NBER WORKING PAPERS SERIES

INCOMPLETE APPROPRIABILITY OF R&D AND THE ROLE OF STRATEGIES AND CULTURAL FACTORS IN INTERNATIONAL TRADE: A JAPANESE CASE

Ryuzo Sato

Rama Ramachandran

Shunichi Tsutsui

Working Paper No. 3797

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
August 1991

Center for Japan-U.S. Business and Economic Studies, Leonard N. Stern School of Business, 100 Trinity Place, New York, NY 10006.
This paper is part of NBER's research program in International Studies.

NBER Working Paper #3797
August 1991

INCOMPLETE APPROPRIABILITY OF R&D AND THE ROLE OF STRATEGIES AND CULTURAL FACTORS IN INTERNATIONAL TRADE: A JAPANESE CASE

ABSTRACT

One of the proudest achievements of classical and neoclassical economics is the derivation of the superiority of free trade. This result is obtained by assuming constant returns to scale, perfect competition and absence of externalities. The recent realization that the incomplete appropriability of R&D is a main source of externalities and hence the effect of R&D on national welfare is potentially subject to strategic manipulations necessitates a careful examination of these assumptions. This paper discusses R&D and diffusion of technology in international trade from two different perspectives. In Section II, we consider the role of cultural, social and historical factors in the appropriation of technology by reviewing how Japan has appropriated foreign technology. In Section III, we survey three strategic trade models to obtain some insights into the role of R&D and diffusion of technology in the context of imperfect competition. The issues we discuss include the effectiveness of R&D polices by a national government and the impact of R&D policies and diffusion of technology on the incentive to do R&D and on the outcome of trade.

Rama Ramachandran
Shunichi Tsutsui
Center for Japan-U.S. Business and Economic Studies
Leonard N. Stern School of Business
100 Trinity Place
New York, NY 10006

Ryuzo Sato
Center for Japan-U.S. Business and Economic Studies
Leonard N. Stern School of Business
100 Trinity Place
New York, NY 10006
and NBER

I INTRODUCTION

One of the proudest achievements of classical and neoclassical economics is the derivation of the superiority of free trade. While the models of international trade differ in specifics, this result is common to all of them and is obtained by assuming constant returns to scale, perfect competition and absence of externalities. The empirical validity of these assumptions has been questioned for some time but the construction of theoretical models incorporating alternate assumptions began only within the last decade and half.

In the earlier models, there are no ambiguities in the benefits of trade as determined by exogenous differences in endowments or technology while, in the new models, they are open to strategic manipulations. This realization leads to a new line of research on the welfare implications of possible national policies. Even neoclassical models accept that the existence of externalities will make it desirable to impose tariffs or subsidies but, in their discussion, the extent of externalities is not determined exogenously by research policies or other endogenous variables. Recent theories identify one source of externalities: the incomplete appropriability of the results of R&D.[1]

The challenge to the neoclassical tradition has moved to a deeper level. The new models are able to endogenize technology only by abandoning simultaneously all three assumptions on which traditional trade theory is anchored. Derivations of welfare results are complicated by a host of factors that must be taken into consideration. Further, the separation between "economic" and "non-economic" factors in the neoclassical economic theory, based as it is on the methodological position that consumers and production units can be treated as black boxes, requires reexamination.

Technology is the core of the production process and the mastery it provides on material surroundings determines most aspects of the economic and some aspects of the non-economic structure of a society. While all this was evident from the time of the industrial revolution, the study of the dynamics of technology evolved slowly along three separate lines. The chronicling of the transformation of the society by economic historians is supplemented and supported by the studies in the history of technology. Industrial organization studies of technological change can be traced back to the seminal works of Hicks (1932), Schumpeter (1942) and Arrow (1962); the first examined the cost motives, the second, the influence of the market structure, and the last, the problem of appropriability. This last tradition arose in studies of international trade and development; it examines if the historical factors that determine the directions of trade through comparative advantage can be modified by the natural evolution of economies and through deliberate policies to promote economic development.

At any point of time, economies which are comparatively poorer are also exporters of raw materials and importers of finished goods.[2] Many of them strive to improve their economic condition by "industrialization". Their ability to achieve it with or without assistance from other nations, the appropriate methodology for doing so, and its consequences are all hotly debated in economic and political literature.

Even confined to the technological aspects of industrialization, the Gerschenkron thesis[3] is that, the greater the backlog of innovations that a country can take over from another, the larger the gap between economic potential and actualities of that economy and the greater the speed with which it can go through the development process. Of course, those nations whose technologies are being imitated do not view this process with equanimity. The Germans have criticized the English and were criticized in turn. The Western nations have, in the post-World War years, tried to circumscribe the ability of the Soviet union and its allies to acquire Western technology. In this case, at least it was accepted that basic research in the Soviet Union was up to Western standards. When it comes to Japan, the criticism is that the country has utilized the results of basic research which are in the public domain to generate applied technology and out-compete the nations that funded the basic sciences. In section III, we use recent strategic trade theory to model the effect of such externalities on the share of international markets.

Once the rate of generation of technology is recognized to have an effect on national welfare, the factors that determine it are subject to strategic manipulation. These factors frequently involve characteristics that are outside the purview of traditional economic analysis. In a recent survey[4], the following are discussed: life expectancy, nutrition, willingness to bear risks, geographical environment, path dependency, labor cost, science and technology, religion, values, property rights, resistance to innovation, politics and the state, war, openness to new information, and demographic factors. A similar set of factors is considered to determine the ability of one nation to learn from the economic systems of others. The early European explorers beheld with awe the Eastern civilizations that they discovered. But, as the industrial revolution progressed, the Atlantic economies began to overtake all others and soon European travelers seemed able to identify, in the visiting countries, the cultural, intellectual and physical deficiencies that explained their backwardness.[5] The growth of the Pacific basin reset the balance once more. As Japan joined the ranks of international economic powers, the criticisms that one European nation leveled against another that was catching up, were collectively directed against the Eastern competitor.

The paradigm of modern economics subsumes under individual rationality most of the cultural and social factors that influence human behavior; by assuming rationality, any discussion of these factors can be avoided. However critical one may be of such an approach, it would be blind not to recognize the vitality of the neoclassical tradition; the insights obtained from it have a great degree of validity. However, the recent realization that appropriability of R&D is the source of the externality necessitates a conscious examination of those influences that determine the generation and diffusion of technology. An analogy can be made with the revolution in value theory at the turn of last century. The then prevalent labor theory assumed that prices were determined by costs, and costs by labor input. In rejecting the anchoring of prices on given costs, the marginalist tradition had to base their model on demand, specified by exogenous tastes, and on supply specified by known technology. Today we realize that both tastes and technology are subject to strategic manipulations and are forced to look for forces that determine the degree of their manipulability. Section II reviews some current discussions that are relevant to Japan.

II JAPAN AND WESTERN TECHNOLOGY

The international diffusion of technology is the result of two reinforcing factors. The existence of differences provides an opportunity, as Gerschenkron pointed out, for nations that are lagging behind to accelerate their development. On the other hand, no nation has developed all the relevant technologies internally. If all the production sectors within a diversified economy are to remain efficient, then the economy has to import some of its technologies.

The diffusion, however, cannot be understood solely in terms of a technological gap. Even within a nation, the best technology frequently coexists with the less efficient ones. An industry, adjusting to the continuous evolution of techniques, should be best pictured as a moving spectrum; at any point it permits a variety of processes but the least productive ones are abandoned and more advanced ones added as the focal point of the spectrum shifts over time.

What is true within an economy is even more so for diffusion across national boundaries. Hence it is not surprising that we notice that even England at the height of her industrial revolution failed to adopt the latest technology.[6] The interplay of the technologies of European nations is recorded and analyzed by historians of technology. Early Western travelers to non-European countries tended to speak eloquently about the splendor of some of the nations they visited or deprecated the backwardness of others. In contrast, the earliest comments on Japan noted the willingness of its citizens to learn from foreigners. The Chinese influence on cultural and political development of Japan is well known.

In a historical study, Sugimoto and Swain (1989) divides the successive waves of cultural influx into Japan before the Meiji restoration into Chinese Wave 1, semiseclusion, and Chinese wave 2 (which overlaps with Western wave 1 and 2). In Chinese Wave 1, direct contact with China was established though <u>Kentoshi</u> missions and followed by the institutes under the <u>ritsuryo</u> system. The earliest of the eighteen missions were of a diplomatic nature but soon it became a means for the absorption of the T'ang culture with the student priests as the main conduit. The four institutions that were set up under the <u>ritsuryo</u> system are the University, the Institute of Divination, the Institute of Medicine and provincial colleges.

The three hundred years of cultural absorption (600 - 894) were followed by five centuries of semi-seclusion (894 - 1401). The University ceased to be a means for appointment of the higher administrative posts and was not rebuilt after it was destroyed by fire. Alternative educational institutions that arose included the departments of the University which became private institutions and the hereditary professorships that became houses of learning. Under the new arrangements, learning became a formalistic preservation of the earlier knowledge derived from Chinese sources. In the later part of this period, some contacts were permitted by the Kamakura regime and through pirate traders. The New Buddhism also encouraged medical studies along Chinese lines.

Chinese Cultural Wave II began when Japan signed the Tally Trade Agreement of 1401. The Ming Court in China at that time was not interested in expanding foreign contact but only in limiting the wako trade. The Japanese merchants and Buddhist priests showed more initiative. Within the country, the rise in the power of the daimyo (local lords) and their decision to move samurais to the castle towns had a profound effect both on the towns and on the surrounding villages.

Merchants and craftsmen followed the militia to the towns, leaving the villagers to provide raw material and foodstuffs. Soon there arose a pragmatic culture in the towns that encouraged secularization and specialization. Each daimyo had an interest in the expansion of mining and crafts within his realm and this encouraged an expansion of commodity production and exchange. The social conditions were favorable to the use of innovative techniques and the importation of books from China facilitated the acquisition of new skills.

The arrival of the Jesuits, with Portuguese backing, in 1543 opened the first contact of the West. The leaders of various military factions welcomed the foreigners as they saw of the benefits of obtaining firearms. Japan used its skills in making sword steel to master the manufacture of Western arquebus (gun with a hook) and began soon to export it. The

Japanese recognized the superiority of the Western ship architecture and navigational methods and were quick to adopt them; by 1610 local ships were only marginally smaller than contemporary Western ships. Similarly imported mercury was used to improve metallurgic refining.

The Jesuits introduced new educational institutions but they did not have a lasting impression due to the ban on books and the reintroduction of the isolation policy in the 1630's. While Japan was learning techniques at a practical level, its native educational institutions did not absorb the intellectual developments of the Renaissance era and the reimposition of the isolation policy resulted in losing much of the gains from the Western contacts.

The next period, 1639 to 1720, showed a flowering of Confucian scholarship and the rise of indigenous astronomy and mathematics. The Chinese influence was almost solely through the import of books, foreign travel being limited. The Confucian academies offered an attractive career for those without hereditary status and the new learning spread more as a result of private initiatives than through official patronage as in the earlier chinese wave. The Western influence disappeared altogether except in medicine where it was kept up by the Dutch. Techniques, particularly in shipbuilding and mining, regressed.

The pedantic traditions of the official Confucianism soon lost its vitality and led to the reintroduction of Western learning in the period, 1720 to 1854, just before the opening up of Japan. The period began with the partial lifting of the ban on books by Shogun Yoshimune (1716 - 1745). Like many other leaders at times of a cultural revolution, Yoshimune had an ambivalent attitude to new science and culture. A Confucian consultant to the shogun, Arai Hakuseki, had interrogated the Jesuit priest, Giovanni Sidotti, who smuggled himself into Japan in 1708 and was impressed by his knowledge. In a memorandum circulated among high officials, Hakuseki recommended a general relaxation on the ban on Western books but it was rejected by the shogun.

Meanwhile Yoshimune considered it among his traditional responsibilities to reform the calendar and it became clear to him that this cannot be achieved without importing books on Western astronomy written in Chinese by Jesuits. Hence he was convinced to permit importation of books not connected with Christianity. Ironically the first and partial calendar reform incorporating Western knowledge could not be achieved until 1798 and a full reform not until 1842; this was due to the delay in learning Newtonian mechanics.

As in Europe at the end of Scholasticism, so in Japan in this period we see a multi-faceted response to the new cultural threat. Some scholars tried to incorporate the new studies into the Confucian tradition. Others, like the schools of National Learning, sought to develop an indigenous tradition marrying classic Japanese texts with Shinto religion and rejecting everything foreign. The clearest break with the past can be said to have come in the field of medicine. Two Edo doctors performed a dissection on an woman who was executed in 1771 and noticed the superiority of a Dutch anatomical atlas they had, over the Confucian texts. Translations which they and their followers brought out led to an integrated western tradition in medicine, the Rangaku movement.

The pull and counterpull between the old and the new continued for some more years. The ban on all but the official school of Confucianism in 1790 was soon followed by the establishment of the "Office for the Translation of Barbarian Texts" in 1811; the Office became the "Center for Western Learning" in 1863. The peasant revolts that became common at the end of the Tokugawa shogunate, the arrival of the British frigate in

Nagasaki in 1808, and the British victory over the Chinese in the Opium War of 1840-42 paved way for the Third Western wave with the arrival of Commander Perry.

The changes that took place after the Meiji Restoration and the reconstruction of the Japanese economy after the Second World War are well recorded and need not be repeated here. The point to note is that the response and methods for transmission of the culture and technology into Japan differed from time to time. Study in China was the most important means for assimilation during the First Chinese Wave while imported books were the major channel in the Second Chinese Wave. Books was the main source of information on the developments in the West though Jesuit missionaries and Dutch tradesmen played a catalytic role. All this was interspersed with periods of isolation which provide historical couterfactuals to widely held beliefs on the nature of Japanese society. The Meiji Restoration increased both the channels and the inflow of foreign information.[7]

The multiplicity of channels and their varying importance have been noted for other countries also. Myllyntaus (1990) lists six factors and ranks their importance for six countries in the nineteenth century (see Table 1). Ichimura (1990) considers the recent experiences of three East Asian Nations (see Table 1).

Sweeny (1987) stresses information flows in Japanese companies. 66.6 per cent of the small and medium enterprises (SME) and 75.4 per cent of the large firms (LF) use business and technical periodicals as a source of technology. Other significant sources (used by 20 per cent or more of firms) of similar information for SMEs are parent companies, enterprises in the same business, and sample fairs. Parent companies and sample fairs are listed as important sources by LFs.(ibid, p. 153). Porter (1990) notes that Japanese companies have long invested heavily in attending foreign conferences, visiting friendly overseas companies, studying the literature, and licensing good technologies rather than attempting to duplicate them (ibid, pp. 397-8).

Dosai (1989, p. 1122) shows that both Japan and the United States spent about the same percentage of GNP on R&D but the growth rate of R&D in Japan during the years 1969 to 1983 was well in excess of that of the United States. Another noticeable difference is in the percentage of business-financed and business-performed R&D. It may partly reflect the manner in which the two governments subsidize research; in Japan, tax subsidies play a greater role than direct subsidies.

Sato (1988) breaks up the R&D expenditure into basic, applied and development expenditure. He notes that the level of expenditure on basic research in Japan declined from 1973 to 1975, remained flat till 1979, and the grew at a fast rate to the 1973 level by 1981. Since the percentage of GDP spent is the same in both countries, the cumulative expenditure on basic research as a percentage of the GDP for the period 1973 to 1983 must be substantially less in Japan than in the U.S. In this sense, Japan can be said to have benefited from the public good nature of basic research in the U.S. Bernstein and Nadiri (1989) argue that the spillover effects reduce R&D investment by the receiving firms. On the other hand, Deolalikar and Evenson (1988) have estimated that Indian firms' elasticity of R&D investment with respect to the U.S. investment in basic research is unity in light industries, greater than two in chemical industries and not significantly different from zero in engineering industries. It is therefore clear that quantitative studies do not give, at this stage, a conclusive answer on the nature of the spillover effects.

111 STRATEGIC TRADE AND R&D: AN INTRODUCTORY ACCOUNT

This section is divided into two subsections. In Subsection 1, we discuss the factors which are not consistent with traditional theories but play an important role in explaining two-way trade (the exchanges of similar goods) which is a large and growing part of the current trade among industrialized countries. In Subsection 2, we discuss three strategic trade models developed by Spencer and Brander (1983), Beath et al. (1989) and Sato and Tsutsui (1987) in order to deepen our insight into the complex issues of technological innovation in trade. In the first model, we discuss the role of R&D subsidy in a highly stylized framework, focusing on how R&D subsidy changes the outcome of trade under duopolistic competition. In the second model, we investigate the incentive of R&D investment and the role of R&D policies when firms are engaged in a risky R&D race to be the first to introduce new technology. In the last model, R&D is thought of as a continuous process and a distinction is made between basic knowledge and applied knowledge. The firms may differ in efficiency of the applied knowledge production. Given the information structures of the firms, we study how the diffusion of the basic knowledge and the difference in efficiency of the applied knowledge production affect the outcome of trade.

1. Departure From Traditional Theories

It is not difficult to see that the non-interventionist trade policy has its foundation on one of the important results in economics. That is, perfect competition is efficient or a system of markets, when each market is perfectly competitive, can achieve the most (Pareto) efficient allocation of resources.

There are a number of conditions which have to be met for a perfectly competitive market to prevail. They include the access to relevant information, and the absence of externalities and public goods. Further, each firm is required to takes prices as exogenously given by the market, believing that it has no influence on market prices so that it can sell whatever amount it wants to. Furthermore, free entry and free exit are required so that no excess profits will be reaped by firms.

The assumption of perfect competition and its derivative that markets do not deviate from it very much have been the core assumptions used in most of traditional economic analysis. Of course, no one denies that such assumptions remain a good approximation for some markets and industries. However, as noted before, the recent pattern of international trade makes it increasingly difficult to accept them as appropriate working assumptions. A large and growing part of current trade, as evidenced with the extensive two-way trade among industrialized nations, seems to be generated by factors which are not quite consistent with the conditions of perfect competition. Among them are the advantages of large-scale production, the advantages of cumulative learning and experience, the temporary advantages created by technological innovation, and imperfect competition. These factors are important characteristics of many manufacturing industries and are easily found in the real world. It is instructive as well as informative to consider how the incorporation of these factors affects our understanding of trade.

First, we need to take into account a dynamic aspect of trade. The advantages of cumulative learning and experience, and the advantages generated by technological innovation not only depicts how the cost structure of a firm changes over time, but also make it possible that the firm can actively influence its cost structure over time through some kinds of economic activities. We consider R&D one of the most important among those activities.

The incorporation of a dynamic dimension into trade makes a stark contrast with the traditional static view on this matter, and consequently, at least in the short run, there arises the possibility that firms earn excess profits above the normal return. But the presence of such excess profits need not be regarded as a manifestation of inefficient resource allocation since it can assume a new role of financing R&D to further cost reduction in the future - the view that was vigorously advanced by Schumpeter (1942).

Second, the consideration of imperfect competition opens up the possibility that firms can act <u>strategically</u>. Under imperfect competition, an individual firm faces a few identifiable rivals in the market or industry and no longer acts as a price taker because it knows what it does affects the market price and thus the behavior of rival firms in the same market. Thus a firm can act strategically in the sense that it takes into account how its behavior affects the behavior of its rivals and how the behavior of the rivals affects its behavior.

The incorporation of strategic interaction makes it necessary for us to adopt the game theoretic approach as in industrial organization in which oligopoly - an intermediate case between perfect competition and pure monopoly - is a main subject.

A type of game is classified in a number of ways, depending on what aspect of the game's structure one looks at. For example, static vs. sequential games; games with perfect information vs. games with imperfect or incomplete information; continuous time vs. discrete time games; deterministic vs. stochastic games. In a static game, every player (the term for a decision maker in the game theory) moves simultaneously and only once, while in a sequential game, some or all players are allowed to move sequentially or more than once in the course of play. In a game with perfect information, every player can perfectly observe all of the past moves including chance moves, while in a game with imperfect or incomplete information, some or all players cannot. In a continuous time game, moves can be made continuously in time, while in a discrete time game, moves can only be made discretely in time. In a deterministic game, no random element is present in the relationship between moves and payoffs, while in a stochastic game, there are some elements which affect players' payoffs randomly. The choice of a particular type of game, of course, depends on what the researcher regards as the most important element in the strategic interaction under investigation.

Game theory has proved to be a very powerful tool in the analysis of strategic interaction, being applied to many areas of economic studies including industrial organization, macroeconomics and resource economics. However, it is worth noting that the game theoretic approach is not without a problem. One problem is concerned with the limitations of game theory. As Binmore (1990) discusses, the standard assumptions used in the game theory regarding common knowledge and rationality of players have difficulties in their relevance to the reality, yet play a crucial role in analyzing games. Another problem is concerned with how to model strategic interaction. It matters greatly what elements one incorporates in the game. Adding new elements such as sequential moves and imperfect or incomplete information makes the game more realistic, but it can give rise to results which are significantly different from those without them.[8] As a result, great care has to be taken in modeling strategic interactions and interpreting the results of the game.

2.1 R&D SUBSIDY

We first discuss the model of Spencer and Brander (1983).[9] This model illustrates the important and interesting role of R&D subsidy in strategic international trade in the simplest possible framework.

Suppose that there are two firms, one domestic and one foreign, producing a homogeneous product and selling all of their output in a world market which is entirely contained in other countries. Note that with this assumption, we can equate the domestic firm's profits to the domestic country's welfare, and hence the objective of the domestic government is reduced simply to promote the domestic firm's profits, assuming that the domestic government is concerned only with the national welfare.

With only two firms in the market, each firm acts strategically, recognizing that its profits significantly depend on what its rival does - the emergence of strategic interaction. To proceed with the analysis, more has to be specified. It is supposed that output is a firm's choice or strategic variable. In this case, the situation facing the firms is called a quantity-setting (Cournot) game. The consideration of output as a strategic variable, however, is not the only way to model the strategic situation. It may be appropriate if quantities are set by physical capacity constraints but inappropriate if firms can choose prices as their strategic variables. It is also supposed that the firms set their output once and for all. This amounts to neglecting the possibility that the firm changes its output at a future time and thus any possibility that the firm can induce collusion with its rival by means of future retaliation. Finally, it is assumed that both firms make their output decision simultaneously.

Under these assumptions, we consider our quantity-setting game. As Brander (1987) argues, each firm knows that it could earn greater profits if it could persuade or force its rival to cut back on output, since the output contraction of its rival firm raises the market price and thus the firm's profits even without any change in the firm's output. So the firm might try to induce the contraction of output or for that matter the exit of its rival from the market by threatening to produce a large output. However, it is difficult to see why one firm, intimidated by such a threat, should be forced to contract the output, since the other firm is well aware that by simply matching the increase, it can induce a price war - the outcome which is not in the best interest of the threatening firm. This argument shows that it is necessary in equilibrium that no aggressive threat by one firm should not be believed by the other. In the terminology of game theory, it implies that we need to consider a Nash equilibrium of the quantity-setting game. Formally, Nash equilibrium requires that at this equilibrium, a unilateral deviation of the firm does not strictly improve its profits.

Now we modify the quantity-setting game so that both firms are engaged in R&D as an effort to improve their production efficiency. Suppose that only the domestic firm succeeds and that the successful R&D makes it possible for the costs of producing an additional unit of output to be substantially reduced (i.e., lowered marginal cost). Suppose further that the foreign firm knows its rival's success. We are interested in how the Nash equilibrium will be affected by this. It is straightforward to see that it is in the best interest of the domestic firm to expand its output. In fact, given the output of the foreign firm, the marginal profits, the difference between the additional revenue from selling an additional unit of output (i.e., marginal revenue) and the marginal cost, are now positive for the domestic firm due to the lowered marginal cost. This gives the domestic firm an incentive to increase its output. The process of output expansion continues as long as the domestic firm's marginal profits are positive.

The next question is how the foreign firm reacts to this output expansion. For this firm, the central issue is whether this output expansion constitutes a non-credible threat. However, knowing the success of the domestic firm and thus its underlying incentive, the output expansion by the domestic firm is no longer mistaken as a non-credible threat to the foreign firm. The domestic firm's success induces the foreign firm to contract its output. To see this, suppose on the contrary that the foreign firm does not respond to the output expansion. Since the output expansion increases total output, it reduces both firms' marginal revenue. Because the foreign firm's marginal cost remains the same as before and because the foreign firm's marginal profits was zero before the output expansion, the foreign firm's marginal profits becomes negative after the output expansion. This gives the foreign firm an incentive to contract its output.

Combined with these two effects, we can conclude that the domestic firm produces more and the foreign firm produces less in the new Nash equilibrium than in the original Nash equilibrium.

Suppose now that both firms are not engaged in R&D originally, but the domestic government can always entice the domestic firm to engage in R&D by providing R&D subsidy. Moreover suppose that there is no uncertainty in the link between R&D subsidy and the outcome of R&D, so that the domestic government can make it possible to reduce the domestic firm's marginal cost through the R&D subsidy. There are two effects of the R&D subsidy. One effect is the cost saving but in effect is just a transfer from the domestic government to the domestic firm. Thus this effect has no impact of the national welfare. But there is another effect to be taken into account. The R&D subsidy, in the eye of the foreign firm, works exactly the same as the domestic firm's discovery of producing output at lower marginal cost.[10] Hence the expansion of output by the domestic firm is credible to the foreign firm.[11] As a result, the domestic firm earns more profits and the foreign firm earns less profits. The net effect of the R&D subsidy is that the profits of the domestic firm rise more than the amount of the R&D subsidy - the phenomenon known as profit shifting.

2.2 R&D COMPETITION AND UNCERTAINTY

We now consider the model of Beath et al. (1989). This model sheds a light on the nature of R&D investment and its relationship to the success of R&D. In particular, it focuses on the two important factors which are absent in Spencer and Brander (1983). The first is about a risky character of R&D investment. In Spencer and Brander (1983), there is no qualitative difference between R&D investment and ordinary capital investment. In reality, however, the former is different in essential ways from the latter in the sense that the success of R&D is not a deterministic function of R&D investment. The second is that firms are frequently engaged in a R&D race to be the first to introduce some new technology or product. These two factors significantly affect the incentive of individual firm to do R&D investment and hence the role of R&D subsidy. Beath et al. (1989) examine the relation between R&D subsidy and the outcome of the R&D race in the presence of those two factors.

The model distinguishes two types of the firm's R&D investment incentives, competitive and non-competitive incentives. The competitive incentive is defined to be the rate of R&D investment chosen by a firm when its rival firm chooses the infinite rate of R&D investment. It measures how much R&D investment a firm is willing to do when its rival firm tries to innovate successfully instantaneously. On the other hand, the non-competitive incentive is defined to be the rate of R&D investment chosen by a firm when its rival firm chooses the zero rate of R&D investment, measuring how much R&D investment a firm is ready to do when its rival firm is not engaged in the R&D race.

A determinant of the relative magnitude of these incentives is found to be the ease of imitation which is defined to be difference between a firm's profits if it innovates before its rival, and the profits it would make if its rival innovated first. If the ease of imitation is very low (for example, the new invention is protected by a highly effective patent), then the competitive incentive is greater than the non-competitive one. In this case, Beath et al. (1989) find that a firm's R&D investment rate is positively related to its rival firm's and that given the firm's R&D investment rate, the firm prefers its rival firm to do less R&D because less R&D by the rival firm enhances the firm's chance of becoming the first to invent and thus secures the relatively high benefits of the new invention.

On the other hand, if the ease of imitation is very high (for example, the new invention is not patentable), then the non-competitive incentive outweighs the competitive one. It is shown that the firm is motivated to reduce R&D investment as its rival firm increases its R&D investment and that given the firm's R&D investment rate, the firm prefers its rival firm to do more R&D because this makes it possible for the firm to reap the relatively high benefits of being an imitator by letting the rival firm bear the costs of the new invention.

The characterization of a Nash equilibrium is fairly straightforward. Suppose that the competitive incentive dominates the non-competitive one for both firms. Then both firms' R&D reaction curves are upward sloping and the outcome of overinvestment in R&D emerges in the Nash equilibrium. Subsidizing the domestic firm in this case will obviously lead to the expansion of the domestic firm's R&D investment. But it also lead to the expansion of the foreign firm's R&D investment instead to the contraction of the foreign firm's R&D investment. The reason is that the foreign firm tries not to be outcompeted in the R&D race. Since the expansion of both firms' R&D investment will reduce both firms' (expected) profits, there arises no profit shifting. Clearly taxing the domestic firm is called for to improve the domestic welfare in this context.

Suppose now that the non-competitive incentive dominates the competitive one for both firms. Then both firms' R&D reaction curves are downward sloping, so that the outcome of underinvestment in R&D appears in the Nash equilibrium. The domestic government is motivated to let the foreign firm do more R&D and bear the costs of the new invention so that the domestic firm will be able to enjoy the benefits of being an imitator. This is not, however, achievable by subsidizing the domestic firm. We notice that subsidizing the domestic firm will lead to the expansion of the domestic firm's R&D investment and to the contraction of the foreign firm's R&D investment. Unlike Spencer and Brander (1983), these changes in the firms' R&D investment will not necessarily increase the domestic firm's (expected) profits, because each firm prefers to let the other firm bear the costs of the new invention. In fact, subsidizing the domestic firm allows the foreign firm to relax its R&D and effectively lets the domestic firm bear the costs. Hence subsidizing the domestic firm is not necessarily welfare improving.

Finally, Beath et al. (1989) point out that subsidizing the domestic firm is potentially beneficial for the domestic country only when two countries differ in their ease of imitation.

2.3 DIFFUSION OF TECHNOLOGY

We consider the model of Sato and Tsutsui (1987) (see also Sato (1988)). They depart from Spencer and Brander (1983) and Beath et al. (1989) by taking the view that a firm's long-run competitiveness is determined by incremental improvements of production efficiency rather than by one-time gains brought about by a single successful new invention. Consequently in the model, R&D activities are thought of as the process of creating new knowledge and the creation of new knowledge is supposed to take place continuously. There are two important characteristics in the model that are absent in the previous two models. First, as newly created knowledge, the outcome of R&D investment has all the complications associated with information goods. Among them, the model focuses on spillovers of knowledge. The spillovers of new knowledge benefit not only the producer of the new knowledge but also those who are not directly engaged in that knowledge production and hence affect the firm's incentive to do R&D investment, creating a free-rider problem. It is to be noted that the model considers the spillovers in the context of continuous knowledge production.

Second, two types of knowledge, basic and applied, are considered. The distinction between them is made based on how easily knowledge can be diffused. The introduction of two types of knowledge is motivated by capturing the fact that the government's R&D subsidy is often concentrated on the technology areas which have the broadest social applicability (i.e., the greatest spillover effect) and the fact that as the development of video cassette recorders for household use illustrates brilliantly, the original idea of VCR (basic knowledge) is quite different from the production technology (applied knowledge) that makes it possible to produce VCR inexpensively.

The firms are engaged in both basic and applied knowledge production. Basic knowledge is characterized as having a strong tendency to spill over, while applied knowledge, regarded more as firm specific knowledge, has a weak tendency to spill over. The production of knowledge as well as output is assumed to take place continuously. In order to focus on the impact of spillover effect of the basic knowledge, it is assumed that only the domestic firm is engaged in the production of the basic knowledge. But the model allows for the possibility that the costs of the basic knowledge production are shared by both the domestic and foreign firms and for the possibility that the efficiency of producing the applied knowledge may vary between the firms.

These assumptions in the model are intended to reflect the reality that some firms tend to excel relatively in the basic knowledge production while others are known to excel relatively in the applied knowledge production. Sato and Tsutsui (1987) examine how the long-run competitiveness of firms are determined when the firms differ in the abilities in producing the applied and basic knowledge and when the basic knowledge spills over.

Since firms are engaged in output and knowledge production, the instantaneous profits of a firm is equal to revenue minus costs of output production minus the costs of the applied knowledge and basic knowledge production. Both the domestic and foreign firms maximizes their discounted sum of instantaneous profits over an infinite planning horizon. In particular, the domestic firm maximizes

$$J_d = \int_0^\infty e^{-rt}[P(q_d+q_f)q_d - C_d q_d - S(C_d,u_d,B) - (1-\sigma)T(B,v)]dt,$$

and the foreign firm maximizes

$$J_f = \int_0^\infty e^{-rt}[P(q_d+q_f)q_f - C_f q_f - \epsilon S(C_f,u_f,\delta B) - \sigma T(B,v)]dt.$$

The notations are as follows. r is a common discount rate. q_i is firm i's output ($i = d, f$). C_i is firm i's effective marginal cost, which is inversely related to the level of the applied knowledge. B is the level of the basic knowledge of the domestic firm. u_i is the rate of change in C_i (i.e., $u_i = dC_i/dt$). v is the rate of change in B (i.e., $v = dB/dt$). Since it is assumed for simplicity that the firms produce homogeneous output, $P(\cdot)$ denotes the inverse demand. Lastly, $S(\cdot, u_i, \cdot)$ is the costs of reducing the effective marginal cost in terms of u_i and $T(\cdot, v)$ is the costs of producing the basic knowledge in terms of v. It is assumed that $S(\cdot,\cdot,\cdot)$ and $T(\cdot,\cdot)$ are convex in their arguments, so that as the levels of applied knowledge and basic knowledge become higher, their incremental increase becomes increasingly more costly.

The parameters σ, δ and ϵ are introduced to specify, respectively, how the foreign firm shares the costs of the basic knowledge production with the domestic firm, to what extent the basic knowledge diffuses from the domestic firm to the foreign firm, and how relatively efficient the applied knowledge production of the foreign firm.

The parameters σ and δ are required to satisfy $0 \leq \sigma \leq 1$ and $0 \leq \delta \leq 1$, while the parameter ϵ needs only to be non-negative. Comments are useful for some values of these parameters in order to clarify their meanings. If $\sigma = 0$, the foreign firm does not share the costs of the basic knowledge production with the domestic firm; if $\sigma = 1/2$, the foreign firm shares the costs equally with the domestic firm; if $\sigma = 1$, the foreign firm pays all the costs of the basic knowledge production. If $\delta = 0$, there is no diffusion of the basic knowledge from the domestic firm to the foreign firm; if $\delta = 1$, the diffusion is perfect in the sense that the level of the basic knowledge of the foreign firm is always equal to that of the domestic firm. If $\epsilon < 1$, then the efficiency of the applied knowledge production of the foreign firm is relatively higher than that of the domestic firm; if ϵ

= 1, the both firms have the same efficiency; if $\epsilon > 1$, the domestic firm has relatively higher efficiency.

The technology game that is discussed in the model can be divided into two stages. In the first stage, the value of the parameter σ can be determined. In the second stage, the firms choose their control variables over an infinite planning horizon. The domestic firm's control variables are q_d (output), u_d (the rate of change in the effective marginal cost) and v (the rate of change in the level of the basic knowledge), while the foreign firm's control variables are q_f (output) and u_f (the rate of change in the effective marginal cost). The parameter σ is conceptually an endogenous variable and its value is likely to be determined as an outcome of the negotiation between the firms. However, the model treats σ as exogenously given in order to concentrate on the analysis of the second-stage technology game, which is already quite complicated.

The technology game outlined above constitutes a differential game. Differential games are essentially the same as sequential games but the former are distinguished from the latter in three respects. First, the dynamics of a differential game is represented solely by so called state variables. Note that in our technology game, the state variables are the level of the basic knowledge B and the firms' effective marginal costs C_d and C_f. Second, the evolution of state variables is governed by a system of differential or difference equations. Finally, the objective of each player is given by the integral or sum of instantaneous payoffs over a planning horizon. Despite these stylistic properties, the same equilibrium concept (i.e., Subgame perfect Nash equilibrium) is applied to solve a differential game.[12]

What remains to be determined is the information structure of a firm. The information structure specifies the extent to which each firm can observe the state variables. Perhaps, a word of warning is called for. Observation must not be confused with spillovers or diffusion. To clarify the matter, let us suppose that the effective marginal cost of the foreign firm is lower than that of the domestic firm and that the domestic firm observes the effective marginal cost of the foreign firm. In this case, the domestic firm simply knows what level of effective marginal cost the foreign firm has at each moment of time. Thus having such knowledge does not help reduce the effective marginal cost of the domestic firm down to that of the foreign firm. On the contrary, the diffusion of the basic knowledge means that the foreign firm's basic knowledge automatically advances whenever the domestic firm's does.

The importance of observation lies in the fact that a firm's observation determines what strategy of the firm constitutes a credible or non-credible strategy. If a firm observes the current levels of the state variables, then the firm has no incentive to sustain a non-credible strategy, because when new information arrives, it is in the interest of the firm to adjust its action rather than to cling to a predetermined one. On the other hand, if a firm has no observation, then the firm cannot adjust its action but has to stick to a predetermined action. Hence the firm is able to sustain a strategy that otherwise may not be credible.

It seems that in the technology game, there arises some instances in which the firms may make only partial observation of the state variables. In particular, the effective marginal cost of a firm may not be observable to the other firm but only to the firm itself due to the firm-specific nature of the applied knowledge. Sato and Tsutsui (1987) consider two types of the information structure for each firm depending on whether or not the firm observes the level of the other firm's effective marginal cost. Following the customs in the literature, we say that a firm has a closed-loop information structure when it has such an observation, while a firm has an open-loop information structure when it has not.

The outcome of the technology game is measured by the steady-state market shares of the firms. It is shown to be dependent upon what type of the information structure each firm has and how the parameters σ, δ and ϵ are configured. Given the fixed σ, $\sigma \neq 1$, the iso-share curve can be drawn in the ϵ-δ parameter space (see Figures 1 and 2). The curve has the following interpretations. If the combination of ϵ and δ happens to be in the area above the iso-share curve, then the domestic firm (resp. the foreign firm) has more (resp. less) than 50% of the market; if it happens to be on the iso-share curve, the domestic firm and the foreign firm have 50% of the market; if it happens to be in the area below the iso-share curve, the domestic firm (resp. the foreign firm) has less (resp. more) than 50% of the market.

We now examine the symmetric cases in which the information structures of both firms belong to the same type. The iso-share curve in Figure (resp. Figure 2) corresponds to the case where both firms have an open-loop (resp. a closed-loop) information structure. Notice that both iso-share curves are upward sloping and are going through (1,1). Some remarks are in order. First, the upwardness of both iso-share curves shows the existence of a trade-off between the rate of the basic knowledge diffusion and the efficiency of the foreign firm in the applied knowledge production. Namely, in order to maintain the equal market share, the efficiency of the domestic firm in the applied knowledge has to increase relatively to counter the adverse effect caused by a high rate of the basic knowledge diffusion. Second, both iso-share curves lie below the equal efficiency line (i.e., $\epsilon = 1$). This shows that the domestic firm can capture more than 50 % of the market regardless of the rate of the basic knowledge diffusion, as long as the domestic firm has relatively higher efficiency in the applied knowledge production (i.e., $\epsilon > 1$). As a result, for the foreign firm to capture more than 50% of the market, it is necessary that the foreign firm has relatively higher efficiency in the applied knowledge production (i.e., $\epsilon < 1$) and the rate of the basic knowledge diffusion is sufficiently high.

Let us turn to the asymmetric cases in which the firms' information structures are different in type. Figure 3 shows the iso-share curve for the case where the domestic firm has a closed-loop information structure, while the foreign firm has an open-loop information structure. The corresponding iso-share curve is upward-sloping and going through $(1,\bar{\epsilon})$, where $\bar{\epsilon} > 1$. As in the symmetric cases, there exists a trade-off between the rate of the basic knowledge diffusion and the efficiency of the foreign firm in the applied knowledge production. In this asymmetric case, however, the entire iso-share curve does not necessarily lie below the equal efficiency line but some portion of the iso-share curve lies above it. Hence there arise cases where even if the foreign firm (resp. the domestic firm) has relatively lower (resp. higher) efficiency in the applied knowledge production, its market share is more (resp. less) than 50%, when the rate of the basic knowledge diffusion is sufficiently high.

The reason is the following. Under these information structures, the foreign firm has to commit itself to a predetermined action but the domestic firm can adopt a so called feedback strategy which permits adjustment of action in the course of play. In a non-strategic context, it is easily seen that the domestic firm is in a more advantageous position than the foreign firm because of the flexibility of a feedback strategy. However, in a strategic context, the domestic firm can be in a less advantageous position than the foreign firm. The foreign firm does not have to revise its action in response to a change in the domestic firm's action, while the domestic firm has to do so in response to a change in the foreign firm's action. The difference in the firms' responses gives to the foreign firm a credible way to impose its action on the domestic firm. This leads to the expansion of the foreign firm's R&D and hence the contraction of the domestic firm's R&D, as in Spencer and Brander (1983). As a result, the foreign firm, even with relatively lower efficiency in the applied knowledge production, may be able to achieve the same level of the applied knowledge and thus 50% of the market.

The other asymmetric case arises if the domestic firm has an open-loop information structure, while the foreign firm has a closed-loop information structure. As one can expect from the previous discussion, the iso-share curve is upward sloping but going through $(1,\bar{\epsilon})$, where $\bar{\epsilon} < 1$. And there arise cases where even if the foreign firm (resp. the domestic firm) has relatively higher (resp. lower) efficiency in the applied knowledge production and the basic knowledge diffusion rate is perfect, its market share is less (resp. more) than 50%.

The qualitative effect of the cost-sharing parameter σ on the iso-cost curve is independent of the information structures of the firms. Namely, as the foreign firm's share of the costs of the basic knowledge production increases (i.e., as the value of σ increases), the iso-share curve shifts downward.[13] To see how this happens, observe that as σ increases, the level of the basic knowledge increases. This benefits both firms in decreasing the costs of reducing the effective marginal cost, and both firms reduce their effective marginal costs. However, the reduction of the domestic firm's marginal cost is greater than that of the foreign firm's. Hence the domestic firm's output increases more than the foreign firm's and thus the market share of the domestic firm rises.

It seems possible to draw a number of policy implications from the above discussions. First, let us consider the issue of whether the domestic government should subsidize the basic knowledge production or the applied knowledge production. To simplify the analysis, suppose that the the basic knowledge diffusion is perfect (i.e., $\delta = 1$) and the information structures of the firms belong to the same type. It then follows that the value of ϵ that gives the equal market share is 1 (i.e., both firms have the same efficiency in the applied knowledge production).

Suppose that subsidizing the basic knowledge production reduces its costs. It can be shown that the effect of such subsidy, however, does not change the value of ϵ that warrants the same market share. In other words, subsidizing the basic knowledge production does not increase the domestic firm's market share. The reason is that since the diffusion is perfect, an increase in the basic knowledge generated by subsidy benefits both firms equally.

Suppose now that subsidizing the applied knowledge production works in such a way that it effectively raises the value of ϵ (i.e., it reduces the foreign firm's efficiency in the applied knowledge production). It is clear that such subsidy raises the domestic firm's market share. As a result, it can be concluded that subsidizing the applied knowledge production is a more effective policy.

Another issue is the control of the diffusion of the basic knowledge and of the firms' observation of each other's effective marginal cost. We can draw two policy implications on this matter. First, from the existence of a trade-off between the foreign firm's efficiency in the applied knowledge production and the rate of the basic knowledge diffusion, it follows that curtailing the diffusion of the basic knowledge, if feasible, constitutes a viable policy, even if the foreign firm's efficiency in the applied knowledge production is sufficiently higher than the domestic firm's. Second, since the firm's observation of the other firm's effective marginal cost deprives it of an ability of commitment, it follows that a policy that facilitates the foreign firm's observation of the domestic firm's effective marginal cost turns out to be more share-increasing than a policy that obstructs it. Here it is interesting to note that a difference in the nature of information between diffusion and observation makes such contrast of the two policies, i.e., the curtailment of diffusion vs. the promotion of observation.

IV CONCLUSION

The theory of technological competition is a new branch of economics but, apart from its infancy, it suffers from the intellectual incompatibility of its progenitors. Until recently, the dominant paradigm of international trade was that of laissez-faire. In contrast, the theory of innovation recognizes the need to internalize the benefits from R&D investments; the possibility of market failure became widely recognized and the need for government intervention vehemently argued. Strategic trade theory recognizes that one of the sources of externalities that nullifies the assumptions of traditional trade theory is the incomplete appropriability of R&D. As a result, an acrimonious debate has arisen as to whether any nation has developed an advantageous position in international trade through the manipulation of technology policy.

Ergas (1987) divides the technology policies of six Western countries - the United States, the United Kingdom, France, Germany, Switzerland, and Sweden - into two categories: "mission oriented" and " diffusion oriented". He relates the policies to two possible purposes, national sovereignty and provision of public goods. He argues that the technology policy of the

U.S., U.K and France are mission oriented and have close links to national sovereignty goals. The decision process is concentrated and the projects which receive funding are few and biased towards industries in the early stages of the technology life-cycle. Further they concentrated on radical innovations.

Ergas considers Germany, Switzerland, and Sweden to be diffusion oriented countries where centralized policy-making is rather limited and funds are widely distributed to industry associations or cooperative research groups. These benefit a large number of small and medium sized firms. Moreover, these countries emphasize education push. The chemical and electric industries, which were highly concentrated, needed a high quality university system which in turn needed a superior school system, and lobbied for these objectives. In contrast, the mechanical industry was highly decentralized and lobbied for vocational training, product standardization, and cooperative research. The German speaking countries developed a comprehensive system of vocational apprenticeship and skill certification. The government provided subsidies to firms to hire research scientists; the program was administered through industry organizations and had very precise eligibility rules to prevent arbitrary selection. Overall the diffusion oriented policy leads to quick dissemination of incremental technologies but firms tend to be conservative in adopting radical alternatives.

The Japanese system seems to be an amalgam of the two approaches. Sato (1988) notes that the government plays a dual role. In supporting a mission oriented policy, it selects a small number of important and powerful companies in the industry so as to protect them from domestic and foreign competition. In the early stages, these are the only companies permitted to import foreign technologies and they are encouraged to develop a cooperative research program and received tax credits and subsidies. But some aspects of Japanese policy are best characterized as diffusion oriented. Once a technology is developed, the government encourages competition. The public school system is well-known for its emphasis on science education at school levels and the universities graduate a high percentage of engineers.

The debate whether government intervention is needed to correct market failure or would only lead to market failure is not confined to strategic trade theory alone. The probability is that the debate will not be resolved in the near future. But one has to be careful when inconclusive arguments are used to evaluate the performance of a nation or, even more, if they are used to compare two nations. Without proper care, any desirable conclusion can be derived depending on a careful marshaling of assumptions and data.

Much of the debate on Japan has concentrated on whether MITI has superior signaling abilities in directing technology trade by firms and whether this requires a response from the Western nations. We seek to show that the channels of transfer of technology to her and her method of utilizing it differ at best only in degree from what prevails in other countries. This will not resolve the debate but hopefully it can bring some perspective to it.

FOOTNOTES

1. See Krugman (1987) for a review of the implications of the new theories of trade.

2. The oil-rich nations are, of course, an exemption to this generalization.

3. Gerschenkron (1962) pp.8.

4. Mokyr (1990) pp. 151-92.

5. See Adas (1989), who gives an excellent review of the evolution of the concept of Western superiority.

6. Hollister-Short (1976) notes that the lag was surprisingly in coal mining though England was dependent on coal for energy.

7. See, for example, Burks (1985).

8. See Kreps and Wilson (1982), Milgrom and Roberts (1982) for example.

9. Strategic trade has attracted much attention of many economists lately. Many issues have been investigated in international trade in the framework of strategic trade. The recent studies include Brander (1986), Brander and Spencer (1984, 1985), Clemenz (1990), Dixit (1984), Fung (1989), Krugman (1984), Levinsohn (1989), Meza (1989), Ono (1989), Tsutsui (1989) and Sato and Tsutsui (1991). This is only a partial list and is not meant to be inclusive.

10. For this to happen, it is necessary that both firms make full observation of the domestic government's R&D subsidy. Therefore, it is to be noted that if the foreign firm makes no such observation, its reaction to the R&D subsidy cannot be the same.

11. The domestic government's R&D subsidy essentially provides the domestic firm with first-mover advantages.

12. See Tsutusi and Mino (1990) for the derivation of a subgame perfect Nash equilibrium in a differential game with an infinite horizon.

13. If the foreign firm pays the entire costs of the basic knowledge production (i.e., $\sigma = 1$), then the iso-share curve coincides with the horizontal axis.

BIBLIOGRAPHY

Adas, M.(1989). Machines as the Measure of Men: Science, Technology and Ideologies of Western Dominance, Ithaca, NY: Cornell University Press.

Arrow, K. (1962). "Economic Welfare and the Allocation of Resources for Invention" in R.R.Nelson (Ed.), The Rate and Direction of Inventive Activity, Princeton, N.J.: Princeton University Press.

Beath, J., Y.Katsoulacos and D.Ulph (1989). "Strategic R&D Policy", Economic Journal, 99, 74-83.

Bernstein J.I. and M.I.Nadiri (1989). "Research and Development and Intra-Industry Spillovers: An Empirical Application of Dynamic Duality", Review of Economic Studies, 56, 249-269.

Binmore, K. (1990) Essays on the Foundations of Game Theory, Oxford, U.K.: Basil Blackwell.

Brander J.A. (1986). "Rationales for Strategic Trade and Industrial Policy" in P.R.Krugman (Ed.), Strategic Trade Policy and the New International Economics, Cambridge, MA: MIT Press.

Brander J.A. and B.J.Spencer (1984). "Tariff Protection and Imperfect Competition", in H.Kierzkowski (Ed.), Monopolistic Competition and International Trade, Oxford, U.K.: Oxford University Press.

Brander J.A. and B.J.Spencer (1984). "Export Subsidies and International Market Share Rivalry", Journal of International Economics, 18, 83-100.

Burks,A.W., Editor (1985). The Modernizers:Overseas Students, Foreign Employees and Meiji Japan, Boulder,CO: Westview Press.

Clemenz, G. (1990). "International R&D Competition and Trade Policy", Journal of International Economics, 28, 93-113.

Deolalikar, A.B. and R.E. Evenson (1988). "Technology Production and Technology Purchase in Indian Industry: An Econometrics Analysis", Harvard Institute of Economic Research, Harvard University.

Dixit, A. (1984). "International Trade Policy for Oligopolistic Industries", Economic Journal, 94, 1-16.

Dosai,G.(1988). "Sources, Procedures, and Microeconomic Effect of Innovation", Journal of Economic Literature, 26, 1120-1169.

Ergas, H.(1987). "The Importance of Technology Policy", in P.Dasgupta and P. Stoneman (Ed.), Economic Policy and Technological Performance, Cambridge, U.K.: Cambridge university Press.

Fung, K.C. (1989). "Tariffs, Quotas, and International Oligopoly", Oxford Economic Papers, 41, 749-757.

Hicks, J.R. (1932). The Theory of Wages, London, U.K.: Macmillian.

Hollister-Short, G.(1976). "Leads and lags in late Seventeenth Century English Technology", History of Technology, First Annual Volume, London, U.K.: Mansell Information/Publishing Ltd.

Ichimura, S.(1990). "Institutional Factors and Government Policies for Appropriate Technologies in Southeast Asia", Institute of International Relations, Osaka International University.

Kreps, D. and R.Wilson (1982). "Reputation and Imperfect Information", Journal of Economic Theory, 27, 253-279.

Gerschenkron, A.(1962). Economic Backwardness in Historical Perspective, Cambridge: The Belknap Press.

Krugman, P.R. (1984). "Import Protection as Export Promotion: International Competition in the Presence of Oligopoly and Economies of Scale", in H.Kierzkowski (Ed.), Monopolistic Competition and International Trade, Oxford, U.K.: Oxford University Press.

Krugman, P.R.(1987). "Is Free Trade Passe?", Journal of Economic Perspectives, 1, 131-144.

Levinsohn, J.A. (1989). "Strategic Trade Policy When Firms can Invest Abroad: When are Tariffs and Quotas Equivalent?", Journal of International Economics, 27, 129-146.

Meza, D.D. (1989). "Not Even Strategic Trade Theory Justifies Export Subsidies", Oxford Economic Papers, 41, 720-736.

Milgrom, P. and J.Roberts (1982). "Limit Pricing and Entry Under Incomplete Information: An Equilibrium Analysis", Econometrica, 50, 443-459.

Mokyr, J.(1990). The Lever of Riches:Technological Creativity and Economic Progress, New York, NY: Oxford University Press.

Myllyntaus, T. (1990). "The Finnish Model of Technology Transfer", Economic Development and Cultural Change, 38, 625-643.

Ono, Y. (1989). "Foreign Penetration, New Entry and National Welfare Under Oligopoly", Journal of Japan and the World Economy, forthcoming.

Porter, M.E. (1990). The Competitive Advantage of Nations, New York, NY: The Free pres.

Sato, R. (1981). Theory of Technical Change and Economic Invariance, New York, NY: Academic Press.

Sato, R. (1988). "The Technology Game and Dynamic Comparative Advantage:An Application to U.S.-Japan Competition", in A.M.Spence and H.A. Hazard (Ed.),International Competitiveness, Cambridge, MA: Ballinger Publishing Company.

Sato, R. and S.Tsutsui (1987). "Information Strategies, Market Barriers and Trade Performance", Center for Japan-U.S. Business and Economic Studies, Stern School of Business.

Sato, R. and S. Tsutsui (1991). "Trade Policy Under Uncertainty", in preparation.

Schumpeter, J.A. (1942). Capitalism, Socialism and Democracy, New York, NY: Harper and Row.

Spencer, B.J. and J.A.Brander (1983). "International R&D Rivalry and Industrial Strategy", Review of Economic Studies, 50, 707-722.

Sugimoto,M. and D.L.Swain (1989). Science and Culture in Traditional Japan, Rutland, VT: Charles E. Tuttle Company.

Sweeny, P.(1987).Innovation, Entrepreneurs and Regional Development, New York: ST.Martin's Press.

Tsutsui, S. (1989). "Cost Differential and Welfare Effects of Interventionist Trade Policies in Oligopolistic International Trade", Journal of Japan and the World Economy, forthcoming.

Tsutsui, S. and K.Mino (1990). "Nonlinear Strategies in Dynamic Duopolistic Competition with Sticky Prices", Journal of Economic Theory, 52,

TABLE 1.

MAIN CHANNELS OF TECHNOLOGY TRANSFER

		United States[1]	Russia[1]	Germany[1]	Japan[1]	Sweden[1]	Finland[1]	The Philippines[2]	Thailand[2]	Indonesia[2]
1.	Importing foreign machinery and equipment	*	*	*	*	*	*	*	*	**
2.	Receiving direct foreign investment	*	**							
3.	Acquiring foreign licenses	*		**		*				
4.	Recruiting abroad or permitting mass migration	**			*	*	*			
5.	Encouraging educational travel		*	*		*	**		**	*
6.	Trade and scientific publications and analyzing foreign products publications and analyzing foreign products	*	*		**	**	*		*	*
7.	Trading Companies							**		

Legend: 1. For nineteenth century; 2. Recent years; **most important channels; *other important channels.
Source: Hyllyntaus (1989), pp. 627 & 638; Ichimura (1990), p. 3

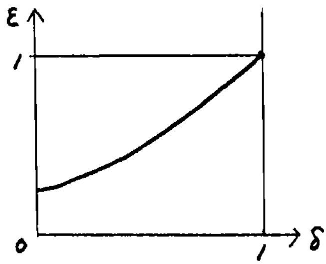

Figure 1

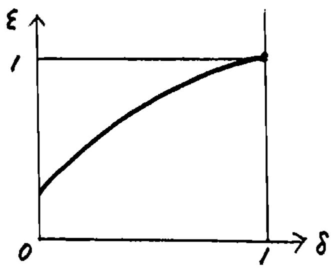

Figure 2

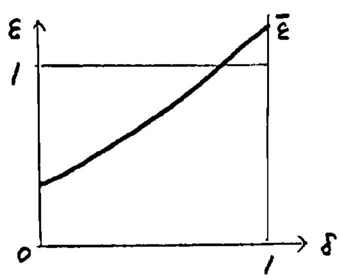

Figure 3