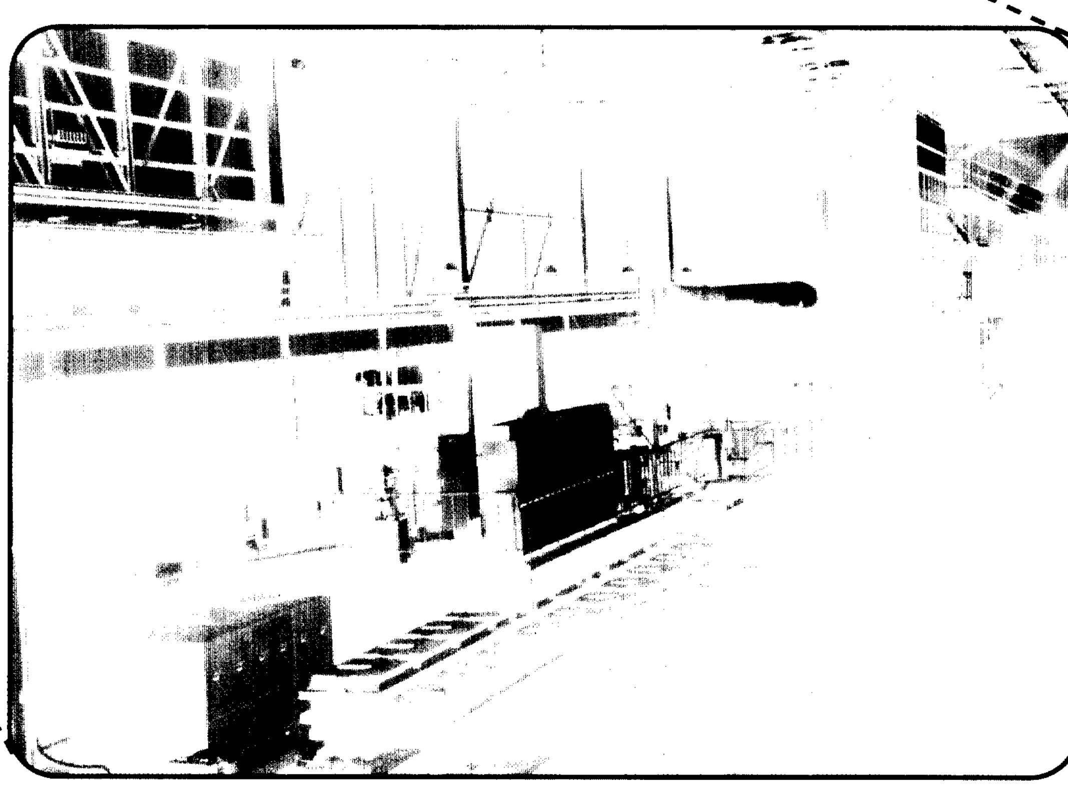
WORLD BANK TECHNICAL PAPER NO. 384
Finance, Private Sector, and Infrastructure Network

Work in progress
for public discussion

WTP384
Nov. 1997

Catching Up to Leadership

The Role of Technology-Support Institutions in Japan's Casting Sector



Sakura Kojima
Yoshitaka Okada

RECENT WORLD BANK TECHNICAL PAPERS

No. 310 Elder and Cooley, editors, *Sustainable Settlement and Development of the Onchocerciasis Control Programme Area: Proceedings of a Ministerial Meeting*

No. 311 Webster, Riopelle and Chidzero, *World Bank Lending for Small Enterprises 1989-1993*

No. 312 Benoit, *Project Finance at the World Bank: An Overview of Policies and Instruments*

No. 313 Kapur, *Airport Infrastructure: The Emerging Role of the Private Sector*

No. 314 Valdés and Schaeffer in collaboration with Ramos, *Surveillance of Agricultural Price and Trade Policies: A Handbook for Ecuador*

No. 316 Schware and Kimberley, *Information Technology and National Trade Facilitation: Making the Most of Global Trade*

No. 317 Schware and Kimberley, *Information Technology and National Trade Facilitation: Guide to Best Practice*

No. 318 Taylor, Boukambou, Dahniya, Ouayogode, Ayling, Abdi Noor, and Toure, *Strengthening National Agricultural Research Systems in the Humid and Sub-humid Zones of West and Central Africa: A Framework for Action*

No. 320 Srivastava, Lambert, and Vietmeyer, *Medicinal Plants: An Expanding Role in Development*

No. 321 Srivastava, Smith, and Forno, *Biodiversity and Agriculture: Implications for Conservation and Development*

No. 322 Peters, *The Ecology and Management of Non-Timber Forest Resources*

No. 323 Pannier, editor, *Corporate Governance of Public Enterprises in Transitional Economies*

No. 324 Cabraal, Cosgrove-Davies, and Schaeffer, *Best Practices for Photovoltaic Household Electrification Programs*

No. 325 Bacon, Besant-Jones, and Heidarian, *Estimating Construction Costs and Schedules: Experience with Power Generation Projects in Developing Countries*

No. 326 Colletta, Balachander, and Liang, *The Condition of Young Children in Sub-Saharan Africa: The Convergence of Health, Nutrition, and Early Education*

No. 327 Valdés and Schaeffer in collaboration with Martín, *Surveillance of Agricultural Price and Trade Policies: A Handbook for Paraguay*

No. 328 De Geyndt, *Social Development and Absolute Poverty in Asia and Latin America*

No. 329 Mohan, editor, *Bibliography of Publications: Technical Department, Africa Region, July 1987 to April 1996*

No. 330 Echeverría, Trigo, and Byerlee, *Institutional Change and Effective Financing of Agricultural Research in Latin America*

No. 331 Sharma, Damhaug, Gilgan-Hunt, Grey, Okaru, and Rothberg, *African Water Resources: Challenges and Opportunities for Sustainable Development*

No. 332 Pohl, Djankov, and Anderson, *Restructuring Large Industrial Firms in Central and Eastern Europe: An Empirical Analysis*

No. 333 Jha, Ranson, and Bobadilla, *Measuring the Burden of Disease and the Cost-Effectiveness of Health Interventions: A Case Study in Guinea*

No. 334 Mosse and Sontheimer, *Performance Monitoring Indicators Handbook*

No. 335 Kirmani and Le Moigne, *Fostering Riparian Cooperation in International River Basins: The World Bank at Its Best in Development Diplomacy*

No. 336 Francis, with Akinwumi, Ngwu, Nkom, Odihi, Olomajeye, Okunmadewa, and Shehu, *State, Community, and Local Development in Nigeria*

No. 337 Kerf and Smith, *Privatizing Africa's Infrastructure: Promise and Change*

No. 338 Young, *Measuring Economic Benefits for Water Investments and Policies*

No. 339 Andrews and Rashid, *The Financing of Pension Systems in Central and Eastern Europe: An Overview of Major Trends and Their Determinants, 1990-1993*

No. 340 Rutkowski, *Changes in the Wage Structure during Economic Transition in Central and Eastern Europe*

No. 341 Goldstein, Preker, Adeyi, and Chellaraj, *Trends in Health Status, Services, and Finance: The Transition in Central and Eastern Europe, Volume I*

No. 342 Webster and Fidler, editors, *Le secteur informel et les institutions de microfinancement en Afrique de l'Ouest*

No. 343 Kottelat and Whitten, *Freshwater Biodiversity in Asia, with Special Reference to Fish*

No. 344 Klugman and Schieber with Heleniak and Hon, *A Survey of Health Reform in Central Asia*

(List continues on the inside back cover)

WORLD BANK TECHNICAL PAPER NO. 384
Finance, Private Sector, and Infrastructure Network

Catching Up to Leadership

The Role of Technology-Support Institutions in Japan's Casting Sector

Sakura Kojima
Yoshitaka Okada

The World Bank
Washington, D.C.

First printing November 1997

Cover photos: "Melting," traditional foundry factory in 1850s, provided by Chuo Malleable Iron Co., Ltd. "Casting line for auto parts," recent foundry factory, provided by Automobile Foundry Co., Ltd.

ISSN: 0253-7494

Sakura Kojima is a lecturer in the Department of Liberal Arts at Tokai University. Yoshitaka Okada is a professor in the Department of Comparative Culture at Sophia University.

Library of Congress Cataloging-in-Publication Data

Kojima, Sakura.
Catching up to leadership : the role of technology-support institutions in Japan's casting sector / Sakura Kojima, Yoshitaka Okada.
p. cm. — (World Bank technical paper ; no. 384)
Includes bibliographical references.
ISBN 0-8213-4054-9
1. Founding—Technological innovations—Japan. I. Okada, Yoshitaka, 1949- . II. Title. III. Series.
TS229.5.J3K65 1997
338.4'76712'0952—dc21 97-30561
CIP

Contents

List of Tables and Figures

Tables

Figures

Foreword

Successful industrialization depends critically on technological development. Continuous improvements in technology enable firms, industries, and national economies to enhance productivity and build competitiveness in new areas. Advances in the economic theory of innovation, together with accumulated experience of policy makers and practitioners, have shed light on the process of industrial technology development (ITD) and the potential role of supporting policies and institutions. Traditional linear theories of innovation, including both "science-push" and "demand-pull" models, have been replaced by an understanding of a more deliberate process of progressive accumulation of technological capabilities by firms and industries. Government's ability to drive ITD through "public goods" investments in basic scientific research is now seen as limited, and important efforts to reform isolated and ineffective public research establishments have recently been mounted, particularly in developing countries. It is also recognized that industrial firms must go beyond "learning by doing" to invest in acquiring technological knowledge and mastery, drawing on stocks of technologies from abroad and from external sources in their own countries. Beyond their individual efforts in technological learning, moreover, firms are stimulated and supported in important ways by the environment in which they operate. This environment includes the policies and economic institutions which both shape firms' incentives to invest in technological learning, and provide complementary assets — technical skills, information, technical and financial support — which make such investments more productive.

Deriving lessons for policy making in developing countries remains a challenge. What are effective technology policies? What sorts of technology supporting institutions (TSIs) are appropriate, and what roles can they play? Empirical study has generally lagged behind the new conceptual understanding of ITD. Although there have been a number of firm-, industry-, and country-level case-studies, there has been a lack of comparative analysis taking account of variation across sectors with different core technologies, industrial structures, and public institutions. In view of this gap, the Asia Technical Department designed and led a multi-country, multi-sector study titled "Institutional and Policy Priorities for Industrial Technology Development". The project assembled research teams in seven economies — China, India, Japan, Korea, Taiwan (China), Mexico, and Hungary — to study how firms in six industrial sectors have expanded their technological know-how, obtained support from external institutional, market, and policy-induced sources, and interacted with TSIs. The study involved both historical research drawing on secondary sources and the administration of surveys (through interviews and by mail) of firms and TSIs using the same questionnaires in each location. Its results provide a rich base of quantitative and contextual information, both empirically detailed and broadly comparative, on the policy and institutional aspects of ITD. Financial support for this effort came from Japanese Government trust fund, Canada's International Development Research Centre (IDRC), Taiwan(China's) IECDF and the World Bank itself.

The following report, "Technology Support Institutions and Japan's Casting Sector" by Sakura Kojima and Yoshitaka Okada, offers an excellent example of the study's results. It illustrates how Japan used technology policy and institutions to improve industrial capabilities and eventually become a world leader in castings, which has been critical to the related success of Japan's machinery and automotive industries. The study suggests that even in a technologically mature sector, such as casting and foundry, a variety of private and public institutions were important in technology diffusion. Professors Kojima and Okada highlight the complementary relationship between private institutions, including business groups and associations, and public TSIs, which have changed over time and have served different firm populations in distinct ways. The report provides examples of successful interaction between firms and TSIs, offering important lessons for policy making aimed at catching-up technologically and moving forward in mature industries.

Carl Dahlman
Director, World Development Report
The World Bank

Abstract—Japan's Casting Sector

Japan's casting and foundry sector has been integral to the developmental success of a range of machine-based industries. Although casting technology is mature -- widely commercially available and with limited scale economies -- institutional and policy support was vital to the Japanese casting industry's rapid gains in quality and productivity. Rapid import and mastery of technological know-how in the early post-war era was essential for the upgrading of the sector. Government encouragement, along with controls on foreign exchange and technology licensing, led private industry to cooperate through business associations in licensing and absorbing major advances in casting technology, thereby making the technology transfer process rapid, efficient and inexpensive.

The presence of a wide variety of institutions has enabled different types of firms to obtain external technical support. In particular, support for small and medium-scale foundries was critical to the rapid diffusion of improved techniques, including quality control, throughout the industry. Even today, casting firms demand diffusion-related services such as information, training, and trouble-shooting, much more than R&D. Support to small firms came through private "institutions", including business networks known as *keiretsu* and industry cooperatives, as well as an elaborate system of public institutes at the local and regional level, particularly in areas with traditional clusters of casting firms. Small *keiretsu*-affiliated firms used technology-support institutions (TSIs) to help them achieve the high quality standards demanded by customers. Larger independent producers relied more heavily on public TSIs to compensate for their lack of access to *keiretsu* networks' technical information and resources.

The role of formal TSIs has changed as industry has developed its capabilities. The early role of industry associations in coordinating technology transfer and absorption diminished with time. Public TSIs at the national and regional level have faced the need to shift their activities towards research to stay ahead of their technologically sophisticated clients, the most advanced of whom had become world leaders in the casting industry's core techniques.

Acknowledgements

This paper is part of the Japanese Project including seven cases of industries. It is one of the seven-country comparative studies of the World Bank's project on "Policy and Institutional Priorities for Industrial Technology Development," organized and led by Mr. Melvin Goldman, a senior World Bank technology development economist.

The Japanese team, consisting of nine members, including myself, was organized under the guidance of Professor Yoshitaka Okada, Sophia University, a distinguished scholar, to systemize our case studies. I found the discussions in our group proved both informative and exciting. Mr. Fumio Nishikawa, the former Chairman, Toray Research Center, an advisor to the International Project-Team, provided much kind help and introduced me to Mr. Tsuneo Horie, President, Taihei Kinzoku Kogyo Co. Ltd., who gave me valuable advice. I was invited to join the project by Professor Ichiro Inukai, International University of Japan, an advisor to the Japanese team.

I am also deeply grateful to the representatives of the eighteen firms and ten technology-support institutions for their extensive cooperation in interviews and detailed answers to my many questions, and to fifty firms which kindly replied to my mailed questionnaire.

Special thanks go to the following people: Masatada Kawabata, Director of the Mie Prefectural Metal Research Institute; Yasuhiko Kondo Ph.D., Director of the Government Industrial Research Institute, Nagoya; Isamu Taki, President of Tokyo International Foundry Engineering Consultant Company; Gohzo Namekawa, manager of the Materials Process Technology Center; Noboru Hatano, Director of the Technical Department, Japanese Association of Casting Technology; Noboru Yamanaka, Manager, Casting Section, Saitama Prefectural Casting and Machinery Research Institute; Tadashi Yoshiwara, a consultant to the Saitama Prefectural Research Institute. Thanks also to June Streitmun-Setoguchi for editing this manuscript. Messrs Bennet Minton and Greg Felker's editorial assistance is also appreciated.

Any responsibility for the content of this paper, however, is entirely mine.

Sakura Kojima

Executive Summary

Japan's high quality, highly productive casting sector has been key to its powerful competitiveness in a range of machine-based industries. Only forty years ago, the sector was technologically far behind the leading industrialized countries. A crucial part of the industry's drive for technological proficiency was the role of technology-supporting institutions (TSIs) and government policies. By encouraging cooperation within industry and establishing TSIs to address a variety of needs, Japan was able to acquire technological capability rapidly and cost-effectively. The TSIs include national research institutes, prefectural research institutes (PRIs), industry associations, inter-company networks, industrial cooperatives, consulting firms and universities. They have evolved along with the industry, though for most of the post-war period, institutions and policies focused on diffusing improved casting techniques and materials. Imported technology contributed greatly to industrial performance in the 1950s and 1960s, and TSIs helped exploit it.

The casting sector supplies semifinished goods to machine industries, and its precision and quality determines that of a spectrum of final products. The industry is composed mainly of small and medium-size subcontractors having fewer than 300 employees. Institutional support for small and independent producers, particularly from PRIs, has been especially important. Collaboration occurs in many ways, such as *keiretsu* and subcontracting. Inter-company links complement formal TSIs. Business associations and cooperatives have helped diffuse technology and provided technical support and information services. Government policies and incentives have both encouraged and relied on private sector cooperation.

TSIs' effectiveness depends on their own dynamism and their client firms' investments in technology. Because of competition, small and medium-size suppliers must be technology-oriented. *Keiretsu* relationships, for example, are not necessarily fixed, and *keiretsu* subcontractors can fall out of the group if their R&D efforts wane. Public TSIs complement small firms' *keiretsu* linkages. Larger independent casting firms seek public TSI support to keep abreast of their *keiretsu*-affiliated competition and to compensate for their lack of access to the large industrial groups' laboratories and other technological resources.

TSIs, long focused on disseminating imported technology and improving production techniques, now face changes that require innovation and more basic R&D. Dynamic TSIs are seeking new support roles and greater expertise. Some of their support functions, such as problem-solving and laboratory services, have declined in importance, while information services and R&D, have assumed increased importance. TSIs thus must reorganize to meet changing times: R&D-oriented TSIs have to strengthen their know-how and strategic research, while non-R&D-oriented TSIs, such as industry associations, need to focus on information analysis and distribution.

Introduction

Historical Background

Many scholars hold that Japan's machine industries became the world's strongest competitors because they are built on small- and medium-sized suppliers and semifinished-goods subcontractors with high technological capability, especially in production control know-how. The casting, forging, metal stamping, and powder metallurgy industries are important suppliers to a range of machine industries.[1] The quality of their parts strongly affects the quality of final products. Most casting firms classified as subcontractors are small- to medium-sized in terms of capital and employees.

After World War II, Japan lagged far behind the west technologically and did not compete internationally. But with imported technology, Japan gradually closed the gap and entered an era of long-term, high-speed economic growth. Japan is often cited as a "Gerschenkron model", that is, a latecomer enjoying the accumulation of innovations developed in advanced countries.[2] Technological progress based on imported technology, coupled with high levels of savings and investment, explains much of her rapid industrial growth.[3] The casting industry was no exception to this pattern. Major innovations were imported, mainly during the 1950s and through the 1960s, and introduced by larger firms who then improved, adapted, applied and disseminated them to small and medium firms.

As often noted, Japanese industry is characterized by intercompany links based on a socially defined division of labor. The subcontracting system originated in military industries and the inter-firm *keiretsu*[4] structure peculiar to Japanese corporations developed along with high postwar economic growth. Larger firms had an incentive—cost reduction—to contract out work. In-house parts production is very low compared to that in the United States, for example. The myriad smaller firms seeking subcontracted work, and their very low wages, promoted subcontracting. Larger assembly firms facing severe international competition transferred technical know-how to subcontractors to raise quality, which was as imperative as cost reduction.

At the end of the 1950s, under pressure of trade liberalization, the Japanese government began promoting factory modernization in small and medium firms to prevent their bankruptcy (Small and Medium Enterprise Modernization Promotion Law, 1963). The policy contributed to mechanization and automation and vastly improved the productivity of small and medium firms. A variety of TSIs also contributed to raising the technological level of these firms.

Main Issues and Hypotheses

This analysis focuses on the institutional factors contributing to the improvement of the technological capabilities of Japanese firms, using the casting industry as a case study because of its important role in the machine industries. Its purpose is to analyze how TSIs and government policies improved the technology of firms and the industry as a whole. Japan's institutional experiences may have important implications for developing nations currently pursuing rapid industrialization.

As a starting point, three major hypotheses are offered:

Hypothesis 1: The technology-support system evolves with the industry's development cycle. Industry and technology follow a "logistics curve" from infancy through growth and maturity to decline. The effectiveness and role of TSIs and related policies follow the curve.

The importance of government policy, for example, has declined as the private sector has grown. Institutions and policies played different roles in the 1950s than they do today. Although my scope concentrates on the present, historical perspective is important.

The casting industry and its postwar development includes:

- the 1950s, an era of massive technological import from overseas,
- the 1960s, a period of technological adaptation and dissemination, and
- the 1970s and onward, when R&D advanced rapidly and the importance of imported technology declined.

Today, Japanese firms and research institutions are moving from R&D involving minor improvements and practical applications to basic technological innovation. In the field of casting, classified as a mature technology,[5] however, there will be little room for innovative technology.

Hypothesis 2: A firm's technological capacity, which is strongly influenced by its size, determines its R&D sources and use of TSIs.

Leadership for technological innovation in Japan has migrated to larger firms and their captive laboratories from university, national and local research institutes, and the former (captive TSIs) have outstripped the latter (non-captive TSIs) in total R&D expenditures, numbers of qualified researchers, and high-tech facilities. Large firms that have acquired technological capability tend to establish links with universities and academic societies in and out of Japan and with foreign firms.

Small and medium subcontractors receive technological support from parent corporations or their main buyers, and technical advice and know-how from firms that supply their equipment and facilities.

Hypothesis 3 The *keiretsu* or subcontracting system influences the interaction of firms with TSIs.

The *keiretsu* and subcontracting system are the most important channels of technological transfer. Now technology developed by the parent firm's research laboratory is transferred to subcontractors. In return for free technology transfer, member firms obey standards of quality, cost reduction and timely delivery. Hence, firms with *keiretsu* relationships do not need outside TSI support as much as do independent firms, who rely on TSIs for R&D.

The Postwar Development of Japan's Casting Industry

Production Trends

The casting industry has been profoundly affected by trends in the machine industries and by the overall economy's boom-and-bust cycles. Prosperity during the Korean War in 1950–1953 and later periods helped Japan recover from World War II. The industry's chief customers were industrial, electrical, and transportation machinery manufacturers. Since the 1960s, the automobile industry has been the most important customer for cast metal products. With the rapid growth of the automobile and other machine industries, casting production grew 7 percent annually from 1950 to 1979 (Table 2.1). Just before the first oil shock in 1973, total car production exceeded 7 million, crude steel reached 120 million tons, and casting output recorded almost 8 million tons. Although temporarily slowed by the oil shock, postwar casting grew sevenfold between 1950 and 1979.

Casting industry employment has declined since the early 1960s, when labor shortages became a serious problem (Table 2.1). It fell from 0.37 percent of all industries in 1960 to 0.19 percent in 1979. Productivity, in contrast, improved from 17 tons per worker to 66 tons, thanks to the rapid automation and mechanization of small and large firms. The casting industry's contribution to Japan's GNP in the 1960s and 1970s remained high, estimated to be 1.41 percent at the highest (1960) and 0.73 percent at the lowest (1978).[6]

Technological Development: Institutions and Policies

Innovations in casting have evolved in three areas—materials, molding, and production process control (mechanization, automation, and computerization).

New materials included meehanite metal, developed in the United States between 1923 and 1926; spheroidal graphite cast iron, developed in the United Kingdom between 1947 and 1948; and high-grade cast iron such as acicular and compacted vermicular (CV) graphite cast iron. The melting of cast iron improved greatly with the invention of hot-blast and water-cooled cupolas. The low-frequency induction furnace eventually replaced the cupola because of its better pollution control. These technologies were imported full-scale into Japan in the 1950s.

Major molding techniques included shell molding, developed by a German scientist in 1944; $C0_2$ gas hardening, developed in England in 1948; and self-curing molds, such as the fluid sand (FS) process developed in the former Soviet Union and its adaptations, such as the N process, developed in Japan. The vacuum casting or V process was developed in Japan in 1971, and molding R&D was an important area in the 1950s and 1960s.

Mechanization of the production process began in the 1950s and later moved rapidly into automation. In the beginning, the shortage of casting machine manufacturers in Japan necessitated the import of equipment such as molding, shot-blast, and sand-control machines. Labor shortages in the 1960s spurred automation, as did enactment of the Antipollution Basic Law in 1967, which led to the import or development of pollution control facilities. The number of casting machine manufacturers grew as mechanization increased.

The period from 1958 to the first oil shock in 1973 saw a sevenfold increase in all imported technologies, including casting.[7] Basic technologies were generally imported first by large firms having relatively high R&D capacity. These companies then applied and improved their imports and disseminated new techniques to other firms, including small-scale subcontractors.

Business associations of casting firms were set up in the 1950s and 1960s for importing, adapting, and disseminating technology. Local public (prefectural) research institutes also helped disseminate information and techniques to small firms. And industrial policies were established favoring dissemination.

Institutions

As the casting industry sought to acquire foreign technologies in the 1950s, a pattern emerged of establishing business associations, often under the leadership of a few large companies, as exclusive licensees of foreign technologies. This strengthened the weak bargaining position of Japanese firms as licensees, reducing the overall cost of technology. The Japanese government's frequent intervention to prevent excessive competition among Japanese firms helped implement and support the process.

Meehanite metal, an innovative, high-grade cast iron mainly used in industrial equipment and machine tools, was introduced into Japan in 1951 by the Mitsui Shipbuilding Co., Ltd., one of Japan's largest firms under a contract with Meehanite Worldwide, a U.S. firm. Mitsui set up an R&D subsidiary, the Japan Meehanite Metal Co. Ltd., later the sole licensee for the material in Japan. Japan Meehanite Metal sublicensed the patent to 28 firms, and provided consulting, overseas information, problem-solving, and advisory services.

For spheroidal graphite cast iron, Toshiba, one of Japan's largest electrical equipment producers, obtained a patent from international Nickel, a U.S. company, in 1952 and proceeded to initiate production and adapt the technology. After the patent expired, the Japan Ductile Cast Iron Association was set up to disseminate the latest cast iron technology and engage in R&D. An association member firm later used centrifugal casting to apply spheroidal graphite cast iron to iron pipes.

CO_2 gas hardening, which uses water glass rather than conventional clay as a binder, was introduced into Japan in 1952 by Hitachi Ltd. Its engineers developed the N process, in which sand is hardened naturally without gas blowing. The FS method was imported by Nippon Casting Co., Ltd., in 1968. It was reintroduced in an improved form by the Japan High Grade Casting Iron Association and then disseminated to association members.

Shell molding was introduced into Japan in 1956 and disseminated by the Japan Shell Molding Association, set up by 26 firms—a number that grew tenfold in the five years after the Association's founding. The association's original role was as sole licensee within Japan. It sublicensed to member firms, but it also worked to acquire and disseminate other technologies from abroad.[8]

The business associations set up in the 1950s did not limit their work to information dissemination; they also did R&D under the direction of technical committees

Table 2.1 Production Trend of Casting Industry (1950-1979)

Year	Total production (ton) (A)	Total production (100 mil. yen) (B)	Employees (C)	Productivity (A)/(C)	Productivity (B)/(C)	GNP (100 mil. yen) (D)	Working population (10,000) (E)	(B)/(D) (%)	(C)/(E) (%)
1950	974707	351	n.a.	n.a	n.a	40347	n.a	0.869953156	n.a
1955	1348898	824	n.a	n.a	n.a	88646	4194	0.929539968	n.a
1960	2869861	2292	165740	17.31543985	1382888.862	162070	4511	1.414203739	0.37
1965	3717332	3111	151270	24.57415218	2056587.559	320699	4787	0.970068507	0.32
1970	6976458	9652	166796	41.8262908	5786709.513	735031	5153	1.313141895	0.32
1973	7774933	12089	142976	54.37928743	8455265.219	1130899	5289	1.068972561	0.27
1975	5537694	12005	123476	44.848343	9722537.173	1487980	5323	0.806798478	0.23
1976	5977839	13266	117026	51.08128963	11335942.44	1672946	5378	0.792972397	0.22
1977	6241557	14493	110039	56.72131699	13170784.9	1862092	5452	0.77831815	0.2
1978	6273458	15010	107191	58.52597699	14003041.3	2050463	5532	0.73202979	0.19
1979	6971014	16894	106226	65.62436692	15903827.69	2217218	5596	0.761945826	0.19

Source: Kenji Chijiiwa, "Trends in the Japanese Casting Industry (1950-1980)," Sohgoh Imono, Vol. 21, No. 12, (1980), p. 3.

composed of large companies. Cooperation among competing firms was fostered by the severe constraints on capital and foreign exchange.

Foreign exchange constraints left technological import under the strict control of the Japanese government. This gave the government great leverage over firms' acquisition and dissemination of technology; companies were under tremendous pressure to implement the latest advances, since taking a lead in importing technology increased later profit margins and market shares. As the Japan Shell Molding Association demonstrated, business associations reduced excessive competition among firms eager to implement the technological advances.

The existence of a few pioneering companies able to adapt and improve imported technology was decisive in Japan's postwar industrial development. Their absorptive capacity, and the efficient institutional arrangements among firms and associations were key to casting development in the 1950s and 1960s.

Consultants such as Japan Meehanite Metal Co. Ltd. also helped disseminate-technology. However, prefectural research institutes and keiretsu relationships were more important. These two routes supported small and medium companies. Later chapters focus on the peculiarly Japanese institution of prefectural research institutes.

Policies

Industrial policy immediately after World War II was interventionist and regulatory, reflecting the war economy. Policies and priorities have since changed, consistent with industrial development and environmental imperatives. During reconstruction, the priority was to rebuild the nation's economic and industrial infrastructure and promote basic industries such as coal, iron, steel, and shipbuilding. These industries were treated preferentially in materials allocation, import quotas, low interest capital financing, etc.

Once the economy had recovered, policy priorities in the first half of the 1950s turned toward streamlining overall industries through tax incentives and low-interest capital loans. Priorities then shifted to promoting a few strategic industries such as synthetic fibers, petrochemicals, electronics and machinery, to which the government gave tax and tariff reductions or exemptions, low-interest financing, and import permits.

With the liberalization of trade and private sector development in the 1960s, the significance of government industrial policy gradually declined. By 1970, the Industrial Structure Council of the Ministry of International Trade and Industry (MITI) began advising the government on the "maximum use of the market mechanism," a turning point in Japan's industrial policy. Since then, the role of government agencies such as MITI has changed from direct and interventionist to indirect and intermediary.

From the late 1950s, the government designated strategic industries as engines of growth, granting incentives to key industries for limited periods. The machinery industry, for example, was designated strategic in 1956, followed by electronics in 1957 and aircraft in 1958. Promotional policy measures included tariff and tax incentives, such as accelerated facilities depreciation and reduced corporate taxes, and financial incentives, such as long-term, low-interest loans and export promotion incentives.

MITI established departments to supervise each strategic industry. Most MITI policies were implemented smoothly because industry associations were consulted beforehand. The National Casting Industry Council was set up in 1945 as a pressure group promoting the casting industry, and two years later MITI established a Casting and Forging Department. In 1961, the casting industry was designated for full promotion under the 1956 Temporary Measures for Promoting the Machinery Industry and, in 1963, was designated a target industry under the Small and Medium Firms Basic Law of 1963.[9]

Since the early 1960s, the promotion of small and medium firms has been a central goal of industrial policy. Large companies, especially in the machinery industry, appreciated the government's policy because their dependence on subcontractors. Under international pressure to liberalize trade and foreign exchange at the end of the 1950s, the government focused on mechanizing and automating small and medium firms to make manufacturers internationally competitive. Policies included improving their technology, training employees, streamlining management, restructuring small business to avoid excessive competition and strengthen cooperation, and eliminating business practices that weakened the bargaining position of small firms.

The Small and Medium Enterprise Modernization Promotion Law granted tax incentives for capital investment and low interest rate financing from the Small Business Finance Corporation. The idea of quality control, introduced from the United States and disseminated by the government, became deeply rooted in small and medium firms. Labor shortages also accelerated small-business automation, resulting by the 1970s in increased productivity, improved quality, and reduced costs, and a strengthening Japan's international competitiveness.

Technology policies constituted an important element of industrial policy. In the early 1950s, technological imports were vital to filling technological gaps, but they were restrained by the Foreign Exchange Control Act and Foreign Capital Regulation of 1950. Prosperity in the late 1950s spurred deregulation of imports. Frequent government intervention in technological transactions between Japanese and overseas firms included advice against domestic competition that would raise royalty payments. With MITI's guidance, Japanese firms introduced overseas technology rather cheaply.[10] The government also provided guidance—again to minimize competition—to ensure that business associations became sole licensees for key technologies.[11]

In the 1950s and 1960s, the government created incentives for technological upgrading by exempting equipment from tariffs, allowing tax deductions for experimental research expenses, providing R&D subsidies, R&D consignments, and low-interest R&D financing. Subsidies for R&D started in 1950 for mining and manufacturing. In the casting industry, TSIs, including business and academic associations, national and regional public research institutes, and universities, received either subsidized or consigned R&D. In 1960 the Materials Process Technology Center was set up under MITI mainly to promote R&D in the casting industry.

Industry Overview

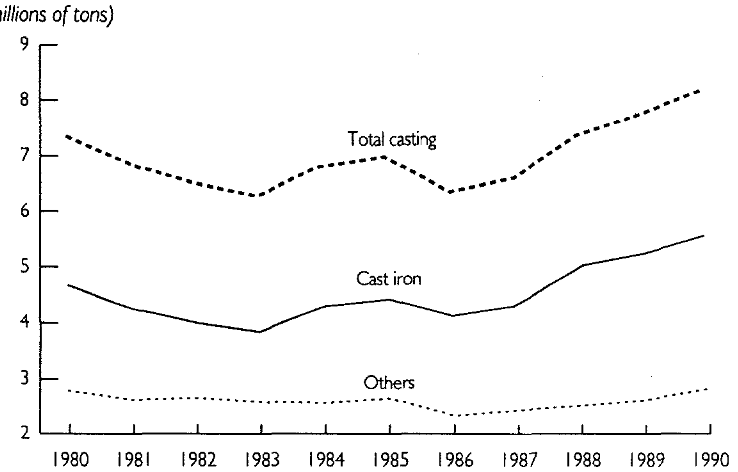
Production Trends from 1981 to 1990

Total casting production in 1990 exceeded 8 million tons and amounted to 2,467 billion yen, or 0.56 percent of Japan's GNP. Japan now ranks third in the world, after the U.S. and the People's Republic of China. Almost all products are consumed domestically.

The casting industry consists of seven subsectors—cast iron, cast iron pipes and fittings, malleable iron casting, steel casting, copper-based alloy casting, die casting, and precision casting. Cast iron is the most important, accounting for two thirds of the industry's total value.[12] Casting production—cast iron in particular—increased steeply from 1987, reflecting the longest period of postwar prosperity (Figure 3.1). Production grew at an annual average of 10 percent in the 1950s, and nearly as fast in the 1960s (Table 2.1). With the first oil shock, production fell sharply in the early 1970s and declined slightly through most of the 1980s. Cast iron production followed a similar trend over the decades. Production began to recover after 1987 (Table 3.1). The value of cast iron production exceeded 1,000 billion yen in 1990.

The automobile industry consumed 54 percent of casting industry output in 1990 (Table 3.2). Its consumption has grown on average 9.7 percent since 1965. Output for industrial machinery—the second largest customer—fell from 31 percent in 1965 to 17 percent in 1990. Other end-users are other industrial machinery at 14 percent, transportation machinery at 5 percent, and electrical machinery at 2.6 percent (Table 3.2).

Figure 3.1 Production Trends by Subsector
(millions of tons)



Source: Annual Statistics of Material Process Industries

Table 3.1 Production Trends in Cast Iron (1980-90)
(tons)

Year	Cast iron	Others	Total casting
1980	4,637,493	2,712,595	7,350,088
1981	4,247,527	2,605,077	6,852,604
1982	3,926,470	2,584,122	6,510,592
1983	3,804,479	2,516,882	6,321,361
1984	4,284,966	2,552,147	6,837,113
1985	4,406,415	2,580,842	6,987,257
1986	4,162,473	2,318,420	6,480,893
1987	4,278,717	2,341,314	6,620,031
1988	4,943,521	2,448,404	7,391,925
1989	5,218,477	2,573,114	7,791,591
1990	5,495,911	2,701,871	8,197,782

Note: Others include pipes and fittings, malleable steel casting, light metal alloy, copper base alloy, die casting, and precision.
Source: Annual Statistics of Material Process Industries, (August 1991), pp. 20-21.

Table 3.2 Cast Iron Production Share by End User
(percent)

End user	1990	1965
Industrial machinery	17.1	31.1
Other industrial machinery	14.1	37.5
Automobile industry	54.3	12.5
Transportation machinery	5.1	5.0
Electrical machinery	2.6	3.6
Miscellaneous	6.5	10.1
Total	100.0	100.0

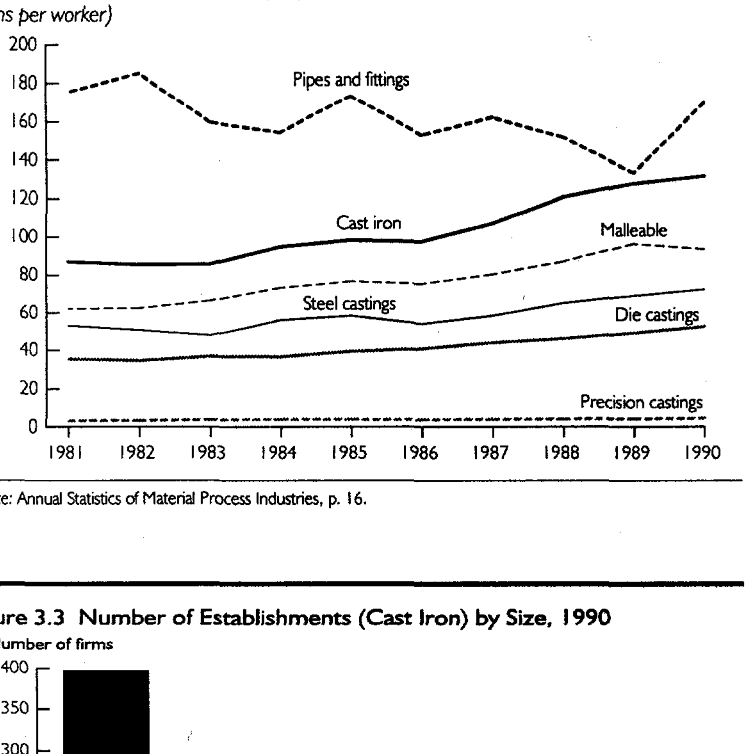
Note: Other industry machinery includes machinery for mining, road building and construction, metal working machinery and machine tools, textile machinery and agriculture and fishery. Transportation machinery includes railways, ships and harbour installations. Miscellaneous rolls, ingot molds and mold boards, pipes and fittings, bearings, valves and cocks, household articles, and others.
Source: Annual Statistics of Materal Process Industries, (August 1991), pp. 50-54.

Table 3.3 Labor Productivity by Subsector
(ton/worker)

Year	Cast iron	Pipes and fittings	Malleable	Steel casting	Die casting	Precision casting
1981	86.8	175.5	62.1	53.4	35.7	3.0
1982	85.3	184.9	62.4	50.9	34.8	3.1
1983	85.6	159.7	66.3	48.0	37.0	3.6
1984	94.8	154.5	73.2	56.3	36.8	3.8
1985	98.2	173.2	76.6	58.4	39.4	3.7
1986	97.4	153.1	75.3	54.3	40.7	3.6
1987	107.0	162.0	80.3	58.4	43.9	3.8
1988	120.6	152.0	86.9	65.0	46.1	4.0
1989	127.6	133.3	96.4	68.9	49.4	4.1
1990	131.7	169.8	93.6	72.4	52.9	4.4

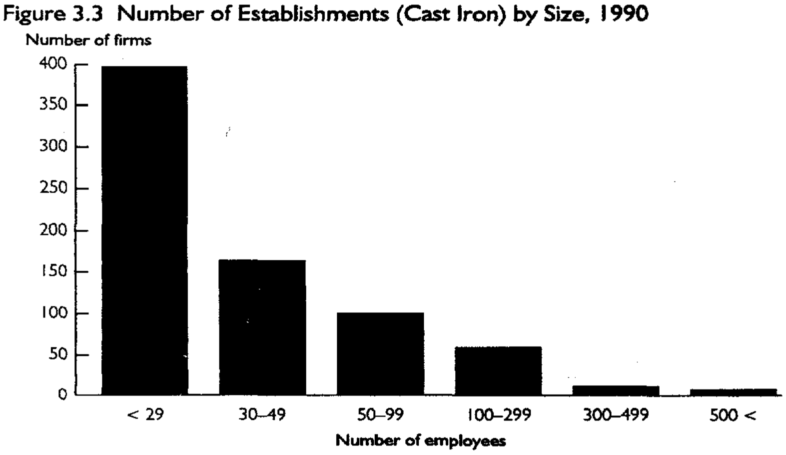
Source: Annual Statistics of Material Process Industries, p. 16.

Figure 3.2 Labor Productivity by Subsector
(tons per worker)



Source: Annual Statistics of Material Process Industries, p. 16.

Figure 3.3 Number of Establishments (Cast Iron) by Size, 1990



Source: Annual Statistics of Material Process Industries.

With its negative "3-D" image as "dirty, demanding and dangerous," casting has had difficulty in attracting new labor, particularly highly skilled workers. Employment stood at 87,558 in 1990, down 12.5 percent from 1981, although total production tonnage increased 19.6 percent in that period, reflecting improved productivity (Table 3.3 and Figure 3.2). Cast iron productivity improved 4.7 percent annually.

The number of casting factories decreased from 1,775 in 1981 to 1,513 in 1990.[13] Cast iron factories, almost half of the total, also fell from 971 to 739 over the period. Most other subsectors, such as steel and nonferrous metal casting follow the pattern, although the number of die casting and precision casting factories both increased 15.8 percent.

Industrial Organization

While casting firms supply all machinery industries, machinery assembly manufacturers also produce their own casting products. Integrated firms with in-house cast-parts production are usually considered automobile or machine tool industries rather than casting firms. Their in-house production was 32 percent of total cast iron production in 1990 (Table 3.4a).[14] Although in-house production tends to increase during recessions, it remained stable throughout the 1980s. Shares for each type of production (integrated, specialized and semispecialized) are given in Table 3.4b.

Integrated firms produce more than 20 percent of all cast iron. They tend to concentrate on mass production, farming out less efficient, diversified and small-lot orders. There remain fields technologically and economically difficult to automate. Most specialized firms which handle less efficient fields, are subcontractors to integrated firms, thus, there is a division of labor between small and medium subcontractors and integrated assembly firms.

Subcontractors fall roughly into one of two categories—*keiretsu* and non-*keiretsu*. *Non-keiretsu* firms fulfill orders from diversified customers, while *keiretsu* subcontractors limit their customer base. Especially in automobile parts industry, most subcontractors are influenced by a *keiretsu* relationship of some type.

In 1990 casting factories numbered 1,513, excluding microfirms employing fewer than 20. The cast iron subsector had the most—739.[15] With fewer than 50 employees accounted for 76 percent of their total (Table 3.5 and Figure 3.3). Since official statistics exclude microfirms, the size of the average firm is smaller than the table indicates. By my estimate, especially in important production areas such as Saitama Prefecture, two-thirds of casting factories are microfirms.[16] Microfirms produce products based on customer specifications and need not engage in R&D. Often family-run and the bottom rung of the subcontracting system.

The major casting areas by production values are Aichi Prefecture at 20 billion yen, followed by Fukuoka at 5.5 billion yen, Saitama at 5.46 billion yen, Hiroshima at 5.3 billion yen, and Tochigi at 4.4 billion yen. Aichi accounts for 22 percent of all production and is strongly influenced by *keiretsu*, thanks to its proximity to Toyota, Japan's largest automobile assemblers. In contrast with Aichi, third-ranked Saitama has a localized industrial structure, featuring a long tradition of specialized resources and skills and many small firms in the same business lines. Saitama has more companies than any other prefecture. Its firms enjoy strong support from both national and prefectural governments.

Table 3.4a Share of In-House Production

Year	Production (ton)	In-house share (%)
1981	4,247,527	35.3
1982	3,926,470	35.5
1983	3,804,479	35.8
1984	4,284,966	34.2
1985	4,406,415	34.1
1986	4,162,473	35.4
1987	4,278,717	35.7
1988	4,943,521	34.0
1989	5,218,477	32.8
1990	5,495,911	31.9

Source: Annual Statistics of Material Process Industries, p. 45.

Table 3.4b Production Share (percent) by Type of Firm

Type	Number of factories	Value (mil. yen)	Quantity (tonnage)
Integrated	43 (5.8)	17,606 (20.0)	102,320 (21.9)
Specialized	634 (85.8)	55,400 (63.2)	284,603 (60.9)
Semi-specialized	62 (8.4)	14,715 (16.8)	80,351 (17.2)
Total	739 (100.0)	8,772 (100.0)	467,274 (100.0)

Source: Annual Statistics of Material Process Industries, pp. 68-72.

Table 3.5 Number (percent) of Establishments by Number of Employees

Size of establishment	Cast iron numbers	Malleable casting numbers	Steel casting numbers	Copper base alloy numbers	Lightmetal alloy numbers	Die casting numbers
< 29	397 (53.8)	15 (40.5)	0 (0.0)	173 (81.2)	104 (60.1)	58 (32.9)
30-49	163 (22.1)	6 (16.2)	72 (61.0)	21 (9.9)	20 (11.6)	36 (20.5)
50-99	100 (13.5)	6 (16.2)	29 (24.6)	12 (5.6)	21 (12.1)	42 (23.9)
100-299	59 (8.0)	9 (24.3)	16 (13.6)	7 (3.3)	19 (11.0)	35 (19.9)
300-490	12 (1.6)	1 (2.7)	0 (0.0)	0 (0.0)	6 (3.5)	3 (1.7)
500-999	6 (0.8)	0 (0.0)	0 (0.0)	0 (0.0)	2 (1.2)	1 (0.6)
1000 <	2 (0.3)	0 (0.0)	1 (0.8)	0 (0.0)	1 (0.6)	1 (0.6)
Total	739 (100.0)	37 (100.0)	118 (100.0)	213 (100.0)	173 (100.0)	176 (100.0)

Source: Annual Statistics of Material Process Industries, p. 13.

The Technology-Support System

Overview

Japan's R&D investment reached 3 percent of the GNP in 1990, the highest in the world. Private firms' expenditures exceed 80 percent of the total, considerably higher than any other developed country, and the large firms and their captive laboratories lead the way. Universities contribute 12 percent of the total and public research institutes 8 percent.[17]

TSIs associated with casting can be classified by ownership and functions (Appendix B). There are seven ownership groups—national, semigovernmental, prefectural, university, business association, corporate research laboratory, and private consulting. Governmental institutes are multisectoral. The Government Industrial Research Institute in Nagoya, founded in 1952 under MITI's Agency of Industrial Science and Technology, is the most prominent. Innovative casting materials have been developed there but, because of the technology's maturity the institute no longer attracts young and talented researchers. In fact, one well-known governmental institute's recent abolition of its casting section is expected to set a trend for prefectural organizations and universities.

Each of Japan's 47 prefectures has at least one technology center. Prefectural research institutes (PRIs) number 171 and employ almost 7,000. The proliferation of PRIs throughout Japan has worked in favor of technology transfer. They are generally multisectoral, but a few, such as those in Saitama and Mie, where casting is several centuries old and of great economic importance, specialize in casting. These organizations provide local small and medium firms with services, including information dissemination, troubleshooting and consulting, training for crafts people and engineers, product and materials testing and analysis, free use of modern laboratory facilities, R&D and regular technical seminars and similar meetings.

The private sector originally urged the creation of PRIs. They were established and managed by local governments, but initially assets such as land, buildings, and major facilities were contributed by leading local companies.[18] Most PRIs have just begun to reorganize their missions and functions. Now that small and medium firms have enhanced their technological level, PRIs have shifted toward research of more technologically-intensive areas. They are setting up networks of local universities and firms in order to exchange information and create breakthroughs in techniques.

The most important semigovernmental institutions are the Materials Process Technology Center (MPTC), established under the MITI, and the Japan Foundrymen's Society (JFS), set up by the Ministry of Education. MPTC, which receives financial support from MITI and business circles, influences casting companies. It promotes industry-wide development and mediates between government and business. The government channels consigned R&D through MPTC to qualified firms, though MPTC itself conducts no R&D. It coordinates project teams for large firms and disseminates information. The JFS is an academic organization providing a liaison between business circles and universities. It is affiliated with the International Committee of Foundry Technical Associations, headquartered in Switzerland. Total membership includes 3,500 scholars and corporate managers, typically from large, R&D-oriented firms.

Business circles also have set up a number of TSIs, such as the Japan Association of Casting Technology (1956), the Japan High-Grade Cast Iron Foundry Association (1959), and some 10 other associations. Some have played historical roles in importing and disseminating technology. With improved technical capability, however, the importance of overseas technologies declined in the late 1970s, and these associations reorganized to adapt to the changing environment. Most business associations now promote networking among firms. Some technical committees of these associations also contribute to corporate innovation, as is shown in Chapter 5.

Some associations function mainly as interest groups rather than as providers of technological support. The Japan Cast Iron Foundry Association (JCIFA), founded in 1938, is the casting industry's most prominent pressure group, and it embraces over 90 local cast iron cooperatives. Its small and medium firm members number almost 1,200. JCIFA and its affiliated cooperatives help the government implement policies promoting small and medium firms. Under the Small and Medium Enterprise Modernization Promotion Law, these cooperatives helped renovate facilities and mediated among those firms to reduce competition and encourage cooperation.

One industrial casting cooperative set up in 1905 in Saitama, provides member firms with joint purchases of pig iron and other resources, transportation and shot-blast services, low-interest loans, sales promotion to other prefectures, joint research on used-sand recycling, training, and laboratory services. Request for its laboratory services has increased to more than 5,000 a month (Table 4.1). Nationwide cooperative are the most important source of technology information to local firms employing fewer than 20.

Private consulting firms, still new to Japanese business, have not grown substantially, mainly because they are thought to be expensive and PRIs still provide free consulting, problem-solving, and technical advice to regional firms. Some consulting firms are subsidiaries, and others are owned by retirees of big companies. Casting consulting firms are small, and usually limit their activities to problem-solving and information dissemination. As casting firms become self-sufficient in problem solving, the need for consulting services has dropped. They typically have only a few, but highly experienced, knowledgeable staff people. These firms often dissolve when their principals retire.

Survey of the Casting Industry and Technology-Support System—Methodology and Sampling

The research is based on a purposive sampling involving interviews with representatives of 18 firms and 10 TSIs, plus a national survey of 50 firms that responded to a mailed questionnaire. The findings of these surveys will be presented descriptively, statistically, and through the presentation of instructive case studies.

Purposive Sampling of 10 TSIs

To give a picture of TSIs for Japan's casting industry, the sample included at least one for each of the nine categories of ownership structure. The ten intensive survey interviews were conducted in the main TSI categories (1)–(6). In addition, brief interviews were conducted with representatives of (7)–(9):

(1) Governmental research institutes: 1
(2) Local governmental (prefectural) research institutes: 2
(3) Semigovernmental institutions: 1

Table 4.1 Monthly Testing and Analysis Requests

Type of requests	Frequencies
Chemical analysis	2,000
Atomic emission spectography	300
Mechanical testing	2,500
Micrography	220

Source: Saitama Industrial Casting Cooperative.

Table 4.2 Size Distribution of 18 Purposively Sampled Firms

Small		Medium		Large	
20–49	50–99	100–199	200–299	300–499	500 <
2	3	3	1	2	7

Note: The Small and Medium Firm Basic Law defines small firms as employing fewer than 20. From the technological point of view, however, the separation at the size of 50 employees proves more useful.
Source: Firm interviews.

(4) Business associations: 1
(5) Private consulting firms: 3
(6) Captive laboratories of private firms: 2
(7) Academic societies: 1
(8) Universities: 1
(9) Business associations (pressure groups): 2

Their names are listed in Appendix B, and more details about the TSIs operations are given in Chapter 4.

Purposive Sampling of 18 Firms

The 18 firms were selected based on size of firm or technical dynamism, type of firm, and regional distribution. As Hypothesis 2 holds, a firm's technological level is the most important factor determining which TSIs are useful to it. In Japan, technological capability correlates with company size. The Small and Medium Firms Basic Law (1963) defines small and medium firms as having fewer than 300 employees and less than 100 million yen in capital. The size of sampled firms is given in Table 4.2.

The technological capability of each firm was evaluated based on nine criteria:

(1) R&D expenditures (share of total sales);
(2) Number of full-time researchers;
(3) Existence of permanent R&D department or laboratory;
(4) Possession of industrial rights and properties, that is, patentable technology or utility models (application patents);
(5) Quality of R&D, originality or equal partnerships with other firms;
(6) Positive attitude toward outside TSIs (memberships in related associations indicates a firm's degree of information-orientation);
(7) Participation in academic societies.
(8) Awards from the government or business associations.
(9) Transition from traditional process control based on human experience and skill to automated control.

Based on these criteria, firms are placed in one of three categories of technological dynamism—most, medium, and least (Table 4.3). As Hypothesis 3 holds, *keiretsu* influences whether firms use TSIs, since keiretsu provides technical support to member firms. Thus, both independent or *keiretsu* firms were included. These two types were further divided based on size and technological level: (1) keiretsu core firms (large firms with high technological capacity) and keiretsu subcontractors (small and medium firms) and (2) independent firms and non-keiretsu subcontractors.[19]

Casting goods are produced by both specialized and integrated firms (assembly manufacturers), which produce goods for their own use. As of 1990, the rate of in-house production was about 32 percent. Although these assembly manufacturers

Table 4.3 Purposively Sampled Firms Classified by Technological Dynamism

		Technological dynamism		
	Size	*Most*	*Medium*	*Least*
Small	(20–49)			2
Medium	50–99		2	1
	100–299		3	1
Large	300–499			2
	500 <	3	2	2

Source: Firm interviews.

Table 4.4 Distribution of 50 Returned Questionnaires and 500 Selected Firms
(by firm size, national survey)

	Size	Returned questionnares	Selected firms[a]
Small	1–19	5	
	20–49	13 (36.0%)	288 (57.7%)
Medium	50–99	12	
	100–199	9	
	200–299	4 (50.0%)	199 (39.7%)
Large	300–499	2	
	500 <	5 (14.0%)	13 (2.6%)
Total		50 (100.0%)	500 (100.0%)

a. Out of 691 firms in the membership list of the Japan Cast Iron Foundry Association, 500 firms were selected by the proportionate stratified random sampling method.
Source: National firm mail survey.

are categorized in the automobile or machine industry rather than in casting, the production share of such integrated firms cannot be neglected, and a few were included in the sample. Casting firms are divided into integrated producers, who engage in casting for their own use in final-goods production, and specialized producers, for whom casting is their main business and who sell to outside customers.[20] Since integrated firms are rarely sub-contractors, the sample was thus divided into six types:

(1) Integrated and *keiretsu*.
(2) Integrated and independent.
(3) Specialized and *keiretsu* core firms.
(4) Specialized and *keiretsu* subcontractors.
(5) Specialized and independent.
(6) Specialized and non-keiretsu subcontractors.

Regional considerations are important because of the differences in industrial organization among geographic areas. The survey covered eight prefectures. As of 1990, Aichi Prefecture ranked first, accounting for a quarter of all production, followed by Fukuoka, Saitama, Hiroshima and Tochigi. Aichi is strongly influenced by the *keiretsu* structure. Third-ranked Saitama and seventh-ranked Mie exhibit a unique industrial organization which might be called "localized", which features a long tradition of specialized production based on local resources and skills and a concentration of small and medium firms in the same business. Localized casting firms enjoy an "agglomeration advantage" and plentiful support from central and local governments, whose research institutes support those firms technologically. Such pattern is also found in the garment and textile industries.

An overview of the 18 firms sampled is given in Appendix A.

National Survey of 50 Firms

The national survey consisted of questionnaires mailed to 500 firms in which 50 answered. While case studies in Chapter 5 are based on the purposive firm survey, the national survey is intended to put case studies in a nationwide context and to confirm statistically TSIs' contribution to the industry's technological development.

A proportionate stratified random sampling by company size (small, medium and large) seemed more effective than a simple random sampling. The population was 691 firms. The size distribution is given in Table 4.4. Details are given in Appendix C.

Research Findings on Ten Sample TSIs

The purposive sampling of ten TSIs clarified the important features of TSIs serving the casting industry.

TSI services

TSIs serve three types of functions: R&D and laboratory activities like testing and analysis; networking, training and information services; and problem solving and consulting. R&D is the most crucial and sophisticated. Five of the 10 TSIs mainly provided research and laboratory services through national and local research institutes, universities, and private laboratories.

Most business associations function as coordinators or organizers and do not engage in R&D, but the value of these TSIs should not be underestimated, since networking and information exchange frequently lead to innovation (see Chapter 5). Most associations have a technical committee composed of large R&D-oriented members who meet regularly and study pertinent technology and industry strategies. Because individual firms maintain strong proprietary restrictions on new technology, these committees exchange only certain information. But they do give members "seeds" for R&D.

The third function, problem solving and consulting, lends important assistance to firms in quality control and productivity improvement.

TSI features

Human resources. The dynamism of an R&D-oriented TSI greatly depends on its staff. Most experienced and capable researchers and engineers are older and the number of undergraduates majors in metallurgy and related subjects has declined. The shortage of younger researchers is a serious problem facing the casting industry and TSIs. The captive laboratories of large firms still attract graduates who are systematically trained in-house. Thus, R&D is moving to captive private institutes, and the shortage of R&D staff is becoming a constraint to non-captive TSI.

Training. R&D-oriented TSIs also emphasize training for their own employees. They prefer a personalized way of training or on-the-job training to formal or outside training. Given staff limitations, researchers at non-R&D TSIs must concentrate on routine work and do not get much professional development. Thus, their functions will be reduced to coordinating intercompany networks with little opportunity for training.

Promotion. Like most Japanese organizations, TSIs have used seniority as a promotion criterion. Even consulting firms do so. It mitigates jealousy and competition and encourages cooperation, but it also discourages talented young researchers. Again, however, the changing management environment has started to erode seniority, and R&D-oriented TSIs have begun favoring achievements such as the number of research papers published, techniques patented, and contributions to firm revenue.

Labor turnover, headhunting and spin-off. The seniority system traditionally depressed turnover. Employees rarely quit before retirement, headhunting is still rare. Starting one's own firm occurs only after retirement.

Cost consciousness. Since some TSIs are non-profit organizations and some are publicly financed, i.e., by the government or prefecture, they do not pay much attention to cost control compared to private institutes. And consulting services are perceived to be inexpensive or even free by the client company. Eight of the 10 TSIs answered that their charges were unrelated to market prices. Their lack of awareness may resulted in stagnant or long-term declining revenues. TSIs with a membership system are financially vulnerable to a decline in members. The only exception, a private institute that is one of the most dynamic TSIs, has had its revenue triple over five years. Its director was discerning about the cost and benefit of R&D.

Sensitivity to client needs. TSIs other than private captive laboratories do not try to meet client needs or bring in more clients. They prefer informal, daily channels for understanding client needs. Formal channels, if used, tend to be seminars or workshops. For business associations, the board of directors is the most important channel. The number of members may indicate whether a TSI satisfies client needs, but research showed that most firms joined business associations for no clear reason. Perhaps their greatest motive may have been to collect information on other companies' activities. In today's strained economy, however, firms are reviewing memberships costs, and some are proposing merger of associations to avoid overlapping functions.

Relationship to outside organizations. Most R&D-oriented TSIs belong to academic associations like the Foundryman's Society, where large firms and universities can engage in information and social exchange. Prefectural institutes maintain connections with local universities and also with national research institutes.

Case studies of dynamic TSIs

"Dynamism" denotes the flexibility to change with times. In order to break out of conventional R&D and become truly innovative, TSIs must strengthen their R&D capacity. The two cases that follow illustrate dynamic TSIs.

Case 1. Case 1 is an R&D oriented institute founded in 1985 as an affiliate of a large firm. It is soon to be spun off as an independent entity. Cited above, it has displayed the strongest cost-consciousness, achieved important innovations and enjoyed a tripling of its revenues. Case 1's R&D staff is positively involved in academic societies and cultivates its connections with other TSIs. The institute takes its R&D staff training very seriously, using external training schools, encouraging participation in in-house and outside seminars, and promoting university study. It has attracted younger researchers, whose ranks have doubled to 54 within the last five years.

Case 1 is sensitive to the needs of its clients (medium and large firms). Its client base has risen from 35 to 50 over five years, and it expects to reach 80 customers in the near future. The institute prefers formal channels in gauging client needs, such as staging presentations of innovations at seminars. It participates in meetings of academic societies. It emphasizes patents and published papers in promotions rather than seniority. Case 1 differs radically from other TSIs surveyed.

Case 2. The Mie Prefectural Research Institute serving a prominent casting area also has proven an exception, given the decline in the need for most PRIs. R&D, laboratory services, technical consulting, and training are its main services. With the increased emphasis on innovative and basic technologies, the Mie PRI refocused on R&D, especially in advanced fields. With the serious threat to the casting industry posed by labor shortages, Mie PRI has emphasized training services, providing primary, secondary, and advanced courses for engineers which are highly evaluated by client companies. Since 1991, it has conducted advanced R&D with firms. Together they have worked to overcome the low fracture resistance that is a common problem in composite materials, using innovative techniques such as fiber-reinforced ceramics. Government organizations support the effort by providing the required fibers.

Some PRIs have tried to rejuvenate themselves by focusing on basic R&D, but have failed because of serious R&D manpower shortage. the Mie PRI has attracted younger researchers thanks to its proximity to a college with a reputation in metallurgy and casting. The Mie PRI's director generously encourages his R&D staff to concentrate on research, which is a great incentive to work hard. Since casting is still important to the Mie economy, local government provides full financial support for the PRI.

Table 4.5 Technology Capacity by Firm Size

Size group	Numbers	Average number of employees	Average R&D ratio to total sales
1-19	5	16	0.33
20-49	13	35	0.53
50-99	12	69	0.49
100-199	9	142	0.78
200-299	4	223	1.43
300 <	7	2,610	2.04
Total	50		

Source: Appendix C.

Table 4.6 R&D Levels by Type of Firm

Type of firm	Number	Average number of employees	Average R&D share (%)	Average R&D staff share (%)
Keiretsu Core	21	298	1.076	11.4
Independent	13	297	1.054	10.3
Keiretsu Subcontractor	7	51	0.571	8.6
Non-keiretsu Subcontractor	9	70	0.111	7.7
Total	50			

Source: National firm mail survey.

Table 4.7 Competition and R&D

Degree of competition	Average share of R&D to total sales (%)
Very Severe	1.07 (N=18)
Severe	0.85 (N=16)
Moderate	0.53 (N=11)
Little or None	0.25 (N= 4)

Source: National firm mail survey.

Table 4.8 Firm Size and Frequency of TSI Use

Size	Average number of TSIs used
1-49	2.8
50-99	3.8
100-199	4.4
200-299	6.3
300-499	5.5
500 <	5.6
Average	4.0

Source: National firm mail survey.

Mie's systematic surveys of the prefecture's casting firms enable it to grasp their needs and to offer them carefully conceived services. Many other PRIs are in a dilemma if they were to concentrate on basic R&D, they would become superfluous to regional firms. Mie avoids the quandary by making its regular need surveys.

Evaluation of Technology-Support System

The national survey of 50 firms indicate which type and size of firms use which TSIs, how they use them, and how the TSIs are useful (for their profiles, see Appendix C).

Technological dynamism

The national survey questionnaire allowed firms to rank their own technological capacity on a scale from 1 (lowest) to 5 (highest). Nine graded themselves 5, 20 gave 4, 20 said 3, and one said 2. Although the answers lack objectivity, they may be instructive.

Firm size and R&D. Nineteen of the 50 firms conducted no R&D.[21] Firms with more than 200 employees conducted some R&D, while 56 percent of the small firms, i.e., those employing fewer than 50, did none. R&D expenditures and staff size relate directly to the number of technology patents.[22] The correlation coefficient between staff size and the ratio of R&D expenditures to total sales is as high as 0.84 (Appendix C). The correlation can be also confirmed in Table 4.5.

Type of firm and R&D. Twenty-eight firms have some sort of *keiretsu* relationship. Of them, 21 are *keiretsu* core firms, and seven are *keiretsu* subcontractors. Thirteen are independent firms and nine are non-*keiretsu* subcontractors. The relationship between firm type and R&D capacity is not clear.

The effect of the *keiretsu* on subcontractor's R&D efforts reveals a paradox.[23] The *keiretsu* relationship guarantees long and stable transactions for subcontractors, so they might tend to become less vigorous in R&D. On the other hand, some *keiretsu* subcontractors work to raise their R&D capacity in response to requests by their parent firm. As the parent firm faces competition, *keiretsu* core and subcontractors are pushed to improve technology, cut costs, raise quality, and quicken delivery. Now, the parent firm selects more R&D-oriented subcontractors. *Keiretsu* subcontractors generally are more R&D-oriented than their non-*keiretsu* counterparts, as Table 4.6 shows. *Keiretsu* subcontractors did surpass their non-*keiretsu* counterparts in average R&D share (Table 4.6) by five times—0.57 percent for *keiretsu* and 0.11 percent for non-*keiretsu*.

Competition and technological dynamism

Despite its dwindling number of firms, casting is the scene of fierce competition. All of the *keiretsu* subcontractors reported that parent firms were demanding sweeping cost reductions and strict deadlines, by having them compete with each other. In response, firms who perceive strong competition have increased their R&D investment (see Table 4.7). It is appropriate to examine how competition affects firms' use of TSIs.

Dynamism and the use of TSIs

An R&D-oriented attitude makes firms more information-oriented, spurring them to diversify their sources. Thus, firms that feel competition use TSIs more frequently. R&D orientation is correlated with firm size. R&D-oriented firms are naturally information-oriented. Thus, the larger in size the firm, the more information-oriented it becomes, as Table 4.8 indicates. *Keiretsu* affiliation appears to affect TSI use. Among firms with the same level of technological capability, independent firms use on average more than five TSIs compared to 3.8 by *keiretsu* core firms.

The pattern is reversed for subcontractors. *Keiretsu* subcontractors use 3.7 TSIs; use 2.9 non-*keiretsu* firms. *Keiretsu* subcontractors are generally more R&D-oriented. For *keiretsu* core firms, the parent firm and related other *keiretsu* core affiliates are the most important source of technology and information. Independent firms, excluded from *keiretsu* groups, must search for diversified information channels.

This analysis suggests that both the factors of technological capacity and the *keiretsu* relationship, influence TSI use. Technological capacity may be more crucial of the two factors: the less R&D-oriented the firm, the lower the frequency of TSI use.

Firm size and the use of training institutions

The size of a firm correlates positively with the frequency of staff training. Almost half of surveyed small firms used no training; all large firms did. Firms employing more than 300 trained in-house and through outside institutions. In-house training was more often used than outside ones (Table 4.9). *Keiretsu* relationships also function as important sources of training for member firms. Some 52 percent of *keiretsu* core firms, for example, depended on parent firms for training, while 31 percent of the independent firms used customers.

Keiretsu subcontractors depended on customer or parent firms for 43 percent of their staff training, while only 22 percent of non-*keiretsu* subcontractors did. Two-thirds of non-*keiretsu* firms used no training at all, compared to only 29 percent of keiretsu subcontractors. *Keiretsu* core firms tend to depend more on outside training institutions, including parent companies', and less on in-house training than independent firms. *Keiretsu* firms, including subcontractors, make greater use of more sources of training.

Evaluation of TSIs

Casting firms' most important technological sources are, in order, customer or parent firms, PRIs and business associations and suppliers (Table 4.10). Thirty firms out of 46 used customer or parent firms and 28 of 30 firms said that customer or parent firms were very useful. Twenty of 28 firms which used PRIs evaluated PRIs as very useful or useful. Business associations were regarded similarly. Sixteen of 24 regarded supplier firms favorably.

Casting firms perceived universities, academic associations and national institutes, which concentrate on basic technology, as less important sources of technology. This is mainly because that Japanese firms prefer development and applied R&D to basic R&D. Besides, they see the serious staff shortages in these institutions. Fifteen of 46 firms used universities, but only 10 favored

Table 4.9 Firm Size and Use of Staff Training (percent)

Size	Firms with no training	Outside training	In-house or OJT	Both types of training
1-49	50	39	28	17
50-99	25	75	50	50
100-199	22	56	56	34
200-299	0	50	75	25
300 <	0	71	86	86

Table 4.10 Evaluation of Major TSIs by Firm Size and Degree of Appreciation of TSI Support

		TSIs					
		Parent/consumer %		PRIs %		Business associations %	
Size	Firms[a]	Rate of use	Appreciation rate	Rate of use	Appreciation rate	Rate of use	Appreciation rate
< 50	15	53	47	73	53	60	33
50-299	24	75	71	58	42	79	50
300 <	7	57	57	43	29	57	43
Total	46	65	61	61	43	70	43

a. Number of firms using at least one TSI. Four out of the 50 sampled firms did not use any TSI. "Appreciation Rate" means the percentage of all TSI-user firms perceiving TSIs favorably.
Source: National firm mail survey.

Table 4.11 Policy Menus Used by Firms

Policies	*Number of firms*	*Evaluation*
Fiscal (tax) incentives	10	Very useful
Grants	13	Very useful
Low-interest loans	5	Fairly useful
Training subsidies	3	Useful
Governmentt procurement	0	—
Standards (JIS)	4	Useful
Protectionism	0	—
Export incentives	0	—
Miscellaneous	0	—

Note: Since governmental policies are available only for small and medium firms, only nine firms responded to this question.
Source: National firm mail survey.

by PRIs and supplier firms. In joint R&D, PRIs and parent or customer firms are followed by universities. PRIs and business associations provide testing and analysis. With the introduction of testing facilities, however, even small firms have become more self-sufficient. Business associations mainly provide intercompany networking services.

Fifty-six percent of the firms used business associations, and 70 percent of the firms regarded them favorably. Those employing fewer than 20, which were passive toward R&D and the least information-oriented, were often excluded from information networks, except through customer firms and local cooperatives.

Table 4.10 supports the hypothesis that a firm's technological capacity and sources of support are a function of its size. Small firms, usually less technologically competent, used PRIs more often and regarded them more favorable than did large firms. Medium firms (50–299 employees) said they relied on customer firms. Less than 30 percent of the large firms regarded PRIs favorable, a matter of course since PRIs serve smaller companies. Large firms, in general highly technologically competent, also appreciated customer firms less as a technology source than did medium firms. Large firms viewed TSIs as one of a number of information channels. Actually, most TSIs are technologically supported by larger firms through being provided lecturers, initiated joint R&D, and offered advice to TSIs.

them as technology sources. The larger the firm, the more likely it was to regard the university as a partner in research or consigned R&D.

Because casting is no longer strategic, firms rarely organize research cooperatives for special themes. Instead, the permanent technical committees of business associations fulfill the role. Use of consulting and private research firms is also rare, and joint ventures with foreign firms are virtually nil.

Customer requirements and competition are the most critical factors promoting technological improvement in firms. Most R&D is demand-driven, and technology support accompanies ordinary transactions. For subcontractors with high R&D capacity, customer or parent firms often share in R&D from the first stage of design. Close cooperation between assemblers and subcontractors is based on mutual trust. They exchange information and discuss improvements. Such close cooperation allows subcontractors to understand customer needs. *Keiretsu* members cooperate in R&D more often than do loosely organized subcontractors.

Firms rely upon TSIs for training, information dissemination, problem solving, joint R&D, and testing and analysis. For training, firms rely on their customer the most, followed by business associations, PRIs and prefectural technology centers. For information services, customer firms, business associations, and supplier or trading firms are used most often. In problem solving, customer firms are the major source of service, followed

Evaluation of Technology Policies

Although the government's support for the casting industry has declined, it maintains non-industry-specific support policies for small and medium firms from which most casting firms benefit.

Firms with fewer than 300 employees and capital assets of less than 100 million yen are entitled to the policy support which includes modernization of facilities, upgrading of technology levels, management streamlining, restructuring of the small-business sector, eliminating business practices disadvantageous to smaller firms, promoting small firms' products, guaranteeing fair business opportunities, and providing benefits for laborers and stabilized labor relations.

The purposive firm survey showed that nine small and medium firms received benefits. They most welcomed fiscal incentives, especially depreciation discounts (Table 4.11). Seven of the nine took advantage of low-interest loans.[24] The Japanese Industrial Standard (JIS), originated in 1949, led to government-sponsored quality control campaigns. Almost 90 percent of JIS-authorized factories are owned by small and medium firms and receive preference in government procurement, items like manhole covers, ditch covers and street lights. Three firms regarded JIS as fairly important. Four benefited from subsidized training course, particularly for computer. Two firms used R&D subsidies. They received mixed reviews, as subsidies are limited and application procedures are complicated and time-consuming. Half of the fifty firms surveyed by mail did not answer whether they took advantage of these policies. Perhaps some used no technology-related policy, others were unsure if the policies they used were technology-related.[25] In any case, 25 of the 50 used at least one policy measure.

The purposive firm survey suggested that casting firms would appreciate government assistance in training R&D researchers and engineers; R&D related to pollution prevention, energy efficiency and production automation; computer-control technology and software; innovations in materials such as composites; and automation of small-lot and diversified-product processes.

The appreciation of the yen has severely hurt the casting industry. Many machine and automobile assembly companies have begun shifting production overseas, especially to Asia, decreasing domestic demand. This, along with the current depression has made it vital that casting firms become R&D-oriented and pressure the government to implement more technology-related policies.

Case Studies: Firm and TSI Interaction in Technological Change

This chapter focuses on interaction between firms and TSIs, taking into account the *keiretsu* relationship, to provide insight into how individual TSI function. Firms are divided into *keiretsu* and non-*keiretsu* for the sake of convenience.

The first section compares two groups having the same technological level. This is followed by the presentation of other cases of how TSIs contribute to firms' innovations, based on the purposive firm survey. Table 5.1 shows R&D staffing compared to total staff.

Comparison of Keiretsu *Core Firms and Independents*

Firm A is a prominent *keiretsu* core firm that specializes in casting and maintains top technology. It performs technological development, adaptation and basic R&D in its captive laboratory. Under the parent, an important auto parts manufacturer, are nine core firms, including Firm A, all belonging to the same command group. The group belongs to Toyota. Labor is divided among core firms, with Firm A specializing in casting. Firm A often sends R&D staff to the parent company's laboratory to exchange information and perform joint research; it also exchanges information with other core member firms. Its most important sources of technology are the laboratory of the parent and Toyota's Central Research Institute. Firm A also employs other core firms, with an influx of information provided via overseas subsidiaries to get technological information.

The *keiretsu* embraces myriads of subcontractors in a complex pyramidal and multilayered organization. New technologies developed by the parent or core firms may be transferred to other *keiretsu* members, including subcontractors, although critical technology is confined to certain firms. In return for the transfer of technology, member firms obey the parent firm's instructions on cost reduction, quality, and timely delivery. The parent firm contracts out less efficient production jobs to subcontractors. During recessions and depression, subcontractors, especially those on the lowest rungs of the hierarchy, bear the severest conditions. Thus, despite the burden of R&D investment, the parent firm enjoys advantages through the *keiretsu*.

Firm A belongs to a variety of business and academic associations to diversify information sources. It uses TSIs to collect information on the R&D activities of other firms, especially those in other *keiretsu* groups. The different *keiretsu* groups themselves rarely exchange information directly. Firm A depends on various outside TSIs for technical training, in addition to its in-house program. The parent firm also is an important training source. Firm A has no connection with public research institutes.

Table 5.1 Average Number of R&D Staffs by Firm Size

Size of firms	Average employees	Average R&D staffs (A)	Average number of other engineers (B)	(A)+(B)
Small (2 Firms)	36	1.5	1.5	3.0
Medium (7 Firms)	132	3.4	6.3	9.7
Large (9 Firms)[a]	1529	133.8	418.3	552.1

a. Due to diversification, average figures in large firms include staffs unrelated to casting technology.
Source: Firm interviews.

Firm B is an independent specialized producer with R&D capacity comparable to that of Firm A. Previously a subcontractor whose R&D depended on a few key customer firms, Firm B improved its technological capacity and succeeded in diversifying its transactions to a wider range of customers. Being a *keiretsu* firm guarantees stable and long-term transactions, but concentrating all one's transactions in one or two baskets is risky during a recession. Thus, some subcontractors, like Firm B, have worked to diversify their relationships with customers in order to achieve greater independence. Compared to Firm A, Firm B acquires more R&D information from outside TSIs. Its important sources are overseas firms and research institutes, and, to a lesser extent, domestic universities and academic societies. Firm B makes the most of outside TSIs to increase its access to scientific "seeds" and maintains personal connections with professors whom it seeks for joint R&D activities.

Comparison of Keiretsu *and Non-*keiretsu *Subcontractors*

The analysis shows that *keiretsu* subcontractors are more R&D-oriented than their non-*keiretsu* counterparts; they use more TSIs. This polarization of subcontractors began in the late 1970s, when assemblers and customer firms, facing economic upheaval and international competition, began selecting more R&D-oriented subcontractors. Subcontractors with lower technological capabilities dropped out of *keiretsu* groups and became even weaker without the technological support of major customers or buyer firms.[26]

Non-*keiretsu* subcontractors tend to depend on prefectural research institutes. Firm C, employing 32, almost two decades ago, had belonged to a prominent *keiretsu* group and received technical support from parent firms. When its *keiretsu* relationship was canceled, Firm C turned for the first time to the Saitama PRI for support. The PRI provides training, seminars, advice and free problem solving. The firm also uses a local casting cooperative. The cooperative provides marketing information, a stable supply of materials including iron and steel at discount, and testing and analysis.

Another case of a non-*keiretsu* subcontractor is Firm D, employing 48. It produces parts and machine tools for more than 50 customer firms. Firm D depends on the PRI and business associations because the customer firms lend no technical support.

Firm E, employing 24, is non-*keiretsu*. It uses PRI and business associations, but local cooperatives are its most important source. Although the least dynamic in terms of R&D, Firm E not only benefits from the cooperatives technical services but from their power as pressure groups. Firm E survives not by technological improvement but by its political access to market share, achieved through participation in small and medium firm cooperatives. It is in Saitama Prefecture, an important casting regions, where it enjoys support both from central and local governments. Small firms, including Firm E, collaborated in the cooperatives during recessions. This unique phenomenon, partly explained by the Japanese tradition of mutual assistance, is most prominent in localized industrial areas like Saitama. With the cooperatives, small firms with diversified transactions feel no need to join other business organizations.

Small firms generally cannot afford to train staff. However, in the case of *keiretsu* subcontractors, customer firms provide support. More precisely, training is an obligation. Customer firms undertake to ensure high quality of products. But, non-*keiretsu* subcontractors, like Firm E, receive no support from customer firms.

Firm F, employing 53, is an unusual *keiretsu* subcontractor and is a rare small firm that is R&D oriented, works to diversify its R&D sources, and makes the most of the services of TSIs, particularly PRIs. Firm F recently developed innovative technology working with PRIs. Only four people work in R&D, but they consulted with the industrial technology center, universities, and other TSIs on technical information and the use of modern facilities, etc. The R&D staff later found a specialist in their technology of interest at PRI in remote Hokkaido. The researcher there worked in joint R&D for some years, and the result was a valuable patent. Firm F shows how the will and attitude of the company owner is crucial to the firm's success. Even with customer support, Firm F went further, was earnest in its staff training, and used business associations to network. The non-*keiretsu* cases above also show that less dynamic firms may not exploit the potential of TSIs. The point could bear further research.

Other Case Studies

Firm G is an independent medium-sized company, it has 80 employees and makes manhole and ditch covers. Competition is severe, both domestically and overseas, partly because the technology is mature and partly because certain Asian nations, especially China, with low-wage labor have entered the market. Despite limited R&D manpower, Firm G does its own R&D. It is information-oriented and makes the most of outside TSIs, particularly PRIs. It received a government consignment from the Small and Medium Enterprises Agency to do R&D on new ways of core making, and studied new technology thought to be superior to conventional methods in cost reduction, energy efficiency, and high productivity. Firm G's local PRI is active in assisting information exchange among firms, local universities, and national research institutes and takes the initiative in bringing firms in different business lines together. Through the PRI's mediation, Firm G came to contract an iron-working firm and, with its cooperation devised an innovative technique involving austenite ductile iron, making manhole covers and ditch covers lighter. Despite its limited human resources, Firm G could develop new technology cheaply with full use of TSI assistance.

Firm H, employing 1,000, took advantage of a technical committee of a business association. As a *keiretsu* core company, Firm H specializes in casting for its parent automobile assembly company. The parent firm and *keiretsu* group are its most important sources of technology. The group consists of almost 200 companies, including 40 core companies that frequently discuss new ideas and research. Firm H also maintains connections with business and academic associations. It sits on technical committees of the Japan Malleable Iron Casting Association, Material Process Technology Center, Japan Foundrymen's Society, and the Japan Association of Casting Technology. The committees usually consist of representatives from larger firms with high R&D capability. Through these regular exchanges, Firm H acquired the seed for patented technology.

Firm H contributes technologically to the *keiretsu* group. Until two decades ago, however, the firm had depended heavily on technological transfer from the parent firm. It had approached as many TSIs as possible, including national and prefectural research institutes in Kanagawa and Tokyo, to improve its R&D. As its R&D capacity improved, however, it came to rely less and less on them. Firm H, which upgraded its R&D capabilities, built a fragile technological base into a robust organization enabling it to become independent of the TSIs that had supplied R&D. Its success lay in the seriousness of its attitude toward R&D, the use of TSIs, and the effectiveness, in turn, of TSIs assistance.

Conclusions and Lessons for Developing Countries

The casting sector is a microcosm of Japan's rise to global technological leadership. Institutional and policy support was critical to its firms' adoption and mastery of technologies. While post-war process innovations in casting techniques and materials were available through formal channels such as licensing, TSIs made acquiring and diffusing techniques more efficient and cost-effective.

In the early post-war period, for example, the government's attempts to control foreign exchange transactions pushed the private sector to cooperate in licensing foreign technology through business associations, thereby strengthening local industry's bargaining position and ensuring that imported technology would be shared widely. Public TSIs disseminated technical information, conducted training, and assisted firms in organizing cooperative research to absorb imported technology. In localities with concentrations of independent casting firms, PRIs provided consulting and technical services. Only in recent years, as the in-house technological capabilities of casting firms matured, have TSIs shifted their focus to R&D.

Government policies encouraged public and private institutions to promote technology diffusion and technical upgrading. Private sector institutions were particularly important, and government programs often served as a catalyst for private sector cooperation for improving production technology. In addition to pressing for collective technology licensing to save foreign exchange, the government implemented subsidies and incentives through business associations and semigovernmental bodies. Apart from on-licensing imported technology, industry associations disseminated information to members and arranged research, though their role in joint research diminished as firms mastered the major process technologies. Government and quasi-government TSIs often assisted as initiators and honest brokers in business networks. Small firms have been served by business cooperatives, which provide bulk purchasing of inputs, joint marketing, training, technical consulting, and joint research on specialized issues like the recycling of process materials. *Keiretsu* networks, by internalizing costs and benefits of learning, allowed large assembly firms in the machine industries to collaborate with their casting subcontractors in adopting and mastering improved production techniques.

While supporting cooperative private-sector technology activities, the Japanese government targeted direct institutional support to small and medium-size and independent casting firms to ensure that they were not left out of technological upgrading. Financial and material support was given to local or regional institutions to serve smaller and non-*keiretsu* firms. PRIs often worked with industry associations and local cooperatives to provide information services, training, trouble-shooting, testing, laboratory use, and R&D. Special TSIs served small firms as part of a larger policy, launched in the 1950s, to modernize small and medium-size firms through low-interest loans, tax incentives, training, and technical assistance.

Public TSIs' direct support to independent and small firms complemented the *keiretsu* networks in upgrading the technological capabilities of the casting sector. Survey results show that, among medium-size and larger firms, specialized independent producers lacking access to a *keiretsu* group's technological resources sought public TSI support. Small firms that were *keiretsu* subcontractors were stimulated by their main customers' exacting quality standards and technical assistance to become more technologically dynamic, and they sought PRI support more frequently than non-*keiretsu* firms. Since a small firm's *keiretsu* membership usually depended on continuous technical improvement, TSI support provided crucial reinforcement to the technological benefits of *keiretsu* networks.

Japan has unique private sector cooperation and institutional support for small firms. But its institutional and policy support for technological upgrading offers guidelines for late-industrializing economies. Most importantly, newly industrializing countries can encourage cooperation to diffuse technology through public, private, and semigovernmental mechanisms. In casting and other materials processing industries, many key technologies are no longer under patent and are thus easily licensed and distributed in a quasi-public manner. An emphasis on diffusion can raise productivity and quality and strengthen firms' capabilities.

Government should use institutions to encourage private sector cooperation. *Keiretsu* structures cannot be easily copied, but subcontracting networks are prominent in the machinery and electronics sectors in most countries. Technical assistance can be encouraged through incentives, and government can offer technical support to local subcontractors. Business associations can help deliver incentives and technical services to members. Public TSIs can also foster private sector networking for research and training.

Special institutional and policy support should be directed toward the small and medium-size firms that often predominate in casting and related industries. Institutions diffusing improved production techniques to such firms are a key part of broader policies and incentives encouraging modernization. Local TSIs that support small and medium-size firms might be established where firms are concentrated and encouraged to work with business associations and firm cooperatives. TSI support to small firms in information services, training, testing, and trouble-shooting can complement the development of technical cooperation through subcontracting.

Appendix A

Profile of 18 Firms in Purposive Firm Survey

Profile of 18 Firms in Purposive Firm Survey

Firm number	Size (employees)	Location/prefecture	Type of firm	R&D (mil. yen)
1	3,511	Niigata	Integrated/independent	2,100
2	2,910	Aichi	Specialized/keiretsu core	280
3	2,660	Tochigi	Integrated/keiretsu parent	17,000
4	1,523	Shizuoka	Specialized/independent	n.a
5	1,251	Ibaragi	Specialized/keiretsu core	150
6	532	Kanagawa	Specialized/keiretsu core	165
7	524	Saitama	Integrated/independent	176
8	425	Mie	Integrated/independent	1,500
9	412	Saitama	Specialized/independent	n.a
10	267	Saitama	Specialized/keiretsu subcontractor	9
11	192	Kanagawa	Specialized/keiretsu subcontractor	427
12	140	Saitama	Specialized/independent	67
13	127	Aichi	Specialized/keiretsu subcontractor	35
14	87	Mie	Specialized/independent	n.a
15	58	Saitama	Specialized/keiretsu subcontractor	4.4
16	53	Niigata	Specialized/keiretsu subcontractor	5.8
17	48	Saitama	Specialized/keiretsu subcontractor	n.a
18	24	Saitama	Specialized/keiretsu subcontractor	1.6

Note: For integrated firms, R&D expenditures include noncasting R&D expenditures as well
Source: Firm interviews.

Appendix B

Major Technology-Support Institutions by Main Purpose and Ownership

1. Research Institutes and Laboratories

1.1 Governmental research institutes

Government Industrial Research Institute, Nagoya (Industrial Science and Technology Agency, MITI)

1.2 Prefectural research institutes

Saitama Prefectural Casting and Machinery Research Institute

Mie Prefectural Metal Research Institute

1.3 Universities

Kagami Memorial Laboratory for Materials Science and Technology (Waseda University)

1.4 Private captive research laboratories[a]

2. Information and Intercompany Networking Coordination

2.1 Semigovernmental institution

Materials Process Technology Center (MITI)

Japan Foundrymen's Society (Ministry of Education)

Japan Information Center for Science and Technology

2.2 Business associations

Japanese Association of Casting Technology

Japan Die Casting Association

Japan Light Metals Association

3. Problem Solving and Consulting

3.1 Private consulting firms

Tokyo International Casting Technology Consulting

Japan Meehanite Metal

Associated Foundry Engineering Co. Ltd.

4. Interest Groups (Business Associations)

Japan Cast Iron Foundry Association

Japan Malleable Iron Casting Association

Steel Casting and Forging Association

Note: This project avoids mentioning the names of specific private companies and their in-house laboratories in order to protect their privacy.

Appendix C

National Survey Data (50 Casting Firms)

National Survey Data (50 Casting Firms)

Group size	Number of returned questionnaires	Firm number	Employees (A)	R&D Staffs (B)	(B)/(A) (%)	Total sales (mil. yen) (C)	R & D (mil. yen) (D)	R & D (%) (D)/(C)
1–19	5	1	9	0	0.00	180	0.00	0.00
		2	15	1	6.67	1,600	0.00	0.00
		3	17	4	23.53	400	8.00	2.00
		4	18	2	11.11	220	0.00	0.00
		5	18	1	5.56	400	0.00	0.00
20–49	13	6	20	2	10.00	280	0.28	0.10
		7	20	1	5.00	400	8.00	2.00
		8	21	1	4.76	140	0.00	0.00
		9	28	3	10.71	350	0.00	0.00
		10	30	1	3.33	440	0.00	0.00
		11	32	0	0.00	510	0.00	0.00
		12	35	2	5.71	1,800	18.00	1.00
		13	36	5	13.89	740	2.22	0.30
		14	37	4	10.81	900	0.00	0.00
		15	43	2	4.65	620	0.00	0.00
		16	44	4	9.09	400	0.00	0.00
		17	45	5	11.11	690	13.80	2.00
		18	48	2	4.17	660	6.60	1.00
50–99	12	19	50	5	10.00	180	0.00	0.00
		20	56	3	5.36	1,100	11.00	1.00
		21	57	4	7.02	2,230	66.90	3.00
		22	60	5	8.33	1,200	3.60	0.30
		23	61	4	6.56	680	1.36	0.20
		24	64	3	4.69	1,700	0.00	0.00
		25	68	3	4.41	2,100	2.10	0.10
		26	70	0	0.00	2,000	0.00	0.00
		27	76	63	82.89	1,200	12.00	1.00
		28	81	3	3.70	1,200	0.00	0.00
		29	92	30	32.61	1,400	1.40	0.10
		30	97	7	7.22	2,300	4.60	0.20
100–199	9	31	102	5	4.90	3,200	0.00	0.00
		32	111	12	10.81	1,600	8.00	0.50
		33	113	23	20.35	1,600	0.00	0.00
		34	120	8	6.67	4,200	126.00	3.00
		35	139	10	7.19	4,600	0.00	0.00
		36	150	10	6.67	2,000	0.00	0.00
		37	168	8	4.76	3,600	108.00	3.00
		38	183	6	3.28	2,500	0.00	0.00
		39	195	20	10.26	4,100	20.50	0.50
200–299	4	40	201	32	15.92	7,600	114.00	1.50
		41	220	5	2.27	5,570	5.57	0.10
		42	230	16	6.96	4,600	138.00	3.00
		43	240	35	14.58	5,900	64.90	1.10
300 <	7	44	302	20	6.62	7,000	7.00	0.10
		45	450	30	6.67	9,400	141.00	1.50
		46	670	13	1.94	12,700	152.40	1.20
		47	706	100	14.16	1,900	57.00	3.00
		48	1,500	300	20.00	69,700	2,091.00	3.00
		49	2,910	200	6.87	97,000	1,455.00	1.50
		50	11,734	2,300	19.60	630,000	25,200.00	4.00
Total	50		21,783	3,323	15.26	906,790	29,848.23	3.29

Note: Firm No. 27 was excluded due to doubtful R&D staff share.
Source: National firm mail survey.

Notes

1. The machine industries include industrial, electrical, and transportation machinery.

2. Minami, Ryoshin (1992), *Nihon no Keizai Hatten (The Economic Development of Japan)*, Toyohkeizai, Tokyo, p.91.

3. *Ibid.*, p.75

4. "*Keiretsu*" refers to the ties among companies in a business group, based upon either capital/board of director membership relationship or long-term economic transaction. The concept embraces the *horizontal keiretsu* (Konzern or combination) mainly organized by a prominent commercial bank, and the *vertical Keiretsu*, e.g., the Toyota or Nissan Group including affiliates and subcontractors. In this paper, *keiretsu* refers to the vertical *keiretsu*.

5. According to the OECD classification.

6. Chijiiwa, Kenji (1980), "Trends in the Japanese Casting Industry (1950–1980)," *Sohgoh Imono*, Vol. 21, No. 12.

7. Prime Minister's Office, Science and Technology Agency (1985), *Annual Report on Technology Importation*, Printing Bureau, Ministry of Finance, Tokyo.

8. Explanation for each imported technology is based on the unpublished document of each TSI, like Japan Meehanite Metal Co., Ltd., Japan Shellmolding Association, etc.

9. The Japan Cast Iron Foundry Association (1991), "The Short History of The Japan Cast Iron Foundry Association" unpublished document, Tokyo.

10. Lynn, L.H. (1982), *How Japan Innovates*, Westview Press, Boulder.

11. Goto, Akira (1993), *Nihon no Gijyutsu Kakushin to Sangyoh Soshiki (Innovations and Industrial Organizations in Japan)*, University of Tokyo Press, Tokyo.

12. Research in this paper is confined to the cast iron subsector.

13. Factories employing fewer than 20 are excluded from official statistics. See MITI (1991), *Annual Reports on Machinery Industry and Iron and Steel Industry Statistics*, Printing Bureau, Ministry of Finance, Tokyo.

14. Sokeizai Sentah (Materials Process Technology Center) (August, 1991), *Annual Statistics of Material Process Industries of Japan 1990*, Materials Process Technology Center, Tokyo, p. 45.

15. MITI, Annual Reports, *op. cit.*

16. My estimate is based on the 1992 membership list of the Japan Cast Iron Foundry Association.

17. MITI, Overseas Public Affairs Office (1992), *Issues and Trends in Industrial/Scientific Technology*, Overseas Public Affairs Office, Tokyo, p.40.

18. Mie Prefectural Metal Research Institute (1990), "The History of Mie Prefectural Metal Research Institute" unpublished documents, Kuwana.

19. Independent or non-*keiretsu* firms diversify their transactions with more consumer firms than do *keiretsu* firms.

20. A third category, semispecialized, firms produce both for in-house consumption and outside sales; in the firm sample, semispecialized firms were included in the specialized firm category.

21. No answer or missing on the item (R&D share) is treated as a zero R&D expenditure.

22. Yoshikai, Masanori (1985), *Nihon no Sangyoh Gijyutsu Seisaku (Japanese Industrial Technology Policy)*, Toyohkeizai, Tokyo.

23. *Ibid.*, p.167.

24. Three major governmental finance corporations specialized in loans confined to small and medium firms: the Smaller Business Finance Corporation, the People's Finance Corporation, and the Bank for Commerce and Industrial Cooperatives.

25. In the questionnaire, the question is confined to technology-related policies. It might have been easier to answer had it included broader policy measures.

26. Kiyonari, Tadao (1990), *Chushoh Kigyo Dokuhon (Readings on Small and Medium Firms)*, Toyohkeizai, Tokyo, p.133.

References

Chijiiwa, Kenji (1980), "Trends in the Japanese Casting Industry (1950–1980)," *Sohgoh Imono*, Vol. 21, No. 12.

Goto, Akira (1993), *Nihon no Gijyutsu Kakushin to Sangyoh Soshiki (Innovation and Industrial Organization in Japan)*, University of Tokyo Press, Tokyo.

Imai, Ken'ichi, et al. (1982), *Naibu Soshiki no Keizaigaku (Economics of Internal Organization)*, Toyohkeizai, Tokyo.

Itami, Hiroyuki, et al. (eds.), (1993), *Nihon no Kigyo Sisutemu (Readings on Japanese Enterprise System)*, Vol. 3: Jinteki Shigen (Human Resources), Yuhikaku, Tokyo.

Itami, Hiroyuki, et al. (eds.), (1993), *Nihon no Kigyo Sisutemu (Readings on Japanese Enterprise System)*, Vol. 4: Kigyoh to Shijyo(Enterprise and Market), Yuhikaku, Tokyo.

Itoh, Motoshige, et al. (1988), *Sangyoh Seisaku no Keizai Bunseki (Economic Analysis of Industrial Policy)*, University of Tokyo Press, Tokyo.

Japan Cast Iron Foundry Association (1991)," The Short History of The Japan Cast Iron Foundry Association," unpublished document, Tokyo.

Kawakami, Yoshiaki (1993), *Gendai Nihon no Chushou Kigyoh (Small and Medium Enterprises in Modern Japan)*, Tax and Accounting Association, Tokyo.

Kiyonari, Tadao (1990), *Chushou Kigyoh Dokuhon (Readings on Small and Medium Firms)*, Toyohkeizai, Tokyo.

Kiyonari, Tadao (1993), *Chushou Kigyoh Runessansu (Small and Medium Enterprise Renaissance)*, Yuhikaku, Tokyo.

Komiya, Ryutaro, et al.(eds.) (1984), *Nihon no Sangyohseisaku (Japanese Industrial Policy)*, University of Tokyo Press, Tokyo.

Lynn, L. H.(1982),*How Japan Innovates*, Westview Press, Boulder.

Mie Prefectural Research Institute (1990), " The History of Mie Prefectural Metal Research Institute," unpublished document, Kuwana.

Minami, Ryoshin (1992), *Nihon no Keizai Hatten (The Economic Development of Japan)*, Toyohkeizai, Tokyo.

Ministry of International Trade and Industry, Research and Statistic Department, *Annual and Monthly Reports on Machinery, Iron and Steel Industry Statistics*, various years and months, Printing Bureau, Ministry of Finance, Tokyo.

Ministry of International Trade and Industry, Overseas Public Affairs Office(1992), *Issues and Trends in Industrial and Scientific Technology: Toward Techno-Globalism*, Overseas Public Affairs Office, Tokyo.

Ministry of International Trade and Industry, Research and Statistics Department (1992), *Census of Manufacturers* 1989, Printing Bureau, Ministry of Finance, Tokyo.

Ministry of International Trade and industry, Small and Medium Enterprise Agency. (1992), *Chusou Kigyoh Shisaku no Aramashi (Outline of the Small and Medium Enterprise Policies of the Japanese Government)*, Japan Small Business Research Institute, Tokyo.

Ministry of International Trade and Industry, Small and Medium Enterprise Agency (1992), *Gijyutsuryoku Kohjo no Tebiki (A Guide to Improving the Technological Capacity of Small and Medium Firms)*, Research Institute of International Trade and Industry, Tokyo.

Prime Minister's Office, Science and Technology Agency (1985), *Annual Report on Technology Importation*, Printing Bureau, Ministry of Finance, Tokyo.

Prime Minister's Office, Science and Technology Agency (1992), *Kagaku Gijyutsu Hakusho (White Paper on Science and Technology 1992)*, Printing Bureau, Ministry of Finance, Tokyo.

Shimotani, Masahiro (1993), *Nihon no Keiretsu to Kigyoh Gurupu (Japanese Keiretsu and Corporate Groups)*, Yuhikaku, Tokyo.

Sokeizai Sentah (Materials Process Technology Center) (1991), *Annual Statistics on Materials Process Industries of Japan 1990*, Materials Process Technology Center, Tokyo.

Yoshikai, Masanori (1985), *Nihon no Sangyoh Gijyutsu Seisaku (Japan's Industrial Technology Policy)*, Toyohkeizai, Tokyo.

Distributors of World Bank Publications

Prices and credit terms vary from country to country. Consult your local distributor before placing an order.

ARGENTINA
Oficina del Libro Internacional
Av. Cordoba 1877
1120 Buenos Aires
Tel: (54 1) 815-8354
Fax: (54 1) 815-8156

AUSTRALIA, FIJI, PAPUA NEW GUINEA, SOLOMON ISLANDS, VANUATU, AND WESTERN SAMOA
D.A. Information Services
648 Whitehorse Road
Mitcham 3132
Victoria
Tel: (61) 3 9210 7777
Fax: (61) 3 9210 7788
E-mail: service@dadirect.com.au
URL: http://www .dadirect.com.au

AUSTRIA
Gerold and Co.
Weihburggasse 26
A-1011 Wien
Tel: (43 1) 512-47-31-0
Fax: (43 1) 512-47-31-29
URL: http://www .gerold.co/at.online

BANGLADESH
Micro Industries Development Assistance Society (MIDAS)
House 5, Road 16
Dhanmondi R/Area
Dhaka 1209
Tel: (880 2) 326427
Fax: (880 2) 811188

BELGIUM
Jean De Lannoy
Av. du Roi 202
1060 Brussels
Tel: (32 2) 538-5169
Fax: (32 2) 538-0841

BRAZIL
Publicacões Tecnicas Internacionais Ltda.
Rua Peixoto Gomide, 209
01409 Sao Paulo, SP.
Tel: (55 11) 259-6644
Fax: (55 11) 258-6990
E-mail: postmaster@pti.uol.br
URL: http://www .uol.br

CANADA
Renouf Publishing Co. Ltd.
5369 Canotek Road
Ottawa, Ontario K1J 9J3
Tel: (613) 745-2665
Fax: (613) 745-7660
E-mail: order .dept@renoufbooks.com
URL: http:// www .renoufbooks.com

CHINA
China Financial & Economic Publishing House
8, Da Fo Si Dong Jie
Beijing
Tel: (86 10) 6333-8257
Fax: (86 10) 6401-7365

COLOMBIA
Infoenlace Ltda.
Carrera 6 No. 51-21
Apartado Aereo 34270
Santafé de Bogotá, D.C.
Tel: (57 1) 285-2798
Fax: (57 1) 285-2798

COTE D'IVOIRE
Center d'Edition et de Diffusion Africaines (CEDA)
04 B.P. 541
Abidjan 04
Tel: (225) 24 6510;24 6511
Fax: (225) 25 0567

CYPRUS
Center for Applied Research
Cyprus College
6, Diogenes Street, Engomi
P.O. Box 2006
Nicosia
Tel: (357 2) 44-1730
Fax: (357 2) 46-2051

CZECH REPUBLIC
National Information Center
prodejna, Konviktska 5
CS – 113 57 Prague 1
Tel: (42 2) 2422-9433
Fax: (42 2) 2422-1484
URL: http://www .nis.cz/

DENMARK
SamfundsLitteratur
Rosenoerns Allé 11
DK-1970 Frederiksberg C
Tel: (45 31) 351942
Fax: (45 31) 357822
URL: http://www.sl.cbs.dk

ECUADOR
Libri Mundi
Libreria Internacional
P.O. Box 17-01-3029
Juan Leon Mera 851
Quito
Tel: (593 2) 521-606; (593 2) 544-185
Fax: (593 2) 504-209
E-mail: librimu1@librimundi.com.ec
E-mail: librimu2@librimundi.com.ec

EGYPT, ARAB REPUBLIC OF
Al Ahram Distribution Agency
Al Galaa Street
Cairo
Tel: (20 2) 578-6083
Fax: (20 2) 578-6833

The Middle East Observer
41, Sherif Street
Cairo
Tel: (20 2) 393-9732
Fax: (20 2) 393-9732

FINLAND
Akateeminen Kirjakauppa
P.O. Box 128
FIN-00101 Helsinki
Tel: (358 0) 121 4418
Fax: (358 0) 121-4435
E-mail: akatilaus@stockmann.fi
URL: http://www .akateeminen.com/

FRANCE
World Bank Publications
66, avenue d'Iéna
75116 Paris
Tel: (33 1) 40-69-30-56/57
Fax: (33 1) 40-69-30-68

GERMANY
UNO-Verlag
Poppelsdorfer Allee 55
53115 Bonn
Tel: (49 228) 949020
Fax: (49 228) 217492
URL: http://www.uno-verlag.de
E-mail: unoverlag@aol.com

GREECE
Papasotiriou S.A.
35, Stournara Str.
106 82 Athens
Tel: (30 1) 364-1826
Fax: (30 1) 364-8254

HAITI
Culture Diffusion
5, Rue Capois
C.P. 257
Port-au-Prince
Tel: (509) 23 9260
Fax: (509) 23 4858

HONG KONG, MACAO
Asia 2000 Ltd.
Sales & Circulation Department
Seabird House, unit 1101-02
22-28 Wyndham Street, Central
Hong Kong
Tel: (852) 2530-1409
Fax: (852) 2526-1107
E-mail: sales@asia2000.com.hk
URL: http://www .asia2000.com.hk

HUNGARY
Euro Info Service
Margitszgeti Europa Haz
H-1138 Budapest
Tel: (36 1) 111 6061
Fax: (36 1) 302 5035
E-mail: euroinfo@mail.matav.hu

INDIA
Allied Publishers Ltd.
751 Mount Road
Madras - 600 002
Tel: (91 44) 852-3938
Fax: (91 44) 852-0649

INDONESIA
Pt. Indira Limited
Jalan Borobudur 20
P.O. Box 181
Jakarta 10320
Tel: (62 21) 390-4290
Fax: (62 21) 390-4289

IRAN
Ketab Sara Co. Publishers
Khaled Eslamboli Ave., 6th Street
Delafrooz Alley No. 8
P.O. Box 15745-733
Tehran 15117
Tel: (98 21) 8717819; 8716104
Fax: (98 21) 8712479
E-mail: ketab-sara@neda.net.ir

Kowkab Publishers
P.O. Box 19575-511
Tehran
Tel: (98 21) 258-3723
Fax: (98 21) 258-3723

IRELAND
Government Supplies Agency
Oifig an tSoláthair
4-5 Harcourt Road
Dublin 2
Tel: (353 1) 661-3111
Fax: (353 1) 475-2670

ISRAEL
Yozmot Literature Ltd.
P.O. Box 56055
3 Yohanan Hasandlar Street
Tel Aviv 61560
Tel: (972 3) 5285-397
Fax: (972 3) 5285-397

R.O.Y. International
PO Box 13056
Tel Aviv 61130
Tel: (972 3) 5461423
Fax: (972 3) 5461442
E-mail: royil@netvision.net.il

Palestinian Authority/Middle East
Index Information Services
P.O.B. 19502 Jerusalem
Tel: (972 2) 6271219
Fax: (972 2) 6271634

ITALY
Licosa Commissionaria Sansoni SPA
Via Duca Di Calabria, 1/1
Casella Postale 552
50125 Firenze
Tel: (55) 645-415
Fax: (55) 641-257
E-mail: licosa@ftbcc.it
URL: http://www .ftbcc.it/licosa

JAMAICA
Ian Randle Publishers Ltd.
206 Old Hope Road, Kingston 6
Tel: 876-927-2085
Fax: 876-977-0243
E-mail: irpl@colis.com

JAPAN
Eastern Book Service
3-13 Hongo 3-chome, Bunkyo-ku
Tokyo 113
Tel: (81 3) 3818-0861
Fax: (81 3) 3818-0864
E-mail: orders@svt-ebs.co.jp
URL: http://www .bekkoame.or.jp/~svt-ebs

KENYA
Africa Book Service (E.A.) Ltd.
Quaran House, Mfangano Street
P.O. Box 45245
Nairobi
Tel: (254 2) 223 641
Fax: (254 2) 330 272

KOREA, REPUBLIC OF
Daejon Trading Co. Ltd.
P.O. Box 34, Youida, 706 Seoun Bldg
44-6 Youido-Dong, Yeongchengpo-Ku
Seoul
Tel: (82 2) 785-1631/4
Fax: (82 2) 784-0315

MALAYSIA
University of Malaya Cooperative Bookshop, Limited
P.O. Box 1127
Jalan Pantai Baru
59700 Kuala Lumpur
Tel: (60 3) 756-5000
Fax: (60 3) 755-4424

MEXICO
INFOTEC
Av. San Fernando No. 37
Col. Toriello Guerra
14050 Mexico, D.F.
Tel: (52 5) 624-2800
Fax: (52 5) 624-2822
E-mail: infotec@rtn.net.mx
URL: http://rtn.net.mx

NEPAL
Everest Media International Services (P.) Ltd.
GPO Box 5443
Kathmandu
Tel: (977 1) 472 152
Fax: (977 1) 224 431

NETHERLANDS
De Lindeboom/InOr-Publikaties
P.O. Box 202, 7480 AE Haaksbergen
Tel: (31 53) 574-0004
Fax: (31 53) 572-9296
E-mail: lindeboo@worldonline.nl
URL: http://www .worldonline.nl/~lindeboo

NEW ZEALAND
EBSCO NZ Ltd.
Private Mail Bag 99914
New Market
Auckland
Tel: (64 9) 524-8119
Fax: (64 9) 524-8067

NIGERIA
University Press Limited
Three Crowns Building Jericho
Private Mail Bag 5095
Ibadan
Tel: (234 22) 41-1356
Fax: (234 22) 41-2056

NORWAY
NIC Info A/S
Book Department, Postboks 6512 Etterstad
N-0606 Oslo
Tel: (47 22) 97-4500
Fax: (47 22) 97-4545

PAKISTAN
Mirza Book Agency
65, Shahrah-e-Quaid-e-Azam
Lahore 54000
Tel: (92 42) 735 3601
Fax: (92 42) 576 3714

Oxford University Press
5 Bangalore Town
Sharae Faisal
PO Box 13033
Karachi-75350
Tel: (92 21) 446307
Fax: (92 21) 4547640
E-mail: ouppak@TheOffice.net

Pak Book Corporation
Aziz Chambers 21, Queen's Road
Lahore
Tel: (92 42) 636 3222; 636 0885
Fax: (92 42) 636 2328
E-mail: pbc@brain.net.pk

PERU
Editorial Desarrollo SA
Apartado 3824, Lima 1
Tel: (51 14) 285380
Fax: (51 14) 286628

PHILIPPINES
International Booksource Center Inc.
1127-A Antipolo St, Barangay, Venezuela
Makati City
Tel: (63 2) 896 6501; 6505; 6507
Fax: (63 2) 896 1741

POLAND
International Publishing Service
Ul. Piekna 31/37
00-677 Warzawa
Tel: (48 2) 628-6089
Fax: (48 2) 621-7255
E-mail: books%ips@ikp.atm.com.pl
URL: http://www .ipscg.waw.pl/ips/export/

PORTUGAL
Livraria Portugal
Apartado 2681, Rua Do Carmo 70-74
1200 Lisbon
Tel: (1) 347-4982
Fax: (1) 347-0264

ROMANIA
Compani De Librarii Bucuresti S.A.
Str. Lipscani no. 26, sector 3
Bucharest
Tel: (40 1) 613 9645
Fax: (40 1) 312 4000

RUSSIAN FEDERATION
Isdatelstvo <Ves Mir>
9a, Lolpachniy Pereulok
Moscow 101831
Tel: (7 095) 917 87 49
Fax: (7 095) 917 92 59

SINGAPORE, TAIWAN, MYANMAR, BRUNEI
Asahgate Publishing Asia Pacific Pte. Ltd.
41 Kallang Pudding Road #04-03
Golden Wheel Building
Singapore 349316
Tel: (65) 741-5166
Fax: (65) 742-9356
E-mail: ashgate@asianconnect.com

SLOVENIA
Gospodarski Vestnik Publishing Group
Dunajska cesta 5
1000 Ljubljana
Tel: (386 61) 133 83 47; 132 12 30
Fax: (386 61) 133 80 30
E-mail: repansekj@gvestnik.si

SOUTH AFRICA, BOTSWANA
For single titles:
Oxford University Press Southern Africa
Vasco Boulevard, Goodwood
P.O. Box 12119, N1 City 7463
Cape Town
Tel: (27 21) 595 4400
Fax: (27 21) 595 4430
E-mail: oxford@oup.co.za

For subscription orders:
International Subscription Service
P.O. Box 41095
Craighall
Johannesburg 2024
Tel: (27 11) 880-1448
Fax: (27 11) 880-6248
E-mail: iss@is.co.za

SPAIN
Mundi-Prensa Libros, S.A.
Castello 37
28001 Madrid
Tel: (34 1) 431-3399
Fax: (34 1) 575-3998
E-mail: libreria@mundiprensa.es
URL: http://www .mundiprensa.es/

Mundi-Prensa Barcelona
Consell de Cent, 391
08009 Barcelona
Tel: (34 3) 488-3492
Fax: (34 3) 487-7659
E-mail: barcelona@mundiprensa.es

SRI LANKA, THE MALDIVES
Lake House Bookshop
100, Sir Chittampalam Gardiner Mawatha
Colombo 2
Tel: (94 1) 32105
Fax: (94 1) 432104
E-mail: LHL@sri.lanka.net

SWEDEN
Wennergren-Williams AB
P. O. Box 1305
S-171 25 Solna
Tel: (46 8) 705-97-50
Fax: (46 8) 27-00-71
E-mail: mail@wwi.se

SWITZERLAND
Librairie Payot Service Institutionnel
Côtes-de-Montbenon 30
1002 Lausanne
Tel: (41 21) 341-3229
Fax: (41 21) 341-3235

ADECO Van Diermen EditionsTechniques
Ch. de Lacuez 41
CH1807 Blonay
Tel: (41 21) 943 2673
Fax: (41 21) 943 3605

THAILAND
Central Books Distribution
306 Silom Road
Bangkok 10500
Tel: (66 2) 235-5400
Fax: (66 2) 237-8321

TRINIDAD & TOBAGO, AND THE CARRIBBEAN
Systematics Studies Unit
9 Watts Street
Curepe
Trinidad, West Indies
Tel: (809) 662-5654
Fax: (809) 662-5654
E-mail: tobe@trinidad.net

UGANDA
Gustro Ltd.
PO Box 9997, Madhvani Building
Plot 16/4 Jinja Rd.
Kampala
Tel: (256 41) 251 467
Fax: (256 41) 251 468
E-mail: gus@swiftuganda.com

UNITED KINGDOM
Microinfo Ltd.
P.O. Box 3, Alton, Hampshire GU34 2PG
England
Tel: (44 1420) 86848
Fax: (44 1420) 89889
E-mail: wbank@ukminfo.demon.co.uk
URL: http://www .microinfo.co.uk

VENEZUELA
Tecni-Ciencia Libros, S.A.
Centro Cuidad Comercial Tamanco
Nivel C2, Caracas
Tel: (58 2) 959 5547; 5035; 0016
Fax: (58 2) 959 5636

ZAMBIA
University Bookshop, University of Zambia
Great East Road Campus
P.O. Box 32379
Lusaka
Tel: (260 1) 252 576
Fax: (260 1) 253 952

ZIMBABWE
Longman Zimbabwe (Pvt.)Ltd.
Tourle Road, Ardbennie
P.O. Box ST125
Southerton
Harare
Tel: (263 4) 6216617
Fax: (263 4) 621670

08/18/97

No. 345 Industry and Mining Division, Industry and Energy Department, *A Mining Strategy for Latin America and the Caribbean*

No. 346 Psacharopoulos and Nguyen, *The Role of Government and the Private Sector in Fighting Poverty*

No. 347 Stock and de Veen, *Expanding Labor-based Methods for Road Works in Africa*

No. 348 Goldstein, Preker, Adeyi, and Chellaraj, *Trends in Health Status, Services, and Finance: The Transition in Central and Eastern Europe, Volume II, Statistical Annex*

No. 349 Cummings, Dinar, and Olson, *New Evaluation Procedures for a New Generation of Water-Related Projects*

No. 350 Buscaglia and Dakolias, *Judicial Reform in Latin American Courts: The Experience in Argentina and Ecuador*

No. 351 Psacharopoulos, Morley, Fiszbein, Lee, and Wood, *Poverty and Income Distribution in Latin America: The Story of the 1980s*

No. 352 Allison and Ringold, *Labor Markets in Transition in Central and Eastern Europe, 1989-1995*

No. 353 Ingco, Mitchell, and McCalla, *Global Food Supply Prospects, A Background Paper Prepared for the World Food Summit, Rome, November 1996*

No. 354 Subramanian, Jagannathan, and Meinzen-Dick, *User Organizations for Sustainable Water Services*

No. 355 Lambert, Srivastava, and Vietmeyer, *Medicinal Plants: Rescuing a Global Heritage*

No. 356 Aryeetey, Hettige, Nissanke, and Steel, *Financial Market Fragmentation and Reforms in Sub-Saharan Africa*

No. 357 Adamolekun, de Lusignan, and Atomate, editors, *Civil Service Reform in Francophone Africa: Proceedings of a Workshop Abidjan, January 23-26, 1996*

No. 358 Ayres, Busia, Dinar, Hirji, Lintner, McCalla, and Robelus, *Integrated Lake and Reservoir Management: World Bank Approach and Experience*

No. 360 Salman, *The Legal Framework for Water Users' Associations: A Comparative Study*

No. 361 Laporte and Ringold. *Trends in Education Access and Financing during the Transition in Central and Eastern Europe.*

No. 362 Foley, Floor, Madon, Lawali, Montagne, and Tounao, *The Niger Household Energy Project: Promoting Rural Fuelwood Markets and Village Management of Natural Woodlands*

No. 364 Josling, *Agricultural Trade Policies in the Andean Group: Issues and Options*

No. 365 Pratt, Le Gall, and de Haan, *Investing in Pastoralism: Sustainable Natural Resource Use in Arid Africa and the Middle East*

No. 366 Carvalho and White, *Combining the Quantitative and Qualitative Approaches to Poverty Measurement and Analysis: The Practice and the Potential*

No. 367 Colletta and Reinhold, *Review of Early Childhood Policy and Programs in Sub-Saharan Africa*

No. 368 Pohl, Anderson, Claessens, and Djankov, *Privatization and Restructuring in Central and Eastern Europe: Evidence and Policy Options*

No. 369 Costa-Pierce, *From Farmers to Fishers: Developing Reservoir Aquaculture for People Displaced by Dams*

No. 370 Dejene, Shishira, Yanda, and Johnsen, *Land Degradation in Tanzania: Perception from the Village*

No. 371 Essama-Nssah, *Analyse d'une répartition du niveau de vie*

No. 373 Onursal and Gautam, *Vehicular Air Pollution: Experiences from Seven Latin American Urban Centers*

No. 374 Jones, *Sector Investment Programs in Africa: Issues and Experiences*

No. 375 Francis, Milimo, Njobvo, and Tembo, *Listening to Farmers: Participatory Assessment of Policy Reform in Zambia's Agriculture Sector*

No. 376 Tsunokawa and Hoban, *Roads and the Environment: A Handbook*

No. 377 Walsh and Shah, *Clean Fuels for Asia: Technical Options for Moving toward Unleaded Gasoline and Low-Sulfur Diesel*

No. 382 Barker, Tenenbaum, and Woolf, *Governance and Regulation of Power Pools and System Operators: An International Comparison*

No. 383 Goldman, Ergas, Ralph, and Felker, *Technology Institutions and Policies: Their Role in Developing Technological Capability in Industry*

No. 385 Rowat, Lubrano, and Porrata, *Competition Policy and MERCOSUR*

No. 386 Dinar and Subramanian, *Water Pricing Experiences: An International Perspective*

No. 387 Oskarsson, Berglund, Seling, Snellman, Stenbäck, and Fritz, *A Planner's Guide for Selecting Clean-Coal Technologies for Power Plants*

No. 388 Sanjayan, Shen, and Jansen, *Experiences with Integrated-Conservation Development Projects in Asia*

No. 389 International Commission on Irrigation and Drainage (ICID), *Planning the Management, Operation, and Maintenance of Irrigation and Drainage Systems: A Guide for the Preparation of Strategies and Manuals*

THE WORLD BANK

1818 H Street, N.W.
Washington, D.C. 20433 USA

Telephone: 202-477-1234

Facsimile: 202-477-6391

Telex: MCI 64145 WORLDBANK
MCI 248423 WORLDBANK

World Wide Web: http://www.worldbank.org

E-mail: books@worldbank.org

ISBN 0-8213-4054-9