PUBLICATION

The Digital Economy and the Role of Government: Information Technology and Economic Performance in Korea

Seon-Jae Kim

January 2002

Program on Information Resources Policy

Center for Information Policy Research

Harvard University

The Program on Information Resources Policy is jointly sponsored by Harvard University and the Center for Information Policy Research.

Seon-Jae Kim is Professor of Information Economics at the School of Social Science, Pachai University, in Korea. He wrote this report while a Research Affiliate at the Program in 2001-2002.

E-mail: pirp@deas.harvard.edu URL: http://www.pirp.harvard.edu
ISBN 1-879716-77-1 **P-02-1**

January 2002

PROGRAM ON INFORMATION RESOURCES POLICY

Harvard University **Center for Information Policy Research**

Affiliates

Anonymous Startup
AT&T Corp.
Australian Telecommunications Users Group
BellSouth Corp.
The Boeing Company
Booz Allen Hamilton
Center for Excellence in Education
CIRCIT at RMIT (Australia)
Commission of the European Communities
Critical Path
CyraCom International
DACOM (Korea)
ETRI (Korea)
Fujitsu Research Institute (Japan)
Hanaro Telecom Corp. (Korea)
Hearst Newspapers
Hitachi Research Institute (Japan)
IBM Corp.
Korea Telecom
Lee Enterprises, Inc.
Lexis–Nexis
John and Mary R. Markle Foundation
Microsoft Corp.
MITRE Corp.
Motorola, Inc.
National Security Research, Inc.
NEC Corp. (Japan)
NEST–Boston
Nippon Telegraph & Telephone Corp (Japan)
PDS Consulting
PetaData Holdings, Inc.
Research Institute of Telecommunications and Economics (Japan)
Samara Associates
Sonexis
Strategy Assistance Services
United States Government:
- Department of Commerce
  - National Telecommunications and Information Administration
- Department of Defense
  - National Defense University
- Department of Health and Human Services
  - National Library of Medicine
- Department of the Treasury
  - Office of the Comptroller of the Currency
- Federal Communications Commission
- National Security Agency
- United States Postal Service

Upoc
Verizon

Acknowledgements

The author gratefully acknowledges the following people who reviewed and commented critically on the draft version of this report. Without their consideration, input, and encouragement, this study could not have been completed: Charles Popper, K. K. Yoon, and S. H. Oh.

These reviewers and the Program's Affiliates, however, are not responsible for or necessarily in agreement with the views expressed here, nor should they be blamed for any errors of fact or interpretation.

This work was supported by a grant (KRF-2000-CA0037) from the Korea Research Foundation.

Executive Summary

This study analyzes the development of the information technology (IT) industry in Korea in 1971–2000 and examines the sources of Korea's economic growth and productivity during that period. The growth contributions from standard input factors as well as from IT capital inputs were calculated on the basis of the growth accounting framework. Also, the growth contribution from the business cycle effect was examined. Most of the contribution to output growth was found to come from non-IT capital input, which accounted for 56 percent, rather than from labor capital, which accounted for only 15 percent. IT capital contributed 16.3 percent to the output growth, but its contribution has been increasing since the 1970s. The business cycle is one of the main deter-minants of the output growth rate, accounting for 8 percent of the total growth. The average annual growth rate of total factor productivity (TFP) during in 1971–2000 was about 0.3 percent, while the average annual growth rate of the business cycle was about 0.6 percent, with a slight increase between 1996 and 2000. The study also examines the source of productivity growth, using the extended growth model and drawing attention to the role that IT and knowledge capital may have played.

Evidence suggests that IT has a strong and positive effect on the growth of labor productivity, but the coefficient of non-IT capital intensity was 0.35, which is 11 times higher than that of IT capital intensity, 0.03.

Knowledge capital also has a positive effect, but not one statistically significant. Even though the coefficient of knowledge capital was not significant, it is a fairly safe prediction that in the future knowledge capital will be an important key to a nation's competitiveness.

The business cycle is an important determinant and, in the long run, will significantly affect productivity growth in Korea. The estimated coefficient, about 0.6, is statistically significant and is fairly large compared to other factors, such as IT and knowledge capital, in productivity growth.

The relationship between TFP and the ratio of research and development (R&D) to output was estimated, and the results suggesting a positive and strong relationship between TFP and R&D investment, accounting for a 27 percent rate of return.

Contents

Tables

Chapter One

Introduction

The "digital economy," with information technology (IT) leading the way, has become the preeminent driver of economic growth and social change worldwide. In the United States, the digital economy has been acknowledged as the new economic system, or the "new economy"—terms often used interchangeably to signify high growth, low inflation, and low unemployment—and has enjoyed a decade-long boom since the early 1990s, with significant investment in and diffusion of IT and its applications. In a digital economy, the development of IT leads to a rise in productivity and employment, which make high economic growth possible. The digital revolution surging over Korea at the turn to the twenty-first century has captured worldwide attention, and the rush into IT ventures has boosted the country's economic growth.[1]

As is widely known, the Korean economy has enjoyed an unprecedented boom since the early 1970s. The gross national product (GNP) and the rate of export grew on average at rates of 8.5 and 36.5 percent, respectively, per year, and per capita income has tripled in real terms. As of 1996, for example, Korea's GNP had reached U.S. $518.3 billion, its per capita income had reached U.S. $11,380, and Korea was ranked the thirteenth largest trading country in the world. This period of growth has been called "the Korea miracle."

In the late 1980s, however, Korea lost a significant portion of its export market, particularly for labor-intensive products, to such newly emerging economic powers as China and other Southeast Asian and non-Asian nations. Like other newly industrialized countries (NICs), Korea faces a new challenge: how to sustain the growth it had enjoyed in the early 1970s. Having lost much of its competitive edge in the labor-intensive industries, in 2001 Korea needs to give greater attention to the more capital- and knowledge-intensive industries such as IT industries in order to compete head-on with advanced countries, which have an advantage over the NICs.

Korea has established itself in certain hi-tech industries, such as memory chips and computing equipment (hardware and software), telecommunication equipment, and other IT-related products. Its development of these industries has been based largely on borrowed technology, which, combined with relatively low wages, has enabled Korea to compete in global markets for such products. NICs in general and Korea in particular have not yet developed "knowledge-based" economies, which are characterized by knowledge-intensive industries and a service economy based on information-based intangible capital. Since the early 1990s, enormous activity in these countries, including the introduction of various direct and indirect government incentive policies designed to encourage investments in the IT industries, has helped them to

---

[1]As of 2000, although the Korea Securities Dealers Automated Quotation (KOSDAQ) market has been in recession, the number of venture enterprises had reached more than ten thousand, for a twofold increase over the figure for 1998.

catch up with advanced countries in the new knowledge-intensive industries. In Korea in particular, tremendous investments in these industries were accomplished by the private sector, because its response to government initiatives has appeared very positive.

As more capital is channeled into the new IT industries in Korea and other NICs, economists are keeping an eye on the debate on the so-called “paradoxical” issues surrounding the slowing of productivity growth in the United States and other advanced countries. This debate centers on the observation that, in spite of the introduction in the 1970s and 1980s of IT with massive capital investments, total factor productivity (TFP) has continued to decline. The debate has yet to be settled, but this observation, if true, holds grave implications for the Korean economy, which relies heavily on major investments in the IT industries to maintain Korea’s position in global competition.

This report examines IT and knowledge capital as new main sources of economic performance in Korea. Because the digital economy emphasizes the importance of intellectual capitals as a new factor in production, the role of IT and knowledge capital in productivity growth is analyzed. The growth contributions from standard input factors as well as IT capital inputs are calculated with an examination of the business cycle effect on the basis of the growth accounting framework. This procedure may cover the “paradoxical” issues of rapid IT investment and slow productivity growth. The study also examines the source of productivity growth, using the extended growth model and drawing attention to the role that IT and knowledge capital may have played. For this purpose, the study investigates whether productivity growth is attributable to IT and knowledge capital directly from the production function, instead of calculating that contribution from income shares. Parallel to that investigation, the study looks at the possible relationship between R&D and TFP. The remainder of this study is organized as follows: **Chapter Two** provides a description of the classification and some statistics of IT industries in the Korean economy focused in particular on the 1990s. **Chapter Three** presents an analytical framework for measuring the sources of economic performance. **Chapter Four** offers the empirical results of the study. The study concludes in **Chapter Five** with a summary and some suggested policy implications.

Chapter Two

IT Industries in the Korean Economy

2.1 Classification and Infrastructure

The information technology industries have not yet been systematically classified. The pioneering knowledge-industry classification of Machlup (1962) and the information-field classification of Porat (1977) involve knowledge and information. These classifications are too inclusive to be meaningful for IT industries, however, and so are not adequate for research on the modern information industries, which bring together computers and telecommunications. Moulton (2000) has defined the IT industries as including information processing and related industries, such as equipment, software, semiconductors, and telecommunications equipment.

Many attempts have been made to classify IT industries rationally. The United States Department of Commerce classifies hardware, communication equipment, software and services, and the communication services industry as IT processing industries.[1] The Organization for Economic Co-operation and Development (OECD) classifies manufacture of information and communications equipment, services of information communication (IC) related goods, and services of intangible goods as information and communications industries. The classification of the Korea National Statistical Office is similar to that of the OECD. According to the Korea Standard Industrial Classification (KSIC), IT industries include the information contents industry and the IC technology industry, which includes the manufacture of IC equipment and IC-related services industries and tangible and intangible goods, including publishing, advertising, graphic design services, the motion picture industry, and television (TV) and radio broadcasting.

Table 2-1 presents the classification of IT industries according to the U.S. Department of Commerce and the Korea National Statistical Office. This study follows the classification used by the Korea National Statistical Office. Since the 1960s, when Korea began to manufacture radios and TVs, IT industries have grown rapidly. In 1967, the government designated the electronics industry as a key export driver, and it therefore received considerable government assistance, including remission of taxes and preferential financing. In the 1970s, the government built the “electronic industrial park,” to provide an inexpensive factory site with a communications system and with convenient access to transportation and other facilities for the manufacture of electronics. The most important period of growth in the IT industries began in the early 1980s, with the production of semiconductors and personal computers (PCs). The greatest growth in the IT industries occurred in 1990s.

---

[1] *The Emerging Digital Economy II* (Washington, D.C.: U.S. Dept. of Commerce, 1999).

Table 2-1

Classification of IT Industries

	Hardware industries	**Communications equipment industries**	**Software/services industries**	**Communications services industries**
United States	Computers and equipment Wholesale trade of computers and equipment Retail trade of computers and equipment and retail Calculators and office machines Magnetic and optical recording media Electronic tubes Printed circuit boards Semiconductors Industrial instruments for measurement Instruments for measuring electricity Laboratory analytical instruments	Household audio and video equipment Telephone and telegraph equipment Radio and TV and communications equipment	Computer programming services Prepackaged software Wholesale trade of software Retail trade of software Computer integrated system design Computer processing, data preparation Information retrieval services Computer services management Computer rental and leasing Computer maintenance and repair Computer-related services, nec	Telephone and telegraph communications Radio and TV broadcasting Cable and other pay-TV services
Korea	**Information and communications technology industries**		**Information content industries**	
	Manufacturing: Computers and peripherals Office appliances Insulated wires and cables (including insulated codes sets) Semiconductor and electronic integrated circuits TV and Radio transmitters, apparatuses for line telephony and line telegraphy Instruments and Appliances for measuring, checking, testing, navigating, and other purposes*	**Services Industries:** Wholesale household electronic appliances: radio, TV, video, computer, software, etc. Rental of computers and office equipment Wired telecommunications Wireless telecommunications Other telecommunications Computers and related activities (software, programming) Software consultancy and supply Data processing and computer facilities management services Maintenance and repair services of machinery and equipment for electric, electronic, communication and precision	**Information Contents:** Publishing: Publishing of newspapers; magazines, and Periodicals; Publishing of recorded audio media Printing: Commercial printing by stencil plate and similar plates; Screen printing Advertising: Advertising agencies; Outdoor advertising; Advertising preparation; Graphic design services Motion pictures industries: Motion picture and video production; Motion picture and video exhibition Broadcasting: Radio and television broadcasting; cable networks; Cable and other program distribution; Broadcast via satellite News agencies activities Libraries and archives activities	

*Does not include industrial process control equipment.

Sources: *The Emerging Digital Economy II* (Washington, D.C.: U.S. Dept. of Commerce, 1999); *Korea Standard Industrial Classification* (Daejon: Korea National Statistical Office, 2000).

Because most countries worldwide are promoting IT industries as a top priority, the Korean government also has invested heavily in its IT infrastructure. The government has actively promoted construction of a national information infrastructure for IT industries though the Basic Act of 1995 for promotion of national information and through "Cyber Korea 21," a national plan to build an information society through policies to encourage wider adoption of IT launched in March of 1999. **Table 2-2** shows the trends in the major informationization indicators. The telephone subscribers have been experiencing a rapid growth, indicating roughly 28.4 million telephone lines in 2000, which are 2.5 telephone lines for each household. Moreover, since the beginning of mobile communications services in 1984, a remarkable growth has been accomplished. In 1991, the number of mobile telecommunications subscribers was roughly 10 million but by 2000 had increased to 27.5 million, for an average rate of 31.2 percent in 1994–2000. According to the International Telecommunication Union (ITU), in 2000 Korea's distribution rate for mobile phones was 61.2 percent, which was seventh highest in the world.

Table 2-2

Trend in Major Informationization Indicators
(Units: 1,000, %)

	1991	**1994**	**1996**	**1998**	**1999**	**2000**	**1994–00 Average Growth**
Telephone subscribers	14,573	17,646	19,601	20,089	20,564	28,449	9.0
Mobile telecom-munications	1,0167	7,323	15,875	23,163	24,195	27,539	31.2
PC supply	2,203	4,459	6,304	8,269	11,500	15,442	28.5
Internet users	–	138	731	3,103	10,860	19,000	133.9
Internet host	–	16	73	203	461	–	94.**
Internet domains	–	0.3	3	26	207	501.5	267.5
IT intellectual properties registered*	–	10.1 (17.3)	10.1 (11.2)	35.4 (119.7)	42.0 (18.7)	30.7 (–26.9)	(20.0)

Note: Figures in parentheses are growth rates.

*Number refers to patents and utility models for the electronic and telecommunications sectors.

**Growth rates for 1994–99.

Sources: National Computerization Agency, *Major Statistics of Intellectual Property* (Daejon: Korea Intellectual Property Office, for the years shown).

The supply of PCs has also increased continuously in the 1990s, which grew on average at a rate of 28.5 percent between 1994 and 2000. This increase relied heavily on, not only the decrease in PC prices, but also the government policy. From 1994 to 2000, the acquisition price of IT equipment for investment fell 18.6 percent annually, while the price of computers fell even faster, at 25.6 percent per year. During this period, Korean government policy also encouraged all citizens to purchase basic information-communication devices such as PCs and software, and toward this end the government supported both a supply of low-priced Internet PCs and a policy of allowing people to make their purchases in installments after opening a savings account at the Korea Postal Service.

With the increased supply of PCs, which grew on average at a rate of 28.5 percent between 1994 and 2000, the number of Internet users also increased rapidly during the same period, from 138, 000 to 19 million, that is, roughly 130 times more users since 1994. Another notable phenomenon was the increase in the number of Internet domains. In 1994, there were only 300 Internet domains in Korea, but by 2000 there were 501,500, for an average rate of increase over seven years of 267.5 percent. As a result, in 2000 Korea ranked second worldwide in the number of registered dot-coms and domain names, a jump from sixth in 1999—and a huge jump from twenty-ninth in 1998. Similarly, the number of Internet hosts as an index for the quantitative expansion of the Internet also grew over those six years, on average at a rate of 94.1 percent. Further reflecting the IT revolution, the number of IT intellectual properties, for example, in the electronic and telecommunications sectors, registered in Korea has increased at an average rate of 20 percent per year from 1994 to 2000.

In addition, Korea had 26,000 neighborhood Internet cafés in 2000, which is a key factor to the use of Internet in information infrastructure and is double the number in 1990. The key to the increase is broadband. According to the ITU, by the end of 2000 in the United States approximately 11 percent of all households were connected to the Internet by high-speed digital subscriber lines (DSLs) or cable. In Korea, where there were 19 million Internet users by the end of 2000, the rate of penetration of broadband was an “eye-popping” 57 percent—far and away the highest in the world. Helping to fuel the broadband boom is the density of the country’s population. About 40 percent of Korean households are in apartment buildings in urban areas where the installation of fiber optic cables can extend high-speed access to many people quickly. Cutthroat competition among broadband service providers means DSL connections can be had for less than U.S. $30 a month.

Although Korea’s participation in the digital revolution has come late, the country’s infrastructure is relatively sufficient to support the digital era. Also, Korea has the potential to catch up with advanced economies, because it has abundant human capital and a highly educated labor force.

2.2 Statistics for IT Industries in the National Economy

Table 2-3 shows the trends in the growth rate for IT industries. The Korean economy's dependence on IT industries clearly has increased considerably. In spite of the financial crisis in late 1997, Korea's IT industries have grown rapidly, at an average rate of 26.9 percent between 1991 and 2000. This figure is much higher than the average growth rate of 4.1 percent for non-IT industries during the same period. Among the IT industries, equipment manufacturing and the service industry grew at an average annual rate of 29.3 percent and 22.8 percent, respectively, between 1991 and 2000. Further, during this decade the contribution rate of IT industries to economic growth, which is calculated by the share of the real value added growth of IT industries

Table 2-3

Trends in the Growth Rate of IT Industries*

(Unit: %)

	1991	1994	1997	1998	1999	2000	1991–2000 Average
Real GDP growth rate	9.2	8.3	5.0	–6.7	10.7	8.8	5.9
IT industries	10.7	26.4	30.5	20.7	36.0	36.5	26.9
Equipment manufacturing	2.2	32.6	39.0	27.1	50.6	30.5	29.3
Services	18.5	21.0	21.8	13.8	28.0	31.8	22.8
Software and computer-related services	23.0	20.3	13.2	1.6	17.1	51.6	16.7
Non-IT Industries	–	7.4	3.3	–9.0	8.1	5.0	4.1
Contribution to real GDP growth	3.6	12.1	37.6	–23.8	32.8	50.5	–
Weight in nominal GDP	9.7	11.3	16.8	19.9	22.3	27.3	–
Equipment manufacturing	6.2 <63.9>	7.6 <67.5>	12.1 <72.2>	14.8 <74.2>	16.7 <74.9>	20.3 <74.4>	–
Services	3.4 <35.1>	3.5 <30.9>	3.8 <22.5>	4.1 <20.5>	4.5 <20.2>	5.5 <20.1>	–
Software and computer-related services	0.1 <1.0>	0.2 <1.6>	0.9 <5.3>	1.0 <5.3>	1.1 <4.9>	1.5 <5.5>	–

Note: Numbers between angled brackets < > are weights throughout all IT industries.

*Excludes IT equipment distribution industry.

Sources: *Report on the Information and Telecommunications Survey* (Daejon: Korea National Statistical Office, for the years shown); *Korea Statistical Yearbook* (Daejon: the National Statistical Office, for the years shown).

in real GDP growth, sharply increased. From this perspective, the relative importance of IT industries as a contributor to economic growth has risen steeply during the 1990s, to more than half of the nation's real GDP growth of 8.8 percent in 2000. Similarly, the weight of IT industries in the nominal GDP also increased, by 27.3 percent in 2000, up from 9.7 percent in 1991.

Because the IT industries are both growing and high–value-added industries, they are considered a new form of social overhead capital that is far more important than traditional social overhead capital (see **Table 2-4**). To set up the cornerstone of IT industry and manage it requires considerable funds as well as continuous investment in R&D. Between 1991 and 2000, the facilities investment in IT industries increased at an annual average of 26.4 percent. At the same time, the contribution rate of these industries to the growth of the nation's total facilities investment also jumped, at an average rate of 58.4 percent, while their weight in the total facilities investment rose at a slightly lower rate, that is, an average annual rate of 18.5 percent. This difference was probably due to the high growth rate of total investment which may have offset the increasing growth rate of IT investment. Thus, the IT industries have increased their

Table 2-4

Trends in the Growth Rate of IT and R&D Investment

(Unit: %)

		1991	1993	1994	1998	1999	2000	94–00 Average	91–00 Average
Korea	Total facilities	14.8	0.3	23.9	–38.8	36.3	34.3	13.9	12.0
	IT facilities	8.0	11.2	40.6	–3.0	54.8	46.5	34.7	26.4
	Contribution rate to total facilities	4.1	266.7	13.0	1.3	36.5	37.1	21.9	58.4
	Weight in total facilities	7.0	7.7	8.7	24.2	27.4	29.9	22.6	18.5
	R&D/GDP*	1.93 (3.2)	2.30 (10.5)	2.58 (11.5)	2.55 (–5.2)	2.46 (–3.5)	2.68 (8.9)	2.61 (2.2)	2.46 (3.6)
	Intellectual properties registered**	0.006	0.004	–6.3	54.8	–9.2	–14.7	13.2	10.7
United States	Total facilities	–	10.5	11.8	15.8	12.1	–	12.4	12.1
	Contribution rate to total facilities	–	33.3	44.9	62.0	77.7	–	–	–

*Figures in parentheses are growth rates.

**Includes patents, utility models, industrial designs, and trademarks.

Sources: *Report on the Information and Telecommunications Survey* (Daejon: Korea National Statistical Office, for the years shown); *Korea Statistical Yearbook* (Daejon: Korea National Statistical Office, for the years shown); *Major Statistics of Intellectual Property* (Daejon: Korea Intellectual Property Office, for the years shown); *Digital Economy 2000* (Washington, D.C.: Dept. of Commerce).

contribution to the total facilities investment, but the weight of the IT industries in Korea's total facilities investment remains lower than that of the United States, which in 1999 accounted for 77.7 percent of the U.S. total facilities investment.

In Korea, in the R&D sector, the yearly increase of the ratio of investment to GDP was marked, 3.6 percent from 1991 to 2000, for an average rate of 2.46 percent. In 1998 and 1999, however, this ratio decreased by –5.2 percent and –3.5, respectively, owing to the 1997 currency crisis. The decrease exacerbated the possibility that the technology gap between Korea and more advanced countries will widen, even though the ratio of R&D investment to GDP increased slightly again in 2000. The number of intellectual properties registered in Korea, however, has increased at an annual average of 10.7 percent, reaching its highest point in 1998, and began to fall in 1999, owing to the lower R&D investment in 1998. Also in 1998, in spite of the financial crisis, the number of intellectual properties registered increased considerably, by 54.8 percent—an increase perhaps due to the increasing importance of intellectual property.

The IT industries also considerably contributed to boosting the nation's export growth. As shown in **Table 2-5**, in 1991 Korea's export of IT was only U.S. $10.8 billion, accounting for 15.1 percent of total exports. With an increased emphasis on expanding IT's marketing influence overseas, in 2000 Korea's IT export increased more than 5 times, to U.S. $58.5 billion, for an average growth rate of 19.2 percent between 1991 and 2000. The weight of IT industries' exports

Table 2-5

Trends in the Export and Import of IT Industries
(Units: U.S. $100 million, %)

	1991	**1994**	**1997**	**1998**	**1999**	**2000**	**91–00 Average**
Total export (A)	718.7 (10.5)	960.1 (16.8)	1,362.6 (5.0)	1,323.1 (–2.8)	1,436.9 (8.6)	1,727.9 (20.2)	– (10.6)
Export of IT industries (B)	108.8 (17.9)	202.3 (40.7)	312.5 (5.6)	305.2 (–2.3)	399.5 (30.9)	585.6 (46.6)	– (19.2)
(B/A)	15.1	21.1	23.0	23.1	27.8	42.8	
Total import (C)	815.2 (16.7)	1,023.5 (22.1)	1,446.2 (–3.8)	932.8 (–35.5)	1,197.5 (28.4)	1,604.8 (34.0)	– (10.8)
Import of IT industries (D)	86.2 (15.5)	120.6 (28.6)	218.9 (11.7)	182.4 (–16.7)	265.2 (45.4)	364.1 (37.3)	– (16.5)
(D/C)	10.6	11.8	15.1	19.6	22.1	25.4	

Note: Figures in parentheses are growth rates.

Sources: *Report on the Information and Telecommunications Survey* (Daejon: Korea National Statistical Office, for the years shown); *Korea Statistical Yearbook* (Daejon: National Statistical Office, for the years shown); and *The Statistical Yearbook of Information and Telecommunication Industry* (Seoul: Korea Association of Information and Telecommunication, for the years shown).

in total exports exceeded 42 percent in 2000. The increase was fueled by an increase in such export products as computers, semiconductors, laser compact disks (LCD), and wireless telecommunication equipments. During this period, the imports of IT industries also jumped, at an average annual rate of 16.5 percent, in a pattern similar to that of exports. This result may have been caused not only by the high growth of domestic IT industries but also by the rapid growth of exports in IT industries. The weight in the total import, however, has remained significantly lower than that of export, accounting for only 25.4 percent in 2000.

The number of people employed in IT industries in 1998, as shown in **Table 2-6**, was 470,000, for 2.4 percent of the total people employed. This number is fairly low compared to 5 percent employed in these industries in the United States. In Korea, 235,000, or roughly 50 percent of the total IT employees, were employed in IT equipment manufacturing industries, while employment in IT services and IT equipment sales accounted for 20.8 percent and 19.8 percent, respectively, of the total IT employees. The weights of IT equipment and software and computer-related services, in particular, have grown more quickly than other sectors, but these numbers do not include such IT occupations as e-commerce, Internet-related activities, or network employees, which would substantially increase the total number of IT employees.

Table 2-6

Trends in IT Employees

(Units: 1,000, %)

	Korea			United States
	1996	**1998**	**2000***	**1998**
Total employees (A)	20,817	19,994	21,061	104,000
IT employees (B)	524<100.0>	470<100.0>	435<100>	5,200
IT equipment	258<49.2>	235<50.0>	281<64.6>	–
IT services	125<23.9>	98<20.8>	93<21.4>	–
Software and computer-related services	40<7.6>	44<9.4>	61<14.0>	1,600
IT equipment distribution	101<19.3>	93<19.8>	–	–
(B/A)	2.5	2.4	2.1	5.0

Note: Figures in angle brackets <> are the weights in total IT employees.

*Excludes IT equipment distribution industry.

Source: *Report on the Information and Telecommunications Survey* (Daejon: Korea National Statistical Office, for the years shown).

Chapter Three

The Analytical Framework: Sources of Economic Performance

3.1 The Role of IT and Knowledge Capital

The economic growth of the NICs since the 1970s was due largely to the rapid rate of growth of factor accumulation, of both labor and capital, and only a little to technological progress or to the TFP of the NICs.[1] This view implies that the NICs have not had remarkable increases in either TFP or technological progress. Recent studies point to the experience in Korea, Taiwan, and Hong Kong of a declining return to capital, which is the predictable consequence of diminishing return on capital investment. Yet Young (1995), in his pioneering work, reported that between 1966 and 1991, Hong Kong had a per capita GDP growth rate of 5.7 percent, but only 2.3 percent TFP, and that during almost the same period (1966–90) Singapore had 6.8 and 0.2, respectively, Taiwan 6.7 and 2.6, respectively, and Korea 6.8 and 1.7, respectively.

Two recent studies of the sources of Korea's economic growth reached interesting results. Yuhn and Kwon (2000) noted that high-quality labor combined with a remarkable growth of capital and materials had a major impact on economic growth, while the role of technical progress in the industrialization process was negligible. The study showed that only 7 percent of the real output growth in the manufacturing sector during 1962–81 was attributable to technological progress in Korea. Robertson (2000) investigated the investment-led growth hypothesis for NICs of East Asia during 1960–94. This study showed that productivity growth and improvements in the quality of labor may explain roughly half the growth in GDP per worker, while the revolution in the investment rate explained only about 30 percent of the growth. Although the capital accumulation of NICs was high, part of it was attributed to capital productivity growth and other inputs. Thus, Robertson concluded that increases in human capital and in TFP together accounted for approximately half the growth in GDP per worker.

Since the early 1980s, IT has been explored and has spread globally in both consumption and production sector, leading to a decline in the prices of computers, communications, and related equipment, the spread of IT raises attention about the linkage between IT and productivity gains as a new issue. From 1980 to 2000, the price of computers and related equipment fell about 24 percent per year, leading perhaps to a vast and continuing substitution of IT equipment for other forms of capital and labor. The question, however, is whether the massive substitution of IT equipment for other inputs was accompanied by technical changes in economic growth. Because evidence of this change has been mixed, there have been many debates on substitution and

---

[1] Young. (1992, 1995); Krugman (1994); Mankiw (1995). For a full citation to these and other works included in the notes, see References.

technical change, that is, on the so-called "productivity paradox" (see **Chapter One**) of rapid IT investment and slow productivity growth.[2]

Until the 1990s, Korea had a significant increase in both labor participation and IT capital investments, and there was little empirical evidence that substitution was accompanied by a technical change in the Korean economy. Perhaps more alarming for the economy, new evidence suggests that the increase in per capita capital in (K/L, where K is capital and L is labor) was subject to diminishing returns, with a visible decline of marginal productivity of capital.[3] If this proves to be the case, then the Korean economy will need to seek a way toward productivity growth that will offset the declining contribution of accumulated capital and other factors. A reasonable way to deal with this issue would be to introduce the role of IT and knowledge capital in the economy.

IT capital can be defined as the stock of wealth that measures the current market value of the IT assets in use or the stock of productive services, which measures the income-producing capacity of the existing IT stock during a given period time.[4] In contrast, knowledge capital can be described as the "hidden" assets of a country that underpin and fuel its growth and drive stakeholder value. This knowledge represents collective intangible assets that can be identified and are measurable.[5]

Traditional assessment of national economic performance has relied on understanding the GDP in terms of traditional factors of production—land, labor, and physical capital. IT and knowledge capital are distinguished from those traditional factors in that they are governed by what has been described as the "law of increasing returns." To assess the impact of IT and knowledge capital on output and productivity growth rates, proper account needs to be taken of the role of each factor as input into the production process.

The first step in this discussion is the standard neoclassical growth model, in which output growth comes from increased input of capital, labor, and technology. For a simple analysis, the basic Cobb–Douglas production function is used for Equation (1) as

$$Y = T\,K^{\alpha}\,L^{1-\alpha}, \tag{1}$$

where Y is output, T is a multiplicative technology parameter, K and L are capital and labor, respectively, α is the capital share of output, and $(1-\alpha)$ is the labor share of output. The technological progress T, also known as the Solow Residual and as TFP, is externally determined.

---

[2]The productivity paradox was first articulated by Solow (1987). For recent discussions, see Gorden (1998), Jorgenson and Stiroh (1999), David (2000), and Sichel (1999).

[3]Hsieh (1999).

[4]See Oliner and Sichel (2000), 8.

[5]Malhotra (2000).

In this simplified model, output Y grows at the same rate as capital K and labor input L. The greater growth rate of output than of capital and labor is presumably attributable to technological progress, T.

In this formulation, TFP is defined as follows:

$$TFP \equiv Y/K^{\alpha}L^{(1-\alpha)} = T, \tag{2}$$

Because productivity is defined as the ratio of total output to total input, and because IT and knowledge are inputs, one would expect growth in IT and knowledge intensity to raise productivity. The contribution of IT and knowledge to productivity growth may be disembodied or embodied. In the embodied approach, IT and knowledge contribute to productivity by raising the TFP, which makes all factor inputs proportionately more productive.

To represent IT and knowledge capital, the total capital (K) is decomposed into IT capital (K_{IT}), knowledge capital (K_{KN}), and other capital (K_{OT}), ($K = K_{IT} + K_{KN} + K_{OT}$), so that the effective capital stock can be written as $[K_{OT} + (1+\phi_1)K_{IT} + (1+\phi_2)K_{KN}]$, where ϕ_1 and ϕ_2 are parameters that measure the excess productivity, such as spillovers or externalities,[6] of IT and knowledge capital relative to other capital. The production function of Eq. (1) can then be specified:

$$Y = T\,[\,K_{OT} + (1+\phi_1)K_{IT} + (1+\phi_2)K_{KN}\,]^{\alpha}\,L^{(1-\alpha)} \tag{3}$$

Substituting ($K - K_{IT} - K_{KN}$) for K_{OT} and rearranging the equation, the share of IT and knowledge capital can be expressed in the total capital stock as

$$Y = T\,[\,K\,\{1+\phi_1(K_{IT}/K) + \phi_2(K_{KN}/K)\}\,]^{\alpha}L^{(1-\alpha)} \tag{4}$$

When the logarithm is taken in both sides of Eq. (4), it can be written as

$$\ln Y = \ln T + \alpha \ln K + \alpha \ln(\,1 + \phi_1\nabla IT + \phi_2\nabla KN\,) + (1-\alpha)\ln L, \tag{5}$$

where $\nabla IT \equiv (K_{IT}/K)$ and $\nabla KN \equiv (K_{KN}/K)$, which are the share of IT and knowledge capital in the total capital stock. Then, the forms for TFP and labor productivity can be written as

$$\ln TFP \cong \ln T + \alpha \ln(1+\phi_1\nabla IT + \phi_2\nabla KN) \tag{6}$$

$$\ln(Y/L) \cong \ln T + \alpha \ln(K/L) + \alpha \ln(1+\phi_1\nabla IT + \phi_2\nabla KN). \tag{7}$$

---

[6]The concepts of spillover and externality may be different aspects of one phenomenon in that spillover focusses on the physical aspect of the unpaid side effects of producers' or consumers' actions while externality focusses on the price-distortion effects.

Eq. (6) represents the increase in IT intensity (∇IT) and knowledge intensity (∇KN) that would be expected to increase TFP as long as $\alpha>0$ and $\phi_1+\phi_2>-1$. IT and knowledge may contribute to technical progress directly, because they are more productive than other types of factor inputs. To address the productivity issue, labor productivity may be discussed rather than TFP. Eq. (7) describes the dependence of labor productivity on overall per capita capital input (K/L) and the share of IT capital in the total capital stock. In this sense, labor productivity would not decrease so long as IT and knowledge capital deepens. Although high gross investment is likely to be offset by rapid depreciation of IT, the increase in productivity of these types of capital would probably offset, or more than offset, the diminishing marginal returns to other physical capital per capita.

This may be true in the case of the rapidly increasing stock of IT capital, but the growth of the stock of other capital has been sluggish. Rapid diffusion of IT has led to a continuing decline in its price and that of related equipment, which, in turn, has led to a continuing substitution of IT equipment for other forms of capital and labor. In addition, IT has been substantially increasing returns on the investment in knowledge capital. Knowledge enables both the creation of new goods and services and the exploitation of new technologies to improve products and processes. In particular, computers and related equipment in the IT industries have been much indebted to the application of knowledge. The increase in knowledge will probably offset diminishing marginal returns to physical capital per capita. Thus, the investment in both IT and knowledge capital may be the right way to boost productivity growth, hence, economic growth in Korea. Although the "paradoxical" debate between IT and productivity gains (see **Chapter One**) has yet to be settled, IT and knowledge capitals have become relatively more important than physical capital.[7]

3.2 Source of Economic Growth and Productivity

The analysis starts with the investigation of IT capital role in order to shed light on the contribution of IT capital to overall economic growth, which can be translated into the standard growth accounting framework. Thus, the growth rate of the output in Eq. (1) can be extended to

$$\Delta ln\mathrm{Y} = S_L\Delta ln\mathrm{L} + S_{IT}\Delta ln\mathrm{K}_{IT} + S_{OT}\Delta ln\ \mathrm{K}_{OT} + \Delta ln\mathrm{TFP}, \tag{8}$$

where S_L indicates labor income shares, S_{IT} is IT capital income share, and S_{OT} is other capital (non-IT capital) income share, respectively. The term S_LL is the growth contribution of aggregate labor input, $S_{IT}K_{IT}$ is the contribution of IT capital input, and $S_{OT}K_{OT}$ is the contribution of all capital other than IT capital. The contribution of IT capital depends critically on the income share, S_{IT}, which is unobservable. To compute S_{IT}, present study follows the method used by the Bureau

[7]Several recent studies, mainly by Sichel (1999) and Oliner and Sichel (2000), have pointed to the IT revolution as a key-driving factor behind economic growth and productivity.

of Labor Statistics (BLS) to impute income shares for other types of capital.[8] With this procedure, the income share for IT capital is

$$S_{IT} = (i + \delta_{IT} - P^*_{IT})P_{IT}K_{IT} / PY, \tag{9}$$

where i is a measure of the nominal rate of return common to all capital, δ_{IT} is the depreciation rate on IT capital, and P_{IT} is the price index for IT capital and its rate of change, P^*_{IT}. The term $P_{IT}K_{IT}$ represents the nominal capital stock, and PY represents total nominal output or income. TFP reflects the change in output that cannot be accounted for by the change in combined inputs. As a result, it measures reflect the joint effects of many factors including new technology, economies of scale, managerial skill, and changes in the organization of production. If the performance of TFP improves over time, it could be interpreted as a sign of an additional growth contribution from IT; but a rise in TFP growth is neither a necessary nor a sufficient condition to show positive externalities of IT capital, because many factors influence TFP growth and can compensate for positive effects from IT.

Under neoclassical assumptions, however, this method encounters several potential difficulties regarding implementation of theory. First, theory assumes that the total input is characterized by constant returns to scale. Second, businesses always make optimal investment decisions, and all types of capital earn the same competitive rate of return at the margin. Third, the absence of externalities eliminates any potential division between private and social marginal products. Introducing additional production factors or allowing for quality changes of the factor inputs often extends this standard growth accounting approach. The weakness of this method, however, is its dependence on factor income shares, which are not only not directly observable but also difficult to measure. One way to overcome this problem is to use growth regression, which allows the estimation of the output elasticities of the factors directly from the regression of the production function, instead of calculating them from factor income shares.

Now, the production function of Eq. (1) can be extended by introducing another input factors in addition to labor and capital and by allowing for quality changes of the inputs. We control the IT and knowledge capital inputs that have an important bearing on the source of productivity growth. Thus, the production function of Eq. (1) can be written as

$$Y = F\{(L_h, L_q), (K_{IT}, K_{KN}, K_{OT}), B\}, \tag{10}$$

where the labor input was decomposed into labor hours (L_h) and labor qualities (L_q), to reflect changes in working hours and the qualities of labor, such as experience, gender, and the educational mix of the work force. Introducing labor quality as a production factor also brings the growth model, which relies on high output elasticities of reproducible capital, more in accordance with income distribution. Capital input also was decomposed into IT capital (K_{IT}), knowledge

[8] In contrast to the BLS, for simplicity the present study omits tax terms.

capital (K_{KN}), and all other capital (K_{OT}). The IT capital in the growth model can be treated not only in the same way as other capital goods but also as a special capital input.

In the first case, IT capital input can be treated in the same way as all other types of capital inputs. In particular, it is assumed that the owners of IT assets can reap most or all of the benefits that accrue from using new technologies. In this case, it is possible to observe market income accruing to IT capital and to make inferences about its overall growth contribution. Were there unobserved benefits or income, this contribution would be underestimated, which leads to the point about IT as a special input. In the special output case the IT input reflects scale economies and network externalities, which improve overall productivity. In this sense, IT not only affects output and labor productivity but also gives rise to additional effects that translate into gains in overall productivity. Such positive externalities are characterized by a discrepancy between a private investor's rate of return and the rate of return for society as a whole. In other words, IT equipment generates benefits above and beyond those reflected in economic growth, which means increasing returns.

Knowledge capital (K_{KN}) input also appeared in the growth model. The consideration of knowledge input as a production factor accommodates two methodological changes into the analysis, economies of scale and knowledge spillovers. Under the assumption of the linear homogeneity of the production function in the physical inputs, increasing standard production inputs by a certain ratio and holding the knowledge input constant will increase the output by the same ratio. Then, increasing all inputs leads to more than a proportional increase of output. Another aspect of knowledge capital is the idea of spillovers. The idea is that knowledge can be transferred at a cost that is much lower than that of originally producing it. In this sense, the process one industry uses to invent a product may also be used by another industry, with no additional high cost to the second industry. Finally, the indicator of the business cycle reflecting factor utilization was introduced into the production function to correct for inefficiencies associated with productivity growth and the business cycle.

This method remains controversial, however, owing to the measurement of inputs for implementation of empirical work.

Capital Stock. Accurate measurement of the stock of capital is crucial to an analysis of economic performance. Measurement of capital stock, however, is not directly observable, and time series need to be constructed by cumulating real investment over time. The basic procedure used to estimate capital stock derives from the perpetual inventory method, which is based on the assumption that the quantity of capital is proportional to the initial level of investment. The net capital stock K_{it} is defined as

$$K_{it} = I_{i,t} + (1-\delta_i)K_{i,t-1}, \tag{11}$$

where I_{it} denotes the quantity of investment occurring (gross investment) in the period and δ_i denotes the constant depreciation for all *i* stock. If the depreciation rate is unknown or there are no time series data constructed, net capital stock can be estimated by the polynomial-benchmark method, which is defined as

$$K_{it} = I_{i,t} + (1-\delta_i)I_{i,t-1} + (1-\delta_i)^2 I_{i,t-2} + \cdots + (1-\delta_i)^{S-1} I_{i,t-S+1} + (1-\delta_i)^S K_{i,t-S} \quad (12)$$

Thus, if there are two estimates of net capital stock and investments based on two benchmark years, the depreciation rate δ_i can be derived from Eq. (12). The estimated δ_i could be used to generate time series capital stock. In some cases, the depreciation rate would have a negative value when the estimated capital stock of the first benchmark year plus the accumulated investment after the benchmark year was less than that of the second benchmark year. Accurate measurement of a particular stock of IT capital requires accurate measurement of its depreciation rates. In general, IT capital goods show rapid rates of loss in value, which affects their high rate of depreciation. Even though the polynomial-benchmark method has drawbacks owing to the assumption that the depreciation rates between two benchmark years are constant, it is still convenient to apply to developing countries, for which data usually are insufficient.[9]

Knowledge Capital. Since Romer (1986) introduced knowledge as an input factor, knowledge has received considerable attention in recent economic growth models.[10] According to Romer, output depends not only on each producer's capital stock but also on the economy-wide capital stock. Knowledge is generated as a not-necessarily costless by-product of the daily work of qualified workers not only engaging in productive work but also searching for ways to improve both processes and products. This argument implies that increases to knowledge are associated with the human capital, that is, that scale economies arise from human capital.

Another argument for "learning by doing" suggests that knowledge can be acquired through investments in physical capital. Innovations to the process of production are often incorporated into new investment goods, and the reorganization of the production process to improve the quality of the product may require new technology. The accumulation of knowledge capital and technological progress may thus be seen as complementary, so that the estimated effect of knowledge capital on productivity growth captures both the production elasticity of knowledge capital and externalities associated with an increase of knowledge capital.

Since the late 1970s, many attempts have been made to find ways to measure knowledge capital, but knowledge capital remains neither well defined nor easily measurable. For empirical estimation, the R&D expenditure is often used as an approximation of the stock of knowledge, based on the assumption that the accumulation of R&D consists of a stock of knowledge that

---

[9]See Pyo (1998).

[10]For an overview, see Lucas (1988), Kydland and Prescott (1990), Barro and Sala-I-Martin (1995), and Kim (2000).

improves the quality of products and production processes and, hence, increases the growth of output and productivity. Measured R&D expenses, however, do not capture all expenditures for improving the quality of products or production processes.[11] Sometimes a "knowledge production function" is employed to describe how new products or new methods of production are discovered using specific resources. But specifying the form of the underlying knowledge production function is difficult, as is measuring with any degree of precision the output and input of the process of inventing a product.

For empirical application, patent statistics are considered as a quantitative number of inventions and often used as a proxy for knowledge capital stock. Several studies, mainly those by Griliches and Mairesse (1984) and Griliches et al. (1987), have pointed out that although there are large stochastic elements and great variance in the value of individual patents, patent applications remain reasonably good measures of the stock of knowledge. Although the measure of knowledge capital does not provide a consistent framework, there is an agreement on measuring a few categories in which intellectual property rights are recognized as a good approximation. For the present study, the statistics of patents, utility models, industrial designs, and trademarks are used in proxy for the knowledge capital stock.

Business Cycles. Business cycles not only capture the repeated expansion and contraction around sustained trends of macroeconomic variables (such as GDP, consumption, investment, employment, export, and import) but also imply their simultaneous movement. Given that fluctuations affect the economic environment, they are of great interest to economists and become the subject of research. The endogenous growth approaches suggest that the sources of long-run growth are not independent of the business cycle, and the impact of those sources cannot be determined unambiguously from theoretical arguments. These approaches emphasize that long-run growth has many determinants and that transitory disturbances may have long-run effects on productivity growth. Arguments of "learning by doing" suggest complementarities between production activity and productivity growth. In addition, R&D can be financed more easily from profits or from retained cash flow and can be more profitable during a period of economic expansion.

In other models, the argument has been made for opportunity costs and the intertemporal substitution of productivity, the so-called opportunity cost approach.[12] This method emphasizes the role of intertemporal substitution between direct production activities and activities to improve production along with the business cycle, thereby allowing the postulation of the positive influence of recession on long-run growth. In this sense, activities to improve productivity are important during recessions, because the return from directly productive activities is lower during recessions, owing to lower demand, and the opportunity cost in terms of

---

[11]See Smolny (2000).

[12]See Saint-Paul (1993).

forgone profits from these activities is lower than during expansions. Recessions are regarded as times when firms engage in activities to improve productivity owing to intertemporal substitution, thus as times appropriate to a reallocation of resources. The effect of the business cycle on long-run growth depends on whether productivity growth and production activity are substitutes or complements.

On the basis of this discussion, a specification of the production function of Eq. (10) in growth rate can be expressed as

$$\Delta ln\ Y_t = \beta_0 + \beta_{1i}\Delta ln\ \Sigma L_{it} + \beta_{2i}\Delta ln\ \Sigma K_{it} + \beta_3 \Delta ln\ B_t + \varepsilon_t, \tag{13}$$

where $L_{it} = (L_{ht}, L_{qt})$, L_{ht} is the working hours and L_{qt} is the quality of labor. $K_{it} = (K_{OTt}, K_{ITt}, K_{KNt})$, and K_{OT} is non-IT capital stock, K_{IT} is IT capital stock and K_{KN} is the stock of knowledge capital. B_t is the indicator of the business cycle, and ε_t is the error term. β_0 is the constant term, all other βs presents elasticities of output with respect to input factors, and t indicates the time index.

To examine labor productivity for both IT and other capital, Eq. (13) can be transformed by dividing the growth rate of the total hours worked into both sides of the equation; then[13]

$$\Delta ln\ (Y/L_h)_t = \beta_0 + \beta_L \Delta ln Lq_{,t} + \beta_{OT}\Delta ln(K_{OT}/L_h)_t$$

$$+\beta_{IT}\Delta ln\ (K_{IT}/L_h)_t + \beta_{KN}\Delta ln\ K_{KN,t} + \beta_B \Delta ln\ B_t + \varepsilon_t \tag{14}$$

3.3 R&D Investment and TFP

It is sometimes taken for granted that R&D plays an important role in increasing the rate of return in economic growth. In the United States, for example, the average rate of return on R&D investment is more that twice the rate of return on investments in capital equipment, and in some countries this rate may be much higher than that. The relationship between R&D investment and productivity growth has been a subject of considerable interest in the economics literature as well as to policy analysts.[14] In general, the producer of a technology benefits not only from its R&D effort but also from technology spillovers. IT is thus both itself the result of continuous innovation and a source of further innovation in the other areas of production in that sector. To analyze the relationship between innovation and the diffusion of innovation and growth, an examination of the relationship of TFP and R&D investment seems particularly appropriate.

The analytical tool often used to link productivity growth to R&D is usually based on a Cobb–Douglas production function that includes the stock of R&D capital as a separable factor of production. Another way of saying this is that R&D can be used as an explanatory variable of TFP.

---

[13]This labor-intensive form may also reduce the problems of heteroscedasticity and multicollinearity.

[14]For recent studies, see Los and Verspagen (2000), Bassanini et al. (2000), and Greenam et al. (2001).

As discussed in **Chapter Three**, the "standard" TFP can be measured on the basis of quality-adjusted labor and capital, which is in the sprit of the Solow residual. Although a measure of TFP that controls for human capital would be more appropriate in this context, here the cruder measure is used because data are available. On the assumption of constant returns to scale with respect to conventional inputs, equilibrium in input and output markets, and a zero depreciation rate for the R&D capital stock, TFP is related to R&D expenditure by

$$\text{TFP}_t = \rho + \gamma(\text{R\&D/Y})_t + \eta_t, \qquad (15)$$

where γ is the net rate of return of R&D and Y is output. Although several econometric and estimation issues are involved in these estimates, the discussion in **Chapter Four** touches only briefly on the result that has emerged from this line of research.

Chapter Four

Empirical Results

4.1 Data Sources

The data for the empirical investigation are from the years 1971 through 2000. Most of the data, except for capital stock, were obtained directly from *National Account* and the *Economic Statistics Yearbook*, both published by the Bank of Korea, and the *Korea Statistical Yearbook*, published by the Korea National Statistical Office. The capital stocks were taken from Pyo (1998), in spite of some criticisms of these data, because they were estimated by both the perpetual inventory method and the polynomial-benchmark method, using the National Wealth Survey for the years 1968, 1977, and 1987, together with total fixed capital formation from *National Account.*[1] Because these data provided only the estimated capital stocks for twenty-eight subsector industries in the manufacturing industries and of ten major sector industries for the other industries, net IT capital stocks were approximately constructed by multiplying the net capital stock of the major or subsector industries by the tangible fixed asset ratios that related in IT industry from the *Enterprise Business Analysis*, published by the Bank of Korea, and the *Report on Mining and Manufacturing Survey*, published by the National Statistical Office.[2] The number of intellectual properties times its registration and maintenance fee was used as a proxy for the knowledge capital stock. Data on intellectual properties were available in the *Major Statistics of Intellectual Property*, published by the Korea Intellectual Property Office. The labor income share was obtained directly from the *Korea Statistical Yearbook*. The growth rate of output and the producer price index at the 1995 constant price were taken from the *Economic Statistics Yearbook*.

To reflect changes in working hours and quality of labor, the number of workers was multiplied by the working hours index and the economy-wide labor quality index in Hong and Kim (1996).[3] The *Report on Monthly Labor Survey*, published by the Ministry of Labor, provided the number of workers, labor hours, and average monthly earnings. For business cycle indicators, the average value of capital and labor utilization was used.[4] The index of manufacturing operation

---

[1]The data set in Pyo was criticized because of the use of a constant depreciation rate between benchmark years and the use of the inconsistent National Wealth Survey, in which data for the 1970s and 1980s have different trends. Because the data for net capital stocks were provided only for the period 1970–96, for the present study the data have been extended through 2000 using the perpetual inventory method.

[2]In growth accounting, although "productive" capital stocks may be a more appropriate measure than net capital stock, for the present study the net capital stock for IT capital was used because the data were available. See Oliner and Sichel (2000).

[3]Because the data are provided only through 1992, all the necessary series were extended through 2000.

[4]Up to the year 2000, the Korean economy had experienced six business cycles and, as of the end of 2000, was in its seventh cycle. See *Korean Economic Trends* (Seoul: Samsung Economic Research Institute, December 2000).

ratios, taken from the *Manufacturing Production Capacity and Operation Ratio Survey* published by the National Statistical Office, and the one-minus (1–) unemployment rate were used for capital and labor utilization, respectively.

4.2 Empirical Analysis

4.2.1 Contributions to Growth Rate of Output

The contribution of each input to output growth was calculated on the basis of the standard growth accounting framework. **Table 4-1** shows the decomposition of the growth of real output. For the calculation of the income share of IT capital, the short-term interest rate (the interest rate on loans for up to one year of general funds for general enterprises) was used as a measure of the nominal rate of return common to all capital. Data for the depreciation rate of IT capital stock are from Pyo (1998), where 13.1 percent was used for the period of 1970–77 and 14.2 percent for 1977–2000.[5] The price index of IT capital was measured approximately as a weighted average value from the producer price indices of major IT industries.[6] To examine the effect of the business cycle, the growth accounting model allowed for factor utilization.[7] The contribution of each input to growth was computed on a year-by-year basis, and then the annual figures were averaged to measure contributions over longer time spans. In the table, the first row shows the growth rate of output, and rows two through six show this growth rate among the contributions from the five inputs: labor, other capital, IT capital, the business cycle, and TFP. The last row shows the trend of TFP only for the manufacturing industry.

The full sample period was divided into four shorter periods, 1971–80, 1981–90, 1991–95, and 1996–2000, to highlight the separate phases of economic growth. The first two columns cover 1971–80 and 1981–90, the early stages of IT industrialization. During those two periods, the output grew on average 7.5 and 8.7 percent per year, respectively. Labor accounted for about 20.0 and 12.9 percent of growth, while the contribution from other capital was much larger, about 86.1 and 40.1 percent, respectively. In 1971–80, the contribution to output growth of IT capital was modest, accounting for 12.8 percent of the output growth rate. The rate increased slightly, to

---

[5] The depreciation rates in Pyo (1998) were estimated 13.1 percent during 1970-1977 and 14.2 percent for the period 1978-1987. Although these rates are somewhat smaller than Shin's (2000) study, where the estimated rate was 22.4 percent, the present study retains these rates until the year 2000 for the sake of comparability.

[6] The weighted average values of the producer price indexes come from five IT-related sectors, including electronic motors,·electronic generators,·electronic transformers, insulated wires and cables, electronic valve and tube components, communication equipment and apparatuses, and TV and·radio·sound- or videorecording or reproduction apparatuses. The weight, on a scale of 1 through 5, was based on the number of items in each sector.

[7] This effect can be accommodated by assuming that the rate of factor utilization differs depending on the business cycle; thus, Eq. (1) will be $Y = T(\tau L)^{\alpha}(\lambda K_{OT})^{\beta}(\lambda K_{IT})^{(1-\alpha-\beta)}$. After taking logs and rearrangement, the output growth will be given by $\Delta ln\, Y = \Delta ln\, T + \alpha \Delta ln\, L + \beta \Delta ln\, K_{OT} + (1-\alpha-\beta)\Delta ln\, K_{IT} + [\alpha \Delta ln\, \tau + (1-\alpha)\Delta ln\, \lambda]$, where τ is the rate of labor utilization, λ the rate of the capital utilization, on the assumption that IT and other capital are the same, and the last term reflects the indicator of the business cycle.

14.3 percent, in the 1980s, while other capital made a much larger contribution, 40.1 percent. Such calculations were the basis for the claim that IT capital had contributed fairly considerably to the growth rate of output in Korea during the 1970s and 1980s, although the ratio of IT to non-IT capital was less than 1 percent.[8]

On the other hand, TFP accounted for –2.4 percent in 1971–80, which may reflect the great eagerness for industrialization characteristic of this period in Korea. The government provided massive investment to build up the heavy and chemical industries with a huge inflow of oil dollars in the mid-1970s, which brought a rapid build-up of capital. This rapid accumulation of capital stock distorted prices and led to technological backwardness, as well as to allocation inefficiencies in the Korean economy. During this period, inefficiencies in the Korean economy became increasingly evident, so that the minus growth of TFP is not surprising. This observation implies that much of the economic growth during 1970s in Korea was attributable to the growth of factor inputs, rather than to technological progress. Because the government's huge investment in the heavy and chemical industries in the 1970s was accompanied by great inefficiency in those industries, in the early 1980s the government carried out the policy in a program of structural reform of the industries.

In the same period, output growth noticeably increased simultaneously with a mild inflation rate. This combination may have affected the growth rate of TFP, which recovered to 2.2 percent in the 1980s. During the 1970s and 1980s, the business cycle accounted for 13.6 and 7.8 percent, respectively, of that output growth. The figure for 1970s is a little bigger than that of IT capital, but its contribution rate decreased to 7.8 percent in 1980s. This [pronoun reference? This decrease?] implies that the accumulation of IT capital was extremely small in the 1970s, but in the 1980s, when the accumulation of IT capital increased, its contribution to output growth increased while that of the business cycle decreased.

In the first half of the 1990s, the situation differed little from that of the early stages. The average growth rate of output dropped to 7.5 percent, which was less than the 1.2 percent annually of the previous period. Non-IT capital stayed around 3 percent, while that of IT capital increased to 1.37 percent, accounting for about 18.4 percent of output growth. This growth contribution of IT capital amounted to about half of the entire growth contribution of other capital. At the same time, the TFP growth rate dropped to 1.2 percent. In contrast to the earlier stages, the first half of the 1990s was characterized by less selective and more liberal industrial policies and by the increased role of the big business group, known as *jaebol*, in resource allocation. The civilian government at this time began to emphasize economic growth, rather than stabilization, while the big business group promoted overcapitalization and overlapping in several major

---

[8]The data show that the ratio of IT to non-IT capital stock was 0.3 percent to 99.7 percent in 1970, 0.7 percent to 99.3 percent in 1980, and 6.1 percent to 93.9 percent in 2000.

industries, which led to technological inefficiencies. Nevertheless, the contribution of IT capital to output growth was significant and has been rising.

Table 4-1

Contributions to Output Growth
(Unit: %)

	1971–80	1981–90	1991–95	1996–00	1971–00
Growth Rate of Output	7.49<100.0>	8.67<100.0>	7.46<100.0>	4.96<100.0>	7.46<100.0>
Contributions from					
Labor	1.50<20.0>	1.12<12.9>	1.34<18.0>	0.21<4.2>	1.14<15.3>
Other Capital	6.45<86.1>	3.48<40.1>	3.01<40.3>	2.62<52.9>	4.19<56.2>
IT Capital	0.96<12.8>	1.23<14.3>	1.37<18.4>	1.22<24.5>	1.22<16.3>
Business cycle	1.02<13.6>	0.68<7.8>	0.54<7.2>	0.49<–9.8>	0.57 <7.6>
TFP					
Whole Industry	–2.44<–32.5>	2.16<24.9>	1.20<16.1>	1.40<28.2>	0.34<4.6>
Mfg. Industry*	1.31	3.60	4.21	4.87	3.14

Note: Figures in angle brackets < > are the weights in the output growth.

*The number did not allow for the business cycle.

IT = information technology TFP = total factor productivity

In the second half of the 1990s, that is, in 1996–2000, the average growth rate of output dropped even more, to about 5 percent per year. The contribution of labor input to output growth also decreased, to 0.2 percent, accounting for only 4.2 percent of the total growth rate, while non-IT capital grew on average 2.6 percent, accounting for 52.9 percent of the output growth. However, the contribution from IT capital to output growth surged in this period. The contribution from IT capital has jumped to 24.5 percent of output growth. The larger contributions since the mid-1990s may reflect faster growth in the real stock of IT equipment compared with the average pace before 1995, and the increased importance of IT capital in the economy. Also since the mid 1990s, TFP increased slightly, to 1.4 percent, while the growth rate of output was perturbed by the business cycle to –0.5 percent. In comparison to the previous period, TFP did not increase by much but, rather, was stable, probably because the environment in which the policy of structural reform had been introduced did not adequately support the anticipated improvements. In particular, since the financial crisis late in 1997 the Korean government had announced various programs of economic reform, including the liberalization policy, none of them completed. Increased competition owing to the beginning of economic liberalization does not appear to have improved either firms' innovative capacity or their productivity.

The last column of the table shows the growth rate of each element for the entire period 1970–2000. Output grew 7.5 percent per year, the average contribution of labor input to output growth was about 15.3 percent. Other capital and IT capital were important sources of economic growth, accounting for 56.2 percent and 16.3 percent respectively, while business cycle accounted for 7.6 percent, and TFP accounted for the remaining 7.6 percent. Although TFP accounted for about 0.3 percent of output growth, if there were no business cycle effect, the average annual growth rate of TFP during this period would have been about 0.9 percent. This growth rate was relatively low, which was similar to the average rate without the effect of the business cycle in 1996–2000, and fairly stable. Much of this output growth may therefore have been due to the growth of factor inputs, rather than to actual technical progress.

In addition, although the TFP growth rate was increased slightly between 1996 and 2000, the picture for TFP growth is subtly different from the growth output. Most of the slowdown in output growth in the1990s can be attributed to a collapse in TFP growth, but the smaller increase of 0.2 percent per year in TFP growth during the period 1996–2000 seems due to a increase in the growth of IT capital inputs. Although the neoclassical model used here does not attribute the pickup in TFP growth to IT, many earlier studies have suggested that the rapid spread of IT has played an important role in the improved performance of TFP since 1990.[9] Finally, the average growth rate of TFP for the manufacturing industries was 3.1 percent between 1971 and 2000, which is similar to what was found in earlier studies.

4.2.2 Sources of Productivity Growth

This section presents estimation results for the sources of productivity growth. The log-linear forms were estimated by the ordinary least-square (OLS) method on the basis of Eqs. (14) and (15). **Table 4-2** shows the results for both the standard and the extended growth models, which explain the results for the labor productivity growth. The first row in the table represents labor productivity from the standard growth model, which is assumed to be constant returns to scale with exogenous technical change. The equation includes changes in the factor utilization as an indicator of the business cycle. The result gives a quite reasonable estimate of the elasticity of productivity growth with respect to both capital intensity and changes in factor utilization. In particular, the coefficient of the business cycle indicator is highly significant, reflecting that change in factor utilization is an important determinant of productivity growth. Its inclusion reduces not only the standard error of the coefficient of capital intensity but also the problem of omitted variables. The next row shows the results of the extended growth model. In general, a times-series analysis gives pure results for the long-run trend of labor productivity growth. The result, however, is relatively reasonable through explanatory variables in the equation, which provide valuable insights into productivity analysis, even though their explanatory power is low. Labor quality was included as an explanatory variable that may reflect the importance of human

---

[9]See Oliner and Sichel (2000), Jorgenson and Stiroh (2000), and the U.S. Dept. of Commerce (2000).

capital. Although the coefficient tended to be insignificantly different from zero, the result indicates that labor quality has a positive effect on productivity growth as physical capital. Thus, in the long run the productivity growth of more highly qualified workers will be higher. Although Korea lacks natural resources, the productivity growth is indebted to the improvement in the quality of labor. Its excellent human resources are well known as one of the strong points of Korea's economy.

Table 4-2

Estimates of Productivity Growth

	Constant	$\Delta ln(K/L_h)_t$	$\Delta ln B_t$	$\bar{R}^2$			
$\Delta ln(Y/L_h)_t$	1.668 (1.82)	0.324 (2.10)	0.051 (3.36)	0.31			
	Constant	$\Delta ln L_{q,t}$	$\Delta ln(K_{OT}/L_h)_t$	$\Delta ln(K_{IT}/L_h)_t$	$\Delta ln K_{KN,t}$	$\Delta ln B_t$	$\bar{R}^2$
$\Delta ln(Y/L_h)_t$	1.578 (1.71)	0.085 (1.05)	0.352 (2.11)	0.028 (2.06)	0.005 (1.23)	0.059 (3.59)	0.36
	Constant	**(R&D)**$_t$	$\bar{R}^2$				
TFP$_t$	0.268 (2.04)	0.273 (2.68)	0.30				

Note: Figures in parentheses are t-statistics.

The estimated coefficients of IT and other (non-IT) capital intensity, 0.03 and 0.35, respectively, are statistically significant. The small coefficient of IT capital intensity can be explained by two hypotheses. The first is the hypothesis of capital stock, which reflects the fact the IT capital remains a relatively small share of the total capital stock because of the short period of IT investment. In the United States, the investment in IT industries has been steady since the 1970s, that is, over a long period, while Korea began to build the underpinnings of the IT industries only in the mid-1990s. This later start has made for a relatively small capital accumulation for these industries, and the effects of IT investment seem to appear in the late 1990s. As mentioned in section **4.2.1**, the ratio of IT to non-IT capital stock was only 6.1 percent to 93.9 percent in the year 2000. The second is the hypothesis of long learning lags. According to this, new technologies diffuse gradually, because a long period is needed for learning how to use new resources. Further, truly revolutionary applications, such as IT applications, often require a major reorganization of production, which may take a long time to discover. As mentioned in **Chapter Three**, Korea's active participation in the IT revolution has come late. If these hypotheses are correct, then it will take a long time to reap the benefits of the effects of productivity growth.

The elasticity of the long-run labor productivity growth was related not only to these input factors but also to other factors, such as knowledge capital. Knowledge capital was included in Eq. (14) as an additional variable. The estimation result was unsatisfactory, indicating a coefficient of a fairly small magnitude and not significant, even though it gives a positive sign. This result appears to reflect the continuing weakness of the knowledge base in Korea. The number of patent applications remains half that of advanced countries, and the number of published theses is only one-fifth that of those countries. In addition, because the capacity to organize the knowledge-based activities of economic bodies remains weak, the Korean economy has not made effective use of knowledge capital to improve productivity growth. Further, some of Korea's newly created and learned knowledge remains unused and therefore has not contributed to the creation of high-value-added industry areas.

The business cycle also is an important determinant and, in the long run, significantly affects productivity growth in Korea. The estimated coefficient is about 0.06 and statistically significant. This is fairly large compared to other factors such as IT and knowledge capital in productivity growth. From this result, it can be concluded that economic activity and productivity growth are complementary, hence, economic expansion will increase productivity in the long run. Since the 1970s, when statistics regarding business cycles were first collected, the Korean economy has experienced six business cycles, all of which have been greatly affected by changes in the external environment. The results seem to support the analysis of the growth contribution in section **3.2**.

Finally, the relationship between TFP and the ratio of R&D to output was estimated in order to shed light on the relationship between innovation and the diffusion of innovation and growth. Although there are a number of econometric and estimation issues concerning these estimates, the result suggests a positive and strong relationship between TFP and R&D investment, accounting for a 27 percent rate of return. This result may be related to a real economic phenomenon, in which R&D has a specific role in the recovery from the productivity slowdown. The investments in R&D has been decreasing since 1996, this result may give a fairly safe prediction that if the current contraction of R&D activity were to continue, Korea's dependence on foreign technology would deepen. In the long run, contracted R&D activity could undermine Korea's competitiveness and the growth potential of its domestic industries.

Chapter Five

Summary and Implications

The Korean economy's dependence on IT industries has increased considerably since the mid-1990s, signaling a rapid transformation into a digital economy. The growth contribution from standard input factors as well as from IT capital inputs was calculated on the basis of the growth accounting framework during the years 1971–2000 and can be characterized as follows. Most of the contribution to output growth comes from other (non-IT) capital input, accounting for 56.2 percent rather than labor capital, which accounted for only 15.3 percent. IT capital contributed 16.3 percent to the output growth, but its contribution has been increasing since 1970s. The business cycle is one of the main determinants of the output growth rate, accounting for about 8 percent of the total growth. The average annual growth rate of TFP during the period 1971–2000 was about 0.3 percent, while that of the business cycle was about 0.6 percent. The TFP growth rate, however, increased slightly between 1996 and 2000. The source of productivity growth was investigated using an extended growth model that draws attention to the role that IT may have played. Although some shortcomings may limit the scope of the empirical work, the results appear worth consideration:

- Both IT and other (non-IT) capital have had a positive effect on productivity growth, but the coefficient of non-IT capital intensity was 0.35, which is eleven times higher than that of IT capital intensity, 0.03. Changes in the quality of labor also have had a positive effect on productivity growth, but they remain small and not statistically significant.
- Knowledge capital also has had a positive effect on the growth of labor productivity. Although the coefficient was not significant, its importance will increase. Traditionally, physical capital has been considered the most important type of capital, but it is a fairly safe prediction that in the future knowledge capital will be an important key to a nation's competitiveness.
- The business cycle was identified as one of the important determinants of economic performance in Korea, affecting output growth in the short run. It also allows changes of factor utilization to be incorporated into a well-determined estimate of factor productivity in the long run. The estimated coefficient was about 0.06 and statistically significant. This is fairly large compared to other factors, such as IT and knowledge capital, in productivity growth.
- The positive and strong relationship between R&D investment and TFP, accounting for a 27 percent rate of return, offers a lesson in the domestic economy. This result may predict that the decrease in R&D investments in Korea during the 1990s had a major impact on the slowdown of TFP. It may also indicate that R&D has had a specific role in the recovery from the productivity slowdown.

These investigations have policy implications for the government's role in promoting IT industries. Even before the Korean financial crisis of 1997, the government had pointed to the "knowledge gap" as a fundamental problem of the Korean economy. Paul Krugman, an economist at the Massachusetts Institute of Technology (MIT), also has suggested that quantitative expansion without the enhancement of productivity may be a major reason for the fragility of the Korean economy.

First, the government needs to build a knowledge-based industrial structure, which would help the private sector to create and use knowledge. In 2002, Korea's technical knowledge base remains weak. Compared to advanced countries, its rate of investment in R&D remains far from appropriate. As result, the capacity to create knowledge is weak, and the competitive power of Korea's high-tech industry in the world market is low. The government needs therefore to lay out a plan to foster knowledge-based industries and, with strong determination, to implement it.

Second, the role of the government will need to change to allow market principles to function more efficiently. Until now, the government's policy direction for the IT industries has been focused on preparing and putting into practice a wide range of supportive policies to generate public response and create a favorable atmosphere, as well as on establishing IT infrastructure. During this process, investment in the IT industries was made without sufficient consideration of efficiency and effectiveness. The government's policy will need to change, however, to suit Korea's circumstances as well as to increase efficiency. Thus, the government will need to invest selectively, that is, only in successful IT firms and only after rigorous evaluation of a firm's performance and potential—a policy this author has suggested calling "Choice and Concentration."[1] As of this writing (early 2002), the government will need to transform its role from market director or resource allocator to that of initiator and coordinator in order to increase the efficiency of the IT industries.

Third, the Korean government will need to increase its economic immunity in order to stabilize itself in face of external factors, such as changes in the exchange rate and global demand for domestic goods and services. In the past, business cycles have almost always coincided with changes in the exchange rate, especially that of the Japanese yen. The yen was strong during six phases of expansion, except during the third cycle, and weak in contraction phases, except during the fifth cycle. This phenomenon means that the Korean economy is greatly affected by changes in the external environment, especially the exchange rate of the yen to the U.S. dollar. In addition, the Korean economy relies heavily on foreign demand, especially from the United States and Japan. Since the end of 2000, however, the world economy has been in recession and the demand for Korea's IT goods and services has therefore decreased. According to the Ministry of Commerce, the export rate fell 20 percent in July of 2000 and July of 2001, for the largest single month decrease since 1967. The main reason for this decrease is the plunging global demand for IT products. The government will therefore need to develop a strong domestic consumption market in order to stabilize Korea's IT industries.

---

[1]See Kim (2000).

Last, promising new IT-related industries suitable to Korea need to be established. For this purpose, the focus of investment will need to be on industries that represent the “digital era,” for example, semiconductors, digital home appliances, telecommunications, and e-commerce. Later, as part of a continued exploration of these new fields, social and government support systems will be needed to foster talented individuals involved in creative research activities.

At the turn to the twenty-first century, Korea faces new challenges. Korea has lost comparative advantages in labor-intensive industries to newly emerging developing countries and, to survive in the global market, must choose to develop comparative advantages in technology-intensive industries. Although the economy is still in recession (2002), the digital era has not closed in Korea. Rather, the continuing transition to a digital economy will determine the future of the nation. With the kind of reorganization suggested in this chapter, the Korean government will be able to establish an efficient economic system that will minimize direct intervention in the economy. In this way, the Korean IT industries will receive another important boost, which, in turn, will lead to economic growth with productivity growth.

References

Bank of Korea. (various years) *Economic Statistics Yearbook*. Seoul: The Bank of Korea. (in Korean)

———. (various years) *Enterprise Business Analysis*. Seoul: The Bank of Korea. (in Korean)

———. (various years) *National Accounts*. Seoul: The Bank of Korea. (in Korean)

Barro, R. J. and X. Sala-I-Martin. (1995) *Economic Growth.* New York: McGraw–Hill.

Bassanini, A., S. Scarpetta, and S. Visco. (2000) *Knowledge, Technology and Economic Growth: Recent Evidence from OECD Countries*. OECD Economics Dept. Working Paper, No. 259.

David, Paul A. (2000) "Understanding Digital Technology's Evolution and the Path of Measured Productivity Growth: Present and Future in the Mirror of the Past" in *Understanding the Digital Economy Data, Tools, and Research*, edited by E. Brynjolfsson and B. Kahin. Cambridge, Mass.: The MIT Press, 49-95.

Gorden, R. J. (1998) "Monetary Policy in the Age of Information Technology: Computers and the Solow Paradox," Chicago: Northwestern University. A paper prepared for the conference "Monetary Policy in a World of Knowledge-Based Growth, Quality Change, and Uncertain Measurement," Bank of Japan, Tokyo, June 18-19.

Greenam, N., J. Mairesse, and A. Topiol–Bensaid. (2001) *Information Technology and Research and Development Impacts on Productivity and Skills: Looking for Correlations on French Firm Level Data*. National Bureau of Economic Research (NBER) Working Paper, No. 8075.

Griliches, Z., and J. Mairesse. (1984) "Productivity and R&D at the Firm Level," in *R&D, Patents, and Productivity*, edited by Z. Griliches. Chicago: University of Chicago Press, 339-374.

Griliches, Z., Z. Pakes, and B. Hall. (1987) "The Value of Patents as Indicators of Inventive Activity," in *Economic Policy and Technological Performance*, edited by P. Dasgupta and P. Stoneman. New York: Cambridge University Press, 97-127.

Hong, S. D., and J. H. Kim. (1996) *The Long-Term Changes in Total Factor Productivity in the Korean Manufacturing Sector 1973–93.* Seoul: Korea Development Institute.

Hsieh, C. T. (1999), "Productivity Growth and Factor Prices in East Asia," *American Economic Review* **87**, 2, 133-138.

Jorgenson, D., and K. Stiroh. (1999) "Information Technology and Growth," *American Economic Review* **89**, 2, 109-115.

———. (2000) *Raising the Speed Limit: U.S. Economic Growth in the Information Age*. OECD Economics Dept. Working Paper, No. 261.

Kim, S. J. (2000) “Venture Capital Investment for Software Industry in South Korea,” *Asian Profile* **28**, 6, 449-470.

Korea Intellectual Property Office. (various years) *Major Statistics of Intellectual Property*. Daejon: Korea Intellectual Property Office. (in Korean)

Korea National Statistical Office. (various years) *Korea Statistical Yearbook*. Daejon: Korea National Statistical Office. (in Korean)

———. (various years) *Manufacturing Production Capacity and Operation Ratio Survey*. Daejon: Korea National Statistical Office. (in Korean)

———. (various years) *Report on Mining and Manufacturing Survey*. Daejon: Korea National Statistical Office. (in Korean)

Krugman, P. (1994) “The Myth of Asia’s Miracle,” *Foreign Affairs* (November–December) 73, 62-78.

Kydland, F., and E. Prescott. (1990) “Business Cycles: Real Facts and a Monetary Myth,” *Quarterly Review, FRB of Minneapolis* **14**, 2, 3-18.

Los, B., and B. Verspagen. (2000) “R&D Spillovers and Productivity: Evidence from U.S. Manufacturing Microdata,” *Empirical Economics* **25**, 1, 127-148.

Lucas, Jr., R. E. (1988) “On the Mechanics of Economic Development,” *Journal of Monetary Economics* **22,** 1, 3-42.

Machlup, F. (1962) *The Production and Distribution of Knowledge in the United States*. Princeton: Princeton University Press.

Madison, A. (1970) *Monitoring the World Economy: 1820–1992*, The Development Center at OECD.

Mankiw, N. (1995) “The Growth of Nations,” *Brookings Papers on Economic Activity* **1**, 275-326.

Ministry of Labor. (various years) *Report on Monthly Labor Survey*. Seoul: Ministry of Labor. (in Korean)

Moulton, B. (2000) “GDP and Digital Economy: Keeping Up with the Change,” in *Understanding the Digital Economy Data, Tools, and Research*, edited by E. Brynjolfsson and B. Kahin. Cambridge, Mass.: The MIT Press, 34-48.

Oliner, S., and D. Sichel. (2000) “The Resurgence of Growth in the Late 1990s: Is Information Technology the Story?” *Journal of Economic Perspectives* **14**, 4, 3-22.

Porat, M. U. (1977) *The Information Economy*, Washington, D.C.: Office of Telecommunications, U.S. Dept. of Commerce.

Pyo, H. K. (1998) *Estimates of Capital Stock of Korea by Industry and by Type of Asset (1954–1996)*. Seoul: Korea Institute of Public Finance. (in Korean)

Robertson, P. (2000) "Diminished Return? Growth and Investment in East Asia," *The Economic Record* **76**, 235, 343-353.

Romer, P. M. (1986) "Increasing Returns and Long-Run Growth," *Journal of Political Economy* **94**, 5, 1002-1037.

Saint–Paul, G. (1993) "Productivity Growth and the Structure of the Business Cycle," *European Economic Review* **37**, 1, 861-890.

Samsung Economic Research Institute. (December 2000) *Korean Economic Trends*. Seoul: Samsung Economic Research Institute.

Shin, I. (2000) "Use of Information Network and Organizational Productivity: Firm-Level Evidence in Korea," *Economics of Innovation and New Technology* 9, 447-463.

Sichel, D. E. (1999) "Computer and Aggregate Economic Growth: An Update," *Business Economics* **34**, 2, 18-24.

Smolny, W. (2000) "Sources of Productivity Growth: An Empirical Analysis with German Sectoral Data," *Applied Economics* **32**, 3, 305-314.

Solow, R. M. (1987) "We'd Better Watch Out," *New York Times Book Review*, July 12, 1987, 36.

United States Department of Commerce. (1999) *The Emerging Digital Economy II*. Washington, D.C.: U.S. Dept. of Commerce.

——— (2000). *Digital Economy 2000*. Washington, D.C.: U.S. Dept. of Commerce.

Young, A. (1992) "A Tale of Two Cities: Factor Accumulation and Technical Change in Hong Kong and Singapore," in NBER, *Macroeconomics Annual*, edited by O. J. Blanchard and S. Fisher. Cambridge, Mass.: The MIT Press.

———. (1995) "The Tyranny of Numbers: Confronting the Statistical Realities of the East Asian Growth Experience," *Quarterly Journal of Economics* **110**, 3, 641-680.

Yuhn, K., and J. Kwon. (2000) "Economic Growth and Productivity: A Case Study of South Korea," *Applied Economics* **32**, 1, 13-23.

Acronyms

DSL	digital subscriber line
GNP	gross national product
IC	information and communication
IT	information technology
ITU	International Telecommunication Union
KOSDAQ	Korea Securities Dealers Automated Quotation
NBER	National Bureau of Economic Research
NIC	newly industrialized country
OECD	Organisation for Economic Co-operation and Development
OLS	ordinary least square
PC	personal computer
R&D	research and development
TFP	total factor productivity
TV	television

PPKIM

ISBN 1-879716-77-1