.67
United Kingdom	1.62	0.27	1.69	−0.73	0.49	−0.10	2.55	0.65	0.19	0.38	0.26	1.07
United States	2.43	0.49	0.71	0.57	0.36	0.31	3.56	0.88	1.01	0.50	0.17	0.99
All G7	**2.18**	**0.38**	**0.90**	**0.07**	**0.42**	**0.42**	**2.56**	**0.69**	**0.74**	**0.28**	**0.18**	**0.67**

Table 2. *(Continued)*

	Period 1989–1995						Period 1995–2003					
		Sources of growth (% points per annum)						Sources of growth (% points per annum)				
		Capital		Labor				Capital		Labor		
Economy	GDP growth	ICT	Non-ICT	Hours	Quality	TFP	GDP growth	ICT	Non-ICT	Hours	Quality	TFP
Seven major developing and transition economies (GD7)												
Brazil	1.97	0.09	0.29	0.99	0.39	0.20	1.94	0.46	0.24	0.67	0.37	0.21
China	9.94	0.17	2.12	0.87	0.45	6.33	7.13	0.63	3.17	0.45	0.39	2.49
India	5.03	0.09	1.18	1.27	0.43	2.06	6.15	0.26	1.77	1.22	0.41	2.49
Indonesia	6.82	0.10	1.62	1.64	0.43	3.04	2.41	0.09	1.47	0.91	0.41	−0.47
Mexico	2.19	0.24	0.95	1.48	0.38	−0.87	3.56	0.23	1.11	1.76	0.31	0.14
Russian Federation	−8.44	0.07	−0.07	−1.02	0.37	−7.79	3.18	0.10	−1.30	0.21	0.44	3.73
South Korea	7.48	0.29	2.31	1.45	0.31	3.13	4.09	0.46	1.67	0.86	0.26	0.85
All GD7	**3.45**	**0.13**	**1.17**	**0.72**	**0.41**	**1.03**	**5.18**	**0.40**	**1.70**	**0.74**	**0.39**	**1.96**

Note: The measures for groups and the world are averages weighted by GDP (in PPP$) share.

excess of the world average of 2.50 percent. The second half of the 1990s was dominated by the Asian financial crisis but, surprisingly, conforms much more closely to the "Krugman thesis" which attributes Asian growth to input growth rather than productivity.

The "Krugman thesis" was originally propounded to distinguish the Asian Miracle from growth in industrialized countries. According to this thesis, Asian growth was differentiated by high growth rates and a great predominance of inputs over productivity as the sources of high growth. In fact, productivity growth exceeded the growth of input during the Asian Miracle of the early 1990s! Moreover, growth in the world economy and the G7 economies was dominated by growth of capital and labor inputs before and after 1995. Productivity growth played a subordinate role and fell considerably short of the contributions of capital and labor inputs to world and G7 growth.

Developing Asia experienced a potent surge in investment in IT equipment and software after 1995. The contribution of IT investment more than doubled from 0.15 percent to 0.43 percent, thereby explaining less than 8 percent of the contribution of capital input before 1995, but almost 16 percent afterward. The rush in IT investment was particularly powerful in China; it rose from 0.17 percent before 1995 to 0.63 percent afterward. India fell substantially behind China, but outperformed the region as a whole, by increasing the contribution of IT investment from 0.09 to 0.26 percent.

Indonesia was the only major economy to experience a decline in the contribution of both IT and non-IT investment after 1995. South Korea's IT investment increased from 0.29 before 1995 to 0.46 percent afterward, while non-IT investment dropped as a consequence of the Asian financial crisis. The contribution of non-IT investment in Asia greatly predominated in both periods and also accounted for most of the increase in the contribution of capital input after 1995. The contributions of hours worked and labor quality declined after 1995, with hours worked dominating in both periods.

Economic growth in the 15 non-G7 industrialized economies accelerated much more sharply than G7 growth after 1995. The contribution of labor input slightly predominated over capital input before and after 1995. The contribution of labor input was 0.81 percent before 1995, accounting for about 40 percent of non-G7 growth, and 1.26 after 1995, explaining 39 percent of growth. The corresponding contributions of capital input were 0.75 percent and 1.12 percent, explaining 37 and 34 percent of non-G7 growth, respectively. Non-G7 productivity also rose from 0.47 before 1995 to 0.89 percent afterward; however, productivity accounted for only 23 and 27 percent of growth in these two periods.

The impact of investment in IT equipment and software in the non-G7 economies doubled after 1995, rising from 0.22 percent to 0.44 percent or

from 29 percent of the contribution of non-G7 capital input to 39 percent. This provided a substantial impetus to the acceleration in non-G7 growth of 1.25 percent. Non-IT investment explained another 0.14 percent of the growth acceleration. However, the increased contribution of hours worked of 0.49 percent and improved productivity growth of 0.42 percent predominated.

The collapse of economic growth in Eastern Europe and the former Soviet Union before 1995 can be attributed almost entirely to a steep decline in productivity during the transition from socialism. This was followed by a modest revival in both growth and productivity after 1995, thereby bringing many of the transition economies close to levels of output per capita that prevailed in 1989. The contribution of capital input declined both before and after 1995, even as the contribution of IT investment jumped from 0.09 to 0.26 percent. Hours worked also declined in both periods, but labor quality improved substantially.

Latin America's growth decelerated slightly after 1995, falling from 2.95 to 2.52 percent. The contribution of labor input was 1.92 percent before 1995 and 1.89 percent afterward, accounting for the lion's share of regional growth in both periods. The contribution of capital input rose after 1995 from 0.72 percent to 0.99 percent, but remained relatively weak. Mexico's IT investment declined slightly after 1995, while non-IT investment increased. Nonetheless, the contribution of IT investment in Latin America more than doubled, jumping from 0.15 percent before 1995 to 0.34 percent afterward or from 21 percent of the contribution of capital input to 34 percent. Productivity was essentially flat from 1989 to 2001, rising by 0.31 percent before 1995 and falling by 0.36 percent after 1995.

Productivity in Sub-Saharan Africa collapsed during 1989–1995 but recovered slightly, running at −1.63 percent before 1995 and 0.36 percent afterward. The contribution of labor input predominated in both periods, but fell from 2.77 percent to 1.89 percent, while the contribution of capital input rose from 0.52 percent to 0.99 percent. Productivity in North Africa and the Middle East, like that in Latin America, was essentially stationary during 1989–2001; it fell from a positive rate of 0.50 percent before 1995 to a negative rate of −0.46 percent afterward.

IV. World Output, Input and Productivity

The final step in our analysis of the world growth resurgence is to describe and characterize the levels of output, input and productivity for the world economy, the seven economic regions and the 14 major economies in Table 3. We report levels of output per capita for 1989, before the transition from socialism, 1995, the start of the worldwide IT investment boom, and 2003, the end of the period covered by our study. We also show input per capita

Table 3. *Levels of output and input per capita and productivity (U.S. = 100 in 2000)*

	Output per capita			Input per capita			Productivity		
Region/Country	1989	1995	2003	1989	1995	2003	1989	1995	2003
World	**18.9**	**20.0**	**23.9**	**38.5**	**38.5**	**42.4**	**49.0**	**52.0**	**56.3**
G7	66.9	72.8	85.5	72.8	77.4	86.4	91.9	94.1	99.0
Developing Asia	6.0	8.5	12.1	19.1	21.5	26.2	31.7	39.7	46.1
Non-G7	51.5	56.0	68.0	61.9	64.9	75.9	83.2	86.4	89.5
Latin America	18.6	20.0	21.0	27.1	28.2	30.5	68.4	71.0	68.7
Eastern Europe	34.3	22.5	29.3	43.2	41.4	42.6	79.4	54.4	68.8
Sub-Saharan Africa	5.3	4.8	5.0	15.7	15.7	16.7	33.5	30.6	30.0
N. Africa & M. East	12.5	14.2	17.0	22.3	23.2	27.3	55.9	61.1	62.3
Seven world major economies (G7)									
Canada	79.4	80.2	91.0	75.0	75.7	83.2	105.9	105.9	109.5
France	54.5	57.4	64.7	53.7	57.4	62.1	101.5	100.0	104.2
Germany	59.0	65.5	69.4	71.6	74.3	78.0	82.4	88.2	89.0
Italy	57.7	62.5	69.9	55.9	59.2	70.7	103.2	105.6	98.9
Japan	56.3	64.4	70.8	72.5	78.3	81.7	77.7	82.2	86.7
United Kingdom	56.9	61.8	73.7	61.7	67.5	73.9	92.2	91.6	99.8
United States	80.6	86.3	106.4	84.4	89.1	101.4	95.5	96.9	104.9
All G7	**66.9**	**72.8**	**85.5**	**72.8**	**77.4**	**86.4**	**91.9**	**94.1**	**99.0**
Seven major developing and transition economies (GD7)									
Brazil	19.9	20.5	21.5	29.3	29.8	30.8	67.9	68.7	69.8
China	4.8	8.1	13.4	17.9	20.7	28.0	26.9	39.3	48.0
India	5.0	6.0	8.6	15.9	17.0	19.9	31.2	35.3	43.1
Indonesia	8.3	11.3	12.2	23.7	26.8	29.9	35.3	42.3	40.7
Mexico	22.2	22.3	26.6	28.0	29.7	34.9	79.3	75.3	76.1
Russian Federation	41.8	25.1	33.5	50.0	48.0	47.4	83.6	52.4	70.6
South Korea	24.3	35.8	46.5	37.1	45.4	55.0	65.4	78.9	84.5
All GD7	**9.0**	**10.2**	**14.0**	**24.4**	**24.0**	**28.3**	**36.8**	**42.4**	**49.6**

Note: The levels for groups and the world are averages weighted by population share.

and productivity for the years 1989, 1995 and 2003, where productivity is defined as the ratio of output to input.

The G7 economies led the seven economic regions in output per capita, input per capita and productivity throughout the period 1989–2003. Output per capita in the G7 was, nonetheless, well below U.S. levels. Taking U.S. output per capita in 2000 as 100.0, G7 output per capita was 66.9 in 1989, 72.8 in 1995 and 85.5 in 2003. For comparison: U.S. output per capita was 80.6, 86.3 and 106.4 in these years.

The output gap between the U.S. and the other G7 economies widened considerably, especially since 1995. Canada was very close to the U.S. in output per capita in 1989, but dropped substantially behind by 1995. The U.S.–Canada gap widened further during the last half of the 1990s. Germany, Japan, Italy and the U.K. had similar levels of output per capita throughout 1989–2003, but remained considerably behind North America.

France lagged the rest of the G7 in output per capita in 1989 and failed to make up lost ground.

The U.S. was the leader among the G7 economies in input per capita throughout the period 1989–2003. Taking the U.S. as 100.0 in 2000, G7 input per capita was 72.8 in 1989, 77.4 in 1995 and 86.4 in 2003, while U.S. input per capita was 84.4, 89.1 and 101.4, respectively. Canada, Germany and Japan were closest to U.S. levels of input per capita with Canada ranking second in 1989 and 2003 and Japan ranking second in 1995. France lagged behind the rest of the G7 in input per capita throughout the period, with Italy and the U.K. only modestly higher.

Productivity in the G7 has remained close to U.S. levels, rising from 91.7 in 1989 to 93.9 in 1995 and 96.7 in 2001, with the U.S. equal to 100.0 in 2000. Canada was the productivity leader throughout 1989–2003, with Italy and France close behind. The U.S. occupied fourth place in 1989 and 1995, but rose to second in 2003. Japan made substantial gains in productivity, but lagged behind the other members of the G7 in productivity, while Germany surpassed only Japan.

Differences among the G7 economies in output per capita can be largely explained by differences in input per capita rather than gaps in productivity. The range in output was from 64.7 for France to 106.4 for the U.S., while the range in input was from 62.1 for France to 101.4 for the U.S. Productivity varied more narrowly from 86.7 for Japan to 109.5 for Canada, with French productivity of 104.2 closely comparable to the U.S.

In the economies of Developing Asia, output per capita rose spectacularly from 6.0 in 1989 to 8.5 in 1995 and 12.1 in 2003 with the U.S. equal to 100.0 in 2000. Levels of output per capita in Asia's largest economies, China and India, remained at 13.4 and 8.6, respectively, in 2003. These vast shortfalls in output per capita relative to the industrialized economies are due mainly to differences in input per capita, rather than variations in productivity. Developing Asia's levels of input per capita were 19.1 in 1989, 21.5 in 1995 and 26.2 in 2003, while Asian productivity levels were 31.7, 39.7 and 46.1, respectively.

China made extraordinary gains in output per capita, growing from 4.8 in 1989 to 8.1 in 1995 and 13.4 in 2003 with the U.S. equal to 100.0 in 2000. India had essentially the same output per capita as China in 1989, but grew less impressively to levels of only 6.0 in 1995 and 8.6 in 2003. China's input per capita—17.9 in 1989, 20.7 in 1995 and 28.0 in 2001—exceeded India's throughout the period. India's 31.2 productivity level in 1989 considerably surpassed China's 26.9. China's productivity swelled to 39.3 in 1995, outstripping India's 35.3. China expanded its lead with a productivity level of 48.0 in 2003 by comparison with India's 43.1.

Indonesia and South Korea grew impressively from 1989 to 1995, but fell victim to the Asian financial crisis during the period 1995–2003. Indonesia

maintained its lead over India in output per capita, but dropped behind China in 2003. Indonesia led both China and India in input per capita during 1989–2003. Indonesia's productivity level led both China and India in 1995, but fell behind both economies by 2003. South Korea made substantial gains in productivity; it achieved a level close to Japan in 2003, while falling considerably short of Japan's impressive input per capita.

The 15 non-G7 industrialized economies, taken together, had levels of output per capita comparable to Germany, Italy, Japan and the U.K. during 1989–2003. Input per capita for the 15 non-G7 economies was also very close to these four G7 economies. However, productivity for the group was comparable to that of Germany, the second lowest in the G7.

Before the beginning of the transition from socialism in 1989, output per capita in Eastern Europe and the former Soviet Union was 34.3, well above the world economy level of 18.9, with the U.S. equal to 100.0 in 2000. The economic collapse that accompanied the transition reduced output per capita to 22.5 by 1995, only modestly higher than the world economy level of 20.0. A mild recovery between 1995 and 2003 brought the region back to 29.3, below the level of 1989, but well above the world economy average of 23.9. Input in the region was stagnant at 43.2 in 1989, 41.4 in 1995 and 42.6 in 2003. Productivity collapsed along with output per capita, declining from 79.4 in 1989 to 54.4 in 1995, before climbing back to 68.8 in 2003.

The downturn in output per capita and productivity was especially severe in the economies of the former Soviet Union. Russia's level of output per capita fell from 41.8 in 1989 to 25.1 in 1995, before recovering feebly to 33.5 in 2003. Russian input per capita remained essentially unchanged throughout the period 1989–2003, while productivity mirrored the decline and subsequent recovery in output, falling from a West European level of 83.6 in 1989 to 52.4 in 1995, before recovering to 70.6 in 2003. We conclude that the transition from socialism failed to restore Eastern Europe and the former Soviet Union to pre-transition levels of output and input per capita by 2003, while productivity remained weaker than before the transition.

For the Latin American region, output per capita rose from 18.6 to 21.0 during 1989–2003, input per capita rose from 27.1 to 33.0, but productivity was essentially unchanged at about two-thirds of the U.S. level in 2000. The stall in productivity from 1989 to 2003 was pervasive, contrasting sharply with the rise in productivity in the G7 economies, the non-G7 industrialized economies and Developing Asia. Nonetheless, Latin America's lagging output per capita was due chiefly to insufficient input per capita, rather than a shortfall in productivity.

Brazil's economic performance has been anemic at best and has acted as a drag on the growth of Latin America and the world economy. Despite productivity levels comparable to the rest of Latin America, Brazil was unable to generate substantial growth in input per capita. Although Mexico

lost ground in productivity between 1989 and 2003, rising input per capita produced gains in output per capita after 1995, despite a slight decline in the contribution of IT investment.

Output and input per capita in Sub-Saharan Africa was the lowest in the world throughout the period 1989–2003, but the level of productivity was slightly higher than Developing Asia in 1989. All the economies of North Africa and the Middle East fell short of world average levels of output and input per capita. Output per capita grew slowly but steadily for the region as a whole during 1989–2003, powered by impressive gains in input per capita, but with stagnant productivity.

V. Summary and Conclusions

World economic growth, led by the industrialized economies and Developing Asia, experienced a strong resurgence after 1995. Developing Asia accounted for an astonishing 60 percent of world economic growth before 1995 and 40 percent afterward, with China alone responsible for half of this amount, but remained well below the world average in output per capita. Sub-Saharan Africa and North Africa and the Middle East languished far below the world average. Eastern Europe and the former Soviet Union lost enormous ground during the transition from socialism and have yet to recover completely.

The growth trends most apparent in the U.S. have counterparts throughout the world. Investment in tangible assets, including IT equipment and software, was the most important source of growth. However, non-IT investment predominated. The contribution of labor input was next in magnitude with labor quality dominant before 1995 and hours worked afterward. Finally, productivity was the least important of the three sources of growth, except for the Asian Miracle before 1995.

The leading role of IT investment in the acceleration of growth in the G7 economies is especially pronounced in the U.S., where IT is coming to dominate the contribution of capital input. The contribution of labor input predominated in the non-G7 industrialized economies, as well as Latin America, Eastern Europe, Sub-Saharan Africa, and North Africa and the Middle East. Productivity growth was the important source of growth in Developing Asia before 1995, but assumed a subordinate role after 1995. Productivity has been stagnant or declining in Latin America, Eastern Europe, Sub-Saharan Africa, and North Africa and the Middle East.

All seven regions of the world economy experienced a surge in investment in IT equipment and software after 1995. The impact of IT investment on economic growth has been most striking in the G7 economies. The rush in IT investment was especially conspicuous in the U.S., but jumps in the

contribution of IT capital input in Canada, Japan and the U.K. were only slightly lower. France, Germany and Italy also experienced a surge in IT investment, but lagged considerably behind the leaders. While IT investment followed similar patterns in the G7 economies, non-IT investment varied considerably and explains important differences among growth rates.

Although the surge in investment in IT equipment and software is a global phenomenon, the variation in the contribution of this investment has increased considerably since 1995. Following the G7, the next most important increase was in Developing Asia, led by China. The non-G7 industrialized economies followed Developing Asia. The role of IT investment more than doubled after 1995 in Latin America, Eastern Europe, North Africa and the Middle East, and Sub-Saharan Africa.

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