TECHNOLOGY, LEARNING, AND INNOVATION

Experiences of Newly Industrializing Economies

Edited by

LINSU KIM

Korea University

RICHARD R. NELSON

Columbia University

CAMBRIDGE
UNIVERSITY PRESS

PUBLISHED BY THE PRESS SYNDICATE OF THE UNIVERSITY OF CAMBRIDGE
The Pitt Building, Trumpington Street, Cambridge, United Kingdom

CAMBRIDGE UNIVERSITY PRESS
The Edinburgh Building, Cambridge CB2 2RU, UK http://www.cup.cam.ac.uk
40 West 20th Street, New York, NY 10011-4211, USA http://www.cup.org
10 Stamford Road, Oakleigh, Melbourne 3166, Australia
Ruiz de Alarcón 13, 28014 Madrid, Spain

First published 2000

Printed in the United States of America

Typeface Times Roman 11/12.5 pt. *System* QuarkXPress [BTS]

A catalog record for this book is available from the British Library.

Library of Congress Cataloging in Publication data

Kim, Linsu.
Technology, learning and innovation : experiences of newly industrializing
economies / Linsu Kim, Richard R. Nelson.
p. cm.
Includes bibliographical references and index.
ISBN 0-521-77003-3 – ISBN 0-521-77987-1 (pbk.)
1. Technology and state – Developing countries. 2. Technological innovations –
Developing countries. I. Nelson, Richard R. II. Title.
T49.5 .K54 2000
338.9′27′091724 – dc21

99-040248
CIP

ISBN 0 521 77003 3 hardback
ISBN 0 521 77987 1 paperback

Contents

List of Contributors *page* vii

Preface ix

1 Introduction 1
Linsu Kim and Richard R. Nelson

PART I A BROAD PROSPECTIVE ON INNOVATION IN NEWLY INDUSTRIALIZING ECONOMIES

2 Technological Change and Industrialization in the Asian Newly Industrializing Economies: Achievements and Challenges 13
Sanjaya Lall

3 Research and Development in the Industrial Development Process 69
Howard Pack

Commentary 95
Bengt-Åke Lundvall

PART II HOW FIRMS LEARN

4 Firm Capabilities and Economic Development: Implications for the Newly Industrializing Economies 105
David J. Teece

5 East versus Southeast Asian Innovation Systems: Comparing OME- and TNC-led Growth in Electronics 129
Michael Hobday

6 Technological Learning and Entries of User Firms for Capital Goods in Korea 170
KongRae Lee
7 International Technological Collaboration: Implications for Newly Industrializing Economies 193
Geert Duysters and John Hagedoorn
Commentary 216
Martin Fransman

PART III INNOVATION POLICIES

8 Policies for Science, Technology, and Innovation in Asian Newly Industrializing Economies 229
Mark Dodgson
9 The Role of Science and Technology Policy in Korea's Industrial Development 269
Won-Young Lee
Commentary 291
Morris Teubal

PART IV THE END OF THE ROAD?

10 The Dynamics of Technological Learning during the Import-Substitution Period and Recent Structural Changes in the Industrial Sector of Argentina, Brazil, and Mexico 307
Jorge Katz
11 Korea's National Innovation System in Transition 335
Linsu Kim
Commentary 361
Howard Pack

Index 366

CHAPTER 1

Introduction

Linsu Kim
Richard R. Nelson

TECHNOLOGY AND INDUSTRIALIZATION IN NEWLY INDUSTRIALIZING ECONOMIES

From the beginnings of the modern discipline, economists writing about economic growth have recognized technological advance as its key driving force (Smith, 776; Marx, 1867; Schumpeter, 1911). In the 1950s and 1960s many studies tried to measure the contribution of technological change to economic growth in countries operating at the frontiers of technology (Solow, 1957; Denison, 1962). The conclusion was that technological advance accounted for the lion's share of growth in worker productivity. Since that time, a vast empirical and theoretical literature has grown up on technological progress in the advanced industrial nations.

More recently, a number of economists have turned their attention to the mechanisms of technological advance in the development of economies that, initially at least, have been far behind the frontiers. The acquisition and progressive mastering of technologies that are new to them, if not to the world, obviously has been a central aspect of the newly industrializing economies (NIEs) that have grown so rapidly over the past thirty years (Pack and Westphal, 1986; Kim, 1997).

Since the early 1960s, countries such as Korea, Taiwan, Singapore, and Hong Kong have transformed themselves from technologically backward and poor to relatively modern and affluent economies. Each now has a significant collection of industrial firms producing technologically complex products and competing effectively against firms based in industrially advanced countries. While Korea recently has been undergoing an economic crisis, due in large part to financial mismanagement, no one denies the strong technological capabilities that Korea has built up.

The key question is, how did the NIEs do it? And what are the lessons for policies in other developing countries?

Some economists argue that what lies behind rapid development in these countries is simply very high investment rates that enabled movements along a production function (Young, 1993; Kim and Lau, 1994; Krugman, 1994). They insist that the greater portion of increased output can be explained by increases in physical and human capital, which brought along modern technology as a more or less automatic by-product. Nelson and Pack (1999) call these arguments "accumulation theories." In contrast, other economists have placed learning about and learning to master new technologies as central in their analysis and focused on what was involved in this achievement. To be sure, acquiring and assimilating the technologies of advanced countries required high rates of investment in physical and human capital. But in addition, this demanded risk-taking entrepreneurship, effective learning, and innovation (Pack and Westphal, 1986; Amsden, 1989; Kim, 1997). Nelson and Pack (1999) call these arguments "assimilation theories."

Regardless of one's theoretical explanation of what has happened, the evidence that new capabilities have been acquired is dramatic. For instance, Korea's export increased from a mere $40 million in 1960 to $125 billion in 1995, with virtually all the increase represented by products that Korea did not know how to produce at the start of the era. In the mid-1960s, Korea began exporting textiles, apparel, toys, wigs, plywood, and other labor-intensive mature products. Ten years later, ships, steel, consumer electronics, and construction services from Korea challenged established suppliers from the industrially advanced countries. By the mid-1980s, computers, semiconductor memory chips, videocassette recorders, electronic switching systems, automobiles, industrial plants, and other technology-intensive products were added to Korea's list of major export items. Korea is now working on such next-generation products as multimedia electronics, high-density television, personal communication systems, and a new type of nuclear breeder. Vogel (1991) concludes that no nation has tried harder than Korea and come so far so quickly – from handicrafts to heavy industry, from poverty to prosperity, from inexperienced imitators to modern planners, managers, and engineers.

The authors of the chapters in this volume are all "assimilation theorists" concerning the phenomena in question. They regard as very misleading the proposition that the remarkable expansion of capabilities of these economies came about more or less automatically as a result of these nations' high rates of investment in physical and human capital. They believe that learning, entrepreneurship, and innovation that have occurred in these economies are extremely important in their own right, and that understanding "how they did it" is the key to perception of the policies needed to effect such transformations.

An important element of the viewpoint shared by the authors is an analysis of how the successful NIEs moved from imitation in the 1960s to innovation by the 1990s. We sketch out key elements of that common view below.

FROM IMITATION TO INNOVATION

The rapid industrialization going on in NIEs in the 1960s and 1970s stemmed largely from imitation – reverse engineering of existing foreign technologies. When relatively simple products are involved, as they were then, reverse engineering does not require specialized investment in research and development (R&D). Only a low level of learning occurs since the firm cannot and is not required to generate new knowledge. Nevertheless, even simple reverse engineering rarely occurs in a vacuum. Reverse engineering involved activities that sensed the potential needs in the market, activities that located knowledge or products that would meet the market needs, and activities that would infuse these two elements into a new project. Reverse engineering also involved purposive search for relevant information, effective interactions among technical members within a project team and with marketing and production departments within the firm, effective interactions with other organizations such as suppliers, customers, and – for more complex products and technologies – local R&D institutes and universities. Such activity required the willingness to take risks and to learn from experience. Considerable trial and error and try-again learning generally was involved in achieving a satisfactory result.

Imitation does not necessarily mean illegal counterfeits or clones of foreign goods; it can also be legal, involving neither

patent infringement nor pirating proprietary know-how. Mansfield (1984) shows that 60 percent of patented innovations were imitated legally within four years of their introduction. Imitation ranges from illegal duplicates of popular products to truly innovative new products that are merely inspired by a pioneering brand. Schnaar (1994) categorizes several distinct imitations: counterfeits or product pirates, knockoffs or clones, design copies, creative adaptations, technological leapfrogging, and adaptation to another industry.

Counterfeits and knockoffs are duplicative imitations, but one is illegal and the other is legal. Counterfeits are copies that sell under the same premium brand name as the original, often (but not always) of low quality, robbing the innovator of due profits. In contrast, knockoffs or clones are in most cases legal products on their own right, copying closely the pioneering products in the absence or expiration of patents, copyrights, and trademarks but selling with their own brand names at far lower prices. Clones often surpass the original in quality.

Duplicative imitation conveys no sustainable competitive advantage to the imitator in a technological sense, but it sustains competitive edge in price if the imitator's wage cost is significantly lower than the originator's. For this reason, duplicative imitation, if legal, is an astute strategy in the early industrialization of low-waged, catching-up countries, as the technology involved is generally mature and readily available and duplicative imitation of mature technology is relatively easy to undertake.

Duplicative imitation alone, however, is insufficient if a NIE is to achieve further industrialization. Both creative imitation and innovation are required not only to catch up in existing industries but also to challenge advanced countries in new industries. Design copies, creative adaptations, technological leapfrogging, and adaptation to another industry are creative imitations. Design copies mimic the style or design of the market leader but carry their own brand name and unique engineering specifications. Creative adaptations are innovative in the sense that they are inspired by existing products but differ from them. Technological leapfrogging can occur to a late entrant's advantage when the latecomer gains access to newer technology and uses it with a more accurate understanding of the growing market than was possessed by the original innovator. Adaptation to another industry illustrates the

application of innovations in one industry for use in another. Creative imitations aim at generating imitative products but with new performance features. They involve not only such activities as benchmarking but also notable learning through substantial investment in R&D activities to create imitative products, the performance of which may be significantly better or production cost considerably lower than the original. Bolton (1993) argues that Japanese strategy represents these features.

Innovation is defined as a pioneering activity, rooted primarily in a firm's internal competencies, to develop and introduce a new product to the market for the first time. The distinction between innovation and creative imitation is, however, blurred. Most innovations do not involve breakthrough inventions but are deeply rooted in existing ideas. On the other hand, as Nelson and Winter (1982) note, imitators working with an extremely sparse set of clues might claim the "innovator" title, since most of the problem is really solved independently.

Many skills and activities required in reverse engineering have easily been transformed into activities called R&D, as some NIEs approached the technological frontier. Skills and activities required in these processes are in fact the same as in the innovation process in R&D.

Several industries in these countries, such as semiconductors, electronics, and biotechnology, are stretching their R&D activities to transform themselves into effective creative imitators as well as innovators. The innovation drive of newly industrializing economies in selective industries in the 1990s is marked by intensified in-house R&D activities and participation in global alliances and reflects their aspiration to become members of the industrially advanced community. In other words, technology and innovation become watchwords in these countries for strengthening competitiveness in the preparation for the twenty-first century. This volume presents articles contributed by leading scholars in the field to discuss innovation and competitiveness in NIEs, particularly those in East Asia.

ORGANIZATION OF THE VOLUME

This volume has four parts, with two to four chapters in each. Each part is concluded by a short commentary on the chapters therein.

Part I provides a broad prospective in two chapters. In Chapter 2, using the experience of the Asian and other industrializing countries, Sanjaya Lall discusses how industrial technological capabilities differ at the national level and the role that policy plays in these differences. He not only offers ten important features of enterprise-level technology capability development but also illustrates how national technological capability can be built on the basis of microlevel capabilities. In Chapter 3, Howard Pack notes that only a small group of Asian countries have succeeded in industrialization even though many developing countries pursued similar strategies. He discusses this success as the outcome of several interrelated features. They include the successful countries' openness to and their ability and willingness to learn from foreign knowledge, their response to competitive pressure from the export market to increase their productivity, and the high productivity of foreign technology as its dissemination and successful use was enhanced by an educated domestic labor force. In conclusion, he notes that although the considerable turmoil experienced currently by some of the NIEs is likely to be a temporary problem, their longer-term difficulty lies in continuing to expand the modern sectors efficiently. At the end, Lundvall provides a short commentary on the two chapters, in which he also introduces his own thoughts on the topics.

Part II examines in four chapters the ways firms learn at the microeconomic level. In Chapter 4, David Teece presents a model of dynamic capability of a firm. He argues that firms are the domains in which economic development really takes place, and that the competence and capabilities of a firm rest fundamentally on organizational processes, market positions, and paths. He also concludes that competence can provide competitive advantage and generate profits only if it is based on a collection of routines, skills, and complementary assets that are difficult to imitate. The chapter provides implications for firms in newly industrializing economies. In Chapter 5, Mike Hobday compares similarities and differences in technological learning in electronics between the OEM (original equipment manufacture) system prevalent in East Asia and the system led by transnational corporations (TNCs) in Southeast Asia. He concludes that despite structural problems, both approaches contributed significantly to industrial innovation and national economic growth. He

also discusses future prospects and challenges for newly industrializing economies.

In Chapter 6, KongRae Lee analyzes how a passenger car producer in Korea as a user accumulated technological capabilities and became a major player in the industry. He examines in detail how the car producer accumulated reverse engineering capabilities through learning by operating the imported capital goods and imitating them, how it assimilated them through learning by designing, and how it became an independent designer through creative learning. He also discusses similar evidence in other industries. In Chapter 7, Geert Duysters and John Hagedoorn discuss different forms of international strategic technology alliances and why strategic alliances shift from traditional equity agreements to more flexible nonequity agreements. They also present empirical data on international strategic technology alliances within the Triad (namely Japan, the United States, and fifteen member countries in Europe), and between the Triad and NIEs. They conclude that Korean firms mostly account for the Triad-NIEs alliances, and that they are clustered in such high-technology industries as electronics, micro-information technologies, and bioengineering. Then Part II concludes with a commentary by Martin Fransman, who also provides his own thoughts on the topics.

Part III analyzes public policies for innovation in Asian NIEs. In Chapter 8, Mark Dodgson examines the relative strengths and weaknesses of science and technology in East Asian NIEs and analyzes the policies being pursued to assist the development of science, technology, and innovation. Despite broad differences in industrial structures, government-business relationships, and legal and financial systems among the emerging Asian nations, he concludes that infrastructure-building policies, such as creating network-oriented intermediary institutions, have a distinct impact on the development of technology diffusion and creation capabilities. In contrast, Won-Young Lee discusses in Chapter 9 the evolution of science and technology policy in Korea's industrial development in the past three decades. He postulates that technological development in Korea has undergone three stages: imitation, internalization, and generation. He then discusses the distinctive characteristics and efficacy of policies at each stage. He also examines the interaction between industrial policy and

science and technology policy. Then, Morris Teubal provides a commentary on the two chapters with his own thoughts.

Part IV concludes the volume with two chapters. In Chapter 10, Jorge Katz presents the Latin American experience of technological learning during the import substitution period and the effect of recent structural change on manufacturing. He concludes that economic growth in Latin American countries was by no means as impressive as it had been in the East Asian nations. But an increasing degree of technological sophistication as an outcome of the learning dynamics resulted in a rapid expansion of labor productivity and of manufacturing exports in Argentina, Brazil, and Mexico in the 1970s. Such progress could not, however, be sustained under the macro-economic and trade policies put in place during the 1980s. Rather, there has been a rise of relatively low-technology labor-intensive industries in the 1980s and 1990s and a large shift of industrial specialization toward raw material processing. In Chapter 11, Linsu Kim discusses how Korea's national innovation system, which functioned relatively effectively in the past, has become problematic in recent years. He diagnoses Korea's problem in such areas as government bureaucracy, industrial structure, quality in education, R&D infrastructure, financial institutions, corporate management, and deteriorating sociocultural factors. That is, the greatest strengths in Korea's national innovation system in the past have become its most serious liabilities in recent years. He also provides a prescription for its reengineering. Finally, Howard Pack provides a commentary on the two chapters with his own thoughts on the topics.

REFERENCES

Amsden, Alice, H. 1989. *Asia's Next Giant: South Korea and Late Industrialization.* New York: Oxford University Press.

Bolton, Michele K. 1993. "Imitation versus Innovation." *Organization Dynamics*, Winter, 30–45.

Denison, Edward F. 1962. *The Sources of Economic Growth in the United States and the Alternatives before Us.* New York: Committee for Economic Development.

Kim, J. I., and L. J., Lau. 1994. "The Sources of Economic Growth in the East Asian Newly Industrialized Countries." *Journal of Japanese and International Economics*, (18), 235–271.

Kim, Linsu. 1997. *Imitation to Innovation: The Dynamics of Korea's Technological Learning.* Boston: Harvard Business School Press.

Krugman, Paul. 1994. "The Myth of Asia's Miracle." *Foreign Affairs*, December, 62–78.

Mansfield, Edwin. 1984. "R&D and Innovation." In Zvi Griliches (ed.), *R&D, Patents, and Productivity.* Chicago: University of Chicago Press, 142–143.

Marx, Karl. 1867. *Capital.* New York: Modern Library, 1934; first published in 1867.

Nelson, Richard R., and Howard Pack. 1999. "The Asian Miracle and Modern Growth Theory." *The Economic Journal*, 109, 416–436.

Nelson, Richard R., and Sidney G. Winter. 1982. *The Evolutionary Theory of Economic Change.* Cambridge, MA: Belknap Press.

Pack, Howard, and Larry E. Westphal. 1986. "Industrial Strategy and Technological Change: Theory versus Reality." *Journal of Development Economics*, 22, 87–128.

Schnaar, Steven P. 1994. *Managing Imitation Strategy: How Later Entrants Seize Markets from Pioneers.* New York: Free Press.

Schumpeter, Joseph. 1911. *The Theory of Economic Development.* Cambridge, MA: Harvard University Press, 1968; first published in 1911.

Smith, Adam. 1776. *The Wealth of Nations.* New York: Modern Library, 1937; first published in 1776.

Solow, R. M. 1957. "Technical Change and the Aggregate Production Function." *Review of Economics and Statistics*, 39, 312–320.

Vogel, Ezra F. 1991. *The Four Little Dragons: The Spread of Industrialization in East Asia.* Cambridge, MA: Harvard University Press.

Young, Alwyn. 1993. "The Tyranny of Numbers: Confronting the Statistical Realities of the East Asian Growth Experience." *Quarterly Journal of Economics*, 110, 641–680.