Imitation to Innovation

The Dynamics of Korea's Technological Learning

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PREFACE AND ACKNOWLEDGMENTS

In 1973, as a first-year doctoral student at Indiana University, I was fortunate to attend an R&D management graduate seminar offered by Professor James M. Utterback, (who is now at MIT). While I was struggling to grasp technology and R&D issues in the United States, many questions lingered in my mind. How can science and technology, which seem to be the key to development in advanced countries, be effectively used for economic and social development in catching-up countries? Are theories related to technology management in advanced countries applicable to catching-up countries? If not, how does technology change in catching-up countries and why?

Since then, I have conducted in-depth research of more than 200 Korean firms across many different industrial sectors for more than twenty years. Using Korea as a case in point, I have published in excess of fifty articles internationally to answer these questions. But because each article could cover only one or two narrowly focused subjects, a monograph was needed to synthesize these diverse issues. This book is a fusion of my previous works plus more recent research findings.

This book took longer to pull together than to write. In this process I was assisted by many individuals and institutions. First and foremost, I wish to extend my deepest gratitude to Professor James Utterback, to whom I dedicate this work. His seminar, plus other courses, offered me such solid micro-level training in the field of innovation issues that I switched my academic specialization from managment science to technology management. Professor Jinjoo Lee (Korea Advanced Institute of Science and Technology), coauthor of my first book, *Technology Innovation: Process and Policy*, has been a major source of intellectual stimulation, inspiration, and support since I was a doctoral student.

On completing the doctoral program, I was privileged to work, from 1975 to 1978, at the Center for Policy Alternatives at MIT, which provided me with an opportunity to integrate micro innovation issues with macro policy issues. I owe a great deal to all members of the center, particularly the late Professor Herbert Hollomon, the late Dr. K. N. Rao, Dr. Blair McGugan, and George Heaton for intellectual inspiration and encouragement. I was also fortunate to be involved in the initial stage of Professor Utterback's book *Mastering the Dynamics of Innovation*. Professors Thomas Allen, Edward Roberts, and Eric von Hippel of MIT's Sloan School also encouraged me to approach technology issues from diverse perspectives.

Then a 1981–1985 World Bank project gave me an invaluable opportunity to focus my research on acquiring of technological capability at the firm level. This marked a turning point of my research interest from product and process innovation to technological capability building and organizational learning. I am indebted to the World Bank for financial assistance and to the participants in the project, particularly Professor Larry Westphal (Swarthmore), Dr. Carl Dahlman (World Bank), Professor Alice Amsden (MIT), and Professor Sanjaya Lall (Oxford) for constructive ideas and inspiration.

The World Bank assignment helped me build an important intellectual foundation for participation in a subsequent international undertaking that examined national innovation systems. This enabled me to broaden my outlook even further by considering technology issues in a new light. I benefited a great deal from discussions with other participants, particularly Professors Richard Nelson and Hugh Patrick (Columbia), Giovanni Dosi (Rome), Charles Edquist (Linkoping), Jorge Katz (Economic Commission for Latin American Countries), David Mowery (Berkeley), Keith Pavitt (Sussex), Nathan Rosenberg (Stanford), Jon Sigurdson (Lund), Luc Soete (Limburg), David Teece (Berkeley), and Morris Tuebal (Jerusalem).

In 1993 Columbia University invited me to spend a year as a visiting professor at its business school and to conduct research at its East Asian Institute. This opportunity gave me an intellectually exciting environment, which enabled me to begin writing this book and to test some of my ideas for it on my graduate students. Professors Gerald Curtis, Gari Ledyard, Andrew Nathan, Richard Nelson, and Hugh Patrick at the East Asian Institute, who were instrumental in inviting me to Columbia, encouraged and inspired me. I also thank Margot Landman and Mala Bachus for their administrative help and Madge Huntington for her professional copyediting assistance. At Columbia Business School, Professors Ming-Jer Chen, Donald Hambrick, Katherine Harrigan, Hugh Patrick, and Michael Tushman were sources of inspiration. I am particularly indebted to Professor Patrick and his staff at the Center on Japanese Economy and Business, who made my teaching there most rewarding, and to Professor Tushman, who encouraged me to publish this book through the Harvard Business School Press.

In 1994 the Institute of New Technology of the United Nations University invited me to spend the summer in Maastricht, the Netherlands, to conduct a seminar and advise Ph.D. interns on their research projects. I extend my gratitude to Professor Charles Cooper, director, and the staff of the institute, particularly Dr. Ludovico Alberto, Dr. Maria Besto, and Professor Shulin Gu, who made my stay most productive. This visit afforded me an opportunity to undertake an extensive literature search and to strengthen the theoretical underpinnings of this book.

Korea University, my home institution for the past ten years, generously gave me a grant to undertake part of the research underlying this book. I am grateful to all the faculty members of its business school, particularly Deans Dong-Ki Kim, Soo-Shik Shin, and Chung Chee and Professor Yoon-Dae Euh, for intellectual as well as personal support. Professor Soo-Young Kwon offered constructive comments on the first several chapters of an earlier draft. I am also indebted to Hyun-Do Seol and Hyun Chin for their able research assistance.

Many people read the entire first draft and offered valuable suggestions. They include Professors Mark Dodgson (Australian National University), Min-Koo Han (Seoul National University), Youngbae Kim (Korea Advanced Institute of Science and Technology), Eleanor Westney (MIT), Danny Miller (École des Hautes Studes Commerciales and Columbia), N.T. Wang (Columbia), Richard Nelson (Columbia), Hugh Patrick (Columbia), Dr. Yooncheol Lim (Science and Technology Policy Institute [STEPI]), Dr. Eul-Yong Park (Korea Development Institute), Dr. Jong-Guk Song (STEPI), and particularly Timothy Wendt (Columbia), who not only made substantive recommendations on the structure and contents but helped me improve the readability of the manuscript. Yoonsun Chung (STEPI) copyedited an earlier draft.

I am also grateful to many at the Harvard Business School Press. Carol Franco, director, strongly believed that a history of Korea's technological learning could be an important book. I was pleased to work with Nicholas Philipson, acquisition editor, whose wise counsel and efficient work style enabled me to write and revise productively. His personal warmth and positive response made my association with the press very enjoyable. Nindy LeRoy, manuscript coordinator, did an excellent job of transforming my manuscript into a book. Thanks also to Gerry Morse for her copyediting skill.

I express my warmest love and appreciation to my wife, Susie, my daughters, Sue and Jean, and my son, Lin, for their unstinting support and prayer throughout the long process of planning and writing this volume. Finally, any glory associated with my work should redound to the loving Almighty God, who has paved my path from many years before the beginning of my academic life until the completion of this work.

CONTENTS

1 Introduction

"In ten years, even the mountains move," says a Korean proverb. This is true in economy, business, technology, society, and even in Korean politics. Few economies in the world have matched the phenomenal economic development of South Korea—hereinafter Korea—in terms of industrialization and technological progress.

RADICAL TRANSFORMATION

Korea has indeed been transformed from a subsistent agricultural economy into a newly industrialized one during the past three decades. As late as 1961, Korea suffered from almost all the difficulties facing most poor countries today. Korea's per capita gross national product (GNP) was less than that of Sudan and less than one-third that of Mexico in 1961.

But beginning in 1962, the Korean economy grew at an average annual rate of almost 9 percent, raising GNP per capita in current prices from $87 in 1962 to $8,483 in 1994 (Table 1-1),[1] which was more than 18 times that of Sudan and 2.3 times that of Mexico.[2] With GNP per capita passing $10,000 and total GNP of $440 billion in 1995,

Table 1-1 Major Economic Indicators (in current price)

	1953	1960	1965
Population (in millions)	21.5	25.0	28.7
GNP ($ billions)	1.4	1.9	3.0
GNP/per Capita ($)	67.0	79.0	3.0
Exports ($ millions)	39.6	32.8	175.1
Structure of GDP			
Percent of Primary	47.3	36.8	38.0
Percent of Mining	1.1	2.1	2.0
Percent of Manufacturing	9.0	13.8	18.0
Percent of Utilities	2.6	4.1	4.7
Percent of Service	40.0	43.2	32.1
Structure of Manufacturing			
Percent of Light Industry	78.9	76.6	68.6
Percent of Heavy Industry	21.1	23.4	31.4

SOURCE: Office of Statistics, *Tong-gyero bon Hankukeo Baljachi* (Korea's Progress in Statistics) (Seoul: Office of Statistics, Republic of Korea, August 1995).

[a]Tentative figure.

Korea ranks eleventh among the world's top economic powers in terms of GNP and seventh in terms of manufacturing value-added.

Korea has also achieved phenomenal growth in its exports, which increased from a mere $40 million in 1963 to $96 billion in 1994. The share of manufactured goods in exports increased from 14.3 percent to more than 92 percent during the same period. As an exporter of manufactures, Korea moved from number 101 in the world in 1962 to number 13 in 1994. Thanks to a flourishing middle class, income distribution in Korea nears that of the Organization for Economic Cooperation and Development (OECD) countries.[3] Ezra Vogel concludes, "No nation has tried harder and come so far so quickly, from handicrafts to heavy industry, from poverty to prosperity, from inexperienced leaders to modern planners, managers, and engineers."[4] Some project that Korea could well become the first country to establish itself as an advanced industrial power since the emergence of Japan.[5]

1970	1975	1980	1985	1990	1994[a]
32.2	35.3	38.1	40.8	43.4	44.5
8.1	20.9	60.6	91.1	251.8	376.9
253	594	1,597	2,242	5,883	8,483
835.2	5,081.0	17,504.9	30,283.1	65,015.7	96,013.2
26.6	24.9	14.7	12.5	8.7	7.0
1.5	1.6	1.5	1.2	0.5	0.3
21.0	25.9	28.2	29.3	29.2	26.9
6.6	5.9	10.1	10.6	13.7	15.8
42.2	41.7	45.5	46.5	47.9	50.0
60.8	52.1	46.4	41.5	34.1	26.9
39.2	47.9	53.6	58.5	65.9	73.1

How have Korea and Korean firms managed to achieve such a phenomenal growth in industrialization in only three decades? What are major factors behind the growth? Most developing countries have tried to industrialize their economies. Yet the great majority of them have made little progress; only a few have managed to make a significant stride in catching up. Under what conditions, then, is catching-up possible? What are the implications for other catching-up countries? What are the implications for advanced countries? More specific questions related to the catching-up process are raised later in this chapter. This book is aimed at answering these questions by explaining Korea's rapid technological learning.

Technological change has been a major determinant of national economic development. In industrialized economies, many studies have shown that more than 50 percent of long-term economic growth stems from technological changes that improve productivity and lead to new products, processes, or industries.[6] For this reason, the question often raised is how science and technology, which appear to be the key to industrial development in advanced countries, can be effectively used for economic and social development in the less developed regions of the world.[7]

TECHNOLOGICAL CAPABILITY AND LEARNING

Korea's rapid industrialization may be attributed to many factors. The most important of all may be the technological change in its industries, which flowed from the accumulation of technological capability over time.[8] The term "technology" refers to both a collection of physical processes that transforms inputs into outputs and knowledge and skills that structure the activities involved in carrying out these transformations. That is, technology is the practical application of knowledge and skills to the establishment, operation, improvement, and expansion of facilities for such transformation and to the designing and improving of outputs therefrom.

The term "technological capability" refers to the ability to make effective use of technological knowledge in efforts to assimilate, use, adapt, and change existing technologies. It also enables one to create new technologies and to develop new products and processes in response to changing economic environment. It denotes operational command over knowledge. It is manifested not merely by the knowledge possessed, but, more important, by the uses to which that knowledge can be put and by the proficiency with which it is used in the activities of investment and production and in the creation of new knowledge. For this reason, the term "technological capability" is used interchangeably with the term "absorptive capacity": a capacity to absorb existing knowledge and in turn generate new knowledge.[9]

Technological capability has three elements: production, investment, including duplication and expansion, and innovation. "Production capability," defined in Table 1-2, refers to numerous technological capabilities required to operate and maintain production facilities. These may be divided into two broad subsets. The first subset includes those capabilities required to achieve efficient operation within the parameters of the original technology and the capability to repair and maintain existing physical capital according to a regular schedule or as needed. The second subset encompasses capabilities needed to adapt and improve the existing production technology, still within the origi-

Table 1-2 Elements of Technological Capabilities

Production Capability

Production management to oversee operation of established facilities

Production engineering to provide information required to optimize operation of established facilities, including raw material control, production scheduling, quality control, troubleshooting, and adaptations of processes and products to changing circumstances

Repair and maintenance of physical capital according to regular schedule and as needed

Investment Capability

Manpower training to impart skills and abilities of all kinds

Investment feasibility studies to identify possible projects and ascertain prospects for viability under alternative design concepts

Project execution to establish or expand facilities, including project management, project engineering (detailed studies, basic engineering, and detailed engineering), procurement, embodiment in physical capital, and start-up

Innovation Capability

Basic research to gain knowledge for its own sake

Applied research to obtain knowledge with specific commercial implications

Development to translate technical and scientific knowledge into concrete new products, processes, and services

SOURCE: Adapted from Larry E. Westphal, Linsu Kim, and Carl J. Dahlman, "Reflections on the Republic of Korea's Acquisition of Technological Capability," in Nathan Rosenberg and Claudio Frischtak, eds., *International Transfer of Technology: Concepts, Measures, and Comparisons* (New York: Praeger Press, 1985), 167–221.

nal design parameters, in response to changing circumstances and to increase productivity. Adaptation and improvement start almost simultaneously with the operation of technology.

"Investment capability" refers to abilities required for expanding capacity and establishing new production facilities. It includes investment feasibility analysis and project execution. The former involves ability to undertake the initial analysis of its profitability, detailed specifications of the project, and ability to ascertain prospects for viability under alternative design concepts. The latter involves abilities in project engineering—both basic and detailed engineering—project management that organizes and oversees the activities involved in project execution, procurement to choose, coordinate, and supervise hardware suppliers and construction contractors, embodiment in physical capital to accomplish site preparation and construction of plants, and start-up operations to attain predetermined norms of manufacturing facilities.

"Innovation capability" consists of abilities to create and carry new technological possibilities through to economic practice. The term covers a wide range of activities from capability to invent to capability to innovate and to capability to improve existing technology beyond the original design parameters. Invention and innovation are the product of both formal and informal activities. The term "innovation" is often associated by many with technological change at international frontiers. Most innovations in advanced countries generally denote a change of the frontier. Major technological innovations, however, are neither the only, nor perhaps the main, sources of productivity improvement in the history of industrial development in advanced countries. Minor changes to given technologies are a vital and continuous source of productivity gain in practically every industry in both advanced and catching-up countries.

The term "technological capability" is used here to indicate the level of organizational capability at a point in time, while the term "technological learning" is used to depict the dynamic process of acquiring technological capability. Thus, I use technological learning and the acquisition of technological capability interchangeably.

This book attempts to shed light on this dynamic process of technological learning in Korea from 1960 to 1995. To this end, it is necessary to understand Korea's economic and social conditions before 1960, which set the stage for the subsequent technological development.

INITIAL SETTING

Possessing one of the world's longest histories as an independent nation, Korea has a long tradition of its own civilization and scientific achievements. Korean astronomy, printing, and ceramics, though many originally based on technologies imported from China, were in some sense more advanced than their Chinese counterparts. The earliest Korean educational institution, *T'aehak* (Great Learning), which was modeled after similar Chinese institutions, was established in A.D. 372 to train prospective government officials, and it continued through succeeding kingdoms until the late nineteenth century. The adoption of Chinese government and educational institutions, though in highly modified form, stimulated the growth of Confucian scholarship among the upper classes. Koreans were good imitators of Chinese institutions.

Sang-Woon Jeon documented hundreds of nineteenth-century Korean scientific and technological achievements ranging from astronomy, meteorology, physics, physical technology, and chemical technology to geography.[10] To mention a few, Korea built the world's earliest known extant observatory in A.D. 647. Subsequently, Korea invented armillary clocks, automatic clepsydras, and sundials, leading to the development of a much more accurate calendar. Another well-known relic of seventh-century high scientific achievements is the artificial cave temple, *Sokkuram*, which required a high degree of mathematical and engineering knowledge. Korea also invented a movable metal type some 200 years before Johannes Gutenberg. Although many basic ideas came from China, attempts were always made to fit foreign inventions to local needs and conditions, leading to significantly important new inventions and discoveries. That is, Koreans also appear to have been good innovators.

Unlike the great majority of developing nations first formed by Western colonial powers, Korea had been a unified, independent state for more than 1,200 years since the Silla dynasty with its own splendid cultural heritage. But surrounded by big powers—China in the west, Mongolia and Russia in the north, and Japan in the east—Korea was frequently subject to foreign invasion. The most recent was by the Japanese, a thirty-six-year colonialization lasting from 1910 to 1945. Prior to that time, Koreans were far better civilized and their society was far better organized than their counterparts in other colonies.

Under Japanese colonial rule, the manufacturing sector averaged an annual growth rate of 9.7 percent between 1910 and 1941.[11] However, the Japanese accounted for 94 percent of the authorized capital of manufacturing establishments in Korea. Such key sectors as metals, chemicals, and electrical appliances were almost wholly owned by the Japanese. Korean firms were much smaller and financially and technologically weaker than those of the Japanese. According to one estimate, there were some 1,600 Korean technicians in the manufacturing sector, but this accounted for only 19 percent of all technicians in Korea. The proportion was much smaller (11 percent) in the key manufacturing sectors mentioned above.

It should also be noted that nearly 300,000 Koreans were experienced in mining and manufacturing when Korea gained independence in 1945.[12] This means that Koreans enjoyed greater participation in these sectors than indigenous populations in colonies under Western rule. This number, however, is small compared with the total population of 25 million, and most of these workers had menial jobs, which explains why imported foreign technology in the postwar years often took the form of turnkey plants.

From 1945 to 1953, unprecedented events significantly disrupted Korean economic development: (1) the political and economic vacuum and chaos caused by the Japanese withdrawal from the Korean Peninsula when Japan surrendered to the Allied forces in 1945; (2) the arbitrary division of the nation into North Korea and South Korea in 1945 and the consequent loss of mining, metal fabrication, and chemical manufacturing and power sectors to the North; and (3) destruction of industry and infrastructure in the 1950–1953 Korean War.

First, when the Japanese withdrew from Korea, much of the physical capital was un- or underutilized owing mainly to the lack of technical and managerial capability. For example, the number of manufacturing and construction establishments had fallen more than 50 percent by 1948; employment declined 41 percent.[13] The shipbuilding industry provides an interesting illustration of the lack of Korean technological capability in 1945. The Japanese left a steel shipyard with four small-steel ships under construction. It took several years for the Koreans to discover the blueprints for the ships, which had lain untouched for almost a decade. By the time the Koreans acquired enough experience to figure out what to do with the half-finished vessels, the ships were so rusted that they had to be scrapped. This is an example of the minimal skill formation achieved by Koreans involved in modern enterprises under Japanese domination.[14]

Second, the division of the nation resulted in disaster by splitting in two an economy that had been built as an integrated whole. South Korea retained nearly two-thirds of the population and agricultural output, but lost more than 90 percent of electric power and more than 75 percent of coal and iron ore production to North Korea. In manufacturing, South Korea had little industry aside from textiles; North Korea kept most of metal fabrication and chemicals. By 1948 the unexpected partition of the nation, together with the sudden evacuation of Japanese entrepreneurs, managers, and technicians, and the disruption of supplies of intermediate products and separation from their markets, had caused a radical drop in manufacturing output to about 15 percent of South Korea's 1939 level.[15]

Third, the Korean War was much more detrimental to the economy