Technology Transfer

Rejuvenating Matured Industries

Shastri Moonan

ROUTLEDGE

Garland Studies on Industrial Productivity

GARLAND STUDIES ON

INDUSTRIAL PRODUCTIVITY

edited by

STUART BRUCHEY
ALLAN NEVINS PROFESSOR EMERITUS
COLUMBIA UNIVERSITY

This page intentionally left blank

TECHNOLOGY TRANSFER

Rejuvenating Matured Industries

SHASTRI MOONAN

Routledge
Taylor & Francis Group
New York London

First published by Garland Publishing, Inc.

This edition published 2012 by Routledge:

Routledge
Taylor & Francis Group
711 Third Avenue
New York, NY 10017

Routledge
Taylor & Francis Group
2 Park Square, Milton Park
Abingdon, Oxon OX14 4RN

Library of Congress Cataloging-in-Publication Data

Moonan, Shastri, 1946–
Technology transfer : rejuvenating matured industries / Shastri Moonan.
p. cm. — (Garland studies on industrial productivity)
Includes bibliographical references and index.
ISBN 0-8153-2997-0 (alk. paper)
1. Steel industry and trade—Technological innovations. 2. Steel minimills—Technological innovations—Case studies. 3. Computer integrated manufacturing systems. 4. Technology transfer—Japan—Case studies. 5. Technology transfer—Developing countries—Case studies. I. Title. II. Series.
TS307.M66 1997
338.4'7672—dc21

97-38585

Table of Contents

List of Figures xi
List of Tables xiii

List of Maps xv

Foreword xvii

Preface xix

I INTRODUCTION 3
- Resurgence of the Steel Industry 3
- Steelmaking and Technology Transfer 4
- Steel-Making Technology and Strategy 5
- Technology Outlook for the Future 7

II AN OVERVIEW 11
- Central Technologies of Steel Minimills 12
- The Transfer of Steelmaking Technology 18
- Modern Steel Technology 31

III THE SCRAP MARKET 39

IV TECHNOLOGY TRANSFER—LITERATURE REVIEW 67
- The Market 67
- Technological Progress 71
- Models of Technology Transfer 76
- A Synthesis of the Three Approaches 78
- Toward a Dynamic Taxonomy of Technology Transfer 82
- Steel Minimill Technologies 87

V	A COMPARISON OF INTEGRATED STEEL MILLS WITH STEEL MINIMILLS	107
	Product Types	107
	Capacities of Mills	108
	Geographic Locations	109
	Raw Materials	111
	Technology	113
	Productivity	116
	Employment Costs	119
	Entry and Exit	120
	Technology Trends	122
VI	THE INTERNATIONAL TRANSFER OF TECHNOLOGY	129
	A Knowledge-Based Framework of Technology Transfer	129
	Knowledge Architecture	131
	Market Direction	144
	Inter Industry Technology Transfer	149
	The Technology Transfer Challenges	155
	Technology Transfer Opportunities to China	156
	The Technology Opportunities Generated in Europe and Latin America	157
	Conclusion	159
VII	JAPANESE CASE STUDY	165
	The Evolution and Unique Contribution of the Modern Japanese Steel Industry	165
	Steelmaking Locations in Japan	173
	Three Key Developmental Characteristics of the Japanese Steel Industry	181
	Lessons of Experience from Development of the Japanese Steel Industry	181

VIII THE DIRECTION OF TECHNOLOGY TRANSFER WITHIN THE STEEL INDUSTRIES IN NEWLY INDUSTRIALIZED AND DEVELOPING COUNTRIES 199
Different Economic and Technological Development Paradigms in NICs and LDCs 201
Options for Increasing Steel Capacity 207
Technological Prospects for NICs and LDCs 223
Conclusion 229

IX FUTURE RESEARCH 233
A Brief Review 233
A View to Future Studies 234
Stock and Flow Variables—an Interactive Model of Technology Transfer 237
The Pathfinding Nature of this Study 238

Glossary 241

Bibliography 247

Index 277

This page intentionally left blank

List of Figures

2.1	Production sequence for steel products	14
2.2	Minimill based on direct reduction	15
2.3	The EOF process	16
2.4	Conventional minimill	17
2.5	Scrap pathways within the world steel industry	32
3.1	Summary of United States scrap in 1990	41
3.2	United States—scrap	42
3.3	Possible trend in United States scrap resources	43
3.4	Summary of scrap in Japan in 1990	44
3.5	Summary of scrap in the 12-member EC in 1990	45
3.6	United States scrap resources	54
3.7	Scrap resources in the European Community	55
3.8	Scrap resources in Japan	56
3.9	World scrap resources	57
3.10	Flow diagram of scrap recycling in production, processing and usage of iron and steel	60
3.11	Schematic comparison of the iron-ore and scrap systems	62
3.12	Iron ore, scrap and primary metals in steelmaking	63
4.1	Schematic representation of causal relationships	69
4.2	Apparent steel consumption of crude steel	73
4.3	World steel exports of finished steel	73
4.4	Production shift toward developing countries	74
4.5	Interdependent variables in the technology transfer process	83
4.6	The interaction of the main elements in the technology transfer process through stock and flow variables	84

7.1	The Purdue Model	169
7.2	Layered software architecture typically used in the modern Japanese steel industry	171
7.3	Energy consumption per ton of crude steel in Japan	184
7.4	Capacity of degassing (RH and DH) facilities in Japan	186
7.5	Change of average sulfur content in NKK's line pipe	187
7.6	Plans for NKK's diversification into the engineering and construction fields	189
7.7	NKK's sales by division	190
8.1	Per capita steel consumption vs. GNP	206
8.2	Steel production in Latin America	208
8.3	Scrap purchased/steel produced	213
8.4	Latin American DRI production	215
8.5	Usual ladle metallurgy processes	218
8.6	Ladle treatments (model reactor)	219
8.7	The NSR System (NSC) for producing clean steel	220
8.8	Reduction of impurities through combination of process	221
8.9	Steel plant productivity in tons of steel ingot produced per man-year	228

List of Tables

1	Residual alloying elements in carbon steel and cast iron: the United States case	30
2	Scrap consumption in Latin American countries	46
3	Possible change in resources of the main types of scrap in the Arab world	47
4	Total theoretical possibilities for scrap recovery in the main Arab countries	48
5	World trade in scrap: main exporting and importing countries in 1990	49
6	Average use of scrap in oxygen converter in selected countries in 1990	53
7	World trends in production or consumption of steelmaking primary metals	59
8	A knowledge asset-based view of technology transfer	130
9	Potential growth of electric furnaces in Europe	141
10	New ironmaking processes in commercial production	153
11	New ironmaking processes under development	154

This page intentionally left blank

List of Maps

1	Geographical Distribution and Industrial Development in Japan	175
2	The Inland Sea Coastline	178
3	The Tokyo Bay Area	179
4	Osaka District	180

This page intentionally left blank

Foreword

For more than a decade I served as the Director of the Alfred P. Sloan Fellows Program, at the Massachusetts Institute of Technology, and have had the privilege of getting to know many outstanding participants. Most of the participants have come from the more developed regions of the world. Rarely has there been participation from the Caribbean. And rarely has there been a participant like Dr. Shastri Moonan of Trinidad and Tobago.

I interviewed Shastri Moonan for the Program in the Spring of 1988. I learned that he had studied law in the United Kingdom and had been admitted to practice as an attorney, and ascertained his success as a businessman and entrepreneur in his native country. I was interested in his motivation to attend the Sloan Fellows Program. He had two primary reasons: his intellectual curiosity in the field of management, and his desire to prepare himself for service to the development of his country.

The Sloan Fellows Program is now in its 66th year and has a very distinguished list of graduates including the current Secretary General of the United Nations, the CEO's of many Corporations, including the Boeing Company, Caterpillar Corporation, Bell South Corporation, and other leaders in government and industry from throughout the world.

Shastri Moonan was an outstanding participant in MIT's Sloan Fellows Program, and went on to complete his Ph.D. at the prestigious Fletcher School of Law and Diplomacy.

Dr. Moonan placed primary emphasis in the study of technology transfer, and his research has led to the publication of this important book.

The author has brought a new perspective for readers to gain a more incisive understanding of how the processes of technology transfer have taken place and continue to take place. Within the matrix of competition enmeshed with globalization, the book offers three levels of analysis within which technology transfer at the intra-firm level, inter-firm level, and inter-industry level are examined. This approach provides value to the field of technology transfer, since in capturing these dynamic processes the reader can understand and even anticipate with measurable accuracy the effects of policies to facilitate technology transfer.

Throughout his career, Shastri Moonan has been an entrepreneur with a purpose. A primary objective has been to develop business that will provide employment for those from depressed areas in his country. He has also pursued advanced education in the United Kingdom and the United States with an orientation to learning that he can use in public service. This book is an outgrowth of Dr. Moonan's pursuit to communicate a new perspective on the process of technology transfer.

Professor Alan F. White, Senior Associate Dean of the M.I.T. Sloan School of Management, Massachusetts Institute of Technology, Cambridge, Massachusetts

Preface

Matured industries face incredible and, at times, intractable problems. If they are to stay alive, they must rejuvenate, they have to compete against the accelerating rate of change. These changes are in organization: at the micro-cosmic level, within the corporations as well as the macro-cosmic level, at the level of the industry. At the same time, there is technological change where the emphasis is on the quality of the product. Time is now a far more valuable commodity—time to market and just-in-time inventory. The steel industry has to assert its presence in the global economy: steel has to be used for more intricate functions and their customers have higher expectations from the products they purchase, as such, quality has become the central theme. Faced with these complex issues, the steel industry had to look for and find solutions. In the steel minimill industry, re-engineering the process and the management became the "answer." The ensuing chapters attempted with piercing agony, yet with excitement, to examine these issues.

THE STRUCTURE OF THE BOOK

Chapter 3, "The Scrap Market," discusses the increasing demand for steel, and hence for scrap, around the world, and examines the structure of the scrap market, scrap being the critical raw material that supplies the electric arc furnaces (EAFs), the ladle refining furnaces, and the continuous casters utilized in the minimill industry world-wide. The various implications of the trend are examined, including the minimill industry's various process routes for utilizing scrap, growing pressure on the volume, reliability, and quality of the world scrap supply and how new technologies (for example, thin-slab continuous casting, oxygen blowing, scrap preheating, and coal injection) are permitting greater penetration of minimill products into integrated product markets. The utilization of various scrap alternatives is briefly discussed, and the chapter concludes with an examination of the shifting economics of steelmaking using the blast furnace and EAF route.

Chapter 4, "Technology Transfer: Literature Review," focuses on the central questions that are being probed in the book. (However, it will limit itself to the analytical constructs which facilitate technology transfer, specifically, central questions 1 through 3 mentioned in Chapter 2.) The chapter will consider the economic underpinnings of technology transfer for both producer and consumer. The role of international competition and the effect of international cooperation on both globalization and capture of market share will be examined, as will steelmakers' responses to different geographic and strategic challenges inherent in the world steel market. With these constructs in place, the chapter will also treat models of technology transfer, and will go on to develop a new synthesis of the existing technology transfer models.

The foundation of this new synthesis lies in an examination of steelmaking in terms of dependent variables and independent variables, or the stock and flow variables that were developed by process engineering theory. The independent variables critical to this examination of the steel industry are the availability and quality of scrap and scrap substitutes. The dependent variables can be grouped into two major categories: organization of the steel firm and the environmental (societal) milieu in which the steel firm operates (including economic, cultural, political, administrative/legal, and infrastructure *issues*).

The chapter develops a dynamic taxonomy of technology transfer, examining the dependent and independent variables in the light of transfer risks, capital requirements, and market expansion and costs reduction. The chapter then concludes with an examination of steel minimill technologies and products in the light of this model of technology transfer.

Chapter 5, "A Comparison of Integrated Steel Mills and Steel Minimills," compares integrated steel mill and minimill technologies, and examines in detail the causative factors behind the technological migration from integrated steel mills to minimills. The chapter will examine such aspects of technological difference as product types, mill capacities, location criteria, use of raw materials, technologies in use, productivity figures and mill efficiencies, varying employment costs, entry and exit into the market, and technologies under development.

Chapter 6, "The International Transfer of Technology," examines how the three minimill technologies (the electric arc furnace, ladle technology, and continuous casting) are being constantly improved by developments in R&D (an intervening variable) and how the developments are being absorbed and assimilated into steelmaking technologies to improve steel minimill efficiency. I shall propose that these developments are inducing structural changes in the iron and steel industry with respect to the following:

1. The size of production facilities is becoming smaller while the efficiencies they achieve are becoming proportionally higher.
2. The market is trending toward achieving lower costs and economies of scale.
3. Firms around the world are rationalizing, relationships between management and labor are shifting, and relationships between manufacturers are often shifting along the competition-cooperation continuum.

The chapter concludes with a discussion of the effects of technology transfer on various regions around the world.

Chapter 7, "The Japanese Case Study," examines, within the context of a case study on the evolution of the Japanese steel industry, how technology transfer can be used to further the development of a national economy in particular and, by extension, the steel industry in general. The literature on technology transfer will now be examined with a market orientation. The following two general questions will be probed and answers offered:

1. How is the competition in this market organized?
2. What are the driving forces in the market?

The attitude toward the use of imported technologies, the *role* of geography, and the steel industry's relationships with other domestic industries will be examined, and six developmental measures of the evolution and performance of the Japanese steel industry will be thoroughly probed: the domestic market, the role of modernization, emphasis on particular product lines, market opportunities and business diversification, workforce loyalty, and governmental support, including the nature of domestic politics and financing arrangements. Further, the central questions set out in Chapter 2 will be examined against the structure of the Japanese steel industry. This examination should demonstrate how Japan has structured its steel industry to continually increase productivity while decreasing cost and price.

Chapter 8, "The Direction of Technology Transfer Within the Steel Industries in Newly Industrialized and Developing Countries," examines the special challenges the newly industrialized and developing countries have faced in developing their steel industries, stating whether the structure of technology transfer is changing and whether the new patterns which may be emerging are doing so within the context of globalization. Intuitively, I feel that the flexibility of the process of technology transfer will be a driving force behind the capture of market share. However, my approach will be scientific and will determine my findings.

Chapter 9, "Future Research," comments on the findings to the answers to the central questions I posed in the second chapter. My comments and suggestions for future R&D by the steel industry as well as for future research on the directions and trends taking place within the steel industry will address to issues:

1. The future direction of the system of industrial organization as it affects technology transfer and competitiveness in the steel minimill industry.

2. The future direction of the steel minimill industry with respect to the usage of scrap and scrap substitutes, operational processes, and development of the new product lines.

The technology transfer process is undergoing rapid change in the steel minimill industry. Corporations with the proprietary knowledge are collaborating with steel manufacturers to produce high quality products at affordable prices. The objective of the technology transfer process is to increase productivity and at the same time reduce costs per unit. Extensive publications over the years attempted to explain how the technology transfer process works. Essentially, this was done by isolating the variables with respect to organizational and societal structure as it impacted with the transfer mechanisms.

Part of the contribution to knowledge is the focus on the limitations of the transfer process dictated by the policies and needs of the host country. Also examined is the question: what are the levels of interaction with the possibilities for accessing capital and achieving market expansion and increased production? These are crucial issues which underline the need for an interactive model of technology transfer based on stock and flow variables.

This page intentionally left blank

Technology Transfer

This page intentionally left blank

I

Introduction

RESURGENCE OF THE STEEL INDUSTRY

Over the past twenty-five years there have been many changes in the technology of steelmaking, so that mills today are in many instances radically different from those of the 1970's. The 1970's is the beginning of the period of the refocusing of the steel minimill industry. By refocusing, expected and unexpected changes ensued. This book will demonstrate how every facet and every phase of ironmaking and steelmaking were revolutionized: from the preparation of raw materials to the delivery of finished products.

In the next twenty-five years there would still be two dominant types of mills that constitute the steel industry: the integrated mill and the minimill. I have devoted a chapter of this book and discussed the differences between the two types. Suffice it to say at this stage, that an integrated mill is large and based fundamentally on the blast furnace for the production of its metal, it is expected to undergo substantial changes. In contrast, we can expect incremental improvements in minimills. The minimills would continue to depend upon the scrap material for their metal. The sizing of the minimill is expected to remain the same with a capacity range from 500,000 to 1,000,000 tons annually. The focus of the minimill for its production capacity is now undergoing changes. Originally producing long products, a number of them have now turned to the production of flat-rolled steel. Most of the present minimills built in the recent past, those undergoing construction or being planned are designed to produce sheets rather than long products. For example, in the United States of America the total capacity of minimills to produce sheets is currently in the area of 7 to 8 million tons, and another 5 million tons of capacity is expected to produce flat-rolled products.

Integrated mills poles of growth shall be found mainly in developing countries. An example of this is in Taiwan by the Yien Loong Group. This integrated mill will be commissioned in the year 2002. It will be made up of three blast furnaces capable of producing 7.5 million tons of steel. In another example, an Australian Group is building a greenfield plant capable of producing 1.5 million tons of slabs for export. The steel for the slabs will be made in an electric furnace from direct reduced iron, so avoiding the limitation from the use of scrap.

STEELMAKING AND TECHNOLOGY TRANSFER

Technology transfer was the consequence in the steelmaking processes and the demand for steelmaking in near market conditions. In the 1950s, the open-hearth furnace produced ninety percent of the steel made in the established steelmaking countries in the world: the United States of America, the United Kingdom and Germany. In the late 1950s the basic-oxygen process (BOF) was introduced, and twenty years later it was the best available technology. In the 1970s the electric arc furnace (EAF) was introduced for minimills. Today, just over sixty percent (60%) of the world steel production employs the basic-oxygen process and about thirty percent (30%) use the electric-arc furnace; the remaining just under ten percent (10%) use the open-hearth process.

It is expected that the BOF and the EAF will remain the two main processes in operation for many years to come. The sizing of mills in the future will be to produce from 300,000 tons to 1,000,000 tons. The EAF will be considered to be the most appropriate technology because of the near-market conditions, and the environmental sensitivity.

Steel made by the EAF melts steel scrap and is dependent on scrap for its metal, which in most cases has tramp alloys, some of which remain in the finished steel. These alloys ordinarily operate as a constraint for some applications. However, with a supplemental charge of direct-reduced iron (DRI), iron carbide (IC) or pig iron (PI), these enhance the quality of steel, enabling it to be available for almost all applications.

STEEL-MAKING TECHNOLOGY AND STRATEGY

1. *The Electric Arc Furnace*

The Electric Arc Furnace (EAF) technology continues to evolve, with additional units being equipped for direct, rather than alternating current, and with the growing acceptance of such features as eccentric bottom tapping, water-cooled roofs and sidewall panels, oxygen injection, off-gas preheating, off-gas preheating of the furnace charge, and various charging systems.

The reasons for the anticipated increase in the electric arc furnace's share of steelmaking include the availability of electrical energy in industrialized countries; demand for steel in developing ones; low investment costs for EAF steelmaking compared with those for integrated mills; developments in EAF technology for better furnace performance, process control, product quality and costs; more use of scrap substitutes and hot metal in EAF steelmaking; and improvements in secondary metallurgical technologies, with higher output and quality.

Both the BOF and the electric furnace use ladle furnaces in the production of steel. This is a supplemental facility and, as such, refines the steel from the BOF and the scrap-melted steel form the electric furnace and increases the capacity of both the BOFs and the electric furnaces since it performs part of the function of steelmaking The BOF charge as it is poured into the ladle furnace has from 2.5 percent to 4.5 percent carbon. This is reduced in the ladle furnace to approximately 0.4 percent.

The furnace operates through electric power and the number of electrodes varies from one to three. The electric furnace is used to melt scrap, and the refining into acceptable steel is done for the most part in the ladle furnace. Thus, since less activity is performed in the BOF and electric furnace, the capacity of the units is increased. The amount of this increase depends on the size of the furnace as well as the amount of refining done in the ladle furnace. The addition of this facility to the steelmaking process is relatively recent. However, it has become widespread in the past few years and may well reach universal proportions in the next century.

The open hearth, which dominated steel production for so many decades, will probably disappear as a process on a world-wide basis early in the twenty-first century, leaving the field to the BOF and electric furnace. There will be modifications in these two processes. As indicated, the electric furnace will be charged with supplemental iron as well as scrap and the BOF will probably be charged with additional scrap.

2. *Continuous Casting*

Continuous casting as an integral part of steel operations is a development of the last third of the twentieth century. Its acceptance has been rapid, so much so that many of the countries producing steel continuously cast more than 90 percent of their production. This is particularly true throughout the industrialized countries such as Japan and the USA and Western Europe. Some of the developing countries have been slower to adopt the process. Examples are China and India. However, in the past few years there has been a decided movement in these countries to increase the proportion of steel that is continuously cast. As the new century dawns, virtually every steel-producing country in the world will have 90 percent of its steel continuously cast.

A number of improvements have been made in this process with the aim of bringing the cast shape closer to that of the finished product. One of the significant advances has been made in producing thin slabs of two inches or less in thickness for sheet production. This requires much less reduction in the hot strip mill compared with the traditional slab of 8 inches to 10 inches thick, which constitutes most of the production from conventional continuous casters. The strip mill required to reduce the thin slab has a maximum of four to five stands, while that required for the 8 inch to 10 inch slabs uses 10 stands and represents a considerably higher investment.

The thin slab has been a great advantage for the minimill, since it operates with an electric furnace and a reduced-size strip mill. Thus the investment in an electric furnace plant with a thin slab caster and a shortened strip mill is far less than in the conventional integrated mill producing sheets with the 10-stand hot strip mill and a thick slab caster.

Unfortunately, at present the electric furnace cannot produce steel that is suitable for all applications. Consequently, sheets produced from the minimill are limited in use. However, as already indicated, there will be an improvement in electric furnace steel through the addition of supplemental iron units, and this, in conjunction with the thin slab caster and the truncated strip mill, will present a cost advantage.

Most of the sheets produced at present are from thick slabs rolled on conventional hot strip mills. However, it is possible that the integrated mills will install, in addition to their conventional slab casters and hot strip mills, thin slab casters along with electric furnaces and shortened hot strip mills. At present Pohang Iron and Steel Corporation in South Korea is installing such equipment at its Kwangyang plant. When the economics of this equipment are recognized, there will be an incentive for other integrated steel companies to follow suit and supplement their current production facilities by employing a thin slab caster.

Another development in continuous casting is the casting of near-net shapes for structural steel. This yields a product that requires far less work in the rolling mills and so reduces cost.

TECHNOLOGY OUTLOOK FOR THE FUTURE

Artificial neural networks were first developed as models of the biological neural networks. However, it was later realized that one kind of neural network, multilayer perceptrons, was useful as a function approximation technique. Multilayer perceptrons feed-forward neural networks can now be looked on as tools of non-linear multivariate data analysis, although they can perform several other tasks. There are various other kinds of neural network that have different sorts of application. Artificial neural networks consist of a number of neurons or nodes, which are simple computational elements directionally connected to other nodes in the network. The neurons collect a weighted sum of signals coming from the links to that neuron, and compute the output through an activation function, typically the logistic sigmoid.

The primary aim of alloy design is to ensure the required properties once the steel is in the direct forged component. This should be done so that the cost is minimized without risk of producing components that do not fulfil the required properties, and is best achieved by a mathematical model that can predict tensile and yield strengths from the chemical composition as well as the forging parameters.

Work is aimed at developing a neural-network-based system for supporting alloy design as well as to help in calculations of alloying additions during steelmaking. It also aids in controlling the required quality variables like mechanical properties after hardening. The system was developed for one low-carbon, hardenable steel grade. To achieve this, it was desirable to have a model that could reliably predict the mechanical properties of steel like the yield strength after hardening, which are the most important quality variables. Other quality variables like elongation at fracture, impact strength and hardness will be within the acceptable limits if the two more important variables are within specifications for the grade of steel considered. The quality variables depend on several factors. The most important of them are the chemical composition and austenitising temperatures, in addition to the dimensions of the component. The strength variables have a non-linear dependence on some concentrations as well as on temperature. Carbon content, for instance, has an almost parabolic effect on tensile strength. Boron has a complicated effect on hardenability, and the effect also depends on the concentration of other elements present in the steel.

Neural networks have been used for solving a variety of problems in steel industries. Among such problems, quality