
Information Technology and the World Growth Resurgence

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Abstract. *This paper analyzes 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 1989–2004. We allocate the growth of world output between input growth and productivity and find, surprisingly, that input growth greatly predominates! Moreover, differences in per capita output levels are explained by differences in per capita input, rather than variations in productivity. The contributions of IT investment have increased in all regions, but especially in industrialized economies and Developing Asia.*

JEL classification: O47.

Keywords: Growth; investment; productivity; information technology.

1. INTRODUCTION

The purpose of this paper is to analyze the impact of investment in information technology (IT) equipment and software on the recent revival of world economic growth. The crucial role of IT investment in the growth of the US economy has been thoroughly documented and widely discussed.¹ Jorgenson (2001) has shown that the remarkable behavior of IT prices is the key to understanding of the American growth resurgence since 1995. 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,

1. See Jorgenson and Stiroh (2000) and Oliner and Sichel (2000). The growth accounting methodology employed in this literature is discussed by Jorgenson *et al.* (2005) and summarized by Jorgenson (2005).

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 resulted from a sharp acceleration in the rate of decline of prices of IT equipment and software. Jorgenson (2001) has traced this to a drastic shortening of the product cycle for semiconductors from three to two years, beginning in 1995.

In Section 2, we describe the growth of the world economy, seven economic regions, and 14 major economies during the period 1989–2004.³ 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 1989–2004 into 1989–95, 1995–2000 and 2000–04 in order to focus on the response of IT investment to the accelerated decline in IT prices in 1995 and the impact of the dot-com crash of 2000. World economic growth has undergone a powerful revival since 1995. The per capita growth rate jumped a full percentage point from 2.72 per cent during 1989–95 to 3.73 per cent in 1995–2000 and higher growth was sustained at a rate of 3.75 per cent after 2000. We can underscore the significance of more rapid growth by pointing out that per capita growth of 2.72 per cent doubles world output by four times in a century, while 3.75 per cent doubles output more than five times per century.

In Section 3, we allocate the growth of world output between input growth and productivity. Our most astonishing finding is that input growth greatly predominates! Productivity growth accounted for less than one-fifth of the total during 1989–95, while input growth accounted for more than four-fifths. Similarly, input growth contributed almost three-quarters of growth from 1995 to 2000 and more than three-fifths from 2000 to 2004. The only departure from this worldwide trend was the revival of economic growth in Eastern Europe after 1995, driven by a rebound from the productivity collapse of 1989–95.

In Section 3, we distribute the growth of input per capita between investments in human capital and tangible assets, especially IT equipment and software. The world economy, all seven regions, and the 14 major economies experienced a surge in investment in IT after 1995. The soaring

2. Ahmad *et al.* (2004) have analyzed the impact of IT investment in OECD countries. Timmer *et al.* (2003, 2005) and Francesco 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 one million in population and a complete set of national accounts for the period 1989–2004 from Penn World Table (2002) and World Bank Development Indicators Online (2006). These economies account for more than 96 per cent of world output.

Information Technology and the World Growth Resurgence

level of US 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.

The contribution of IT investment to growth of the G7 economies has moderated substantially since the dot-com crash of 2000. The IT contribution has slowed for the Non-G7 industrialized economies as well. However, the contribution of IT investment has continued to rise for Developing Asia, Latin America, Eastern Europe, North Africa and the Middle East, and Sub-Saharan Africa. The contributions of Non-IT investment and labor input to world growth declined after the dot-com crash, but total factor productivity growth rose substantially, reflecting increases in all regions except North Africa and the Middle East.

In Section 4, we present 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 US output per capita in 2000 as 100.0, world output per capita was a relatively modest 24.9 in 2004. Using similar scales for input and productivity, world input per capita in 2004 was a substantial 37.7 and world productivity a robust 66.0. Section 5 concludes the paper.

2. WORLD ECONOMIC GROWTH, 1989–2004

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 the seven regions and 14 major economies presented in Table 1. Following Jorgenson (2001), we have chosen GDP as a measure of output. We employ the Penn World Table, presented by Heston (2002), as the primary data source on GDP and purchasing power parities for economies outside the G7 and the European Union before enlargement in May 2004.⁴

We have revised and updated the United States data presented by Jorgenson (2001) through 2004. Comparable data for Canada have been constructed by Statistics Canada; see Baldwin and Harchaoui (2003). Data for France, Germany, Italy and the United Kingdom, and the economies of the European Union before enlargement have been developed for the European Commission by Timmer *et al.* (2003, updated 2005). Finally, data for Japan have been assembled by Jorgenson and Motohashi for the Research Institute on Economy, Trade and Industry; see Jorgenson and Motohashi (2005). We

4. Maddison (2001) provides estimates of national product and population for 134 countries for varying periods from 1820 to 1998 in his magisterial volume, *The World Economy: A Millennial Perspective*.

Table 1 The world economy: shares in size and growth by economy and region

Group	Period 1989-95				Period 1995-2000				Period 2000-04						
	Average share		GDP		Average share		GDP		Average share		GDP				
	GDP growth	Growth	GDP growth	Growth	GDP growth	Growth	GDP growth	Growth	GDP growth	Growth	GDP growth	Growth			
<i>Group summaries</i>															
World (110 economies)	2.72	100.00	3.73	100.00	3.75	100.00	3.75	100.00	3.75	100.00	3.75	100.00			
G7 Economies	2.19	49.22	3.25	39.69	3.25	47.24	3.25	41.15	2.20	45.00	2.20	26.44			
Developing Asia	7.54	20.06	5.91	55.67	5.91	24.44	5.91	38.67	6.51	27.31	6.51	47.45			
Non-G7	2.08	9.22	2.89	7.05	2.89	8.97	2.91	6.95	2.91	8.70	2.91	6.76			
Latin America	2.92	8.68	2.02	9.34	2.02	8.41	2.94	4.55	2.94	7.91	2.94	6.20			
Eastern Europe	-6.38	7.46	2.27	-17.50	2.27	5.48	4.79	3.34	4.79	5.59	4.79	7.14			
Sub-Saharan Africa	1.57	2.21	3.26	1.28	3.26	2.15	1.88	3.74	3.74	2.13	3.74	2.13			
North Africa and Middle East	3.97	3.15	3.91	4.59	3.91	3.31	3.46	3.46	4.30	3.37	4.30	3.87			
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Economy	Period 1989-95				Period 1995-2000				Period 2000-04						
	GDP share		GDP		GDP share		GDP		GDP share		GDP				
	World	Group	World	Group	World	Group	World	Group	World	Group	World	Group			
G7 (seven economies)	1.39	4.78	2.35	3.02	1.20	3.67	4.82	2.28	5.44	2.24	2.76	4.98	2.24	6.25	1.65
Canada	1.30	6.78	3.34	4.02	1.59	2.38	6.60	3.12	4.82	1.98	2.18	6.51	2.93	6.46	1.71
France	2.34	10.46	5.15	11.17	4.43	1.80	10.23	4.84	5.67	2.33	0.51	9.66	4.35	2.22	0.59
Germany	1.52	7.44	3.66	5.14	2.04	1.92	7.09	3.35	4.18	1.72	1.39	6.74	3.03	4.24	1.12
Italy	2.56	16.62	8.18	19.41	7.71	2.09	16.07	7.59	10.33	4.25	1.48	15.26	6.87	10.26	2.71
Japan	1.62	7.31	3.60	5.40	2.14	2.85	7.27	3.43	6.37	2.62	2.63	7.29	3.28	8.71	2.30
United Kingdom	2.44	46.62	22.94	51.84	20.58	4.29	47.92	22.63	63.18	25.99	2.75	49.56	22.30	61.87	16.36
United States	2.19	100.00	49.22	100.00	39.69	3.25	100.00	47.24	100.00	41.14	2.20	100.00	45.00	100.00	26.44
All group															

Information Technology and the World Growth Resurgence

<i>Developing and transition economies (seven economies)</i>															
Brazil	1.82	13.36	3.25	5.86	2.18	1.74	11.40	3.04	3.75	1.41	2.48	9.57	2.82	3.79	1.88
China	10.05	31.26	7.57	75.57	27.98	7.93	39.12	10.39	58.69	22.07	8.39	43.20	12.68	57.91	28.37
India	5.13	19.78	4.81	24.39	9.06	5.74	20.66	5.50	22.45	8.45	5.95	20.64	6.06	19.63	9.63
Indonesia	7.73	5.97	1.45	11.11	4.12	1.84	5.88	1.57	2.04	0.77	2.55	4.96	1.46	2.02	0.99
Mexico	2.04	8.25	2.01	4.06	1.51	3.52	7.47	1.99	4.98	1.88	3.67	6.76	1.99	3.96	1.95
Russia	-8.43	15.52	3.81	-31.47	-11.83	1.60	9.26	2.47	2.81	1.06	5.88	9.01	2.65	8.48	4.16
S. Korea	7.44	5.86	1.42	10.48	3.89	4.50	6.21	1.65	5.29	2.00	4.50	5.86	1.72	4.22	2.07
All group	4.16	100.00	24.32	100.00	36.92	5.29	100.00	26.61	100.00	37.64	6.26	100.00	29.37	100.00	49.02

have linked these data by means of the OECD's purchasing power parities for 2002; see OECD (2005).

The G7 economies accounted for slightly under half of world product from 1989–95. The per capita growth rates of these economies – 2.19 per cent before 1995, 3.25 per cent from 1995 to 2000, and 2.20 per cent during 2000–04 – lagged considerably behind world growth rates for these periods. The G7 shares in world growth were 39.7 per cent during 1989–95 and 41.2 per cent from 1995 to 2000, but only a meager 26.4 per cent during 2000–04. This led to a decline of four percentage points in the G7 share of world product from 49 per cent in 1989–95 to 45 per cent during 2000–04.

During 1989–95 the United States accounted for 22.9 per cent of world product and 46.6 per cent of G7 product. The US share of G7 output rose to 47.9 per cent from 1995 to 2000 and 49.6 per cent during 2000–04. After 1995 Japan fell from its ranking as the world's second largest economy to third largest after China, but remained second among the G7 economies. Germany dropped from fourth place before 1995, following the United States, China and Japan, to fifth place after 1995, ranking behind India as well. However, Germany retained its position as the leading European economy. France, Italy and the United Kingdom were considerably smaller, but similar in size. Canada was the smallest of the G7 economies.

The US growth rate jumped from 2.44 per cent during 1989–95 to 4.29 per cent in 1995–2000, before subsiding to 2.75 per cent from 2000 to 2004. The period 2000–04 includes the dot-com crash of 2000, the shallow US recession of 2001, and the recovery that followed, while the period 1995–2000 encompasses the IT-generated investment boom of the last half of the 1990s. The United States share in world growth exceeded its share in world product only during 1995–2000. The remaining G7 economies had lower shares of world growth than world product throughout the period 1989–2004.

The 16 economies of Developing Asia generated only slightly more than a fifth of world output before 1995, but 24.4 per cent from 1995 to 2000 and a stunning 27.3 per cent after 2000! The burgeoning economies of China and India accounted for more than 60 per cent of Asian output during 1989–95, 65 per cent in 1995–2000, and 68.6 per cent after 2000.⁵ The economies of Developing Asia grew at 7.54 per cent before 1995, 5.91 per cent from 1995 to 2000, and 6.51 per cent after 2000. These economies generated an astounding 55.7 per cent of world growth during the remarkable revival of 1989–95! Developing Asia's share in world growth declined to 38.7 per cent during 1995–2000, below the G7 share of 41.2 per cent, but recovered to 47.5 per

5. Our data for China are taken from the Penn World Table (2002). These data are based on Maddison (1998) rather than official Chinese estimates. Maddison (2006) and Alwyn Young (2003) present persuasive evidence that the official estimates exaggerate the growth of output and productivity in China. For extensive references to the debate over Chinese growth rates and a review of the issues, see the recent critique of Maddison by Holz (2006) and Maddison's (2006) reply.

Information Technology and the World Growth Resurgence

cent after 2000. China alone accounted for more than a quarter of world growth during the period 1989–2004.

The 15 Non-G7 industrialized economies generated 9.2 per cent of world output during 1989–95. However, these economies had lower shares in world growth than world product throughout the period 1989–2004. Their shares in world output dropped to 9 per cent during 1995–2000 and 8.7 per cent after 2000. All of the economies of Eastern Europe experienced a decline in output during 1989–95 after initiating the transition from socialism to a market economy. Collectively, these economies reduced world growth by 17.5 per cent during the period 1989–95, lowering their share of world product by almost two percentage points from 7.5 per cent during 1989–95 to 5.5 per cent in 1995–2000, and 5.6 per cent after 2000.

During 1989–95 the 9.2 per cent share of the Latin American economies in world growth exceeded their 8.7 per cent share in world product. Growth in these economies declined to 4.6 per cent of world growth in 1995–2000 and revived modestly to 6.2 per cent after 2000. Brazil and Mexico were responsible for about 60 per cent of Latin American GDP throughout the period 1989–2004. However, the shares of these two major Latin American economies in world product fell below their growth shares, leading to gradual declines in their product shares from 5.3 per cent in 1989–95, to 5 per cent during 1995–2000, and 4.8 per cent after 2000.

The 11 economies of North Africa and the Middle East, taken together, were comparable in size to France, Italy or the UK, 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 4.6 per cent during 1989–95, well above their 3.2 per cent share in world product. During 1995–2000 their share in world growth fell to 3.5 per cent, still above the corresponding share in world product of 3.3 per cent. This trend continued with a growth share of 3.9 per cent and a product share of 3.4 per cent after 2000. Growth shares in the economies of Sub-Saharan Africa lagged behind their shares in world product before 2000, but the two shares were essentially the same after 2000.

3. SOURCES OF WORLD ECONOMIC GROWTH

In this section, we allocate the sources of world economic growth among the contributions of capital and labor inputs and the growth of productivity. About 35–40 per cent of world growth can be attributed to the accumulation and deployment of capital and another a quarter to a third to the more effective use of labor. We find that productivity, frequently described as the primary engine of economic growth, accounted for only 20–40 per cent of growth.

We have derived estimates of capital input and property income from national accounting data for the G7 economies. We have 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. Finally, we employ purchasing power parities for capital and labor inputs constructed by Jorgenson (2003).⁶ 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.⁷

Our second objective is to explore the determinants of the growth of capital input, emphasizing the role of investment in information technology equipment and software. We have derived estimates of IT investment from national accounting data for the G7 and the economies of the European Union before enlargement. We measure the contribution of IT investment to economic growth by weighting the growth rate of IT capital input by its share in the value of output. Similarly, the contribution of Non-IT investment is a share-weighted growth rate of Non-IT capital input. The contribution of capital input is the sum of these two components.

We have revised and updated the US data presented by Jorgenson (2001) on investment in information technology and equipment.⁸ Data on IT investment for Canada have been constructed by Statistics Canada; see Baldwin and Harchaoui (2003). Data for the countries of the European Union have been developed for the European Commission by Timmer *et al.* (2003, updated 2005). Finally, data for Japan have been assembled by Jorgenson and Motohashi (2005). We have relied on the WITSA *Digital Planet Report* (2006), as the starting point for estimates of IT investment for the remaining economies.⁹

Our third objective is to analyze the determinants of the growth of labor input, focusing on the role of investment in human capital. 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. Labor quality growth captures the impact of changes in the composition of labor

6. Purchasing power parities for inputs follow the methodology described in detail by Jorgenson and Yip (2001).
7. We employ data on educational attainment from Barro *et al.* (2001) and governance indicators constructed by Kaufmann *et al.* (2004) for the World Bank; for further details, see the electronic version of the paper: <http://post.economics.harvard.edu/faculty/jorgenson/papers/papers.html>
8. US 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 *et al.* (2005).
9. 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 (2006). Additional details are given in the appendix to the electronic version of this paper: <http://post.economics.harvard.edu/faculty/jorgenson/papers/papers.html>

Information Technology and the World Growth Resurgence

input. These arise, e.g., through increases in the education and experience of the labor force. The contribution of labor input is the sum of the two components, weighted by the share of labor in output. Finally, 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 1.13 per cent, more than 41.5 per cent of the growth rate of 2.72 per cent. Labor input contributed 1 per cent or slightly <36.4 per cent of growth, while productivity growth was 0.61 per cent per year or just over 22.4 per cent of growth. During 1995–2000 the contribution of capital input climbed to 1.51 per cent, nearly 40.5 per cent of output growth of 3.73 per cent, while the contribution of labor input rose to 1.27 per cent, around 34 per cent. Productivity increased to 0.96 per cent per year or 25.7 per cent of growth.

After 2000 world growth continued at an accelerated rate of 3.75 per cent. The contribution of capital declined to 1.28 or 34.2 per cent of the world growth. The contribution of labor fell to 1.07 or 28.5 per cent of growth. More rapid growth was maintained by a jump in productivity growth to 1.4 per cent per year or 37.3 per cent of the growth of output. We arrive at the astonishing conclusion that the contributions of capital and labor inputs greatly predominate over productivity as sources of world economic growth throughout the period 1989–2004!

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 from less than a quarter of the contribution of capital input during 1989–95 to well over a third from 1995 to 2000. The share of IT in the contribution of capital input receded to slightly less than a third after the dot-com crash of 2000. However, it is important to emphasize that the contribution of Non-IT investment was more important throughout the period 1989–2004.

We have divided the contribution of labor input between hours worked and labor quality. Hours worked was the major source of the contribution of labor input to economic growth throughout the period 1989–2004. The contribution of hours rose from 0.53 per cent before 1995 to 0.92 per cent during 1995–2000, but fell back to 0.70 per cent after 2000. The contribution of labor quality declined steadily from 0.45 per cent before 1995 to 0.34 per cent during 1995–2000 and to 0.37 per cent after 2000.

After 1995 world economic growth jumped by a full percentage point. The contribution of capital explained 0.38 per cent of this acceleration, while productivity growth accounted for 0.35 per cent, and labor contributed 0.28 per cent. The jump in IT investment of 0.29 per cent was by far the most important source of the increase in capital. This can be traced to the more rapid rate of decline of IT prices after 1995 analyzed by Jorgenson (2001). The substantial increase of 0.39 per cent in the contribution of hours worked offset the decline in the contribution of labor quality.

Table 2 presents 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 2.19 per cent. The capital contribution of 1.69 per cent from 1995 to 2000 was 52 per cent of the higher growth rate of 3.25 per cent. After 2000 the capital contribution fell to 1.05 or 47.7 per cent of the substantially lower G7 growth rate of 2.20 per cent.

Labor input growth contributed 0.50 per cent to growth of the G7 economies before 1995, 0.87 per cent in 1995–2000, but only 0.36 per cent after 2000. Hours worked predominated during 1995–2000, growing at 0.63 per cent, while labor quality rose at 0.24 per cent.

Growth in hours was only

- (1) 0.07 per cent before 1995 and 0.28 per cent after 2000, while labor quality growth was 0.43 and 0.17 per cent, respectively. Productivity accounted for 0.42 per cent before 1995, 0.69 per cent during 1995–2000.
- (2) 0.79 per cent after 2000. Productivity ranged from <20 per cent before 1995 to 36 per cent after 2000.

The powerful surge of IT investment in the United States 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 more than doubled from 0.39 during the period 1989–95 to 0.82 per cent during 1995–2004, before receding to 0.47 per cent after 2000. The contribution of Non-IT capital input predominated in all three sub-periods, but fell steadily throughout 1989–2004. 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.

In Developing Asia the contribution of capital input increased from 1.81 per cent before 1995 to 2.22 per cent in 1995–2000 and rose again to 2.27 per cent after 2000. The contribution of labor input fell from 2.33 per cent during 1989–95 to 1.64 per cent during 1995–2000 and recovered slightly to 1.68 per cent after 2000. The significant slowdown in the Asian growth rate from 7.54 per cent before 1995 to 5.91 per cent during 1995–2000 can be traced almost entirely to a sharp decline in productivity growth from 3.41 to 2.04 per cent. Similarly, the modest revival of growth to 6.51 per cent can be attributed to higher productivity growth of 2.57 per cent. Productivity explained slightly over 45 per cent of Asian growth before 1995, <35 per cent in 1995–2000, and around 40 per cent after 2000.

The first half of the 1990s was a continuation of the Asian Miracle, analyzed by Paul Krugman (1994), Lawrence 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 Asian economies, except the Philippines, had growth rates in excess of the world average of 2.72 per cent. The second half

Table 2 Sources of output growth by period

Economy	Period 1989-95						Period 1995-2000						Period 2000-04					
	Sources of growth (% points per annum)			Sources of growth (% points per annum)			Sources of growth (% points per annum)			Sources of growth (% points per annum)			Sources of growth (% points per annum)			Sources of growth (% points per annum)		
	GDP growth	ICT	Non-ICT	Hours	Quality	TFP	GDP growth	ICT	Non-ICT	Hours	Quality	TFP	GDP growth	ICT	Non-ICT	Hours	Quality	TFP
<i>Group summaries</i>																		
World (110 economies)	2.72	0.26	0.87	0.53	0.45	0.61	3.73	0.55	0.96	0.92	0.34	0.96	3.75	0.42	0.86	0.70	0.37	1.40
G7	2.19	0.39	0.89	0.07	0.43	0.42	3.25	0.82	0.87	0.63	0.24	0.69	2.20	0.47	0.58	0.08	0.28	0.79
Developing Asia	7.54	0.14	1.67	1.80	0.53	3.41	5.91	0.33	1.89	1.17	0.47	2.04	6.51	0.44	1.83	1.20	0.58	2.57
Non-G7	2.08	0.14	0.41	0.40	0.28	0.85	2.89	0.31	0.50	1.60	0.26	0.23	2.91	0.27	0.52	1.48	0.26	0.37
Latin America	2.92	0.14	0.52	1.31	0.46	0.49	2.02	0.29	0.66	1.29	0.41	-0.62	2.94	0.30	0.57	1.41	0.41	0.25
Eastern Europe	-6.38	0.09	-0.15	-1.75	0.45	-5.01	2.27	0.23	-0.85	-0.31	0.43	2.77	4.79	0.31	-0.50	-0.12	0.46	4.65
Sub-Saharan Africa	1.57	0.10	0.20	2.19	0.70	-1.62	3.26	0.23	0.43	1.86	0.51	0.24	3.74	0.27	0.54	1.54	0.51	0.88
N. Africa and M. East	3.97	0.15	0.65	1.99	0.68	0.51	3.91	0.30	0.78	1.85	0.60	0.37	4.30	0.42	0.72	2.22	0.60	0.34
<i>G7 (seven economies)</i>																		
Canada	1.39	0.49	0.27	0.08	0.55	0.00	3.67	0.94	0.77	1.08	0.21	0.66	2.76	0.45	0.67	1.29	0.15	0.20
France	1.30	0.20	0.92	-0.17	0.61	-0.26	2.38	0.39	0.81	0.45	0.35	0.37	2.18	0.37	0.29	0.64	-0.08	0.97
Germany	2.34	0.28	1.03	-0.41	0.33	1.12	1.80	0.44	0.92	-0.03	0.21	0.25	0.51	0.34	-0.20	0.09	0.18	0.10
Italy	1.52	0.26	0.85	-0.35	0.38	0.37	1.92	0.48	1.00	0.55	0.46	-0.58	1.39	0.36	0.66	0.75	0.21	-0.58
Japan	2.56	0.31	1.16	-0.39	0.54	0.94	2.09	0.78	0.38	-0.42	0.26	1.10	1.48	0.31	0.21	-0.32	0.21	1.06
United Kingdom	1.62	0.29	1.67	-0.72	0.49	-0.11	2.85	0.79	0.20	0.61	0.33	0.93	2.63	0.57	0.54	0.65	0.27	0.59
United States	2.44	0.49	0.71	0.57	0.37	0.30	4.29	1.02	1.11	1.12	0.19	0.84	2.75	0.57	0.86	-0.16	0.40	1.08
All group	2.19	0.39	0.89	0.07	0.43	0.42	3.25	0.82	0.87	0.63	0.24	0.69	2.20	0.47	0.58	0.08	0.28	0.79
<i>Developing and transition economies (seven economies)</i>																		
Brazil	1.82	0.07	0.22	0.94	0.53	0.06	1.74	0.25	0.21	0.96	0.50	-0.18	2.48	0.27	0.05	1.01	0.49	0.64
China	10.05	0.17	2.21	2.56	0.56	4.55	7.93	0.48	2.69	0.82	0.48	3.46	8.39	0.63	2.73	0.81	0.48	3.73
India	5.13	0.08	1.12	1.10	0.56	2.28	5.74	0.17	1.39	1.59	0.53	2.07	5.95	0.26	1.39	1.58	0.53	2.20
Indonesia	7.73	0.07	1.42	1.18	0.57	4.50	1.84	0.06	1.10	1.50	0.55	-1.37	2.55	0.08	0.50	1.42	0.57	-0.02
Mexico	2.04	0.25	1.03	1.56	0.38	-1.18	3.52	0.29	1.32	1.52	0.31	0.08	3.67	0.28	1.63	1.67	0.32	-0.23
Russia	-8.43	0.06	-0.07	-1.57	0.47	-7.31	1.60	0.10	-1.62	-0.10	0.50	2.72	5.88	0.15	-1.09	-0.01	0.56	6.28
S. Korea	7.44	0.21	2.02	2.00	0.41	2.79	4.50	0.34	1.30	0.80	0.34	1.72	4.50	0.39	0.84	1.20	0.34	1.74
All group	4.16	0.12	1.22	1.21	0.52	1.08	5.29	0.31	1.46	1.00	0.48	2.04	6.26	0.41	1.56	1.03	0.48	2.78

of the 1990s was dominated by the Asian financial crisis but, surprisingly, conforms much more closely to the 'Krugman thesis' attributing 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 growth. In fact, the peak of productivity growth in Developing Asia, absolutely and relatively, was 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, not productivity.

Developing Asia experienced a steady increase in the contribution of investment in IT equipment and software to economic growth. The contribution of IT investment more than doubled from 0.14 per cent before 1995 to 0.33 during 1995–2000. The contribution of IT investment increased to 0.44 per cent after 2000. The rush in IT investment was particularly powerful in China, rising from 0.17 per cent before 1995 to 0.48 per cent during 1995–2000 and increasing again to 0.63 per cent after 2000. India lagged substantially behind China and the rest of Developing Asia as well.

Indonesia was the only major economy to experience a decline in the contribution of both IT and Non-IT investment during 1995–2000, the period of the Asian financial crisis. Indonesia's IT investment recovered slightly after 2000, but Non-IT investment continued to slump. South Korea's IT investment increased from 0.21 before 1995 to 0.34 in 1995–2000 and 0.39 after 2000, while Non-IT investment dropped as a consequence of the financial crisis. The contribution of Non-IT investment in Asia greatly predominated throughout the period 1989–2004 and the contribution of hours worked outweighed labor quality as a source of growth in labor input.

The pattern of economic growth in the 15 Non-G7 industrialized economies was similar to G7 growth before 2000 with a sharp acceleration after 1995. However, the Non-G7 economies maintained rapid growth after 2000, while the G7 economies reverted to pre-1995 growth rates. The contribution of labor input predominated over capital input throughout the period 1989–2004. Non-G7 productivity growth fell from 0.85 per cent before 1995 to 0.23 per cent in 1995–2000, before rebounding to 0.37 per cent after 2000. Productivity accounted for more than 40 per cent of growth before 1995, but <8 per cent from 1995 to 2000 and <13 per cent after 2000.

The impact of investment in IT equipment and software in the Non-G7 economies doubled from 0.14 per cent before 1995 to 0.31 per cent during 1995–2000, before falling back to 0.27 per cent after 2000. This provided a substantial impetus to the acceleration in Non-G7 growth rates in the face of sharply declining productivity growth. Non-IT investment explained an important part of the growth acceleration. However, the increased contribution of hours worked from 0.40 per cent before 1995 to 1.60 in 1995–2000 and 1.48 per cent after 2000 greatly predominated.

Information Technology and the World Growth Resurgence

The collapse of economic growth in Eastern Europe and the former Soviet Union during 1989–95 can be attributed to a steep decline in productivity during the initial transition from socialism. This was followed by a modest revival in both economic growth and productivity growth from 1995 to 2000, bringing many of the transition economies back to 1989 levels of output per capita. The contribution of capital input declined throughout the period 1989–2004, even as the contribution of IT investment jumped from 0.09 per cent before 1995 to 0.23 per cent in 1995–2000 and 0.31 per cent after 2000. Hours worked declined sharply during 1989–95 and continued to fall after 1995, but labor quality improved substantially.

Latin America's growth decelerated slightly after 1995, falling from 2.92 to 2.02 per cent in 1995–2000, before recovering to 2.94 per cent after 2000. The contribution of labor input was 1.77 per cent before 1995, 1.70 from 1995 to 2000 and 1.82 per cent after 2000, accounting for the lion's share of regional growth. The contribution of capital input shifted toward IT, but remained relatively weak. Nonetheless, the contribution of IT investment in Latin America more than doubled, jumping from 0.14 per cent before 1995 to 0.29 per cent in 1995–2000 and 0.30 after 2000. Productivity collapsed after 1995, falling to a negative 0.62 per cent in 1995–2000, before recovering to 0.25 per cent after 2000.

Productivity in Sub-Saharan Africa collapsed during 1989–95, running at –1.62 per cent, before recovering to 0.24 per cent in 1995–2000 and rising sharply to 0.88 per cent after 2000. As in Latin America, the contribution of labor input predominated throughout the period 1989–2004. Productivity in North Africa and the Middle East dropped from 0.51 per cent before 1995 to 0.37 per cent in 1995–2000 and 0.34 per cent after 2000. In Sub-Saharan Africa and North Africa and the Middle East, growth of capital and labor inputs greatly predominated over productivity as a source of economic growth.

4. WORLD OUTPUT, INPUT AND PRODUCTIVITY

The final step in analyzing the world growth resurgence is to characterize the evolution of levels of output, input and productivity for the world economy, the seven economic regions and the 14 major economies. In Table 3, we present levels of output per capita when the transition from socialism began in 1989, at the start of the worldwide IT investment boom in 1995, at the beginning of the dot-com crash in 2000, and at the end of the period covered by our study in 2004. We also present input per capita and productivity for these years, where productivity is defined as the ratio of output to input.

Differences in per capita output levels are mainly due to differences in per capita input, rather than disparities in productivity. Taking US output per capita in 2000 as 100.0, world output per capita was a relatively modest 18.6 in 1989. Using similar scales for input and productivity, world input per

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

Country	Output per capita				Input per capita				Productivity			
	1989	1995	2000	2004	1989	1995	2000	2004	1989	1995	2000	2004
<i>Group summaries</i>												
World	18.6	19.9	22.4	24.9	30.5	32.5	35.3	37.7	61.0	61.2	63.5	66.0
G7	67.2	73.3	83.3	89.0	76.4	81.2	89.0	92.0	88.0	90.2	93.6	96.8
Developing Asia	5.8	8.2	10.3	12.7	20.2	23.5	26.7	29.8	28.7	34.8	38.5	42.5
Non-G7	57.1	62.1	69.5	75.7	63.4	65.5	72.0	77.2	90.0	94.9	96.4	98.1
Latin America	19.4	20.8	21.3	22.6	28.2	29.5	31.1	32.7	68.8	70.6	68.4	69.1
Eastern Europe	29.0	19.7	22.5	27.8	39.2	36.3	35.7	36.5	74.0	54.4	63.0	76.2
Sub-Saharan Africa	5.5	5.1	5.3	5.6	13.1	13.5	14.0	14.7	41.5	37.7	37.7	38.4
N. Africa and M. East	11.0	12.2	13.5	15.0	20.3	21.9	23.8	25.9	54.2	55.7	56.9	57.9
<i>G7 (seven economies)</i>												
Canada	76.0	77.0	88.3	94.9	75.3	76.3	84.6	90.2	100.9	100.9	104.3	105.1
France	60.0	63.3	69.9	74.7	64.1	68.7	74.5	76.5	93.5	92.1	93.9	97.6
Germany	59.7	66.3	72.0	73.2	79.4	82.5	88.5	89.7	75.1	80.3	81.4	81.7
Italy	55.7	60.5	66.0	69.9	61.4	65.2	73.2	79.3	90.8	92.9	90.2	88.2
Japan	57.4	65.2	70.8	75.1	76.0	82.2	85.1	86.6	75.5	79.3	83.2	86.8
United Kingdom	59.9	65.0	74.2	81.4	65.6	71.6	78.0	83.6	91.4	90.8	95.1	97.4
United States	79.6	85.6	100.0	107.1	84.5	89.2	100.0	102.5	94.2	95.9	100.0	104.4
All group	67.2	73.3	83.3	89.0	76.4	81.2	89.0	92.0	88.0	90.2	93.6	96.8
<i>Developing and transition economies (seven economies)</i>												
Brazil	20.9	21.2	21.6	22.6	31.8	32.3	33.2	33.8	65.5	65.7	65.1	66.8
China	4.7	8.0	11.3	15.3	19.8	25.7	30.7	35.8	23.6	30.9	36.8	42.7
India	4.8	5.8	7.1	8.5	18.1	19.1	21.0	23.1	26.4	30.3	33.6	36.7
Indonesia	6.2	9.0	9.2	9.7	22.8	25.1	27.6	28.9	27.3	35.8	33.4	33.4
Mexico	22.7	23.0	25.5	27.8	28.5	31.0	34.2	37.6	79.7	74.3	74.6	73.9
Russia	32.8	19.8	21.7	28.3	40.2	37.6	36.1	36.5	81.6	52.6	60.3	77.5
S. Korea	25.5	37.5	45.0	52.6	46.7	58.1	64.0	69.7	54.6	64.5	70.3	75.4
All group	8.3	9.7	11.8	14.5	22.0	25.2	28.2	31.3	37.6	38.4	41.9	46.4

*The levels for group and the world are averages weighted by population share.

Information Technology and the World Growth Resurgence

capita in 1989 was a considerable 30.5 and world productivity a very substantial 61.0. The level of world output advanced to 19.9 in 1995, jumped to 22.4 in 2000, and leapt again to 24.9 in 2004, reflecting impressive progress in mobilizing world inputs. World productivity edged upward modestly to 61.2 in 1995, bounded to 63.5 in 2000 and then rose again to 66.0 in 2004.

It is not surprising that world productivity is much closer to US levels than world input per capita. As globalization has proceeded, technologies have been transferred with relative ease from industrialized economies to the developing world. Mobilization of inputs in developing economies has been remarkable, but has required far more time and effort. Institutional barriers to accumulation of human and non-human capital must be overcome and networks among the cooperating activities must be established and enhanced. Obsolete methods for organizing production must be displaced by up-to-date techniques that employ information technology equipment and software.

The output gap between the United States and the other G7 economies has widened since the American growth resurgence began in 1995. The G7 economies led the seven economic regions in output per capita, input per capita and productivity throughout the period 1989–2004. Output per capita in the G7 was, nonetheless, well below US levels. Taking US output per capita in 2000 as 100.0, G7 output per capita was 67.2 in 1989, 73.3 in 1995, 83.3 in 2000, and 89.0 in 2004. By comparison, US output per capita was 79.6, 85.6, 100.0 and 107.1 in these years.

Canada was very close to the US in output per capita in 1989, but fell substantially behind by 1995. The US–Canada gap widened further during the last half of the 1990s, despite impressive gains in Canada. Germany, Japan, Italy and the UK had similar levels of output per capita throughout 1989–2004, but remained considerably behind the two North American economies. France lagged behind the rest of the G7 in output per capita in 1989 and failed to gain ground during the period 1989–2004.

The United States was the leader among the G7 economies in input per capita throughout the period 1989–2004. Taking the United States as 100.0 in 2000, G7 input per capita was 76.4 in 1989, 81.2 in 1995, 89.0 in 2000, and 92.0 in 2004, while US input per capita was 84.5, 89.2, 100.0 and 102.5 in these years. Canada, Germany and Japan were closest to US levels of input per capita with Germany ranking second from 1989 to 2000 and Canada ranking second in 2004. Italy lagged behind the rest of the G7 in input per capita from 1989 to 2000, surpassing only France in 2004. The UK made substantial progress toward achieving input levels comparable to those of Germany and Japan.

Productivity in the G7 has remained close to US levels, rising from 88.0 in 1989 to 90.2 in 1995, 93.6 in 2000, and 96.8 in 2004 with the United States equal to 100.0 in 2000. Canada was the productivity leader throughout the period 1989–2004 with the United States in second place, but rapidly closing

the gap after 2000. Japan made substantial gains in productivity, overtaking Germany in 2000, but lagged behind the other members of the G7.

Differences among the G7 economies in output per capita can be explained by both differences in input per capita and productivity gaps. For example, the range in output in 2004 was from 69.9 for Italy to 107.1 for the United States, while the range in input was from 76.5 for France to 102.5 for the United States. Productivity varied from 81.7 for Germany to 105.1 for Canada.

In the economies of Developing Asia output per capita rose spectacularly from 5.8 in 1989 to 8.2 in 1995, 10.3 in 2000 and 12.7 in 2004, with the US equal to 100.0 in 2000. Levels of output per capita in Asia's largest economies, China and India, remained at 15.3 and 8.5, respectively, in 2004. These vast shortfalls in output per capita, relative to the industrialized economies, are due primarily to differences in input per capita, rather than productivity gaps. Developing Asia's levels of input per capita were 20.2 in 1989, 23.5 in 1995, 26.7 in 2000 and 29.8 in 2004, while Asian productivity levels were 28.7, 34.8, 38.5 and 42.5, respectively.

China made extraordinary gains in output per capita, growing from 4.7 in 1989 to 8.0 in 1995, 11.3 in 2000 and 15.3 in 2004, with the United States equal to 100.0 in 2000. India had essentially the same output per capita as China in 1989, but grew less impressively to only 5.8 in 1995, 7.1 in 2000 and 8.5 in 2004. China's input per capita exceeded India's throughout the period, rising to 35.8 in 2004 by comparison with India's 23.1 in the same year. India's productivity level of 26.4 in 1989 considerably exceeded China's 23.6 in that year. China's productivity rose to 30.9 in 1995, outstripping India's 30.3. China extended its lead over India in 2000 and by 2004 had attained a productivity level of 42.7 by comparison with India's 36.7.

Indonesia grew impressively from 1989 to 1995, but failed to recover from the Asian financial crisis of the late 1990s. Nonetheless, Indonesia maintained its lead over India in output per capita, but dropped behind China in 2000. Indonesia led India in input per capita throughout the period 1989–2004, but fell behind China in 1995. Indonesia's productivity level was ahead of both China and India in 1995, but fell behind both economies by 2000. South Korea made substantial gains in input per capita, surpassing France and approaching Italy, while falling considerably short of Japan and Germany. However, Korean productivity levels remained well below those of the G7 economies.

The 15 Non-G7 industrialized economies, taken together, had levels of output per capita, input per capita, and productivity comparable to the United Kingdom during period 1989–2004. Before the beginning of the transition from socialism in 1989, output per capita in Eastern Europe and the former Soviet Union was 29.0, well above the world economy level of 18.6, with the United States equal to 100.0 in 2000. The economic collapse that accompanied the transition reduced output per capita to 19.7 by 1995, slightly below the world economy level of 19.9. A mild recovery between

Information Technology and the World Growth Resurgence

1995 and 2000 brought the region back to 22.5, well below the level of 1989 and only slightly above the world economy average of 22.4.

Input in Eastern Europe and the former Soviet Union shrank from 39.2 in 1989 to 36.3 in 1995 and then remained stagnant at 35.7 in 2000 and 36.5 in 2004. Productivity collapsed along with output per capita, declining from 74.0 in 1989 to 54.4 in 1995, before climbing back to 63.0 in 2000 and, finally, surpassing the 1989 level at 76.2 in 2004. We conclude that the transition from socialism failed to restore the region to pre-transition levels of output and input per capita by 2004, while productivity was only slightly higher than before the transition.

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 32.8 in 1989 to 19.8 in 1995, before recovering feebly to 21.7 in 2000 and more sharply to 28.3 in 2004. Russian input per capita declined after 1989, but then remained essentially unchanged throughout the period 1995–2004. Russian productivity mirrored the decline and subsequent recovery in output, falling precipitously from a level of 81.6 in 1989, comparable to that of Germany and Japan, to 52.6 in 1995. Russian productivity recovered to 60.3 in 2000 and jumped to 77.5 in 2004, but remained below the 1989 level.

For the Latin American region output per capita rose from 19.4 to 22.6 during 1989–2004, input per capita rose from 28.2 to 32.7, but productivity was essentially unchanged throughout the period at about two-thirds of the US level in 2000. The stall in productivity from 1989 to 2004 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. Mexico lost ground in productivity between 1989 and 2004, but made steady gains in input per capita and expanded output per capita substantially after 1995.

Output and input per capita in Sub-Saharan Africa was the lowest in the world throughout the period 1989–2004, but the level of productivity was slightly higher than that of Developing Asia until 2000. 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 1989–2004, powered by impressive gains in input per capita and productivity.

5. SUMMARY AND CONCLUSIONS

World economic growth, led by the industrialized economies and Developing Asia, experienced a strong resurgence after 1995. Developing Asia accounted

for almost half of world economic growth during 1989–2004 but remained well below the world average in output per capita. Sub-Saharan Africa and North Africa and the Middle East also languished 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.

Growth trends apparent in the United States 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 hours worked outweighing labor quality. Finally, productivity was the dominant source of growth only in Eastern Europe and the former Soviet Union during the recovery from the output and productivity collapse of 1989–95 that accompanied the beginning of the transition from socialism to a market economy.

The leading role of IT investment in the acceleration of growth in the G7 economies is especially pronounced in the United States. 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 an important source of growth in Developing Asia during the Asian Miracle before 1995, but growth of capital and labor inputs rose in importance after 1995, contrary to the 'Krugman thesis'. 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 was most striking in the G7 economies. The rush in IT investment was especially conspicuous in the United States, but jumps in the contribution of IT capital input in Canada, Japan and the United Kingdom were only slightly lower. France, Germany and Italy also experienced a surge in IT investment, but lagged considerably behind the leaders. IT investment subsided among the G7 economies after the dot-com crash of 2000, while the contribution of Non-IT investment varied considerably and explains important differences among growth rates of the G7 economies.

The surge in investment in IT equipment and software is a global phenomenon, but the variation in the contribution of this investment has grown considerably since 1995. The moderation in IT investment in the industrialized countries after the dot-com crash of 2000 was accompanied by continued expansion in the contribution of IT in the developing world, especially in Asia. The contribution of IT investment more than doubled after 1995 in Developing Asia, Latin America, Eastern Europe, and North Africa and the Middle East, and Sub-Saharan Africa.

Finally, despite spectacular growth rates in Developing Asia, levels of output per capita remain below world averages. Differences in per capita output levels are mainly due to input per capita rather than productivity. This reflects the fact that technology is relatively easy to transfer from

Information Technology and the World Growth Resurgence

industrialized economies to developing economies, while mobilization of capital and labor inputs requires much more time and considerably greater effort. Outmoded techniques of production must give way to newer methods that incorporate the latest technologies, especially those that utilize information technology equipment and software.

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D. W. Jorgenson and K. Vu

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