Foreign Direct Investment, Spillovers and Catching Up
—The Case of Taiwan

by

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Declaration

This dissertation was written while I was studying at the Australia-Japan Research Centre at the Australian National University. The opinions expressed are my own, unless otherwise indicated.

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Abstract

Foreign direct investment, by definition, provides the host country with capital, supported by a package of knowledge and entrepreneurship. Such investment thereby makes a positive contribution to the economic growth and development of the host country; for instance, by complementing insufficient domestic mobilisable resources, such as savings, foreign exchange and tax revenue. This investment may also contribute to a rise in the host country's technological level through technology transfer. Foreign direct investment has been recognised as a more efficient channel for technology transfer to developing countries than licensing and buying. However, the most significant contribution of foreign direct investment comes from externalities for local industry arising from spillover effects. These externalities are mainly due to foreign subsidiaries being unable to capture all the economic rent from their productive activities.

The spillover from foreign firms to the local market occurs through four main channels: increased competition in local markets, training of local workers, links to local industries, and the acceleration of technology transfer. This thesis analyses these specific contribution of foreign direct investment in Taiwan. The interest is in two particular points. First, the strategic behaviour of foreign subsidiaries in the presence of spillover effects is analysed to determine the possibility that these effects lead to a shrinkage of the technological gap between foreign and domestic firms. The findings are that spillover effects can shrink the technological gap between foreign firms and indigenous firms, but that the best strategy for foreign firms to maintain their competitive power and prevent the catching-up is to transfer technology dynamically.

Secondly, the effect that foreign direct investment has on the improvement of productivity efficiency—the rate of technological progress, and technical efficiency in Taiwan—is analysed. A study is made to ascertain whether variations in productive efficiency among local firms correlate to the presence of foreign subsidiaries in the economy. In addition, the mechanisms through which the spillovers from foreign direct investment are transmitted are also studied. Measures of the growth of total factor productivity are employed to represent productivity efficiency. A decomposition of total factor productivity is conducted to find the sources of growth.

Foreign direct investment is found to have an ambiguous effect on productivity in Taiwan's manufacturing sector even though foreign direct investment and productivity are correlated. If spillover effects of foreign firms could force indigenous firms to reduce managerial slack or to adopt more efficient production processes, they would operate in a more efficient manner. More efficient operation

implies higher productivity growth. However, adjustment to foreign entry would also require some adjustment in indigenous firms' production processes or the exit of inefficient firms. This could impose additional production costs and would be detrimental to productivity growth. These two effects might counteract each other and result in insignificant spillover effects.

Alternatively, scale economies appear to be a more important factor in explaining productivity growth in most Taiwanese industries than the spillover effects of foreign direct investment. The underdevelopment of Taiwanese firms in technology and information, as well as the relatively small size of Taiwan's domestic market, means that links to the world market are critical if scale economies are to be exploited. On the other hand, foreign direct investment is one of the most efficient channels for obtaining production knowledge and access to world markets, and the inflow of foreign capital has probably contributed to the achievement of economies of scale in Taiwan's manufacturing sector. Its contribution to productivity growth is mainly seen through a scale effect.

At the firm level, the analysis shows that local firms have improved cost efficiency over time and that there is a trend towards a shrinking of the technological gap between local and foreign firms in the Taiwanese electronics industry. The evidence also shows that foreign direct investment provides a spillover effect through which an improvement in labour quality is passed on, leading to greater cost efficiency in production. Better labour quality can be achieved in many ways; for instance, though education, learning-by-doing, or labour turnover. Education has long-term effects which need a relatively long time series analysis to examine thoroughly. Learning-by-doing can result in improved technical efficiency, as can labour mobility, particularly when accompanied by a positive and significant scale effect. The opportunity of learning-by-doing comes from expansion in the market which, in turn, can be attributed to the beneficial effect of foreign direct investment—providing information and knowledge about relevant markets.

The inflow of foreign capital contributes to the upgrading of technical know-how and a narrowing of the technological gap between local firms and foreign firms. This might suggest that developing countries should adopt preferential foreign investment policies. Preferential foreign direct investment policy is certainly welcomed by foreign firms, but it also leads to distortions in resource allocation and reductions in the national welfare of the host economy. An alternative policy concentrating on the creation of a favourable investment environment is preferred, particularly one with an emphasis on raising labour quality.

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1 Introduction

The role of technological change has long been recognised as a key factor in stimulating economic growth; for instance, Solow (1957) estimated the average rate of technological change in the non-farm US economy from 1909 to 1949 at about 1.5 per cent per year. Based on these findings, he concluded that about 82 per cent of the increase in output per capita during that period was attributable to technological change, whereas only a minor percentage of the increase was due to increases in capital-labour ratio. Denison (1974) attempted to include many qualitative variables —such as changes in labour quality associated with increases in schooling—that had been omitted by earlier studies. He concluded that technological change was responsible for about 47 per cent of the total increase in gross national product (GNP) in the United States, and about 76 per cent of per capita income, between 1929 and 1969. Ohkawa and Rosovsky (1973) estimated that the average rate of technological change was about 6.8 per cent per year, contributing about 70 per cent of the increase in output per capita from 1955 to 1961 in Japan. Maddison (1970) used the same approach to estimate the contribution of technological change in 23 developing countries, finding that Taiwan had the largest proportion of gross domestic product (GDP) growth, with 38 per cent that could not be accounted for by an increase in labour and capital. Kuo (1983) estimated that an even higher proportion of growth in Taiwan was attributable to technological change. Yet these earlier studies appear to be contradicted by Kim and Lau's (1993) recent findings that technological change contributed little to the economic growth of the East Asian newly industrialised countries when compared with five industrialised countries: US, UK, Germany, France and Japan. Despite this, many findings imply that technological change has a significant impact on economic growth.

The role of technology transfer

Technology consists of three principal elements: (i) product design, (ii) production techniques, and (iii) management systems. Changes in technology take place as a consequence of innovation, invention and imitation. In turn, these changes are followed by a diffusion of the new technology, either nation-wide or internationally, which changes the technological level in domestic or overseas markets.

Since 'technology' embraces all forms of know-how or technical information, as well as organisational and managerial skills, it may affect not only the productive level but also productive efficiency. According to the classification of Mansfield *et al.*

(1982), there are three major categories of knowledge: general, industry-specific, and firm-specific. *General knowledge* refers to information commonly applicable across all economic activities; *industry-specific knowledge* refers to the know-how of special solutions or procedures acquired in previous manufacturing experience with a related product or process; and *firm-specific knowledge* refers to information that is specific to a particular firm's experience and activities, but that cannot be attributed to any specific item the firm produces. This knowledge may be in the form of written materials, or embodied in technical assistance or on-the-job training, or built into fabricating or processing equipment.

From the above definition, there are real difficulties in measuring the technological level of a market. It is even harder to measure the international gap in technology, but the existence of such a gap creates scope for a continual process of technological diffusion.[1] In general, the process of transferring technology is more prominent in developing countries, because of the substantial technological differences between developed and developing countries. Production technology that is capable of converting inputs into consumable output at competitive costs is not as widely available in developing countries. In addition, creating new technology through research and development (R&D) is enormously costly and risky, and the necessary skilled labour may also not be available. Importing technology not only bypasses the risky invention and innovation stages, but also allows a high degree of freedom in the choice of technologies, enabling the recipient to cut short the development path. Hence, developing countries represent a quite substantial share of world technology demand and only a tiny part of the supply.[2]

Vernon's (1966) product cycle theory suggests that developing countries will be the beneficiaries of technology transfer, due to relatively restricted market demand which is constrained by low national income or shortage of capital for investing in R&D activities. Even though developing countries generally lack the resources and incentive to develop new technology, it would be inappropriate to conclude that they invest nothing in R&D activities. Since their markets tend to be smaller, and factor prices, consumer tastes, capability, and cost and quality requirements are not the same

1 Monkiewicz (1989, ch. 7) notes that there are two great obstacles in measuring the technological gap internationally: that of methodology and that of statistics. However, he suggests that a multidimensional evaluating approach, which covers scientific research activities, inventive activities, and investment activities provides a more objective assessment of a country's technological position. Therefore, he suggests that this is a better method for identifying the gap than the frequently-used imitation lag method.

2 This trend has changed significantly since 1980, however, because of the improvement in the performance of less developed countries (LDCs) which has made the Newly Industrialised Economies (NIEs), such as Taiwan, Hong Kong, Singapore, and Korea, new technology exporters.

as in the countries which generate new technologies, recipient countries usually have to adapt the transferred technology to their own needs. Hence, a large proportion of their R&D expenditure goes toward adaptation.

Although technology is a part of human knowledge and it is convenient to use the term 'technology transfer', it is not simply a matter of assuming that there is a blueprint and that all one has to do with applying imported technologies is follow instructions. Much of the core of technology is not written down, and publications and reports may be much less effective in transfer than the movement of engineers or skilled workers. Because of the variety of ways of transmitting knowledge, only a little information is available on how rapidly a technology can spread from one country to another.

The rate of international technology diffusion depends on the age of the technology being developed and the channel of transfer. Vernon and Davidson (1979) found that the speed of new innovations transferred abroad rose significantly after 1955 in the United States, with more recent innovations tending to diffuse faster than earlier ones. McFetridge (1987) found that transfer is faster in the early stages of international diffusion, later slowing down. A few studies have attempted to determine whether the industrial characteristics of early-adopting countries differ systematically from those of late adopters. As for the channel of technology transfer, Mansfield *et al.* (1982, ch. 2) estimated that the mean age of technologies transferred to developed countries through foreign subsidiaries was 5.8 years, significantly less than that for developing countries (9.8 years). Technologies transferred through licensing or joint venture took much longer (13.1 years). On the basis of this study, foreign direct investment appears to be a more efficient channel for technology transfer.

A variety of institutional arrangements can be employed to transfer technology internationally. Apart from non-commercial forms of transfer, such as the exchange of books and journals, and the migration of workers, three principal channels are commonly used:

(i) Export of goods and services. Exports can provide information to importers, and the role of exporters in improving the efficiency of usage of products is also a form of technology transfer. Moreover, reverse engineering provides an opportunity to acquire technology.

(ii) Foreign direct investment. In many cases, firms become multinationals because they want to exploit a technological lead. Freight costs and tariffs may hasten decisions to invest abroad. In establishing foreign subsidiaries, multinational firms transfer technology in a variety of ways. They train administrative personnel and managers; communicate information and capabilities to engineers and technicians; help the users of their products to use them more effectively; and help suppliers to upgrade their technology. A joint venture may also be a form of foreign direct investment. A joint venture is generally an operation owned jointly by a firm with technology and a firm in a host country lacking technology. Joint venture agreements are often made by smaller firms that need capital to complement their technology.

(iii) Licensing agreements. Licensing agreements cover matters such as patents, trademarks, franchises and technical assistance. They may require the licensee to pay a certain percentage of its sales to the licensor, or to buy certain inputs. Another type of 'licensing' arrangement is sale of technology—a lump-sum purchase which involves the granting of a licence allowing the purchaser to use the technology.

A firm can employ many channels simultaneously at different operation sites, the combination of which is determined by the characteristics of the parties involved and the structure of their motivations and interests.

Role of foreign direct investment in technology transfer

The decision of technology owners as to which channel provides the best arrangement through which to market their technology depends on the realisable stream of benefits and costs, given the characteristics of the technology and the nature of the market. The costs are mainly calculated from the loss due to market competition that the technology owners may face in the future. Therefore, if the innovators believe that licensing or selling will give away valuable know-how to foreign producers who are potential future competitors, or if they want to maintain the quality of their products, they will prefer to produce abroad. But if they cannot obtain the necessary resources or if the nature of the particular technology market is competitive, they may prefer licensing. The policies of the host country's government may also affect technology transfer. A policy of detailed screening or restriction of foreign direct investment can increase the cost of technology transfer through the direct investment channel. Foreign investment was discouraged in the past by the Japanese, Korean and Mexican governments, but encouraged by Taiwan, Singapore and Hong Kong. In addition, the stage of industrial development of the host country may influence the firm's decision.

Many theories of foreign direct investment attempt to explain the incentives for firms to internalise their international technology transfer. Dunning (1988, ch. 4) states that foreign direct investment is associated with ownership-specific advantages in enterprise, where these are derived from technology and marketing skills, relatively cheap financial and monetary factors, and so on. Technology transfer through foreign direct investment is likely to result in different patterns of resource usage and allocation from those which would accrue from an arm's-length transaction. This is because direct investment always involves the transfer of a package of interrelated technologies and it saves transaction costs through internalised sales or purchases.

Teece (1977) indicates that the costs of technology transfer are more significant than is commonly thought, because market failure may be greater across borders than within a country, and the cost of international technology coordination between independent firms is extremely high. These costs can be reduced where transfer takes place within the same enterprise; that is, where there is internalisation. Buckley and Casson's (1976) internalisation theory stresses that internalisation can reduce transaction costs within multinationals. They identify few imperfect external markets[3] which cause relatively high transaction costs to impede free trade and make licensing expensive. They conclude that high transaction costs lead firms to prefer to internalise technology transfer.

Meanwhile, Findlay (1978) suggests that internalising technology transfer can create demonstration effects within the recipient economy and strengthen local competition, thus contributing to local technological learning and innovation efforts. Therefore, the more foreign direct investment there is, the more rapidly the recipient's technology will catch up. Rugman (1980) suggests that the rise of foreign direct investment is a response to failure in goods and factor markets throughout the world because of market distortions or specific technology, knowledge and other information owned by the firms.

Though these studies suggest different reasons as to why firms internalise technological transfer transactions instead of licensing or selling, they arrive at similar conclusions. First, technology is comparatively easily adopted, or there are cost savings to technology owners via foreign direct investment rather than via market mechanisms. Secondly, technology transfer proceeds more smoothly and brings more technological benefits to the receiving economy when internalised.

There are other advantages in firms internalising technology transfer rather than licensing. Foreign subsidiaries can utilise fully location-specific advantages by lowering production costs in host countries, for example through lower labour costs. Firms may also wish to provide better services to the host market via subsidiaries. This factor is especially important to industries where product differentiation, rapid model changes, advertising and retailing are of great significance, because exporting firms have to do their utmost to satisfy local tastes and requirements. Apart from

[3] According to their findings, market imperfection occurs when there are costs of property rights, when discriminatory pricing is needed but is prohibited, when there is buyer uncertainty over the value of knowledge to be traded, or when products are perishable and the seller needs to protect quality.

economic concerns, such as prospects for market growth, non-economic factors, such as political stability in the host country, may act as incentives in attracting firms to undertake international production.

From these studies, the choice between direct investment and licensing can be summarised as being influenced by the size of the market, the riskiness of the investment, the policy of the host government, the management and performance of the firm, industrial market structure, and the range of technologies and products involved. The more stable the market, the newer the technology, the larger and more international the firm, the larger the power of the firm in factor markets and the lower the absorptive capacity of the licensee, then the higher the propensity for a foreign firm to prefer direct investment over licensing.

Foreign direct investment and the host economy

Although foreign firms may prefer direct investment, the attitude towards such investment tends to be quite different among recipient countries, especially developing countries. The technological activities of foreign subsidiaries are often viewed with suspicion in these countries, because the subsidiaries want to maximise their profits. The host government may fear that, in pursuit of profits, foreign subsidiaries will engage in activities that are contrary to the host country's interests and policies. The host country may also worry about multinationals 'taking over'. Above all there is the fear of becoming dependent on foreign technology. This fear often makes host governments wish to retain as much control as possible in the hands of indigenous firms.

Costs to the host country

Even though new technology can save costs in material inputs or productive activities, its transfer may not always be beneficial. Since most new technology is developed in more industrialised countries, it tends to be geared to their factor endowment where labour is basically a relatively scarce factor in the market. The benefits to the host country therefore depend on the appropriateness of the technology to local factor endowments and other conditions. Developing countries generally have abundant unskilled labour, and if capital-intensive technology is transferred, not only are there employment implications, but diffusion of technology may be slower, as discussed later. In addition, it may be costly to adapt technology transferred to fill the gap between the technology supplier and the recipient in terms of the scale of production, available industrial materials, the capabilities of local supporting industries, product design and even the differences in industrial standards and specifications. How efficiently the technology can be adapted is a crucial issue for the recipient in evaluating the benefits of the process of technology transfer.

The obstacles associated with technology adjustment may be due to intrinsic factors in developing countries that work against technology adaptation:

(i) skilled labour may be scarce;

(ii) a small market and monopoly advantages may reduce the incentive to find new technology. A small market may limit the gains of adapting new technology, and monopoly advantages may keep firms profitable without their having to adopt new technology; and

(iii) distortions in the prices of goods and factors, such as capital subsidies and preferential interest rate policies, may encourage the use of more capital relative to labour.

For other reasons also, foreign direct investment may not be unequivocally beneficial to the host countries. For example, the repatriation of profits to parent firms may cause balance of payments difficulties in the host country, multinationals may use their monopoly power to exploit consumers in the host country, or the host country government may fear a loss of economic independence.

Because of these concerns, many developing countries adopted a nationalistic approach and tended to restrict the inflow of foreign direct investment during the 1950s and 1960s. However, the importance of technology to economic growth and the fading of nationalism in foreign direct investment policy since the 1970s have both encouraged the growth of multinational firms, especially from Japan and European countries where domestic economies also faced industrial restructuring and led them to invest abroad. Foreign direct investment has become increasingly important in international technology transfer.

Benefits to the host country

Foreign direct investment appears to be an efficient channel for technology transfer to developing countries, and so these countries are seeking to attract foreign investment to gain the benefits perceived. Foreign direct investment, by definition, provides the host country with capital, supported by a package of knowledge and entrepreneurship. Such investment is thereby expected to make a positive contribution to the economic growth and development in the host country; for instance, to complement insufficient domestic mobilisable resources, such as savings, foreign exchange and tax revenue. This investment may also contribute to macroeconomic policy objectives, such as employment and balance of payments objectives. In addition, the entry of foreign firms may encourage entrepreneurship and provide information that would otherwise remain inaccessible to local firms. As a whole, the goals of multinationals and of host countries may coincide on certain issues, but there may also be conflict over a wide range of issues, such as tax avoidance, income distribution, anti-competitive behaviour and technology transfer.

In brief, the economic effects of foreign investment are directly associated with economic growth, output, employment, the balance of payments (foreign exchange, international trade), productivity, technological know-how and the training of labour and management. On the other hand, such investment may generate indirect effects which are critically associated with the inter-industry and intra-industry linkages to the local economy. These indirect effects involve the extent to which multinationals, through markets or other mechanisms, interrelate with locally produced materials and components suppliers or whether they prefer to set up new (supporting) firms and industries. Developing countries must pay considerable attention to these linkage effects. The economic impact of foreign direct investment on a host economy will be discussed further in Chapter 3, focusing on Taiwan's experience.

Many theories seek to elucidate the contribution of foreign direct investment to host countries: for instance, the industrial organisation theory (Hymer 1960; Kindleberger 1969); the product-cycle theory (Vernon 1966); the currency-premium theory (Aliber 1970); the dynamic comparative advantage theory (Kojima 1973, 1978); the intermediate-market internalisation theory (Buckley and Casson 1976); an eclectic theory (Dunning 1977); the risk-diversification theory (Rugman 1980); and the development-stage theory (Dunning, 1981). Apart from these theoretical analyses, many empirical studies focus on specific performance measures, such as R&D expenditures (Safarian 1969; San 1989), adoption of new technology (Globerman 1979; Schive 1979), specialisation and efficiency (Caves 1974; Blomstrom 1989), and exporting and importing intensities (Safarian 1969; Schive 1981; Chen 1992; Tu 1992), each providing partial analyses of the impact of direct foreign investment. Despite these studies, there is still little quantitative information available on the benefits of foreign capital inflows. A few models have been developed to evaluate the costs and benefits of foreign capital inflow into host countries. For instance, MacDougall's two-factor one-commodity partial equilibrium model, the standard Heckscher-Ohlin-Samuelson general equilibrium model, and Caves' specific-factors model provide analyses of these effects. The first model concludes that foreign investment is always beneficial to the host country; the second finds that such investment is detrimental if there are no taxation levies on the profits of foreign firms;

and the conclusion of Caves' model lies somewhere in between. Conclusions about the impact of foreign direct investment on the host economy remain controversial.

A number of studies claim, however, that one of the most significant contribution of foreign direct investment comes from their externalities to local industry (which also called spillover effects), and these studies provide empirical evidence of their existence, despite much of that evidence being only weakly supported. Foreign firms generally possess property rights to technology and knowledge but, through the realisation of external economies or spillovers, host countries derive indirect gains. These externalities are mainly due to the foreign subsidiaries being unable to capture all the rents from their productive activities.

The spillover effect from foreign direct investment

In general, the spillover from foreign firms to the local market occurs through four main channels: increased competition in local markets, training of local workers, links to local industries, and the acceleration of technology transfer.

The first channel is increased competition in the host country's market. Compared with local firms, foreign firms may suffer some disadvantages, such as lack of information about consumer tastes and factor market conditions, and unfamiliarity with local legislation and commercial rules. At the same time, they have advantages that help them overcome the entry barriers set by host countries—including relatively cheap capital costs, superior marketing ability, and high research and development intensity. With these advantages, a foreign firm may be expected to have the ability to enter markets where the entry barriers are relatively high. Foreign entry can therefore increase the degree of competition in host country markets, driving out inefficient local firms or forcing them to improve their productivity by investing in physical and human capital or by importing new technology. Overall productivity is thereby increased, thus changing the market structure of the host economy.

Several studies provide evidence on indirect productivity gains for host countries from the presence of foreign capital inflow (Dunning 1958; Brash 1966; Safarian 1966). Also, more direct tests of foreign investment and spillovers have been undertaken by Caves (1974), Globerman (1979), and Blomstrom (1989).

Another source of spillover is the training of labour and managerial personnel. Training may take place within the subsidiary or the parent firm, or even outside the foreign firm. Such training raises productivity in the host economy, thus creating a spillover benefit, which may be accelerated through the mobility of trained workers. Since managerial talent, scientists and skilled labourers are relatively scarce in developing countries, this type of spillover is important.

The third potential source of spillover is the impact of links into the local economy. These links may take a variety of forms. For instance, foreign firms hire a certain amount of local labour and use a certain amount of local materials. The wages and interests they pay contribute to the domestic economy. Important linkages are created through purchasing and selling strategies. Foreign firms may buy materials or intermediate inputs from local suppliers or sell products to local processors, which create links into the local economy. Because foreign subsidiaries may insist on higher standards of quality control, reliability and accurate delivery time for their domestic purchasing to complement their global strategy in sales and marketing, local suppliers may be forced to improve their performance. This kind of spillover may be more likely to happen in countries where legislation requires domestic content in the investment. A number of case studies provide evidence on this type of spillover effect, for instance Dunning (1958), Brash (1966), Lall (1980), and Schive and Majumdar (1990).

The fourth kind of spillover comes from the effect of the presence of the foreign subsidiary on speeding up technology transfer. Technology transfer is not only a central activity of foreign firms, it also stimulates domestic firms to pursue access to a specific technology because of the learning-from-watching effect. Without the presence of foreign firms, local firms may not be aware of the existence of new technology, or realise its profitability. There are also some studies on this type of spillover, such as Reuber (1973), Mansfield *et al.* (1982), Blomstrom and Wang (1989), and Blomstrom *et al.* (1992).

These spillover effects from the presence of foreign subsidiaries appear to constitute a major gain for a relatively backward country, especially through the dissemination of management, training and technical skills. The literature provides evidence of the existence of such spillovers; it does not, however, analyse the response of foreign subsidiaries in the face of these 'leakages' to indigenous firms. For instance, given the trade barriers imposed by host countries and potential spillover effects, the reasons foreign firms were motivated to undertake direct investments rather than exports has not been analysed. Similarly, when forced with the threat of indigenous firms catching up technologically, the strategies of foreign subsidiaries regarding technology transfer may vary.

Such externalities probably increase the recipient country's welfare while reducing the profits of foreign firms, therefore making them reluctant to transfer technology in the long run. For instance, given the existence of spillovers, the output of foreign firms may decline because indigenous firms become more efficient in production. The profits of foreign firms may also be affected, depending on changes in market prices. What optimal choice in transferring technologies can a foreign subsidiary then make to maximise its profit and output? How does its behaviour in turn affect the output and profit of indigenous firms? How is the welfare of the host country affected? These questions are worth examining more carefully. A discussion of the strategic responses of foreign subsidiaries to show the importance of spillover effects and their effects on the decision-making of foreign firms may make up for a deficiency of analyses of this matter in the literature.

Background to empirical study

Foreign firms and host governments may react differently to spillovers, but is there any externality from foreign direct investment? This question will be explored in the empirical study, in which the contribution of foreign direct investment to the Taiwanese economy is analysed as a case study.

Reasons for choosing Taiwan

There are three principal reasons for choosing Taiwan as the case study:

(i) Data availability: because of the difficulties in collecting adequate data as well as in identifying the channels of diffusion, most empirical studies have concluded that spillovers have little impact. Nevertheless, the rapid economic growth of the Taiwanese economy, accompanied by a rapid inflow of foreign direct investment during the high growth period, provides a convenient case for testing the importance of spillovers. In addition, there is the relatively ready availability of two sources of firm-level economic survey data for Taiwan. The Investment Commission of the Ministry of Economic Affairs has, since 1974, conducted an annual survey of foreign firms in Taiwan. The survey data cover firms' production and financial statistics, providing the most reliable and comprehensive information available on the activity of foreign subsidiaries. The second source of data is the census data on the manufacturing sector, conducted every five years and providing information on each plant's production, financial and assets statistics. These data sources can be used to examine the impact of foreign investment in Taiwan.

(ii) Lack of literature in this field: explanation of the rapid growth of Taiwan's economy has been attempted in a number of studies focusing on the role of individual sectors in the economic development or the inter-sectoral analysis, and in more comprehensive studies covering trade, industry and the labour market. Some of these studies have analysed the process of technology transfer, but none has attempted to investigate the relationship between foreign capital inflow and technology transfer, or the spillover effect on Taiwan's economy. Some of the studies in the field of foreign direct investment focus on its overall contribution to the early stages of Taiwan's development—alleviating the shortages of domestic capital and foreign exchange, increasing employment, and raising tax revenues—while others concentrate on partial analysis, such as foreign firms' strategic behaviour in relation to local purchasing, exports and technology transfer. Some observe the performance of different foreign subsidiaries, by the country of origin of capital. There are a few studies of linkage effects, through an analysis of local purchasing and local content, for instance Schive (1981), Schive and Majumdar (1990), and Chen (1992). To rectify this deficiency in the literature, this study attempts to analyse the existence of spillover effects from foreign direct investment to the Taiwan economy.

(iii) Important role of capital inflow in economic development: technology is a type of knowledge which is hard to measure and is generally embodied in capital, equipment or human beings, being particularly related to capital flow. Capital inflow reflects technology transfer. During the modernisation of the Taiwanese economy, three phases of capital import contributed to development. These inflows not only brought in financial capital but also provided technology and technical know-how.

Inflow of capital to Taiwan

Capital inflow is a means of technology transfer; it may, therefore, be advantageous to have a general idea of the inflow of capital to Taiwan before undertaking an empirical study of its relation to technology transfer.

The first phase of capital inflow into the Taiwanese economy came with the immigration from the mainland in the late 1940s. Taiwan's economy had suffered severe damage during the Second World War. Ports, electricity supply and communications were ruined by heavy bombing, and it was estimated that three-quarters of its industrial capacity was destroyed. The supply of chemical fertilisers dried up and agricultural production by the end of the war was probably back to the level of 1910. In addition, about 30,000 Japanese technicians, administrators and professionals, who accounted for a significant share of the human capital resources as well as the bulk of the large-scale industrial resources, left Taiwan in 1945.

Under colonial rule the Taiwanese had not been permitted to occupy any senior government or managerial positions, and there was little education beyond the primary level. This created a vacuum which was then filled by the mainlanders. Informal estimates indicate that around two million of mainland Chinese entered

Taiwan between 1946 and 1965, accounting for one-third of the Taiwanese population in this period. Although nearly half of the mainlanders evacuated with the government were military forces, there was also a small group of experienced and educated personnel, as well as capitalists who were unwilling to remain under communist rule on the mainland. By 1950, the mainlanders had 35 per cent of the jobs in the public service sector. Their entry helped to reduce the requirement for investment in human capital and to establish good conditions for economic growth in the following period.

The textile industry was the most significant industry in the immediate postwar period. Lin (1969) reviews the development of Taiwan's textile industry which was strictly banned by the Japanese rulers before the war, with nearly 90 per cent of demand being serviced by imports from Japan. During the vacuum period, due to the lack of physical and human capital, the textile industry remained underdeveloped. However, the establishment of Chinese government in Taiwan led to increased demand, which stimulated the revival of the textile industry. Fortunately, with the aid of US cotton and the immigration of former owners and mainland technicians who brought in capital, experience, and management know-how, the bottleneck of economic development was removed. The share of the textile industry in total industrial output grew from 4.7 per cent in 1949 to 14.3 per cent in 1950 (Huang 1952), and was the fastest growing industry till the 1970s. Even nowadays, firms managed by mainlanders still form a significant proportion of Taiwan's textile industry.

The second phase of capital inflow was US aid. The main program of US economic aid to Taiwan began in 1951 and, although new commitments ceased at the end of 1964, aid in the pipeline continued to be disbursed to 1967. During this period, US economic aid totalled US$1.5 billion, averaging about $90 million per annum or around $6 per capita per annum. Compared with other developing countries in Asia, Taiwan was one of the largest recipients of US aid (Jacoby 1966).

Almost all of the aid was in the form of grants, or soft loans repayable in local currency. It covered most of the savings gap during the 1950s and early 1960s, accounting for over 30 per cent of gross capital formation and 90 per cent of the trade deficit.[4] In addition, non-project aid in Taiwan consisted of a large commodity import program, hence the aid program could be viewed as a series of inputs of resources into the economy. These resource inputs included:

(i) imports of industrial materials for domestic processing,

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4 Data from *Taiwan Statistical Data Book*, yearly, Council for Economic Planning and Development, ROC.

(ii) imports of capital goods,

(iii) imports of human capital, knowledge, skills, and technology via US technicians and the training of Taiwanese, and

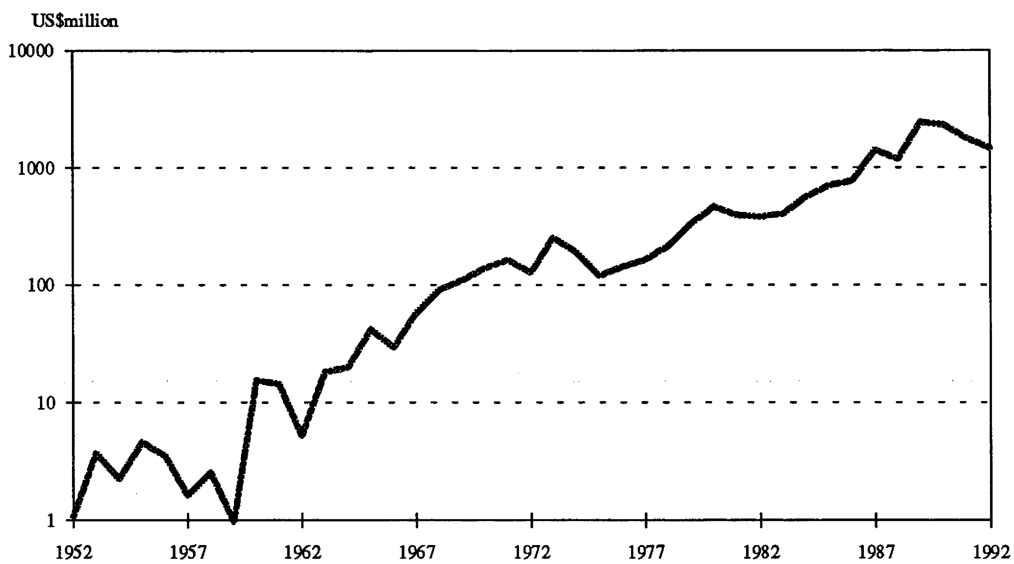
(iv) imports of consumer goods.

A large proportion of these resources involved technology transfer. In addition, aid to education constituted a large amount of project funds. The major projects included trade and industrial education, vocational agriculture education, science education, and American technicians transferring their expertise through pilot demonstrations and teacher training. Trade and industrial education was one of the most effective projects. It led to greater emphasis on the teaching of practical skills, more cooperation with industry, and better public attitudes towards vocational training. The training program and US technicians working in Taiwan were the best-known forms of aid in 1960 (Jacoby 1966, p. 165).

The third phase of capital inflow was foreign direct investment. It would be more accurate to use the actual basis of foreign capital inflow in accounting for the contribution of foreign direct investment, but it is impossible to ascertain the actual amount of foreign capital in a host economy.

Foreign direct investment in Taiwan between 1952 and 1992 on an approvals basis is charted in Figure 1.1.

Figure 1.1 Foreign direct investment in Taiwan (approvals basis), 1952-1992 (semi-logarithmic scale)



Source: Investment Commission, Ministry of Economic Affairs (1993), *Statistics on Overseas Chinese and Foreign Investment, Technical Cooperation, Outward Investment, Outward Technical Cooperation, Republic of China*, Taipei, Taiwan.

As shown on figure, foreign direct investment was negligible in the 1950s with only about US$35 million for the period 1952-60, averaging US$3.9 million per annum, and it remained at a low level during 1961-66, averaging about US$21 million per annum. However, there has been an upward trend in foreign direct investment since 1966, due to the establishment of the first export processing zone in that year.[5] From 1952 to 1992, accumulated foreign direct investment approved was about US$164 billion, averaging US$0.4 billion per annum. This represented 2.4 per cent of average fixed capital formation in the whole economy, and the foreign capital share in the industrial sector was about 6 per cent. This percentage would be higher if account was taken of the contribution of the manufacturing sector.[6]

Economic impact of foreign direct investment on Taiwan

Apart from its role in capital formation in Taiwan, foreign direct investment has also been associated with the country's successful export growth. The influence of foreign direct investment on Taiwan is reviewed comprehensively in Chapter 3, with an emphasis on those effects which relate to technological change; for instance, the contribution to exports, employment, linkage to domestic industry and technology.

Foreign firms' exports represented about 27 per cent of Taiwan's total exports in the 1970s, and 19 per cent in the 1980s. Their contribution to manufacturing employment was also significant, averaging 15.4 per cent from 1975 to 1980 and dropping to 10.7 per cent in the 1980s. These figures underline the active and important role of foreign direct investment during Taiwan's development, particularly in the area of exports and employment.

At the same time, foreign direct investment also played a role in encouraging technology transfer from abroad. Unfortunately, there are only limited data on technology transfer available in the literature and statistical data, most of it based on individual surveys. Schive (1983) undertook a survey in Taiwan in 1973 and found that foreign direct investment had encouraged technology transfer, and that adaptation of the technology depended on foreign capital participation and the characteristics of the industry. He concludes that foreign firms played an important

5 There are five Export Processing Zones (EPZs), and three of them were set up during the 1960s — Kaohsiung in 1966, Nantze and Taichung in 1969.

6 The arrival figures of foreign capital can only be obtained from the balance-of-payment which is reserved by the Central Bank of ROC, hence, not only the manufacturing sector but the actual inflow of foreign capital are not available in the publications. An accurate ratio for manufacturing section is unobtainable. Schive (1979) had attempted to estimate the average contribution of foreign direct investment to capital formation in the manufacturing sector and found it around 6 per cent from 1952 to 1975, and up to 8.6 per cent in the early 1960s based on estimated arrivals.

role in introducing new products and technologies in the automobile, electronics and plastics industries, but less significantly in the machinery and textile industries. Another survey, by Yen (1989), found that 57.4 per cent of the products produced by US firms in Taiwan were new products in the market, and nearly 60 per cent of them were copied after a lag of only five years. These findings indicate that foreign direct investment accelerates technology transfer.

Another benefit from foreign direct investment in Taiwan has been its effect on training. Scott (1979) pointed out that some of the products in export processing zones require a high degree of engineering and manual skills to produce. Hence, foreign firms not only have to train the operatives but also the managers and technicians, some of whom are also sent abroad to be trained. He also observed that American firms, in particular, prefer hiring Chinese managers and technicians because they are much cheaper and have no language problems in communication. The managers and technicians who are trained in this way earn higher salaries.

Furthermore, there is a certain turnover of personnel, who often subsequently work for local firms or establish their own business.[7] The phenomenon of labour mobility is indeed rather common in Taiwan. The average separation rate of employees in the manufacturing sectors is around 3-4 per cent. Unfortunately, there are no available data to verify turnover rate between foreign firms and indigenous firms. Yen (1989) found that newly established foreign firms preferred to hire managers and technicians who had had experience in other foreign firms. This fact implies that there may be high mobility among foreign firms. Despite the paucity of data, mobility from foreign firms to local firms is often considered to be higher than among foreign firms. Assuming this is to be the case, labour turnover is an important channel for disseminating new technology and know-how in the Taiwanese economy.

According to the theory of human capital, human capital accumulation involves the whole range of formal schooling, post-school training and on-the-job training. In general, more investment in human capital increases productivity and thereby earnings, if wages are paid in accordance with productivity. The observed differentials in earnings among individuals are the result of differences in human capital acquisition. According to this theory, a worker in a foreign subsidiary has the opportunity to accumulate higher human capital because of intensive on-the-job training programs which are commonly underwritten by foreign subsidiaries. In this sense, labour turnover from foreign subsidiaries to local firms can accelerate the diffusion of knowledge and the growth of industry. An industrial level estimation of

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7 Businessweek March 3 1986 (p. 63-70) reported that General Instrument Corp.'s Taiwan subsidiary competes with 11 companies founded by the former employees.

the Mincer type (Mincer 1974) on wage profiles[8] in the preliminary study provides evidence. The estimation shows that labour mobility is higher in industries with higher foreign capital participation in Taiwan, as indicated by the returns to experience being higher than the returns to tenure in industries with high foreign involvement.

There is also some transfer of technology as a result of foreign firms' purchasing local materials through linkage to the local economy. The most common indicator for measuring the linkage effect is the behaviour of foreign firms in respect of local procurement. The average local procurement ratio in Taiwan remained rather steady during 1975-89, ranging from 50 per cent to 55 per cent. A study by Schive (1990) indicates that Taiwan Singer Co. provided a variety of services to supporting firms; for instance, opening up their tool room to parts suppliers to help them make tools and fixtures, and solving technical problems.

These studies all suggest the existence of spillovers from foreign direct investment into the Taiwanese economy. However, indigenous firms may also generate a similar contribution to the economy. The literature suggests that the impact of foreign direct investment on development would be minimal if foreign subsidiaries simply behaved in a similar way to indigenous firms. A comparison of the performance of foreign subsidiaries and local firms is therefore made in Chapter 4. If foreign subsidiaries are superior in their utilisation of scale economies, advanced technology, or marketing know-how, there is a gap and potential catch-up by domestic firms to foreign firms. The differences in performance between foreign and local firms are tested in Chapter 4.

If foreign subsidiaries do perform differently from local firms, their contribution to the host economy may also be different. No systematic study has previously been attempted to assess this question for Taiwan. This study therefore attempts to provide evidence of the existence of spillovers by testing productivity efficiency among industries and firms.

Firstly, industrial level analysis is undertaken in Chapter 5. The hypotheses that spillovers raise the productivity of indigenous firms, and that the productive efficiency in an industry is a function of foreign capital participation, are examined. It is hypothesised that the higher the proportion of foreign capital in an industry, the higher productive efficiency will be. An index number approach is used to measure total factor productivity (TFP) across industries. A Spearman's rank correlation is used to test the relationship between TFP and the inflow of foreign capital, following a decomposition of TFP into scale and foreign spillover effects to identify the sources of TFP growth. The second part of the empirical analysis tests for spillovers across

8 Mincer-type human capital earning functions assume that wages are a quadratic function of education and experience.

firms in an industry. The firm-level analysis is presented in Chapter 6, comparing productivity differences over three periods in the same firm as a function of spillovers. The analysis is based on decomposition of TFP growth into scale, cost efficiency, technological progress and price effects.

The industrial level and firm-level productivity analyses provide evidence that the spillover effects from foreign direct investment are a source of the growth of total factor productivity, and thereby information helpful to policy makers in their attempts maximise national welfare by optimising resource allocation. Summaries of the major findings and their policy implications are included in Chapter 7. This chapter also suggests some directions for further work on the subject.

The thesis seeks to analyse a specific contribution of foreign direct investment —in the form of spillover effects—in a developing country. The interest is in two particular points: first, the strategic behaviour of foreign subsidiaries in the presence of spillover effects is analysed to determine the possibility that these effects lead to a shrinkage of the technological gap between foreign and domestic firms. Secondly, the effect that foreign direct investment may have on the improvement of productivity efficiency, the rate of technological progress, and technical efficiency in the host country is analysed. An attempt is made to ascertain whether variations in productive efficiency among local firms correlate to the presence of foreign subsidiaries in the economy. An attempt is also made to identify the mechanisms through which the spillovers from foreign direct investment are transmitted. Measures of total factor productivity are employed to represent productivity efficiency, and two approaches—the index number approach and the production frontier approach—are employed to measure the growth of total factor productivity. Throughout the thesis, the empirical evidence is drawn from data on the Taiwanese manufacturing sector.

2 Analytical Framework

Traditional trade theory predicts that a country will enjoy comparative advantage in the export of goods which embody its relatively abundant factors of production and import goods embodying its relatively scarce factor of production, on the assumption that the same technology is available across countries. For instance, Ramaswami (1968) demonstrates that, in trade between two countries sharing the same technology, a country can gain more through monopsonistic imports of a relatively scarce factor than through monopolistic export of one that it has in relative abundance. This may explain why some developing countries strongly encourage the inflow of foreign capital, which is scarce in most of these countries. Yet some countries impose strict limitations and control over foreign capital inflow, as noted in Chapter 1. The Ramaswami model is recognised as far too simple to yield 'real world' answers.

Theories of foreign direct investment have tried to clarify its net impact on host countries. Tsai (1990) focuses on three of the models developed to study the costs and benefits of foreign capital inflow on a host country and to evaluate the impact of foreign direct investment; namely MacDougall's (1960) two-factor one-commodity partial equilibrium model, the standard Heckscher-Ohlin-Samuelson general equilibrium model, and Caves' specific-factors model (1971). However, these models leave important questions unresolved.

These theories concentrate on evaluating the net effect of foreign investment without taking into account the learning effect and other externalities which indigenous firms may gain from the foreign subsidiaries. This may result in underestimation of the impact of foreign direct investment on the host country. The presence of such externalities may raise the welfare of the host country through the growth of local enterprises or the diversification of consumer choice. This may lead the foreign firms to make different decisions from those they would otherwise, especially when they face competition in the local market. The different managerial strategies of foreign firms may in turn affect the output and profit of local enterprises and the welfare of the host country if there are spillover effects.

In what follows, the implications of foreign direct investment for host countries in the presence of spillover effects will be examined and the various sources of spillovers as well as their potential impact on the host economy will be reviewed. In general, local markets can gain efficiency in production via the absorption of spillovers, thus improving economic performance. Investigation of the possibility that local firms can catch up with foreign firms in production technology and performance via the absorption of spillovers is of interest. The benefits of the inflow of foreign capital may lead the host government to introduce incentives to encourage inflow, but the threat of local firms' catching up may affect the decision-making of foreign firms. Their response to the presence of spillovers is then examined. Firstly, the decision to export or undertake foreign direct investment is examined by incorporating the tariff protection of the host country and the presence of spillover effects. Secondly, the response to technology transfer in the presence of externalities is investigated. Assuming profit maximisation by the foreign subsidiary, is there any incentive for it to transfer better technology continually even in the face of spillover effects? Does the technology transfer benefit indigenous firms? And, does the transfer increase the welfare of the host country? In general, if the transfer is beneficial and the impact is positive, it is possible for policy makers to decide whether to encourage inflow or leave it to market forces to produce an optimal allocation of foreign direct investment among countries. For instance, a policy maker can enact preferential financial treatment for foreign investors to encourage capital inflow.

As a disseminator of information and technology, as a supplier of new or better quality products, and as a stimulator of competition and entrepreneurship, foreign direct investment can play a role in improving the economic performance and the competitiveness of local enterprises in the host country. Some may argue that information or technology transferred by foreign firms only leads to geographical diffusion without diffusion to local users, because ownership and control of the technology or information remain in the possession of the foreign subsidiaries. However, knowledge, to some extent, is a public good; there is no absolute way to limit its use to one firm or person once it has been dispersed. Hence, the host country can, in principle, gain indirect benefits through the diffusion of know-how via the presence of foreign firms. The spillover effects of foreign firms in host countries are commonly divided into two categories: the influence on the efficiency of host country competitors; and the influence on local suppliers and consumers—that is, linkage effects.

The contribution of spillovers to productive efficiency

The spillover effects of foreign direct investment on the efficiency of domestic firms have been studied by Caves (1974) for Australia, Globerman (1979) for Canada, Blomstrom (1989) for Mexico, and Haddad and Harrison (1993) for Morocco. Each hypothesise that spillovers should stimulate the productivity of rival firms by increasing competition, enhancing human capital formation, and speeding up technology transfer. More specifically, they postulate that if there is a positive statistical relationship between the level of productivity of the domestically owned sector in an industry and the share of foreign subsidiaries in that sector, then foreign direct investment may be assumed to be a productivity-raising force. It is further suggested that, over time, the productivity of domestic and foreign firms would tend to converge. Labour productivity, or changes in labour productivity, is taken as the variable to be explained in most of these studies. The productivity variable is then regressed on a number of explanatory variables which might influence it, including the presence of foreign firms: capital intensity, labour quality, degree of concentration in the industry, and the extent of scale economies. The relationship between the presence of foreign firms in a particular industry and the labour productivity of that industry is weakly established in the Australian and Canadian studies, but is stronger in the Mexican case.

Blomstrom and Wolff (1989) also find notable productivity spillovers within industries. They find strong evidence that foreign firms acted as a catalyst to productivity growth in Mexico's manufacturing sector and that foreign direct investment speeded up the productivity convergence process between Mexico and the United States.

There are four channels by which the entry of foreign firms affects their local competitors. First is the increased competition in the local market; second is the enhancement of human capital (via more or better training of labour and management, or through recruitment of such resources from foreign-owned subsidiaries); third is the speeding up of technology transfer; and fourth is the linkage to the domestic economy via their purchasing or sales strategies.

Increased competition

The first potential effect is on competition in the host market. Probably the most widely acknowledged externality of foreign direct investment on a host country's industry is its impact on the competitive position and performance of individual rival firms. In general, the influence of a new entrant on the producers in a particular industrial sector will depend on the existing characteristics of that sector, namely:

(i) the number and size of firms;
(ii) the composition of their output and market;
(iii) their innovatory capacity;
(iv) their existing and potential economic performance, that is profitability, productivity, and market share;
(v) their entrepreneurial ethos;

(vi) the market prospects for the industry and whether or not existing firms are operating at surplus capacity; and

(vii) the extent to which the industry is protected from competition by import restrictions and subsidies.

The market competition is thus determined by these factors. However, the entry of foreign direct investment may increase this competition since they are more efficient than local firms. Their entry may induce those marginal inefficient firms to exit or force local firms to adopt more efficient ways in production. Their impact on market competition depends on the nature and extent of the ownership advantage of foreign firms. The greater the ownership advantages of foreign firms which can be effectively transferred or developed in a foreign location, the greater the potential impact on competitors. Aside from this, the form of entry may also affect its influence on the host market. The acquisition of local enterprises in a technologically advanced and fast-growing sector is likely to have a very different competitive impact on other firms in that sector than the setting-up of a completely new venture, or the purchase of a small firm in a traditional and declining sector. Also, the choice of joint venture or wholly-owned investment is likely to have a different effect on market competition.

From the perspective of local enterprises, it will be important to improve performance in the face of foreign firms' competition by strengthening their innovatory capacity, productivity, marketing and so forth. Their ability to respond to competition depends on their capacity either to create or acquire competitive advantage similar to that of the foreign firms. However, in developing countries, domestic firms may be technically far behind foreign producers, and often they cannot hope to respond positively to the challenges of competition. Under these circumstances, local enterprises can put effort into making cooperative or technical service agreements with foreign competitors. In some cases, a patent may inhibit a local firm from producing an identical product to a foreign competitor. Yet, by reverse engineering and knowledge derived from R&D, an indigenous firm can try to develop substitutes or break into entirely different segments of the market. Domestic firms may also try to obtain some help from their own government to reduce costs of production or transactions via negotiation. The third option for local firms is to exit from the market. In all cases, the entry of foreign direct investment will either force existing inefficient indigenous firms to improve their productivity or drive them out, freeing the resources they had controlled to more productive companies.

The pressure of competition makes local firms modify and improve the product range or productive response, and introduce new marketing and distribution methods to reduce transaction costs. It appears that a most significant positive influence of foreign direct investment is the increase of competition in the domestic market.

Several studies provide empirical evidence of the impact of foreign investors on their competitors. Dunning (1958, 1992) found that the entry of foreign direct investment squeezed out many competitors and potential competitors in UK semiconductor and auto industries, as well as in the colour television industry in the United Kingdom and the United States. Meanwhile, local enterprises enjoyed improvement in product quality, diversification of the range of products and a boost to research and development (R&D) expenditure, as well as the upgrading of managerial and marketing techniques. His studies conclude that foreign direct investment has acted as a stimulus to efficiency in host countries. He also concludes that the most beneficial aspects of foreign direct investment have occurred in those countries and sectors where the existing or potential innovatory and production capacity of the indigenous firms is the strongest.

A number of studies confirm the negative relationship between the entry of foreign subsidiaries and market concentration in the host economy (for instance, Dunning (1974) and Knickerbocker (1978)). Some econometric analyses also confirm this negative relationship in the presence of foreign direct investment (Caves (1974); Globerman (1979); Blomstrom (1989)). Thus it is possible to conclude that foreign direct investment tends to reduce the level of concentration and to increase competition in host country industries.

Training and recruitment

The second source of spillover to a host country is the training of labour and management which takes place in the foreign firms and then becomes available to the economy in general when trained workers change jobs. A worker who is trained in a foreign subsidiary may find it advantageous to exploit the human capital thus acquired by moving to a domestic firm or by becoming an entrepreneur. According to the theory of externalities, when a firm recruits trained workers, it usually will not pay the full costs of their training, particularly the cost of general training. However, the movement of labour from foreign firms to domestic firms brings both new skills (specific training) and experience (general training) which will increase the efficiency of the hiring firms. Moreover, a foreign firm has the privilege of accessing human resources throughout its global networks, and so the presence of a foreign subsidiary brings some of these advantages to local firms by offering a pool of differently trained and experienced labour through the external market.

The available evidence on spillovers from the training of employees by foreign firms comes mainly from developing countries where the stock of accumulated human capital in productive knowledge is relatively scarce, basically because of lesser R&D expenditure. Gershenberg (1987), using survey data on Kenya, found that joint venture firms made a significant contribution to the training of local management and the dissemination of managerial know-how throughout the society. Blomstrom (1989) finds that many managerial personnel in locally owned Mexican firms had started their careers in a multinational company. This led to a substantial improvement in the management practices within Mexican firms. Schive (1990) also finds that Taiwan Singer conducted numerous training programs, including the study of heat treatment, the inspection of finished products, the use of measurement instruments, and the introduction of new concepts and techniques of factory management. The efforts of Singer led Taiwan's sewing machine industry to outstrip Japan's within a short period, the training program being one of the major contributions to this success. Schive also finds that Singer transfers management technology through assistance to its local suppliers. This influence is also confirmed in other studies by Behrman and Wallender (1976), Lall (1979) and others. Yen (1989) finds that newly established domestic firms tended to recruit managers and technicians who had worked for foreign firms in Taiwan. This mobility strengthened over time. His conclusion is that labour mobility, especially from American foreign subsidiaries, enhanced technology transfer into Taiwan's manufacturing sector.

The training spillover effect in developed countries may be less significant than that in developing countries, yet, as illustrated by Lorenz (1982) using the micro-electronics industry in the United States as a case study, the diffusion of technology is greatly enhanced if there is a high mobility of engineering, scientific and managerial personnel.

Accelerated technology transfer

The third possible source of spillover from foreign direct investment is that foreign firms may speed up the transfer of technology. As noted in Chapter 1, technology transfer through foreign direct investment is absorbed relatively easily and reduces cost. The entry of foreign firms may also improve the productive efficiency of domestic firms and narrow the technological gap. The threat of catching up by host country firms accelerate the rate at which foreign subsidiaries import new technology. On the other hand, developing countries, with limited indigenous resources for research and development, are particularly dependent on foreign firms for accessing modern technology. It is also likely that the magnitude of spillover varies with the flows of technology to the foreign subsidiaries in the host country—the more technology that is available, the larger the spillover potential.

Several studies stress this type of spillover effect. Mansfield *et al.* (1982), in a detailed study of technology exports by US firms, finds that the introduction of technology abroad speeds up the appearance of competing products or processes by at least 2.5 years in about one-third of their survey. Moreover, their study of British firms finds that over half of the American subsidiaries in the United Kingdom believed that at least some of their products or processes had been introduced to the recipient market more quickly than otherwise they could have been. Yen's study (1989) finds that over half of American subsidiaries in the Taiwan manufacturing sector introduced new products to the market, especially in the fast-growing chemical and electronic industries.

Linkage effects

Apart from these three possible sources of spillover, there is another: the impact on local suppliers and customers or the linkage effect. There are two types of linkages: backward linkages, extending back from the purchases made by a firm; and forward linkages, extending through the inputs that it supplies to other processes and activities.

Backward linkages

The extent to which foreign subsidiaries may affect the economic welfare of suppliers of their raw materials and intermediate products depends on the quality of the goods and services they buy from them, the influence they exert on the terms of procurement and the impact they have on the technological capability and managerial initiative. The first two rest on decisions about the local content of each of the products produced by foreign subsidiaries. The lower the proportion of local content, the more dependent the firm will be on the open market for its purchases. Foreign firms' strategies on local purchase depend on:

(i) whether products are intended for the local or the world market. If they are mainly oriented to the domestic market, they tend to have a higher proportion of local content in order to satisfy the specifications and tastes of local users.

(ii) whether activities are coordinated with those of the organisation of which it is a part. This decision often rests on comparative transaction costs between internalising or purchasing in external market. The costs of engaging in external transactions include many of the costs of market failure, such as the search costs for potential suppliers, the costs of negotiating with the chosen suppliers and conditions of supply, and a variety of costs associated with buyer uncertainty. However, the decision sometimes depends on the degree of foreign ownership in the subsidiary. Foreign subsidiaries with a higher proportion of foreign ownership tend to link to their parent firms more closely than otherwise. Because it is easier for them to access information and knowledge within their global network, they are commonly vertically integrated with their parent firms.

(iii) the stage of development of the host country. In some developing countries, foreign subsidiaries may have to engage in more manufacturing operations than they would normally wish, simply because of the lack of a domestic supplier capability or inadequate safeguards against the adverse effect of market failure.

(iv) government policy, which may also affect the sourcing decision. The main instrument used by governments to assist local suppliers is restrictions on imports of competitive components and raw materials for foreign subsidiaries or local content requirements.

Aside from these, the age and experience of foreign subsidiaries may also affect procurement decisions. Most foreign direct investment begins with newly established subsidiaries undertaking simple finishing operations and importing most of their intermediate products. Gradually, as and when domestic technological and productive capacity and the prices of indigenous intermediate products become more competitive, the ratio of local content will increase.

The impact of foreign firms on the quality of their purchases and the efficiency with which they are provided also creates linkages to the domestic economy.

The literature identifies seven main types of linkages which purchasers may form with their suppliers:

(i) <u>information linkages</u>: including exchanges of information on market characteristics and trends, on future investment intentions, and on foreign suppliers of machinery, parts, materials, components and so on.

(ii) <u>technical assistance</u>: including help given or received on such matters as innovation and product design, proprietary product specifications, development processes, factory layout, tooling, quality control, labour training, inventory management, machine maintenance, inspection and testing procedures, provision of used machinery and specialised tools and equipment.

(iii) <u>financial assistance</u>: including loans, pre-financing of machinery and tools, and special price agreements and financial help to local suppliers in visiting companies in the home country of the parent company.

(iv) <u>procurement assistance</u>: embracing help in obtaining capital equipment, raw materials, and other intermediate products at competitive prices.

(v) <u>location</u>: giving advice on the siting of a new plant or an existing establishment.

(vi) managerial and organisational assistance: giving assistance on a range of financial, accounting and general managerial control procedures, and also giving technical advice about the costing of products.

(vii) other assistance: helping to obtain market share in the open market, including the export market, advice on diversification strategies, dealing with foreign suppliers, and so on.

Foreign firms may only provide those linkage benefits which are to their own advantage. In order to maximise their own profits, foreign firms may assist domestic suppliers to upgrade intermediate inputs and improve productive efficiency and profitability, particularly in developing countries where supporting industries are underdeveloped. Numerous studies provide empirical evidence on this type of linkage effect. Brash (1966) examines the impact of General Motors in Australia on its local suppliers, through its insistence that they meet standards of quality control. Lim and Pang (1977) survey the electronics industry in Singapore and find that foreign firms are willing to assist in the establishment of local supplier firms, providing technical assistance, financial aid, managerial advice, and market information. Schive (1990) also finds similar linkages from foreign firms in Taiwan's sewing machine industry. Reuber (1973), Cohen (1975), Lall (1979), Kumar (1989), and others also provide empirical evidence on this spillover effect. However, systematic analyses of the effects of foreign participation on industries outside their own are lacking; more research is needed to draw any strong conclusion about these effects.

Forward linkage

Some of the reasons for forward linkages are similar to those for backward linkage, although the nature of the costs and benefits of internalised and external transactions may be different. The most commonly discussed forward linkage is the linkage established with buyers of technically complicated products. Foreign subsidiaries may advise their customers on how to use and maintain machinery and equipment to help them make the best use of their products. The subsidiaries may also provide information and offer functional guidance about the technical characteristics and usage of the products being sold and the servicing requirements.

Dunning (1958) gives examples of the way in which US firms helped their customers make the best use of their products. Schive (1990) also finds evidence of the same strategy. Blomstrom (1991) concludes that this kind of spillover might become more important in the future. Because newly developed technologies are generally knowledge- and research-intensive, small countries may have to accept a certain degree of dependence on the technology of multinationals. It is more important for small countries to have the capability to use advanced technologies than to produce them.

Strategic responses in the presence of spillovers

If host countries gain spillover benefits from foreign direct investment, the question is whether they should adopt policies to maximise these benefits. In the 1960s and 1970s, many developing countries introduced various performance requirements or tried to frame an environment within which foreign subsidiaries would operate. These policies commonly paid special attention to encouraging foreign firms to foster technology transfer. This often took the form of requirements for local content. In the short run, these requirements may have some merit in protecting local production, but they may sometimes force foreign subsidiaries to buy products that are not economic and this increases the costs of production, especially where domestic firms are protected from external competition. The pressure on firms to use local products might impede the upgrading of quality standards and the innovation of more efficient production methods. Nonetheless, the economic rationale for such policies was clear.

On the other hand, with increasing technical competence and greater experience, local suppliers eventually become competitive with their foreign rivals, especially when foreign subsidiaries spill over benefits to the external market. It may be better if government policies focused on improving market conditions rather than on administrative controls and direct technology transfer requirements. Blomstrom and Wang (1989) conclude that, if host countries want to encourage foreign firms to transfer technology, they should concentrate on supporting indigenous firms to learn from foreigners, rather than stipulating performance requirements for the foreign subsidiaries. Blomstrom *et al.* (1992) examine technology imports by American subsidiaries in 33 foreign countries and find that imports are positively correlated with the income level of the host country and competitive pressure in the host country, while negatively correlated with the level of distortions and various host country performance requirements. This negative impact of performance requirements on foreign firms' technology transfer activities is also confirmed by McFetridge (1987).

For host governments, these studies imply that policies to maximise inflows of technology and to foster spillovers should rely on creating a more competitive market environment. They may also mean putting effort into increasing domestic technological capability, such as through subsidies to education and training. Local firms may obtain dual benefits from these alternative policies.[1] First, the foreign firm is forced to upgrade its production processes and import new technology in order to adapt to the competition in the host market, in pace with competitors' productivity improvement. Second, the continuous inflow of technology increases the spillover potential, while the support to local firms increases the likelihood of actual spillovers.

Spillover effects improve the productive efficiency of host country competitors; however, such externalities may threaten the performance of foreign subsidiaries and affect their strategic technology transfer choices. The form of the 'catching-up' threat and the response of foreign firms is a critical issue. It is commonly acknowledged that technology is a key determinant of economic growth and international competitiveness as well as trade performance, and foreign direct investment has become the most important actor in the generation, application and international transfer of technology. In addition, technology transfer via foreign subsidiaries produces spillover effects through the learning processes of indigenous firms. In reality, the transfer of new technology is generally at the discretion of foreign firms, especially when they have to face the cost imposed by the 'learning-from-watching' of the indigenous firms. Such leakages sometimes become a threat to the foreign firms, as they spawn their own competition by creating a local pool of managers and skilled technicians. Watanabe (1980) investigates the Hong Kong electronics industry and finds that local engineers who worked in the US subsidiaries which assembled parts and components imported from the United States learned assembly line techniques. Many of them then started their own small firms, later competing with the American subsidiary. The same situation occurred in Taiwan's electronics industry during the rapid growth era.

The catching up of indigenous firms

There is one theoretical model which can be employed to explain whether foreign firms face threat from domestic firms via continuous technology transfer—the North-South model. Ownership advantages allow foreign subsidiaries to accumulate higher human capital, either technology or management, and their products embody higher level techniques and quality than the products of domestic firms. By adopting new technology or by learning-by-watching, indigenous firms have the chance to enhance their techniques and quality. This transmission process is similar to that described in the North-South model. Utilising this model exposes the possibility of the indigenous firms' catching up to foreign firms in the presence of technology transfer.

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1 Blomstrom (1991) indicates that there is possibly a 'virtuous circle' of productivity and technology growth in host countries, in contrast to the 'vicious circle' that happens when foreign firms are allowed to operate without any competition.

The North-South model was developed by Krugman (1979), and extended by Dollar (1986) and others, and is basically a model of Vernon's (1966) product cycle theory. In this approach, new products are generally assumed to be introduced continuously and produced in the North. With some time lag, the South—the less developed region—acquires some of the knowledge and begins to produce the products which were formerly produced only in the North. The North produces only 'new' goods and the South produces only 'old' products. Complete specialisation in production is assumed in this approach,[2] and the relative wage rate determines the products to be produced in each region. Higher per capita income in the North depends in part on the rents from their monopoly of newly developed products.

The implications of this model are relevant to the present study. Foreign subsidiaries may be considered as the 'North', with new technology being continuously transferred from parent firms to maintain competitive advantage in a host economy. The products produced by foreign subsidiaries are usually new to the host market. Meanwhile, indigenous firms—like the 'South'—learn the production techniques after some 'imitation lag' and their products are 'old' compared with those of the foreign subsidiaries.

Krugman's model assumes there is only one factor input,[3] that is labour, and the only source of wage differential between regions is the 'special ability' of the North.[4] The perfect competitive market assumption implies that relative wage rates are equal to the prices of goods produced in both regions. Meanwhile, the relative demand for goods in the North and South, which depends on the relative prices of these goods, is derived from a utility function.[5] In addition, the demand for labour is equal to total output (total demand) for each of the goods times the number of each type of good. Hence relative wages can be expressed as a function of relative labour forces and the ratio of new to old goods in the world market. This implies that either region can improve its terms of trade by extending the range of goods that it produces. An increase in innovation will raise wages in the North, while an increase in technology transfer will raise wage rates in the South because of an increase in the number of goods produced.

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2 This condition implies that the wage rate is equalised in both regions, otherwise it is a disadvantage for the North to produce old products because of its relative higher wage rate.

3 The model also assumes that the cost function is the same for all goods and that there is no labour productivity differential between regions.

4 Special ability implies an advantage for developed countries in producing new products, which Vernon and others suggest includes a more skilled labour force, external economies, and a simple difference in 'social atmosphere'. These special abilities enable the North to gain the monopoly rent in its products and are reflected in the higher wage rate.

5 This assumes that all individuals in the North and South have the same utility function. This assumption is more convenient in this study because the individual is located within one country.

The stock of new and old products is determined over time by two processes of technological change—innovation and technology transfer. Innovation is the process by which new products are created; technology transfer is the process by which new products are transformed into old products. Both of these are assumed to be taking place continually in the model. Because of these two processes, the world economy tends towards a moving equilibrium where relative wages are constant, with a fixed differential in favour of the developed country. However, this wage differential is an increasing function of the rate of innovation and a decreasing function of the rate of technology transfer. Beyond the steady state, the model also predicts that a higher rate of innovation benefits the developed countries, while the most striking conclusion is that technology transfer can actually make the developed country worse off. This model concludes that the monopoly of the developed countries is continually eroded by the higher relative rate of technology transfer but can be maintained by accelerating innovation.

On the other hand, it is widely acknowledged that there is a wage differential between foreign subsidiaries and local firms because workers in foreign firms own higher accumulated human capital through training programs. Therefore, continual technology transfer from parent firms ensures the differential of wage rates between foreign subsidiaries and domestic firms. However, the introduction of new technology and the mobility of skilled workers from foreign subsidiaries enhances the learning capability of domestic firms, which leads to a shrinkage of the wage differential. As a result, according to this model, local firms may have an opportunity to catch up with foreign firms if technology transfer from parent firms slows down or if domestic firms increase their technology capability. An application of this model obviously provides insight into the relationship between foreign subsidiaries and indigenous firms. Foreign subsidiaries have to adopt new technology continually from their parent firms in order to maintain their leadership in the host market when there are spillover effects.

The differences between foreign subsidiaries and local firms in technology, wages, profitability and other strategies will be tested in Chapter 4. Under this model, if foreign subsidiaries enjoy performance superiority, there would be a catching-up process indicated by higher productivity growth of local firms.

If foreign subsidiaries face a potential catching-up threat from domestic firms with or without these externalities, then how does the host government react to attract the inflow of foreign capital and enlarge such externalities? How do foreign firms react when they face spillovers: export or internalise? Is there incentive for them to transfer technology continually? The latter two questions refer to the cost-benefit evaluation of strategies that foreign firms may make, while the reaction of host governments is based on consideration of the welfare of the whole economy.

The response of foreign firms

Exports versus foreign direct investment

Since spillover effects have the potential to shrink the technology gap between foreign subsidiaries and indigenous firms, the host government tends to initiate favourable policies to attract the inflow of foreign capital. The major tools that host governments have commonly used are tariff policy, tax policies and other financial treatments. Tax deductions, tax holidays and preferential interest rates have been widely implemented in developing countries. In general, the contents of these policies are roughly the same across countries. From the viewpoint of foreign firms, it is hard to discriminate between one country and another in deciding on location. In this sense, tariff policy may be a major concern for foreign firms, since particularly high tariff rates have commonly been levied in the early development stage of developing countries. But tariff and other trade barriers are likely to decrease with the growth of a country, because a growing economy requires increasing interdependence with outside world. Increased openness flows from two factors: one is pressure from international organisations, mainly the GATT (General Agreement on Tariffs and Trade); the other is internal pressure from the offset of high tariffs in distorting the resource allocation and reducing national welfare. Nowadays, tariff barriers have become less and less important in foreign firms' location decisions, but compared with other instruments, tariff policy is still a potential tool for influencing foreign firms' strategic behaviour. Cost considerations determine the site of overseas production; however, if domestic firms benefit from spillover effects and catching-up, how are foreign firms' decisions affected? The trade-off between cost reduction and the threat of catching-up is a critical issue for foreign firms.

In general, tariffs affect foreign firms' investment decisions in two ways: via direct and indirect effects. An industry protected by tariffs makes larger profits or potential profits, so this policy can lead to a movement of capital and labour into this industry—either via domestic or foreign factors. Furthermore, tariffs may induce 'defensive investment', because foreign firms may seek to restore their export market and profits which were shrunk as a result of host markets being protected by tariff barriers. Furthermore, foreign firms may also wish to utilise their production techniques, distribution channels, goodwill and other know-how, and so they tend to invest in the same industry in which they operate in their home countries.

Aside from these direct effects, there are some indirect effects which work to counteract the favourable direct effect. For instance, a tariff may encourage one industry but discourage other industries which are located downstream or upstream of the protected industry. A tariff is like an export tax on these industries and will lead to a reduction of foreign capital inflow into them. In addition, when the host country reaches full employment, the protected industry squeezes other industries as factors crowd into this industry and distort factor prices. The distortions increase costs and make industries less profitable, discouraging foreign capital inflow.

Taking into account both direct and indirect effects, the tariff effect in attracting foreign capital inflow is ambiguous. Nevertheless, according to the pure theory of international trade, if capital is homogeneous and mobile among industries, general protection through import tariffs will induce foreign capital inflow when the imported products are on the whole the capital-intensive goods, because tariffs raise the rate of return on capital. The simple Heckscher-Ohlin model assumes no 'factor reversals', so a country is likely to import goods which are intensive in the country's relatively scarce factor. If capital-intensive products are imported, then presumably the scarce factor is capital. A net capital importer will import capital-intensive products. This suggests that tariffs may indeed induce foreign capital inflow.

Many empirical studies have found that foreign firms believe that it is more profitable to establish or expand subsidiaries behind tariff barriers than to export. Wilkins (1974) observes that many US enterprises withdrew their overseas investments due to domestic depression in the 1930s, but some were compelled to expand their production abroad because higher tariffs were imposed by host governments. The high tariffs forced firms to undertake direct investment to supply foreign markets behind the customs walls that once were the export markets.

Similar evidence has been provided by other studies. The survey by Toyo Keizei (1985, 1992) of Japanese enterprises' foreign investment activities also reports that high protection of the domestic market was one of the major motivations for Japanese firms undertaking investment abroad. Brash (1966) also reports that bypassing tariff barriers was an important motive for American companies in setting up subsidiaries in Australia. Saham's (1980) survey of British firms established in Malaysia in the 1960s finds that overcoming tariff barriers stands out as the most important motivating factor in deciding on international production. Nevertheless, Chen and Wang (1990), surveying Taiwan's electronics firms in Southeast Asia, find that trade barriers are one element but not a major one in motivating investments.

The influence of tariff structure on the location decisions of foreign direct investment is also confirmed in empirical studies. Horst (1971, 1972) tests the data of

Canadian two-digit manufacturing industries in 1963 and finds that Canadian tariff policy has had a definite impact on the choice between exporting and Canadian subsidiary production. The higher the Canadian tariff, the smaller the share of US exports and the larger the share of Canadian subsidiary production in total US sales to the Canadian market. Reuber (1973) finds that a substantial proportion of foreign investors benefited from tariffs on their outputs. Other studies (Streeten (1962); Balassa (1965); Schmitz and Bieri (1972)) also support the hypothesis that foreign direct investment can be induced through high tariffs.

In theoretical analysis, the tariff rate is commonly modelled as an exogenous given in examining the optimal behaviour of foreign direct investment. For instance, Horst (1971, 1972) explores the profit-maximising strategy of foreign firms selling in two national markets. He finds that the choice of producing and selling in each country depends on the barriers to trade and the differentials between the two countries in the real costs of production. Rugman (1980) and Smith (1987) also take the tariff rate as an exogenous variable in their studies. Brander and Spencer (1987) extend Horst's study by treating the tariff as an endogenous variable, assuming unemployment in the host country. The host government, which needs to maximise national welfare, is therefore influenced by the employment consequences of tax and tariff policy. They find that a higher tariff on imports rather than taxes on local production leads to foreign direct investment if there is unemployment in the local market. These studies show that tariff structures appear to be a major influence on foreign firms' investment decisions. However, these studies take no account of the response by domestic firms.

In contrast to these studies, Liu (1991) incorporates spillover effects to examine the strategic response of foreign firms and the optimal choice of the host government in tariff policy. In the beginning, he assumes that the foreign firm has to pay the same tax rate[6] as domestic firms when a subsidiary is established. The subsidiary will disseminate the externalities to the domestic market which can be acquired without cost by learning-by-watching. On the other hand, the foreign firm has to pay a tariff when it exports to the host country and the tariff rates are designed to maximise the interests of the host government. The welfare function of the host government is measured by the sum of consumer surplus, domestic firms' profits and the revenue received by the government.

In this game theoretic model, the foreign firm possesses better production technology and has the option to export or to establish a subsidiary in each period.

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6 The tax rate is an exogenous variable in his model, which cannot be adjusted systematically due to administrative difficulty in changing policy or the existence of precommitment.

The host government first declares the tariff level in each period and, in each stage, each player will act in its best interests given previous decisions and future expectations. The spillover that the domestic firms acquire is assumed to be positively correlated with the subsidiary's output in the previous period. That means the more the foreign subsidiary's output in the previous period, the larger the spillover effects in relation to domestic firms in the current period. The model also assumes decreasing returns on the learning-by-watching effect, that is, spillovers are a decreasing function to the accumulated learning opportunities. An increase in the spillover effects would increase the domestic firm's output in the second period and narrow the technological gap between it and the foreign subsidiary, thereby reducing the output of the subsidiary in the second period.

The model concludes that the foreign firm will invest directly when the tariff is higher than the tax rate. The foreign firm may establish a subsidiary to overcome a high tariff. However, the establishment of a subsidiary is at the expense of losing relative cost advantage, and reducing the subsidiary's profit. In addition, due to the leakage of spillovers, the exposure of the foreign technology to domestic firms will reduce the subsidiary's cost advantage and profits. When there is strong learning ability among domestic firms, the minimum tariff required to induce foreign direct investment is higher than that without the learning effect. For the host government, the larger the learning effect, the higher the tariff needed to attract foreign investment. On the other hand, the larger the spillovers, the lower the output level of the foreign subsidiary. The effect of a decrease in the output of the subsidiary on tax revenue and consumer surplus, to some extent, will not compensate for the domestic firms' gain from learning. Under these circumstances, a high tariff rate may encourage foreign firms to export instead of undertaking direct investment, if there are strong spillover effects.

This result, which suggests that tariff policy is not certain to attract foreign direct investment when there are strong learning effects by domestic firms, appears different from the traditional analysis of trade protection and investment theory—a static analysis which takes no account of the existence of spillover effects and concludes that a tariff is a motivation for foreign direct investment. By referring this analysis to other preferential policies on foreign direct investment, the protection and incentive policies may not be as effective as expected in attracting foreign capital inflow, and an alternative policy is preferable. Taiwan's case is an example. The transformation of Taiwan government's attitude towards foreign direct investment and its effectiveness in attracting foreign capital inflow are discussed in the next chapter.

The response of foreign firms on technology transfer

After deciding to invest overseas, foreign firms' major concern in respect of technology transfer will be in response to strong learning ability in the host economy. Under the assumption of a fixed stock of technology, foreign subsidiaries may lose their technological edge in the presence of spillover effects, and so may be cautious in making their investment decisions. Where a foreign firm has undertaken investment and established a subsidiary, the best response to offset the erosion of its advantage in production is to try to transfer technologies continually in order to increase the stock of technology in subsidiaries, as per the North-South model. For foreign firms, this strategic response should be able to compensate for losses—otherwise there is no incentive to keep transferring technology. Two studies are relevant here: one is Das' (1987) study on the optimal behaviour of a foreign subsidiary in a host country when there is indigenous firm learning ability; the other is the study by Blomstrom and Wang (1989) in which they emphasise the importance of this learning effort in increasing the rate of technology transfer from parent firms to subsidiaries.

The Das study simulates the strategic behaviour of foreign firms in the presence of spillovers. Following his assumption, market structure incorporates dominant firms (the foreign subsidiaries) with a competitive fringe (the indigenous firms). Because of their foreignness and their superiority to the indigenous firms, the foreign subsidiaries have a strong incentive to coordinate their actions to maximise their profits. The assumption is that foreign subsidiaries form a cartel with collusive price leadership,[7] (although this is a strong and debatable assumption), because cartel theory indicates that, to persist and raise prices, a cartel must

(i) be able to detect and prevent cheating by members;
(ii) have a substantial share of resources; and
(iii) face a relatively inelastic supply response from non-members—low substitutes for the products and inelastic secondary market supplies.

In reality, all of these conditions are not easily met among a group of foreign subsidiaries. However, it is convenient to use this general analysis to highlight the special character of foreign subsidiaries and their relationship with local firms in host country markets.

The character of foreign subsidiaries makes them able to play the dominant role in the host market. Industrial organisation theory indicates that a firm or a group

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[7] It is possible for an industry to have a price leadership role in markets without a single large firm. Markham (1951) describes three types of price leadership: (1) dominant-firm price leadership; (2) collusive price leadership; and (3) barometric price leadership. It is the second type that is discussed here. Barometric price leadership occurs when one (typically large) firm is thought by other firms to have superior information, so they attempt to duplicate its behaviour.

of firms with a large share of the market, and which can affect market price by varying output, is called a dominant firm, whereas the competitive fringe consists of many smaller firms, each with a trivial share of the market. There are several reasons why some firms gain substantial market power, while others do not:

(i) a dominant firm may have lower production costs than fringe firms, because it is more efficient than its rivals, it has better management or better technology, it owns the experience in learning-by-doing, or its production has economies of scale.
(ii) a dominant firm may have a superior product in a market where each firm produces a differentiated product. This superiority may be achieved through advertising or through goodwill generated by its having been in the market longer. This factor can be distinguished more in investment in developed countries; it is of minor importance in the case of investment in developing countries.
(iii) a group of firms may collectively act as a dominant firm. Firms have the incentive to coordinate their production and pricing activities in order to increase their collective and individual profits by restricting market output and raising the market price.

It has been stressed that foreign subsidiaries own firm-specific advantages in production, technology and management, and there is no doubt that they can produce at lower costs. Kumar (1989) and others find that foreign subsidiaries have higher advertising expenditure, providing evidence that they often achieve a higher brand reputation in a product differentiated market. However, identical products are assumed by Das (1987) to emphasise the cost-saving technology transferred by the foreign firms.

The Das model provides a well known and neat model of the response of foreign firms to technology transfer to the host market in the presence of spillover effects, and discusses its potential impact on the domestic firms and host country welfare, it is worth examining the model in detail.

According to the price leadership theory, the dominant firm sets the market price and is followed by fringe firms. Fringe firms are price takers in the market. They can sell as much as they want at the going market price but they cannot affect the price through their actions. The following assumptions are made in the model:

(i) a quadratic cost function is used;
(ii) the spillover is costless to indigenous firms;

(iii) the cost to indigenous firms is inversely related to the spillover which can increase the efficiency of production;

(iv) the rate of efficiency growth in indigenous firms is positively related to the output level of the foreign subsidiary; and

(v) there is no exit or entry of firms.

Das first derives the aggregate supply of domestic firms in the market from the defined cost function which satisfies assumptions (i) and (iii). That is,

$$Q_l = nbP + n(A - \overline{A}) \tag{1}$$

where Q_l is the total output of the competitive fringe, n is the total number of firms in the fringe, P is the price, b is the slope of supply curve, $\overline{A}$ is the upper boundary on A required to guarantee positive cost for all levels of output, and A represents the efficiency of the indigenous firms. According to assumption (iv), the change in efficiency of the indigenous firms in any period, $\dot{A}$, is directly related to the amount of output of the foreign subsidiary during that period. Das defined $\dot{A}$ to be linear in output of the foreign subsidiary Q_f, ie. a constant ratio (α) to Q_f. Hence,

$$\dot{A} = \alpha Q_f,\ \alpha > 0 \tag{2}$$

The residual demand faced by the foreign subsidiary is derived by subtracting the output of the competitive fringe. Assuming the unit costs of the foreign subsidiary as given, then the problem for the foreign firm is to maximise the discounted sum of profits for the whole continuous period T subject to the constraint of the indigenous firms' improving in efficiency, that is,

$$\max \int_0^T e^{rt}(P - \theta c)[D(P) - nbP - nA + n\overline{A}]d_t \tag{3}$$

$$s.t.\ \dot{A} = \alpha Q_{f,}\ A(0) \text{ given,}$$

where $Q_f = D(P) - nbP - nA + n\overline{A}$ and $D(P) = a + D'P$ is the linear market demand function, r is the discount rate and θc is the unit cost of foreign subsidiary. Variations in θ reflect changes in technology for the foreign subsidiary. This implies the technology transferred is the cost-saving process technology. A fall in θ indicates a flow of new cost-saving techniques from the parent firms.

Setting the Hamiltonian and solving this dynamic optimisation, the optimal pricing policy for the foreign subsidiary is derived in equation (4):

$$P(t) = \frac{(\theta c - \lambda)(D' - nb) - a + nA - n\bar{A}}{2(D' - nb)} \tag{4}$$

Where $\lambda = \mu\alpha e^{rt}$, λ may be interpreted as the shadow price of marginal increase in spillovers by the indigenous firm.[8] The market price determined by the foreign firm is negatively related to the level of the indigenous firm's efficiency, and its shadow price, but positively related to the variable θ, which implies that the more cost-saving technology used by the subsidiary, the lower its unit cost and thus the market price.

From the first order conditions and the given initial condition of A(0) as well as the transversality condition $\lambda(T) = 0$, $A(t)$and $\lambda(t)$ are explicitly solved:

$$A(t) = A^* - \frac{A^* - A(0)}{L}[ke^{\eta_1 t + \eta_2 T} - \frac{1}{k}e^{\eta_1 T + \eta_2 t}]$$

$$\lambda(t) = \frac{[A^* - A(0)]n}{L(D' - nb)}(e^{\eta_1 t + \eta_2 T} - e^{\eta_1 T + \eta_2 t}) \tag{5}$$

where $\eta_2, \eta_1 = \frac{1}{2}[r \pm (r^2 + 2\alpha rn)^{1/2}]$ are the eigenvalues of the system. Defining $k = 1 + 2\eta_2/\alpha n$, $L = ke^{\eta_2 T} - (1/k)e^{\eta_1 T} > 0$, and $A^* = \frac{1}{n}(n\bar{A} + a + \theta c(D' - nb))$,[9] it can be noted that $\eta_2 = r - \eta_1 = -k\eta_1$ and $e^{\eta_1 t + \eta_2 T} - e^{\eta_1 T + \eta_2 t} > 0$ for $0 \le t < T$. By differentiating this equation, the influence of both A and λ along the optimal time

8 With λ being negative, the magnitude of ($-\lambda$) can also be interpreted as a 'markup' over the static market price. A rise in λ indicates a fall in the 'markup' and the market price. Since a fall in the market price tends to raise the output of the foreign subsidiary, which in turn increases the rise in efficiency of the indigenous firm, the profits of the foreign subsidiary then tend to decline.

9 For an equilibrium to exist, θc must always be less than the price at which $Q_f = 0$. This price can be calculated to be equal to $-(a - nA + n\bar{A})/(D' - nb)$. Therefore, $\theta c < -(a - nA + n\bar{A})/(D' - nb)$ implies $A^* > A(t) > A(0)$.

path is increasing.[10] These results imply that the efficiency of the competitive fringe is always increasing over time due to the positive output of the subsidiary, and thus its adverse effect on foreign subsidiary's discounted profits due to a marginal increase in A, measured by (-λ), is declining over time (λ being negative).

Since a decline in the market price tends to raise the foreign subsidiary's output, and a rise in the efficiency of the competitive fringe tends to lower it, how does the foreign subsidiary's output shift over time? Differentiating foreign subsidiary's output Q_f with respect to time t,

$$\begin{aligned}\frac{\mathrm{d}Q_f}{\mathrm{d}t} &= (D' - nb)\dot{P} - n\dot{A} \\ &= (D' - nb)(\dot{A}\frac{\partial P}{\partial A} + \dot{\lambda}\frac{\partial P}{\partial \lambda}) - n\dot{A} \\ &= \frac{n}{2}\frac{(A^* - A(0))}{L}[(\eta_1 + \eta_2)(e^{\eta_1 T + \eta_2 t} - e^{\eta_1 t + \eta_2 T})] < 0\end{aligned} \tag{6}$$

The output of the foreign subsidiary tends to decline monotonically. Since the efficiency of the indigenous firm is increasing over time, the best response of the foreign subsidiary is to lower the rate of increase in the indigenous firm's efficiency, that is, by lowering its output over time. The decline in price and output of the foreign subsidiary indicates that its profits decline over time.

On the other hand, a fall in the market price indicates an increase in market demand, $D(P)$, and the sales of the foreign subsidiary declining over time suggest that the output and sales of the indigenous firm increase over time. However, this does not imply that the profits of the indigenous firm increase over time. The profits of the local firm, π_i, are subject to two opposing effects: the rise in A tends to raise it on the one hand, whereas the fall in market price tends to lower it on the other hand. In equilibrium, local firms produce till the marginal cost is equal to the market price, therefore,

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10 $\dot{A} = \frac{A^* - A(0)}{L}[\eta_1 k e^{\eta_1 t + \eta_2 T} - \frac{\eta_2}{k} e^{\eta_1 T + \eta_2 t}] > 0$

$\dot{\lambda} = \frac{[A^* - A(0)]n}{L(D' - nb)}[\eta_1 e^{\eta_1 t + \eta_2 T} - \eta_2 e^{\eta_1 T + \eta_2 t}] > 0$

$$\pi_i = PQ_i - \frac{1}{b}[\frac{1}{2}Q_i^2 - (A - \overline{A})Q_i] - fixed\cos t$$
$$= \frac{1}{2b}Q_i^2 - fixed\cos t \qquad (7)$$

As shown, the profits of the competitive fringe rise over time as long as Q_i rises over time.

Finally, how does the welfare of the host country change along the optimal path? Welfare can be measured by the sum of consumers' surplus and the profits of domestic firms. Since the market price goes down over time, it suggests that consumers' surplus rises with time. In addition, the profits of the indigenous firms also rise. Both effects increase over time, suggesting rising of welfare in the host country.

The study concludes that the dynamic market price in the presence of the spillovers by the indigenous firm is higher than in its absence.[11] Along the optimal path, the price of the product, market share and the profits of the foreign subsidiary all decline over time. However, the market share, the profits of the indigenous firms and the welfare of the host country increase over time.

This conclusion is the same as that in a study by Liu (1991). Under these circumstances, how may the foreign firm respond to keep its competitive advantage in the host market? Will it keep on transferring technology or will it suspend the subsidiary? A profit-maximising foreign firm will evaluate the costs and benefits before making any strategic response. It is necessary to examine how technology transfer from the parent firm affects the optimal paths of market price, and the output and profits of the foreign subsidiary as well as the effects on the indigenous firms and the welfare of the host country.

The technology transferred by a foreign firm is assumed to be cost-saving technology. Thus technology transfer to the foreign subsidiary is indicated by a decline in θ. The impact of changes of θ on the optimal time paths of the efficiency level of the indigenous firm and the shadow price can be examined by differentiating the optimal time paths given in (5):

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[11] The first-order necessary conditions for the Hamiltonian shows

$$D(P) - bP - A + \overline{A} + (D' - b)(P - \theta c + \lambda) = 0$$

In the static case (with $\lambda = 0$), $D(P) - bP - A + \overline{A} + (D' - b)(P - \theta c) = 0$, but in the dynamic environment (λ being negative), $D(P) - bP - A + \overline{A} + (D' - b)(P - \theta c + \lambda) < 0$. Therefore, the market price in the presence of learning by the local firms is higher than that in its absence.

$$\frac{dA(t)}{(-d\theta)} = -\frac{c(D' - nb)}{nL}[ke^{\eta_2 T}(1 - e^{\eta_1 t}) + \frac{1}{k}e^{\eta_1 T}(e^{\eta_2 t} - 1)] > 0 \tag{8a}$$

$$\frac{d\lambda(t)}{(-d\theta)} = -\frac{c}{L}(e^{\eta_2 T + \eta_1 t} - e^{\eta_1 T + \eta_2 t}) < 0 \tag{8b}$$

A fall in θ, which is due to new technology transfer from the parent firm to its subsidiary, implies that the indigenous firm becomes more efficient and the 'markup' rises in magnitude with time, that is, λ falls. How a fall in θ affects the market price and output of the foreign subsidiary can be investigated. Totally differentiating equation (4) obtains,

$$\begin{aligned}\frac{dP(t)}{(-d\theta)} &= \frac{1}{2}[\frac{1}{(D' - nb)}\frac{dA(t)}{(-d\theta)} - \frac{d\lambda(t)}{(-d\theta)} - c] \\ &= \frac{1}{2}\{\frac{1}{(D' - nb)}\frac{dA(t)}{(-d\theta)} + \frac{c}{L}[e^{\eta_1 T}(\frac{1}{k} - e^{\eta_2 t}) + e^{\eta_2 T}(e^{\eta_1 t} - k)]\} < 0\end{aligned} \tag{9a}$$

$$\frac{dQ_f(t)}{(-d\theta)} = \frac{1}{2}\frac{(D' - nb)c(1-k)}{L}(\frac{1}{k}e^{\eta_1 T + \eta_2 t} + e^{\eta_2 T + \eta_1 t}) > 0 \tag{9b}$$

that is, the market price falls and the output of the foreign subsidiary increases. A fall in the market price increases market demand and, at a given level of technology used by the foreign subsidiary, its sales decrease. The reduction of unit cost due to new technology transferred maintains the competitiveness of the foreign subsidiary and thus its output grows. This suggests that the positive effect of savings in costs from technology transfer outweighs the negative effect on the foreign subsidiary's output of the higher efficiency of the local firm. The implication of this result is that the foreign subsidiary allows the rate of increase in efficiency of the indigenous firms to rise as a consequence of technology transfer from the parent firm.

As for the profits of the foreign subsidiary along the optimal paths when new technology is transferred,

$$\begin{aligned}\frac{d\pi_f(t)}{(-d\theta)} = \frac{c}{2}[&(D' - nb)(P - \theta c)(1-k)(\frac{1}{k}e^{\eta_1 T + \eta_2 t} + e^{\eta_2 T + \eta_1 t}) \\ &+ Q_f(1+k)(e^{\eta_2 T + \eta_1 t} - \frac{1}{k}e^{\eta_1 T + \eta_2 t})] > 0\end{aligned} \tag{10}$$

the profits of the foreign subsidiary are higher in every period. The subsidiary apparently benefits from the technology transfer in spite of the leakage of knowledge to the host country. Intuitively, when cost declines due to technology transfer, the foreign subsidiary can make more profits in each period if and only if it achieves to the same price and quantity path as before. Hence, the discounted profits along the optimal path can never be lower if new technology is transferred continuously.

On the other hand, the effect of a reduction in the foreign subsidiary's unit costs on the indigenous firm's output tends to decline with the decrease in market price and increase with the increase in efficiency, as given by

$$\frac{\mathrm{d}Q_i(t)}{(-\mathrm{d}\theta)} = nb\frac{\mathrm{d}P(t)}{(-\mathrm{d}\theta)} + n\frac{\mathrm{d}A(t)}{(-\mathrm{d}\theta)}$$

The net effect remains ambiguous, as indicated by the following equation; the first term is greater than zero, but the second term is less than zero:

$$\frac{\mathrm{d}Q_i(t)}{(-\mathrm{d}\theta)} = \frac{c}{2L}[2D'(\frac{1}{k}e^{\eta_1 T}(1-e^{\eta_2 t}) + ke^{\eta_2 T}(e^{\eta_1 t}-1)) + \frac{nb(1-k)}{k}(e^{\eta_1 T+\eta_2 t} + ke^{\eta_2 T+\eta_1 t})] \qquad (11)$$

Owing to this ambiguity, the profits of the indigenous firm are also ambiguous.

$$\frac{\mathrm{d}\pi_i(t)}{(-\mathrm{d}\theta)} = \frac{Q_i}{b}\frac{\mathrm{d}Q_i(t)}{(-\mathrm{d}\theta)} \qquad (12)$$

The effect of technology transfer on the discounted profits of the indigenous firm turns out to be ambiguous. This result implies that technology transfer is not necessarily favourable to the local industry. The more elastic the market demand and inelastic the domestic firms' supply curve, the more benefit indigenous firms may enjoy, because elastic demand indicates a greater rise in the output of the foreign subsidiary when market price falls, and hence the more efficient the indigenous firm is. On the other hand, the lower the slope of the indigenous firm's supply curve, the greater the chance that it benefits because its output does not go down much as market price falls, due to the technology transfer.

Given that the indigenous firm does not necessarily gain from the technology transfer of the foreign parent firm to its subsidiary, what is the welfare change along the optimal time path? Since

$$\frac{dW(t)}{(-d\theta)} = -D(P)\frac{dP(t)}{(-d\theta)} + \frac{d\pi_i(t)}{(-d\theta)}$$

substituting (7) and using $dQ_i = Q_i dP + (Q_i/b)\,dA$, obtains,

$$\frac{dW(t)}{(-d\theta)} = [Q_i - D(P)]\frac{dP(t)}{(-d\theta)} + \frac{Q_i}{b}\frac{dA(t)}{(-d\theta)} > 0 \qquad (13)$$

that is, technology transfer by foreign firms can still improve the welfare of the host country. This is because a fall in θ leads to a rise in the efficiency of the indigenous firm which has positive effects on the host country's welfare. Furthermore, a fall in θ also leads to a fall in market price which can raise welfare, since $D(P) - Q_i > 0$.

The above analysis tries to model the choice for foreign firms in deciding their international technology transfer strategy given the existence of spillovers from subsidiaries to indigenous firms in the host country. This analysis concludes that market price is higher when there are spillovers and, along the optimal time path, the output and profits of the foreign subsidiaries decline, whereas the output and profits of the indigenous firms increase. The model also predicts that, even if the foreign firms are unable to appropriate the whole of the rent on technology transfer due to spillovers, it is still beneficial to transfer new technology into the host country. While the indigenous firms do not necessarily benefit from the better technology used by the foreign firms, the welfare of the host country increases.

In contrast to this analysis, Blomstrom and Wang (1989) emphasise the learning effort made by indigenous firms. Indigenous firms can improve their efficiency by capturing larger spillover effects through their investment decisions when foreign subsidiaries appear. Learning technology is not free to the indigenous firms. An indigenous firm's technology level is an increasing function of its learning investment and diminishing returns occur as the learning effort scales up. Another characteristic of the learning process derives from the hypothesis of Findlay (1978): the rate of technology progress in a relatively 'backward' country is an increasing function of the gap between its own level of technology and that of the 'advanced' country.

Besides the inclusion of costly spillovers, Blomstrom and Wang (1989) also assume that technology transfers from the parent firms to the subsidiaries involve some costs. The cost of this transfer is assumed to be a monotonically decreasing function of the age of technology being developed, following the hypothesis of Teece (1977).

Since both the foreign subsidiary and the indigenous firm can make their own investment decisions to maximise their profits, there is strategic interaction between them. In this sense, the model breaks down each firm's decision into two steps (Blomstrom and Wang 1989; p.6):

> At every moment each firm chooses its output to maximise its momentary profit, given the status quo of both firms' technology levels and its competitor's current output. Intertemporally each firm chooses its technology investment to maximise the present value of its profit stream.

This model predicts the following:

(i) In equilibrium, the strategic response of the foreign firm in the face of learning effort by the indigenous firm is to invest in more advanced technology. On the other hand, the domestic firm's investment in learning depends on the marginal benefit of the first unit of resource spent on such activities exceeding the loss in current profits. If the cost is very high, the domestic firm will not invest in learning at all because technology can be gained from learning-by-watching.

(ii) The higher the operation risks—for example, political instability or low potential economic growth—the more reluctant foreign firms will be to transfer technology.

(iii) Technology transfer is positively related to the level of the indigenous firm's learning effort. The more rapid and the more advanced is the technology transfer, the lower the domestic firm's discount rate, the more efficient the learning activities, and the higher degree of substitution between the competing products.

(iv) The more costless technology spills over from the foreign firm to the domestic firm, the faster the technology transfer.

(v) The learning investment of the individual domestic firms decreases if there is a positive externality in their learning process; that is, the social rate of return to learning is higher than the individual rate of return.

The model traces the closing up of the technology gap between foreign firms and domestic firms if the growth rate of the innovation falls short of the rate of imitation. The possibility of a shrinking technology gap depends on the actions taken by the indigenous firms through their learning investment.

In summary, these studies indicate that the profits of foreign firms in the presence of spillover effects are lower, and made lower still when indigenous firms put effort into learning. To keep their competitive advantage in the host country, it is necessary for foreign firms to transfer technology continually. In addition, for the host government, there are limitations to influencing the choice of production location by foreign firms, so that the optimal policy is to support indigenous firms in learning from the foreigners. Since the ability to learn is related to the stock of technical knowledge, government policy should put effort into vocational training programs, education, collecting information on new technologies, encouraging efficiency in learning, and so forth.

Conclusion

Perhaps the most important incentive for a host country in attracting foreign direct investment is the possibility of accessing modern technology. This involves the by-product of the establishment of foreign subsidiaries. Local firms can obtain indirect productivity gains when the entry of foreign firms creates external economies. These benefits are generally referred to as 'spillovers'.

In general, there are four sources of spillovers which may affect indigenous firms' productivity. One source of spillover effect is that the entry of relatively efficient foreign firms may affect the market structure of an industry by increasing pressure on its competitiveness. The second source is that indigenous firms may gain training for workers and management—training which has been underwritten by the foreign subsidiaries but which is shared by the indigenous firms when those workers become available to the whole economy. The third source is the hastening of technology transfer through the demonstration effect and the learning effort on the indigenous firms. Another source of spillovers, the linkage effect, either backward or forward linkage, may be the most significant but the most difficult to measure. New technology accompanied by foreign direct investment may stimulate local suppliers of the intermediate products to improve product quality and lower costs in order to compete for the foreign market. New products introduced by the foreign firms may also stimulate productivity improvements in local firms who use these products as an input.

These spillover effects are beneficial to the host countries, but to the foreign firms they perhaps threaten their advantage in technology and profits over time. The North-South model, which takes no account of spillover effects, predicts that the South will catch up if the North stagnates in R&D investment. Hence, if foreign firms slow down technology transfer to their affiliates, they may lose their advantage in the host market. Apparently, the learning ability of indigenous firms, which is accelerated by the spillover effects, may make the threat more than an abstract one for foreign firms. Foreign firms' investment decisions may, therefore, be affected if they find it less profitable to open subsidiaries behind tariff walls than to undertake export activity, in the presence of the spillover effects.

In the traditional Heckscher-Ohlin trade framework, it is well understood that high tariffs can stimulate foreign capital inflow. However, in the presence of spillover effects, high tariffs may not be as effective as expected in encouraging capital movement. Foreign firms may find that, even with high tariffs, the loss of technological edge cannot be compensated for by the gain arising from tariff-jumping. They will then tend to expand export markets instead of producing internationally. Hence, tariff policies may be ineffective in inducing foreign direct investment in the presence of spillover effects. Other policies are therefore preferable.

On the other hand, the best response for foreign firms in maximising their profits in the host country is to transfer technology continually. In static conditions, the profits of foreign firms in the presence of spillover effects is lower than otherwise, and made worse when the indigenous firms put effort into absorbing the spillover effects. The dynamic transfer of technology is the best way for them to keep their leadership in host markets. Since the entry of foreign firms can increase national welfare, the best policies by host governments in extracting such externalities involve encouraging domestic firms to do their best in learning. Learning ability depends on the accumulated human capital, which, according to human capital theory, can be enhanced by education, learning-by-doing, vocational training and absorption of new information. It appears best for policy makers to think of improving the efficiency of learning than to interfere in the private sector, through preferential financial and fiscal supports.

The decisions of foreign firms vary when there are spillover effects to the host market. Meanwhile, the existence of such effects also recommends foreign direct investment policy designed to attract foreign capital inflow and to gain the technological benefit in developing countries. Although it is suggested here that foreign firms' advanced technologies in one way or another are transferred to domestic firms through spillover effects, the difficulty of measuring these effects means that there have been few empirical tests of spillover effects of foreign direct investment, and only one study of a developing country—Mexico. The growth of East Asian economies over the past four decades and the contribution of foreign direct investment to their growth have been highly appraised, but no one has attempted to study spillovers from foreign direct investment in these countries econometrically. This thesis will attempt to fill this gap by taking Taiwan—a model with rapid growth and large foreign capital involvement—as a case study, particularly focusing on the electronics industry.

Furthermore, in contrast to the partial productivity analysis in other studies, an overall measurement of productivity growth, total factor productivity (TFP) growth, is employed in this thesis. Partial productivity analysis restricts previous studies to an industry level analysis. The concept of TFP growth not only allows industry analysis, but also makes firm-level analysis possible. In this thesis, the industry level analysis examines the significance of foreign penetration (representing the impact of foreign capital on technical change) and economies of scale for TFP growth. Firm-level analysis decomposes TFP growth into technological progress, technical efficiency and economies of scale factors to examine whether domestic firms gain technological benefit through spillovers from foreign direct investment and whether there is a catching-up process in progress.

The structure of the empirical study in this thesis is as follows. Chapter 3 describes Taiwan's policies in attracting foreign direct investment and the contribution of, as well as the strategic behavioural changes of foreign direct investment in Taiwan. Chapter 4 examines the differences in performance between foreign firms and domestic firms. Following this chapter, TFP growth is measured for each industry in the manufacturing sector of Taiwan and then decomposed TFP growth is used to examine the contribution of foreign capital across industries. The last chapter in this empirical study provides a firm-level analysis. Frontier productivity analysis is employed to assess the significance of technical efficiency, technological progress and economies of scale in TFP growth. Then the effect of labour quality change on technical efficiency is examined, because the improvement in labour quality is one of the major sources of spillover efficiency from foreign direct investment.

3 Foreign Direct Investment in Taiwan

Foreign firms are said to possess superior financial techniques, marketing, and technology. The entry of these firms can create spillover effects into a domestic market through their demonstration effect, or domestic firms' learning-by-watching processes, as described in Chapter 2. Other than these spillovers, economic development theory also suggests that foreign capital inflow can complement the host country's shortage of savings and foreign exchange, accelerating economic development. The contribution of foreign direct investment to a host economy should be evaluated by adding up these two effects. This chapter focuses on the contribution of foreign direct investment in Taiwan, the case under study. A positive contribution by foreign firms to the Taiwanese economy does not automatically imply positive spillovers, but is suggestive of the interest in exploring their effects.

The contribution of foreign investment also depends on the scale of capital inflow. It is necessary to examine how a host government may influence the mode and magnitude of the movement of foreign direct investment by means of specific foreign direct investment policy. A host government's expectation of the contribution of foreign direct investment will affect the policy approach. Following the discussion in Chapter 2, it may be more effective to establish a favourable investment environment —as Taiwan's government did—than to formulate and enact specific foreign direct investment policy. Hence, the Taiwanese government's policies towards foreign direct investments are discussed in the next section to explain how the economic environment can affect, for example, the location decision of foreign capital. A review of the impact of foreign direct investment on Taiwan's economy, particularly the effect on technology, capital formation, employment, and linkages, follows in order to evaluate the contribution of foreign direct investment to the development of Taiwan's economy more generally.

Policies towards foreign direct investment

Growth theory stresses that the progress of labour and capital influences the rate of economic growth. The significant contribution of technological change to economic growth is also highlighted in many studies, such as Solow (1957) and Denison (1974) in America, Ohkawa and Rosovsky (1973) in Japan, and Kuo (1983) in Taiwan. Foreign direct investment appears as an important channel for the diffusion of technology internationally, alongside direct purchasing and licensing of new technologies. Hence, foreign firms are potentially an important means of economic progress. However, some countries take a hostile attitude towards foreign capital inflow, while others take a positive view. There are many possible explanations for host government caution towards foreign direct investment. Fears about technological dependence on foreign countries and companies tend to lead to host government restrictions on foreign capital inflow. Japan may be taken as a typical case of this response. The Japanese government promulgated a restrictive policy towards foreign capital inflow during the 1950s, with severe limitations on the proportion of foreign equity that could be held in different industrial sectors. Only US$2.9 million foreign direct investment flowed into Japan during 1950-55. These restrictions were lifted after the liberalisation of trade and foreign exchange in the 1960s, yet licensing agreements have remained the dominant form of technology inflow into Japan.

Besides the pursuit of technological independence, foreign exchange concerns may also encourage host governments to enact restrictive policies. India, for example, initially proposed an open policy towards foreign direct investment, with no restrictions on the remittance of profits and dividends, tax concessions, fair compensation in case of acquisition, and so on (Kumar, (1989, ch.1)). When the outflow of remittances grew sharply and became a significant burden on the foreign exchange reserves, leading to the foreign exchange crisis in the late 1960s, the government adopted a more restrictive policy. The amount of foreign direct investment and the proportion of foreign ownership were subject to strict screening by the Foreign Investment Board, foreign investments unaccompanied by technology transfer were not welcomed, royalty payments were restricted to five years, and a number of other conditions were attached to foreign direct investment. By the end of the 1970s, stagnant export growth of manufactured products led the government to realise that India's lack of international competitiveness was due to technological backwardness, inferior product quality and high costs. These could be partly attributed to the highly protected local market. The Indian government became committed to the liberalisation of policies regarding foreign direct investment.

Other host country governments viewed foreign direct investment as inputs to complement the savings, foreign exchange and budgetary revenue gaps in the economy, and enacted policies to encourage foreign capital inflow. Taiwan enacted the Statute for Encouragement of Investment in 1960; South Korea enacted the Foreign Capital Inducement Law in 1966; and Singapore passed the Economic Expansion Incentives Act in 1967. The broad features of these laws are similar: exemption for five years from taxes on profits, duty free import of capital equipment and of materials used in exported commodities, and no restrictions on either the percentage of equity that the foreign firm can own or on the remittance of profits and dividends. These laws generally set out the criteria for the inflow of foreign capital. For example, the Korean law gave priority to capital-intensive industries, industries using foreign technology, industries enjoying foreign tariff preference, and heavy chemicals. The Taiwanese government also pursued a selective policy towards foreign direct investment in accordance with its development objectives after 1950,[1] discussed in more detail below.

In addition to providing an inclusive tax incentive package to attract foreign capital inflow, the Taiwanese government also developed industrial, financial, trade and other policies in order to establish a favourable investment climate for both domestic and foreign capital. These policies interacted with each other and played a crucial role in encouraging both domestic and foreign investments. Instead of a specific foreign direct investment policy, a favourable economic environment was built by these comprehensive economic policies which succeeded in attracting foreign capital inflow, thereby enhancing the contribution of foreign direct investment. A review of the Taiwanese government's policies is essential to explain the growth of foreign capital inflow and to the evaluation of foreign firms' contributions to Taiwan's economy.

Taiwan government policy

The first efforts to encourage the inflow of foreign capital by the government of Taiwan were in 1954 (Statute for Investment by Foreign Nationals) and 1955 (Statute for Investment by Overseas Chinese). These statutes provided general guidelines for directing foreign direct investment towards those industries which would contribute to economic growth, towards the improvement of existing industries, and the promotion of exports.

Despite these intentions, foreign capital inflows remained modest in 1950s; less than US$35.6 million on an approvals basis. On an arrivals basis, foreign capital inflow was even lower, according to the report of Council for Economic Planning, merely about NT$8 million.[2] Another characteristic of foreign direct investment at this stage was the large number of investments from overseas Chinese.[3] From Table

1 Nevertheless, Schive's (1990) study finds that these policies had only weak and insignificant effects in guiding foreign direct investment to the desired industries.

2 The data come from the Four Year Economic Plan and are reported in New Taiwan dollars. Since multiple and floating exchange rate systems continued till 1959, no appropriate exchange rate can be applied to compare the two data sets directly.

3 The investments made by overseas Chinese were generally regarded as different from those of other foreigners in some aspects. For instance, they were relatively small in scale, were concentrated in service and light industries, and had similar technology to that of domestic firms.

3.1, it can be seen that 58 cases of overseas Chinese investments were approved during 1950s compared to 28 cases of investments by other foreigners.

From an historical point of view, it is obvious that policies other than foreign direct investment policy affected the inflow of foreign capital more substantially during the 1950s. These policies and other factors included domestic market-oriented economic policies, the multiple exchange rate system, severe import restrictions and control, the instability of the foreign exchange rate, the precarious political situation, difficulties in obtaining land for industrial planting, lack of investment incentives, high inflation rate and social instability.

Table 3.1 Foreign direct investment in Taiwan, 1952-92 (on approval basis) (US$1,000)

	Overseas Chinese			Foreign Investment			Total FDI	
	Cases	Amount	%	Cases	Amount	%	Cases	Amount
1952-60	58	10,440	29.3	28	25,212	70.7	86	35,652
1961-70	643	152,576	29.1	559	371,002	70.9	1202	523,578
1971-80	774	801,671	37.1	675	1,357,502	62.9	1449	2,159,173
1981-92	851	1,520,701	11.0	2985	12,252,308	89.0	3836	13,773,009
Total	2326	2,485,388	15.1	4247	14,006,024	84.9	6573	16,491,412

Source: Investment Commission, Ministry of Economic Affairs, *Statistics on Overseas Chinese & Foreign Investment, Technical Cooperation, Outward Investment, Outward Technical Cooperation, Republic of China*, 1993, Taipei, p. 1.

By the 1960s, Taiwan's political situation had stabilised with the assistance of US aid and military defence. Improvements in the economic environment made Taiwan more attractive to foreign investors. These improvements included currency reform, industrial policy reform, an expanded domestic market (owing to the growth of national income), lower protective customs duties, a tightening of credit and public expenditure, and the channelling of private savings into bank deposits for industrial use, as well as improved transportation, power supply and education facilities.

The termination of the use of exchange certification and foreign exchange rate devaluation were the main elements of currency reform, which began in 1958. A fixed exchange rate of US$1 = NT$40 was established by 1963. A pegged US dollar exchange rate not only sustained the economic growth of Taiwan, but also provided incentives to foreign direct investment by reducing the risk of investments. The size of the domestic market also expanded. Average income growth was 7.2 per cent in the 1950s, although high population growth—a natural rate of population growth in excess of 3 per cent per annum—meant that per capita income grew at only 2.9 per cent per year. However, by the 1960s, population growth had slowed to 2.2 per cent and, with annual economic growth (as high as 9.9 per cent), the growth rate of real per capita income rose to 6.4 per cent, which raised purchasing power and expanded the domestic market. Taiwan's economy had broken out of Nurkse's (1953) vicious cycle of poverty by this stage and taken off.

The adverse effects of industrial policy directed at import substitution began to emerge. The high cost of production under protection led inefficient firms to drive out efficient firms and hinder industrial competitiveness. The import substitution policy came to an end, leading to a slowing-down of growth as a whole. Outward-looking industrial policy reform was necessary if high industrial growth was to be sustained. Export-oriented policies saw a reduction of protective customs levies in order to lower production costs and increase international competitiveness. The production and export of manufactured products was also promoted via the provision of preferential interest loans to export industries.

Economic reforms established a good environment for foreign investors. However, the most influential government policy was the issuing of the Statute for Encouragement of Investment in 1960, which provided a large variety of incentives, including a five-year exemption from corporate income tax for new investors, or acceleration of asset depreciation; a maximum of 25 per cent corporate income tax after the completion of the five-year tax holiday; exemption from or reduction of stamp, deed and business taxes for export transactions; and acquisition of plant sites on government-designated industrial land or in industrial districts. The government also set up an ombudsman's office to assist foreign investors, and designed a simplified approval procedure.

A further stimulus to foreign direct investment was provided by the establishment of export processing zones (EPZs) in 1966. EPZs were designed to provide a complete set of facilities for foreign investors to establish plant, but one other important purpose was to complement export-oriented industry policy by encouraging exports via foreign investments. Around the same time, US, European and Japanese firms faced rapidly rising labour costs at home, and a number of marginal firms were trying to relocate their operations overseas. EPZs were set up just in time to attract multinationals to establish off-shore plant for the production of labour-intensive parts or for assembly operations. Taiwan's EPZs not only provided a huge employment opportunity to absorb the abundant labour force, but also contributed to economic growth through their payments for local purchases and to employees. The high export ratio of EPZs' firms, nearly 100 per cent in the early period, also created a value-added effect in the domestic economy.

In addition to EPZs, the Taiwanese government also established a number of industrial districts around the whole island after 1964. Private enterprises, foreign or local, could get assistance for the acquisition of land and the provision of transportation and other public facilities in these industrial districts. The facilities were similar to those in EPZs except that EPZs were off-shore operations. As a result of these initiatives, the Taiwanese government created a relatively attractive climate for foreign investors and foreign capital dramatically increased from that time. Riedel (1975) and Ranis (1979) both found that policy changes by the government of Taiwan greatly influenced the flow of foreign direct investment during the 1960s.[4]

By the 1970s, the desire to upgrade the economic structure to produce more sophisticated manufactured products led the Taiwanese government to carry out ten big construction projects: six in the improvement of transportation and harbour facilities, and four in the establishment of basic heavy industries. These improvements produced an even better investment climate. As a result, foreign investment in Taiwan continued to grow, except for a short period between 1974 and 1975 associated with the establishing of political relations between the United States and mainland China, and with the world economic recession.

Another surge of foreign capital inflow into Taiwan has taken place since 1986. The main push has come from the continuous liberalisation of the domestic market, trade, financial, and foreign exchange markets. Most of the new foreign capital flowed into relatively underdeveloped industries, such as banking, insurance, transportation, and services, which were heavily capital-intensive and highly protected before liberalisation. The lack of know-how, technology and physical capital usually made it disadvantageous for domestic enterprises to enter into these sectors and the liberalisation of the domestic market attracted many multinationals to exploit these uncultivated fields with their abundant capital and wide experience. Another factor promoting this recent increase in foreign direct investment was the reconnecting of the economic ties between Taiwan and mainland China after 40 years' separation. Many multinationals attempted to utilise the experienced and skilled labour force in Taiwan to gain access to the mainland Chinese market, because of the same language, and historical and social background. The government's 1991 Six Year Economic Plan also encouraged foreign investors to join the market.

The distribution of foreign direct investment reveals that the electronics and electrical appliances industry ranks at the top in the manufacturing sector, as shown in Table 3.2. Up to 1990, there were 648 projects approved, with a total amount of US$3 billion invested in this industry, accounting for 27 per cent of the total foreign capital inflow. The chemical industry ranks next and then machinery equipment and

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4 Riedel (1975) found that investments from the United States were attracted by the relatively cheap labour in Taiwan, while Japanese investments were mainly encouraged by government policy.

instruments, basic metals and metal products, food and beverage processing. As the electronics industry appears to be most affected by foreign direct investment, the development and the impact of foreign direct investment on this industry is therefore examined later in this study.

Table 3.2 Statistics on approved foreign investment by industry, 1952-91, (US$1,000)

(I)

	Food		Textile		Clothing & footwear		Timber	
	Cases	Amount	Cases	Amount	Cases	Amount	Cases	Amount
1952-79	39	13,702	30	31,947	62	15,328	25	5,233
1980	3	5,613	-	1,635	-	748	-	-
1981	3	15,947	1	1,186	1	1,866	-	-
1982	2	16,712	-	1,387	1	2,710	-	112
1983	1	7,701	1	285	-	332	2	1,223
1984	6	7,014	-	838	1	1,108	1	21
1985	10	18,673	1	1,835	1	1,861	2	1,565
1986	8	6,346	1	3,376	-	677	2	538
1987	8	75,649	2	5,447	4	3,826	2	6,939
1988	15	56,860	1	18,185	3	3,647	2	3,587
1989	15	214,164	5	43,972	3	5,033	2	11,934
1990	11	108,527	1	15,560	1	3,287	3	13,159
1991	6	37,478	2	39,168	2	13,332	-	13,320
1992	9	54,021	1	15,218	-	-	1	8,613
Total	136	635,407	45	168,545	79	53755	43	66,244

(II)

	Pulp & paper		Leather & fur		Plastic & rubber		Chemical	
	Cases	Amount	Cases	Amount	Cases	Amount	Cases	Amount
1952-79	12	4,400	18	2,991	81	35,655	152	228,523
1980	-	332	-	-	5	9,087	9	55,218
1981	-	-	-	-	4	15,797	11	38,835
1982	2	6,825	-	-	3	1,841	14	33,667
1983	2	3,664	-	-	7	12,043	11	33,817
1984	-	189	1	1,098	1	21,776	21	122,930
1985	-	235	4	2,777	6	5,692	11	2123,88
1986	-	433	2	250	9	19,149	19	133,669
1987	1	1,573	1	2,372	13	68,163	41	167,272
1988	5	6,772	-	798	9	54,519	22	97,811
1989	1	20,049	1	288	16	78,349	20	519,301
1990	-	7,073	2	1,979	2	23,110	17	502,472
1991	-	1,245	1	166	1	16,823	16	194,597
1992	-	1,485	1	1,767	4	70,088	7	105,014
Total	23	54,275	31	14,487	161	432,091	371	2,445,515

(III)

	Minerals		Metals		Machinery		Electronics	
	Cases	Amount	Cases	Amount	Cases	Amount	Cases	Amount
1952-79	46	36,603	165	132,101	103	139,690	309	725,308
1980	9	10,415	14	29,040	5	11,747	16	106,026
1981	6	5,014	9	43,727	7	38,462	13	79,484
1982	2	4,553	16	44,330	9	14,846	12	67,704
1983	3	6,951	12	12,648	14	141,455	22	102,981
1984	1	802	7	17,335	11	39,385	35	265,916
1985	3	6,454	12	50,767	9	85,841	16	133,919
1986	7	11,565	19	27,742	25	109,847	59	228,225
1987	10	47,452	47	120,704	36	74,390	74	371,559
1988	8	34,738	24	62,154	20	136,854	33	222,143
1989	6	29,431	30	168,679	18	88,272	26	381,234
1990	5	32,789	22	183,175	13	126,590	33	345,437
1991	2	30,797	11	90,391	19	174,866	38	561,716
1992	4	10,490	6	29,921	21	95,973	40	309,199
Total	112	268,054	394	984,237	210	1,278,218	726	3,900,850

Note: industry classifications:

Food = food and beverage processing industry
Textile = textile industry
Clothing & footwear = garment and footwear industry
Timber = lumber and bamboo products industry
Pulp & paper = pulp and paper products industry
Leather & fur = leather and fur products industry
Plastic & rubber = plastic and rubber products industry
Chemical = chemical industry
Minerals = non-metallic minerals industry
Metals = basic metals and metal products industry
Machinery = machinery equipment and instrument industry
Electronics = electronics and electric appliances industry

Source: Investment Commission, Ministry of Economic Affairs, *Statistics on Overseas Chinese & Foreign Investment, the Republic of China*, 1992

Taiwanese government policies appear to have provided incentives to foreign investors, although there is no way to test the effect of policy changes on the magnitude and pattern of foreign direct investment. The case of Taiwan suggests that a good investment environment is more effective than direct interference in attracting foreign direct investment. A liberalised market appears to be particularly important to foreign investors.

The contribution of foreign direct investment

Foreign investment provides not only capital, but also the transfer of a package of technology, management know-how and other techniques from the investing country to the host country. From the viewpoint of the host country, such investment can help in filling the gaps between economic plans or policy targets and domestically mobilisable resources. In economic development theory, foreign direct investment is seen as the strategic factor filling the savings gap, the foreign exchange or trade gap, the budgetary gap, and the management and skill gap in the host country.

Apart from these roles, foreign direct investment may also assist in the attainment of macroeconomic policy objectives. For instance, it can create jobs, reducing unemployment. Foreign direct investment can also generate micro effects in the form of inter-industry and intra-industry linkages. Through these effects foreign firms interrelate, via local markets or other mechanisms, to locally produced materials and components, as well as helping to set up supporting industries. Information which foreign firms pass on to indigenous firms regarding, for example, world market outlets and sources of supply, may otherwise remain unknown to local firms.

It is difficult to quantify the effects of foreign direct investment precisely, or even to predict their direction. For example, a high export ratio generates a positive effect on foreign exchange, but a low local content of the product and remittance of profits reduces its impact. Moreover, each foreign subsidiary has its own response to the economic environment, which increases the difficulty of aggregating all information unless a complete census is available. It is impossible to evaluate how the economy would have behaved in the absence of foreign capital inflow. It may be hard to give the exact quantitative effects of foreign direct investment on the Taiwanese economy, but it is possible to examine whether the impact of foreign direct investment is favourable, and to examine strategic changes in technology transfer, material sourcing, and sales over time caused by foreign direct investment. There are various channels through which foreign direct investment may affect the host country's economy. Among them, the strategies of foreign firms on technology, capital formation, employment, linkages, and export performance can lead to technological changes. For instance, an effect of foreign direct investment on capital formation may raise the capital-labour ratio of production. High employment may induce labour quality changes through training programs. (See Chapter 2 as a source of spillovers). Therefore, the contribution of foreign direct investment to Taiwan's economy is examined in respect of the effect on technology, capital formation, employment, linkages, and export performance in this chapter.

Effect on technology

For a developing country, technology transfer via foreign investment is thought to be crucial because the process of creating technology through R&D can be enormously costly. In addition, the necessary skilled labour may be insufficient in a host's labour market. Hence, by adapting existing technologies, the host country can avoid the risks of invention and innovation, and at the same time can promote economic growth via the relocation of resources. It is now widely accepted that foreign direct investment, particularly from multinational corporations, is an efficient channel in transferring technology to the developing countries, along with licensing and buying technology. There are some obstacles to the transfer of technology through licensing or selling; for instance, the difficulty of maintaining control over business secrets, patents, or trademark rights. Furthermore, negotiating a proper price for the new technology, taking into account the interests of both licenser/seller and licensee/buyer (for the former, evaluating the transaction cost; for the latter, forecasting the potential market) is a task full of uncertainty. Licensing agreements were only a minor channel of technology transfer in Taiwan, according to the statistical data. From 1952 to 1992, a total of 3,783 projects of technical cooperation between local and foreign enterprises were approved by the government. However, 2,465 of these were approved during the 1980s, and rather fewer before then.

There are several reasons why Taiwanese firms were hesitant to engage in licensing agreements: one was lack of awareness by Taiwanese firms of the importance of technical know-how patents and other industrial properties. Even when they understood the importance of property rights in using new technology, they did not know the right party to negotiate with in arranging the terms of licensing. They were also not adequately informed of the availability of new technology. Another important reason, as noted by Schive (1986), was that some Taiwanese firms which had experience in contracting licensing agreements complained that some licensers were retaining the core of the technology being transferred, which made them rely more heavily on importing technology and materials than they would have otherwise.

Although new technology may be able to save costs in material inputs or productive activities, this does not mean that technology transfer by foreign direct investment is absolutely beneficial. Benefit depends on the appropriateness of the technology, the efficiency in adapting it, and the speed of transferring new technologies from foreign firms. In most cases, adaptation is required to take into account conditions in the host country. The most frequent adjustment in technology is to scale down the plant and equipment to adapt to the smaller market size of the host country. Adaptation is sometimes adjusted to the requirements of the local customs and legal regulations. For example, local content is requested on a case by case basis as a criteria of approval in Taiwan. Sometimes, adaptation is required to take advantage of low labour costs or to make up for the absence of skilled labour. Since foreign firms usually carefully select product lines *ex ante*, adjustment to the low labour cost may not happen as frequently as expected.

Apart from these factors, some intrinsic factors in the developing countries may also work against adaptation, such as a shortage of skilled labour, a small market, monopoly advantages, and distortions in the price of goods and factors.

However, these intrinsic unfavourable factors were minimised in Taiwan. For instance, the government realised at an early stage that the shortage of skilled workers might hinder economic development, and so it has provided vocational training programs since 1966. These programs are mainly concentrated in the pre-employment stage. According to Chang (1985), there are around 200,000 to 300,000 workers per year being trained through such programs, accounting for 3-5 per cent of total employment. In addition, some workers receive vocational education in private industrial or commercial training schools, and local enterprises are also beginning to place emphasis on follow-up vocational training after employment. The government has also initiated a skills test as a way of providing an equitable guideline for determining a worker's pay, and also recognition of the worker's skills. Furthermore, the high mobility in the labour market may also partly counteract the shortage of skilled labour, particularly the turnover of trained workers from foreign firms.

Secondly, in order to overcome small-market restrictions, the Taiwanese government promoted export-oriented industrialisation in the 1960s. It sought to sustain a highly interdependent relationship with the world market; there is no border between domestic and world markets. In order to maintain competitiveness in the world market, Taiwanese firms have to put effort into continuously improving products and quality. A monopoly advantage usually can last only for a short period.

Thirdly, the Taiwanese government enacted some industrial policies, such as preferential financial supports for the development of selected products, which indeed distorted factor markets to some extent. However, the complicated procedures and tough criteria commonly made small and medium firms hesitant or unable to apply for support. Over 90 per cent of Taiwan's firms are small or medium size, and they have been relatively neglected by the government's policies. The lack of attention by the government has reduced the distortion in factor markets because only a small proportion of firms can obtain subsidies and produce those products selected by industry policy. The allocation of factors is essentially decided by the market in the case of small and medium sized firms.

High labour quality, export-oriented policies, and lesser distortion in factor markets demonstrates that the economic environment in Taiwan has overcome the intrinsic disadvantages in absorbing transferred technology. Since technical cooperative projects have been relatively negligible, the Taiwanese economy has relied heavily on foreign direct investment to transfer technology, even though such investment gives less autonomy in the process of production and decision making than licensing and buying technology.

Improved quality of labour has attracted foreign firms to invest. The inflow of new technology and foreign capital has further raised the level of labour quality, which in turn has attracted an inflow of new investments and technologies. At the same time, the knowledge of domestic firms in technology, marketing and information has improved. A more competitive environment was established in Taiwan through technological changes, a process which demonstrates the relationship between foreign direct investment and accelerated technology transfer. Schive (1983) studied whether foreign direct investment encouraged technology transfer into Taiwan and concluded that:

(i) foreign firms were more likely to use foreign technology than indigenous firms;
(ii) firms with majority foreign ownership tended to use imported technology; and
(iii) the minority ownership foreign firms used less foreign technology, but still more than indigenous firms.

His study suggests that foreign direct investment has encouraged technology to transfer across borders, but that the adaptation of new technology depends on the degree of foreign participation.

In the 1980s, licensing agreements became relatively attractive as a form of technology transfer to Taiwan; contracted cases increased very fast. One explanation for them may be that the property and patent right of newly developed technology has been strictly scrutinised; to imitate is no longer permitted. Under these circumstances, the owner of technology usually prefers to contract a licensing agreement that would maximise profits from franchising and reduce the risk of disseminating technology. Another explanation is that many Taiwanese firms have realised the importance of R&D and now have the ability to invest in R&D.[5] Import of technology is no longer restricted to obtaining new skills or know-how in the production process. Developing new products which closely match local consumers' preferences and promoting quality are now the major concerns of Taiwan's firms. Licensing agreements preserve independence of management and production processes, and prevalent technology in the market, which may be seen as preferable at this stage. A possible third explanation is that Taiwanese firms tend to prefer a period payment of royalties or fees to foreign

5 The total R&D spending as a percentage of GNP rose from 0.85 in 1984 to 1.70 in 1991. R&D expenditure in the manufacturing sector also rose, from NT$9 billion in 1981 to NT$44 billion in 1991.

firms. These are usually paid according to the quantity of products marketed.[6] The global economic environment changes make licensing agreements preferable to foreign direct investment.

Although the importance of transferring technology via foreign investment is decreasing in Taiwan, foreign investment has played a large role in technology transfer over the past three decades. The operations of foreign subsidiaries diffused technology to the local industries, and the mobility of trained or skilled workers from foreign subsidiaries to the local market also expanded the capacity of Taiwanese firms to absorb new technology.

Effect on capital formation

Since capital formation is an aspect of industrialisation and a developing country usually suffers a savings gap (domestic savings falling short of intended investment), foreign direct investment is generally regarded as a source of funds to supplement domestic savings efforts. According to Nurkse's proposition (1953), a country is poor because it is stuck in 'the vicious circle of poverty'; that is, trapped in a circular problem in capital formation.

Nurkse proposed that both demand and supply sides of capital formation have a circular chain. On the supply side, low savings result from the low level of real income which is a reflection of low productivity. A low level of productivity again is largely due to the lack of capital which in turn is a result of the low savings.

On the demand side, the inducement to invest may be low because of low consumption levels due to the low level of real income resulting from low productivity. The low level of productivity is a result of the small amount of capital used in production caused partly by the small inducement to invest.[7] In order to break out of this vicious circle, Nurkse suggests, a massive injection of capital from abroad

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6 Taiwanese firms' dislike of making lump sum payments for the purchase of once-and-for-all patents or know-how results from two factors. One is that most firms are small, and lacking in capital. They can not afford to buy the once-and-for-all patents and know-how. The other is that they lack foresight in product markets and complete information on new technology; since a large percentage of the market and technology information lies under the control of Japanese general trading companies or Western multinationals.

7 The supply side circle:

low income → low savings → low investment → low productivity
↑ ← ← ← ← ↓

The demand side circle:

low income → low consumption → low induced investment → low productivity
↑ ← ← ← ↓

is necessary. Foreign capital can help to pull developing countries out of this low level equilibrium trap.

Taiwan experienced a savings gap in the early developing period. Fortunately, with a huge inflow of US aid, it succeeded in breaking out of the vicious circle of poverty. After the termination of US aid, Taiwan continued to raise its gross savings ratio[8] and to mobilise internal savings from households, agriculture and enterprises, as well as from the public sector, to cover the gap. In addition, the increasing inflow of foreign capital filled the savings gap. On the whole, a favourable saving-investment process was constructed in Taiwan at quite an early stage. Table 3.3 sets out the trend in gross fixed capital formation in Taiwan.[9] Gross fixed capital formation (GFCF) as a proportion of GNP continued to expand from around 13.6 per cent in the 1950s, reaching a peak around 27 per cent during the 1970s and falling to 21.7 per cent in the 1980s. Continuous investment is obviously one of the engines to the development of the Taiwanese economy.

Table 3.3 Average gross fixed capital formation (GFCF) and foreign direct investment (FDI), 1952-92 (NT$ million)

	GNP (a)	GFCF (b)	GFCF by manufacturing (c)	FDI (d)	(b)/(a) %	(d)/(b) %	(d)/(c) %
1952-60	36,401	5,217	2,021	88	13.6	2.3	6.6
1961-70	131,074	25,426	11,164	882	18.4	3.2	7.5
1971-80	732,682	203,486	96,605	2,920	27.0	1.6	3.4
1981-92	3,239,583	695,234	274,928	19,117	21.7	2.6	6.5
Average	1,166,883	260,460	107,195	6,542	20.4	2.4	6.0

Source: Council for Economic Planning and Development, *Taiwan Statistical Data Book*, 1992, Taipei, ROC.

With regard to Taiwan's capital formation, as shown in Table 3.3, foreign direct investment played a minor role compared to the fast expansion of the domestic economy. The contribution of foreign capital inflow to gross fixed capital formation was often below 4 per cent over the past 40 years, with a few exceptions, and the average from 1952 to 1992 was as low as 2.4 per cent. Foreign capital inflow affected gross fixed capital formation only insignificantly, but its contribution to capital formation in manufacturing has been higher, as seen in the last column of Table 3.3. The average percentage for the whole period was 6 per cent, while during the rapid

8 The gross savings ratio to GNP increased from 10 to 15 per cent in the first half of the 1950s to over 30 per cent in the 1970s and 1980s, and to about 30 per cent recently.

9 It should be noted that the FDI figures in Table 3.2 are based on the actual arrival value which is more realistic than the approval basis in reflecting its impact on the Taiwan economy.

growth period of the 1960s it was as high as 7.5 per cent. This ratio would be even higher if it referred only to the manufacturing sector,[10] because foreign capital mainly flowed into the electronics and electronic appliances, chemical, machinery and equipment and basic metal industries, some of these investments being heavily capital intensive. The inflow of foreign capital into industry on an approvals basis, either money flow or projects, conforms basically with the growth pattern of the manufacturing sector, as noted in Table 3.2. This tendency can be explained by the demonstration effect of investment and the high growth of an industry which creates expectations for future growth and attracts capital inflow.

In spite of the greater importance of foreign capital in the manufacturing sector's capital formation, these figures might also underestimate the contribution of foreign direct investment to capital formation because some cash remittances and importation of equipment by foreign firms are not reported to the Ministry of Economic Affairs, and so do not appear in their figures. In addition, expenditure of foreign firms is accounted for as a part of the national income, but part of the payments made by foreign firms are retained as household savings, which functions as investment through the financial system. This part is also excluded from the above accounting.

The contribution of foreign capital to capital formation in Taiwan may not appear to be as important overall as expected but, while its exact contribution is not easy to measure, it has played a significant role in key sectors of the economy.

Effect on employment

Developing countries commonly experience high unemployment rates, hence job creation is one of the crucial issues in setting up economic policies. There are three types of economic policies which can significantly influence the employment effects of foreign direct investment: foreign investment policies (for instance, local sourcing requirements); policies aimed at creating greater backward and forward linkages of foreign firms; and localisation requirements, especially the hiring of local technical, professional and managerial staff. On the other hand, from the viewpoint of foreign firms, to utilise cheaper labour in order to reduce production costs and enhance competitiveness is a major reason for undertaking international production. The requirements on both sides (investor and recipient) lead to employment creation. The contribution of foreign direct investment to employment is unambiguous.

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10 Due to the lack of actual arrival figures in the manufacturing sector, the ratio is unobtainable. However, Schive (1979) estimated that the average contribution of FDI to capital formation in the manufacturing sector was about 6 per cent from 1952 to 1975, with the highest being 8.6 per cent in the early 1960s.

In general, foreign direct investment creates direct and indirect employment in the host economy. The direct employment effect is determined by the characteristics of the foreign firm, such as size, technology embodied in production, foreignness and other factors. A large firm (relative to the local market) tends to use technology with a higher capital/labour ratio and to procure a relatively low wage expenditure share to total output value-added. However, its foreignness usually increases its import propensity, thus minimising domestic technological development potential which then limits the creation of jobs in the domestic market. The direct effect on employment also depends on the choice of techniques and the composition of output. The more capital-intensive the technology, the fewer the jobs created. At the same time, the composition of output depends on the objective of the investment, that is, whether investment is import-substituting or export-oriented. Some evidence shows that when a foreign firm produces import-substitution goods, it is indifferent to whether capital-intensive or labour-intensive methods are used in production, whereas it tends to utilise cheaper labour when the investment is intended to expand its world market share.[11]

There are also some indirect employment effects, which by their nature are more complex and difficult to quantify. Figure 3.1 depicts the major conceivable indirect effects that can lead to indirect employment repercussions, including the backward and forward linkages to the rest of the local economy, the multiplier effect of the wage bill, and the feedback of these effects on the local economy. For instance, a foreign firm which engages in import-substituting activities, generally sourcing higher local inputs than in export-oriented production, may create more indirect employment opportunity in the local economy. The employment effect also emanates from the creation and expansion of distribution and marketing facilities in the host country, especially where investments are oriented to local markets.

The degree of the foreign firm's impact on employment also depends on the availability of local inputs (that is, raw materials, parts and components, and various services). The employment effects of a foreign firm can be considerably constrained by the capacity of material suppliers and user industries in the country where it operates. Without an adequate supply of parts, components and raw materials, a firm cannot operate efficiently; and without growth of forward consuming industries, a firm cannot expect to grow. The entry of foreign firms, therefore, does not only provide intermediate products to local markets and thus facilitate the development of

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[11] An ILO (International Labour Organisation) study (1981) indicated that the major incentive for multinationals investing in EPZs has been the comparatively low wages in the countries concerned. On the other hand, for many of the host countries, a major consideration in developing EPZs has been the potential that labour-intensive production seems to offer for rapid employment creation.

forward user industries, but also its demands for materials and intermediate goods can improve those supporting industries. These forward and backward linkages obviously create employment opportunities in the local economy. However, it is practically impossible to isolate and evaluate these indirect employment effects, hence the total employment effect of foreign direct investment is generally underestimated in the literature. In brief, the strategies of foreign firms in production, marketing, technology and even repatriation can affect job creation and thereby the contribution to employment in the host country.

Many studies, such as Riedel (1975), Schive (1990) and others, have found that a large proportion of foreign investment in Taiwan takes advantage of the cheap and good quality labour. Many of the investments are export-oriented and embody labour-intensive technology. In addition to this, foreign investment in Taiwan is relatively small, compared with investment in other countries like Korea,[12] especially the investment in the latter from Japan. Under these circumstances, foreign subsidiaries in Taiwan tend to be relatively labour-intensive. On the other hand, an ILO (International Labour Organisation) report (1981) indicates that when foreign investment engages in extracting industries (eg minerals and agriculture production), the employment effect is negligible and limited, whereas investment in manufacturing industries (eg textile or electronic production) in the export-promoting sector can create considerable employment through linkages. The manufacturing sector has undoubtedly shared the largest proportion of foreign investment among all sectors in Taiwan's economy,[13] particularly among those with export-oriented industries. With all these characteristics, foreign direct investment can create employment opportunities in the Taiwanese market.

Table 3.4 shows that foreign firms employed around 247,000 workers in 1975, representing 4.5 per cent of Taiwan's total employment. This percentage remained rather steady till the mid-1980s, when some foreign subsidiaries ceased their operations. As a whole, the percentage is not significant, if indirect employment effects are excluded. However, without employment by foreign firms, the unemployment rate in Taiwan might have been as high as 6 to 7 per cent, above the natural unemployment rate in full-equilibrium (4 per cent). Foreign capital has definitely mitigated the unemployment problem of Taiwan. This effect was more remarkable in the early stages when there was huge unemployment hidden in the agricultural sector.

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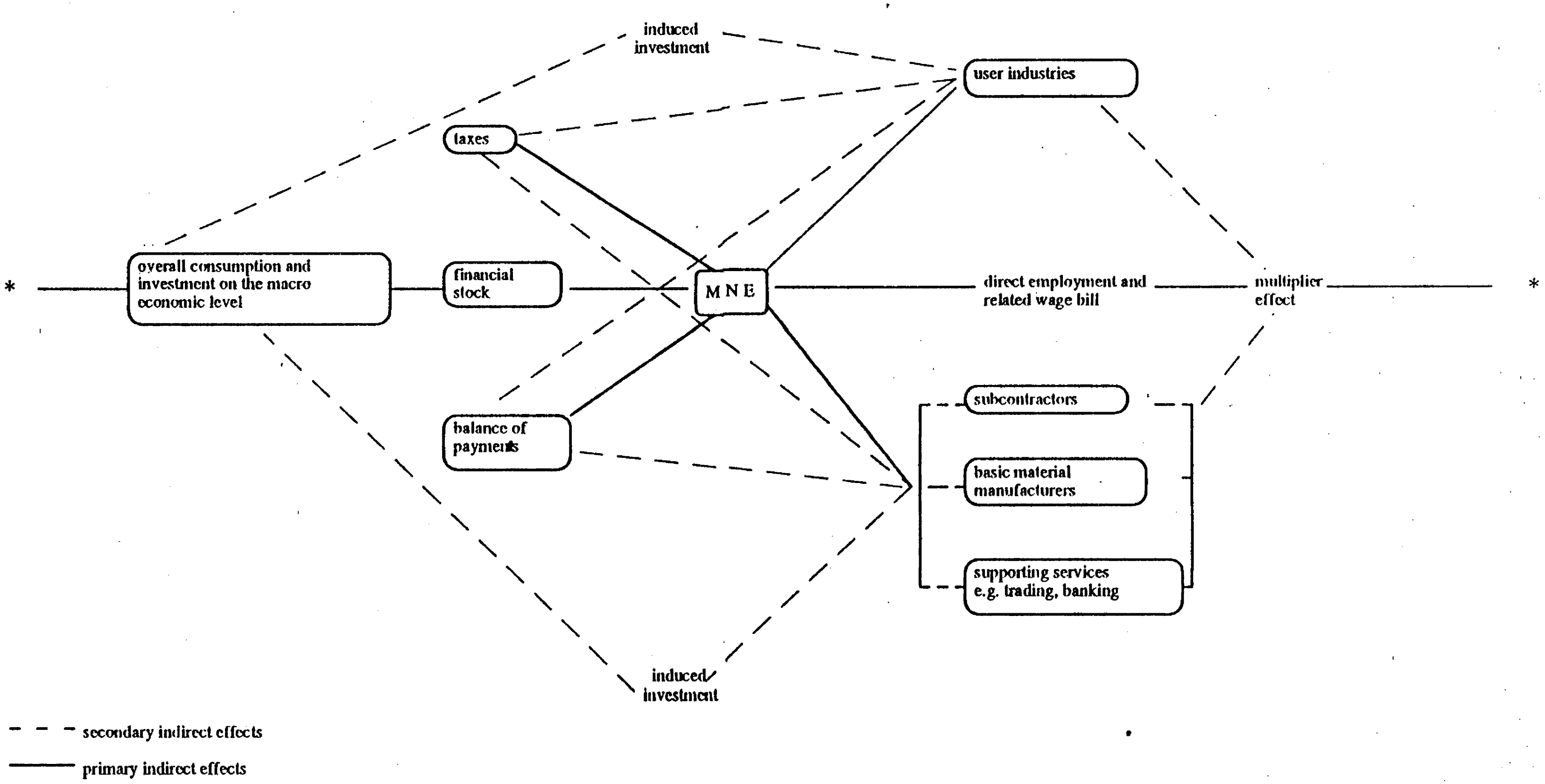
12 This is based on a comparison of the data in Lee (1980) and Investment Commission (1993).

13 The manufacturing sector shared around 90 per cent of total foreign capital till the mid-1980s, when the Taiwanese government began to open the service sector to foreigners.

Figure 3.1 Total employment effects of multinational enterprises (MNEs)



Source: ILO, *Employment Effects of Multinational Enterprises in Developing Countries*, 1981, Geneva.

If the manufacturing sector alone is considered, the average employment percentage would have been near 15 per cent during the 1970s, and 8 to 10 per cent in the second half of the 1980s. Foreign firms had a more profound effect on employment in the manufacturing sector than other sectors of the Taiwanese economy. The decreasing trend implies that foreign direct investment tends to employ more capital-intensive technology in later stages. This may be attributed to the strategic responses of foreign subsidiaries to catching-up by indigenous firms.

Table 3.4 Employment effect of FDI (1,000 persons)

	All industries	Manufacturing	Foreign firms (total)	Foreign firms (manufacturing)	(c)/(a)	(d)/(b)	unemployment rate	
							exclude FDI	include FDI
	(a)	(b)	(c)	(d)	%	%		
1975	5,521	1,518	247	222	4.5	14.6	6.8	2.4
1976	5,669	1,628	290	263	5.1	16.2	6.8	1.8
1977	5,980	1,767	298	273	5.0	15.5	6.7	1.8
1978	6,228	1,892	319	295	5.1	15.6	6.7	1.7
1979	6,424	2,084	357	334	5.6	16.0	6.8	1.3
1980	6,547	2,138	330	309	5.0	14.5	6.2	1.2
1981	6,672	2,146	322	298	4.8	13.9	6.1	1.4
1982	6,811	2,169	326	288	4.8	13.3	6.8	2.1
1983	7,070	2,305	267	237	3.8	10.3	6.4	2.7
1984	7,308	2,494	339	308	4.6	12.4	7.0	2.4
1985	7,428	2,488	262	230	3.5	9.3	6.3	2.9
1986	7,733	2,614	298	271	3.9	10.4	6.4	2.7
1987	8,022	2,810	306	263	3.8	9.4	5.7	2.0
1988	8,107	2,798	283	242	3.5	8.6	5.1	1.7
1989	8,258	2,803	291	244	3.5	8.7	5.1	1.6

Source: Calculated from the survey data of Investment Commission, Ministry of Economic Affairs, 1975-1989, Taipei, Taiwan.

Another interesting issue is the relationship between the employment effect and the export strategy of foreign firms. The literature suggests that export-oriented investment tends to utilise labour-intensive technology (Caves 1980), implying that foreign firms which export more will employ more labour. Spearman's rank correlation coefficient test statistic is used to test this hypothesis in Taiwan during the 1975-89 period. Firstly, testing the relationship between employment and export ratio across firms year by year, the estimated coefficients are in the range which leads to the rejection of the null hypothesis before 1986 and approaches the critical value in later years. When the test is applied to the whole data set (10,075 observations), the coefficient is 0.31; the null hypothesis is also rejected. The results confirm that foreign firms with higher exports create more job opportunities. These results are in line with

Schive (1979) who estimated that the jobs created could be attributed to exports by weighting employment per firm with its export ratio, and found that the weighted employment of foreign firms was about 75 per cent of the total labour employed by them, higher than the average export ratio: 50 per cent.

Secondly, the test is applied at the industry level, the estimated Spearman's rank coefficients were insignificant for some years, because of the domestic market orientation in industries, such as the non-metallic and metallic industries. The export ratio and employment in the chemical and pulp paper industry fluctuate vigorously,[14] which could also bias the estimated results. However, this result also conforms to Schive's study. As a whole, export-oriented investment in Taiwan did indeed create job opportunities in the labour market.

In addition, the relationship between export and capital-labour ratio was also estimated. The capital-labour ratio is represented by the fixed assets per worker. The Spearman's rank correlation test shows a negative association between the export ratio and the fixed assets per worker during the whole sample period. The estimated coefficients range from -0.34 to -0.5, with -0.45 the average for the whole 9,945 observations, indicating that the lower the rank of the foreign firms export ratio, the higher the rank of its capital-labour ratio. The estimate suggests that foreign investment in Taiwan is inclined to be labour-intensive and export-oriented.

The strategies of foreign firms appear to tally with the pattern of comparative advantage in Taiwan's economy, thus creating considerable employment. The contribution of foreign investment to the labour market in Taiwan is remarkable even if the indirect employment effect is excluded. The indirect employment effect, like the direct effect, also depends on the strategies of foreign subsidiaries.

Effect on linkages

Another important contribution of foreign investment, as suggested by Ranis and Schive (1985), are the linkage and learning processes. These include purchases of locally made raw materials, introduction of new industries and marketing techniques, and training of local skilled labour and management. Foreign firms' linkages to the host economy basically depend on their strategies in purchasing, managing, and marketing. Many host governments enact requirements which govern the behaviour of foreign direct investment under the approval entry system, thereby sharpening the response of foreign firms to the development of linkages to the host economy.

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[14] This fluctuation may be due to the sampling difference for the whole period, especially because these two industries have many heterogenous products or large scale deviations.

Theoretically, there are two types of linkage effect: backward linkage, which extends back from the purchases made by a firm; and forward linkage, extending through the inputs that it supplies to other processes and activities. No matter which kind of production process is used, there may be incentives to develop downstream or upstream industries in the host economy with the encouragement of a specific demand for outputs or a concrete supply of inputs by foreign firms, unless the production processes of products need only the inputs of primary factors (capital and labour), as in the extraction industries.

Of these two effects, forward linkages are more diversified and concealed in the activities between foreign firms and local firms, making their effects more difficult to measure. Backward linkages, therefore, generally receive more attention, particularly when the host country promulgates import-substitution policies. The potential backward linkage effect may also differ considerably in terms of the activities undertaken by multinationals. For instance, Dietz (1985) finds that a multinational engaged in producing export-oriented, labour-intensive products and vertically integrated with its parent firm may induce relatively low linkage effects, because under the globalised production of multinationals, the subsidiary's inputs tend to be imported from the parent company or parent suppliers, with a relatively small proportion of local purchasing. This phenomenon is generally recognised to be more prominent in the foreign firms located in EPZs,[15] because these firms prefer to utilise their global production networks and cheaper labour costs.

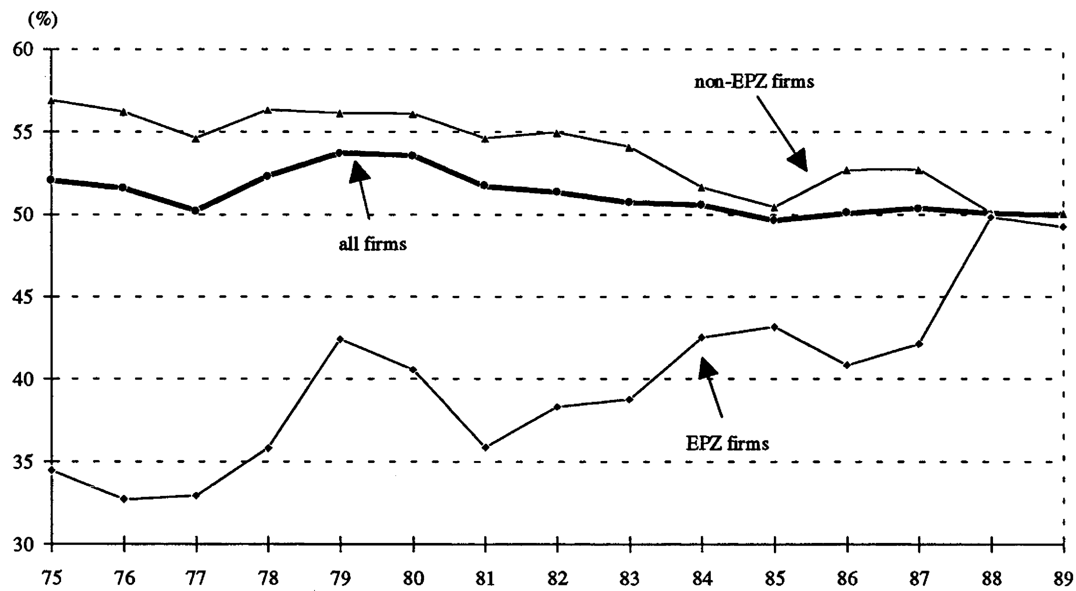
The most popular and simplest indicator for measuring the degree of realised backward linkage effect is the extent of local procurement by foreign subsidiaries. Local procurement can be crudely calculated by the ratio of materials purchased from the domestic market to the total materials expenditure of a foreign firm. This ratio only represents the direct linkages of a foreign firms to the domestic market. The magnitude of indirect linkages depends on the input-output relationship of the products purchased. For simplicity, the indirect linkage effects are not included here. Figure 3.2 shows the time trend in local procurement by foreign subsidiaries in Taiwan.

The average local procurement ratio by foreign subsidiaries in Taiwan remained rather steady during 1975-1989, ranging from 50.7 per cent to 55 per cent, with a slight downward trend in the 1980s. This downward trend was mainly due to the reduction of local purchasing by foreign subsidiaries outside the EPZs. The average local procurement ratio of these non-EPZs' subsidiaries declined from 58.1

15 An opposite argument suggests that this view overlooks the point that an export-oriented industry generally faces more severe competition in the world market. This pressure forces the firm to pursue and adjust production to lower cost, which is usually accompanied by higher local procurement.

per cent in 1975 to 52.4 per cent in 1989. The trend for foreign firms located in EPZs, however, has been increasing: from 33.5 per cent in 1975 to 50.9 per cent in 1989.

Figure 3.2 Trends in local procurement by foreign firms in Taiwan, 1975-89



Source: Calculated from the survey data of Investment Commission, Ministry of Economic Affairs, 1975-1989, Taipei, Taiwan.

Nevertheless, local procurement by EPZ firms has always been lower than that undertaken by firms outside the EPZs until recent years. Relatively low local procurement by EPZ foreign firms could be due to:

(i) low labour costs being one of the major incentives for investing abroad. Firms in EPZs are usually attracted by the lower wage costs, and their production processes tend to be relatively simple in the context of their global production. They import most of their equipment and intermediate materials from other production sites;[16]

(ii) high export ratios. Compared with products for the domestic market, export goods generally contain more imported materials to maintain product quality and market competitiveness. Therefore, a high export ratio suggests that high importation by these firms is to be expected. Table 3.5 shows that a very high proportion of products are being exported by foreign firms in EPZs. The export to sales ratio of these firms remained above 93 per cent until 1986. Since then the export ratio has stayed as high as 50 to 60 per cent. The ratio was much

16 This type of investment, it has been argued, not only incurs low linkage effects with local industries, but the value-added of its products is also insufficient.

higher than the average for foreign direct investment in Taiwan, around 50 per cent to 62 per cent with a drop to 33 per cent in 1989.

(iii) freedom to import materials into EPZs and convenient import processes. This has been an important incentive in foreign investors' decision to locate their operations in Taiwan. However, this convenience tend to encourage firms in EPZs to use more imports in their production; and

(iv) a high percentage of foreign equity. Foreign participation may influence a firm's sourcing strategy in respect of the use of local materials. Firms in EPZs generally prefer majority foreign ownership in order to hold management control,[17] either out of concern for the globalisation of multinationals or for the convenience of practising transfer pricing.[18]

Table 3.5 Export ratios of foreign direct investment in Taiwan, 1973-89, (NT$1,000)

	FDI sales (a)	FDI export (b)	Export ratio (b)/(a) %	EPZ sales (c)	EPZ export (d)	EPZ export ratio (d)/(c) %
1973	66,536	41,243	61.99	-	-	-
1974	-	-	-	-	-	-
1975	96,089	55,218	57.5	13,757	13,602	98.7
1976	144,421	88,696	61.4	20,109	20,086	99.8
1977	169,133	102,916	60.9	21,142	21,069	99.6
1978	226,945	136,119	60.0	28,455	28,198	99.2
1979	292,119	164,215	56.2	30,628	30,537	99.1
1980	323,012	177,608	55.0	37,301	36,335	97.1
1981	361,486	202,384	56.0	35,067	34,737	98.5
1982	362,416	196,741	54.3	49,490	49,226	97.1
1983	321,662	172,876	53.7	53,068	52,527	96.3
1984	552,402	282,864	51.2	43,078	42,913	98.6
1985	421,086	220,520	52.4	32,810	32,620	98.6
1986	497,144	264,942	53.3	75,132	73,931	94.8
1987	590,664	297,343	50.3	100,518	98,002	93.3
1988	698,688	304,958	43.7	53,004	44,661	67.1
1989	873,911	288,608	33.0	153,916	72,172	51.9

Source: Calculated from the survey data of Investment Commission, Ministry of Economic Affairs, 1975-1989, Taipei, Taiwan.

Nevertheless, the upward trend of local procurement by EPZ firms suggests that they now link more closely to the domestic economy. As a whole, the hypothesis

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17 The average percentage of foreign participation has always been above 80 per cent in EPZs which is higher than the average of firms outside, 50-60 per cent.

18 Lall (1973) indicated that transfer price is one key factor affecting the decision making of foreign firms.

that foreign investment forms an economic enclave in the host economy is apparently rejected in Taiwan, even for the EPZs.

On the other hand, the decreasing trend in local procurement by firms outside the EPZs might suggest that there is no strong linkage of these firms to the domestic economy. Yet this conclusion might not be warranted in Taiwan's case. Schive (1979) studied the local procurement of foreign firms during the early 1970s, and found that there was an increasing trend towards using local materials from 1972 to 1978. From these two data sets it can be concluded that there was an upward trend in local procurement before 1980, which turned downward later. The earlier upward trend might suggest that foreign firms indeed generated backward linkage effects in an earlier period. This is particularly important in the early development stage; the underdeveloped Taiwan economy required information and assistance from a variety of sources in establishing a broadly based industrial structure. This trend also suggests spillovers by foreign firms.

The subsequent downward trend in procurement might suggest that there was a strategic change by foreign firms in sourcing materials. This can be explained by increases in the price of importing materials around 1980.[19] This implies that because of technological changes in Taiwan or new technology being transferred, foreign firms were forced to import new materials that could not be produced in the domestic market.

Furthermore, in personal interviews conducted with several EPZ firms, some pointed out that their production technology had seen only minor changes since establishment because of the globalised production of the multinationals. On the other hand, firms outside the EPZs facing severe competition from indigenous firms have to pursue products or technology innovation more intensively. Foreign firms outside the EPZs created larger linkage effects to the domestic market than EPZ firms. But in both EPZs and outside, foreign direct investment had indeed created backward linkages to Taiwan's economy during the past four decades.

Effect on balance of payments

As for the influence of foreign direct investment on foreign exchange, the shortage of foreign exchange may act as a constraint to economic development, as the deficiency of savings does. When foreign direct investment is undertaken there is an initial effect: the balance of payments can benefit from the associated capital inflow. This may only be a one off effect. There may also be some effect over time if a foreign-owned

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19 According to Taiwan's statistical data, the unit value index of imports jumped to a very high level during 1981-85.

enterprise can generate a net positive flow of export earnings. These effects can be examined from the following three perspectives:

(i) Whether the investment is domestic market or export-oriented. If the foreign firm has an export-oriented strategy, then most of its products will be exported, earning foreign exchange, which will improve the balance of payments.
(ii) The percentage of local content in the products produced by foreign-owned firms. If the product has a high local content (which means it has a relatively low proportion of imported raw materials and intermediate imports), then there is a positive effect due to an expansion of domestic output.
(iii) The distribution of foreign firm's profits between the host country's factor inputs and the government; that is, tax revenue and the retained share. The remittance of dividends, interest, royalties or administrative charges to the parent firm generates adverse effects on the balance of payments of the host country.

These various effects on the balance of payments can be broadly classified into the export effect (related to (i)), the import-substitution effect and the import effect (from (ii)), and the remissions effect (from (iii)). The first two effects can improve the balance of payments, while the other two worsen it. Since these effects can only be evaluated on a firm-by-firm basis, the net impact of the operations of foreign firms on balance of payments should be examined empirically for the specific country.

In the case of Taiwan, foreign capital inflow mainly took the form of cash inflow, machinery and equipment importation, and retained earning reinvestment. Schive (1979) estimated that about 81 per cent of the capital inflow was in cash terms, while machinery and equipment accounted for 4 per cent, materials 1 per cent and reinvestment 14 per cent. There is no doubt that cash inflow contributed directly to the balance of payments. The importation of machinery and equipment that cannot be produced or supplied by the domestic market can also be seen as a contribution to the balance of payments. As to the retained earning reinvestment, since the profits of foreign-owned firms take no account of national income and there is also no restriction on remittances in Taiwan, the retained earning reinvestment can thus contribute to balance of payments only indirectly, in the short run.

There is no doubt that foreign investment has favourable export expansion effects; however, the net trade effect was of the most concern to the Taiwan economy in the early development period. To calculate the net trade effect, it is necessary to take account of the imported raw materials and intermediate inputs as well as exports. One way to examine this impact is through the percentage changes in the local content of the foreign subsidiary's products, with a low proportion of import content generally leading to positive net trade effects.

The difficulty in the collection of data and the complexity in measuring the local content of products prevents accurate calculation of the net trade effect. However, a simple comparison of the exports from and imports by the foreign subsidiaries is calculated in Table 3.6 to give some insight into the net trade effect.

As shown in Table 3.6, the total exports of the foreign firms contributed a large proportion to Taiwan's total exports, over 10 per cent and even above 20 per cent in earlier periods. Foreign direct investment contributes significantly to Taiwan's exports. Meanwhile, foreign firms were responsible for a relatively low percentage of Taiwan's total imports suggesting that the foreign exchange earnings of foreign subsidiaries are probably larger than their overseas payments, since Taiwan has accumulated foreign reserves from the 1970s. These data, better than a direct comparison of the value of foreign firms' exports and imports, suggest that foreign direct investment might have had a positive net trade effect in relation to international trade in Taiwan.

Table 3.6 The effect of FDI on the Taiwan economy, 1973-89 (NT$ million)

	GNP (a)	Total Export (b)	(b)/(a) %	FDI Sales (c)	FDI Export (d)	(d)/(b) %	Total Import (g)	FDI Import (h)	(h)/(g) %
1973	410,289	170,723	41.6	66,536	41,243	24.2	145,079	19,905	13.7
1975	586,307	201,468	34.4	64,835	41,100	20.4	141,611	22,539	15.9
1976	702,694	309,913	44.1	88,220	61,041	19.7	186,975	31,927	17.1
1977	823,871	355,239	43.1	103,750	68,292	19.2	214,635	34,669	16.2
1978	989,271	468,509	47.4	138,852	90,344	19.3	271,840	45,733	16.8
1979	1,196,238	579,299	48.4	177,729	105,945	18.3	367,394	57,516	15.7
1980	1,488,953	712,195	47.8	212,855	128,328	18.0	502,984	68,245	13.6
1981	1,764,278	829,756	47.0	232,486	135,217	16.3	617,110	72,010	11.7
1982	1,899,289	864,248	45.5	218,692	130,878	15.1	568,781	96,139	16.9
1983	2,103,261	1,005,422	47.8	205,114	114,724	11.4	639,689	65,134	10.2
1984	2,368,478	1,204,697	50.9	324,320	192,532	16.0	681,647	103,972	15.3
1985	2,515,049	1,223,019	48.6	281,596	169,475	13.9	616,009	88,193	14.3
1986	2,925,772	1,507,044	51.5	373,381	188,844	12.5	648,589	110,734	17.1
1987	3,288,973	1,707,608	51.9	491,145	229,751	13.5	739,628	141,699	19.2
1988	3,585,294	1,731,804	48.3	493,324	251,611	14.5	1,030,968	131,788	12.8
1989	3,968,975	1,747,800	44.0	585,447	231,335	13.2	986,135	152,897	15.5

Source: Calculated from the survey data of Investment Commission, Ministry of Economic Affairs, 1975-1989, Taipei, Taiwan.

The positive net trade effect of foreign direct investment in Taiwan suggests that foreign direct investment may also contribute to Taiwan's balance of payment. In a developing country like Taiwan, the role of foreign investment in filling the foreign exchange gap is crucial to economic development. Taiwan's balance of payments situation has shown great improvement, realising a sizeable surplus on the current account and huge foreign exchange reserves in the 1970s. It is necessary to examine whether this improvement can be attributed to the inflow of foreign investment.

According to Lall and Streeten (1977), the direct balance-of-payment effect, which they defined as the immediately effect on foreign exchange, can be calculated by taking a firm's exports plus the inflow of equity or loans from abroad, and deducting capital goods imported, remittances, and technical fees or royalties. Following their definition, Table 3.7 calculates the direct balance-of-payment effects of foreign direct investment in Taiwan.

Table 3.7 Direct balance-of-payment effects, 1975-89, (NT$ million)

	Direct balance-of-payment effects	Contribution of component (%)			
		Exports	Imports		Remittance
			Materials	Machinery	
1975	2,754.73	39.0	28.2	-	3.7
1976	8,489.16	50.3	31.6	-	3.0
1977	10,868.54	50.9	31.1	-	3.8
1978	22,371.53	55.8	33.3	-	3.1
1979	14,915.08	48.9	32.9	-	2.6
1980	19,076.74	50.0	28.0	3.1	3.6
1981	23,216.02	48.9	29.5	4.4	3.5
1982	27,654.53	53.0	28.6	4.3	6.6
1983	17,734.20	53.0	30.5	3.4	8.2
1984	48,499.19	52.6	32.0	4.8	8.9
1985	33,194.88	48.4	57.3	7.0	26.4
1986	18,963.29	45.0	31.8	3.6	12.7
1987	294.44	43.6	34.7	44.5	13.6
1988	-10,458.96	40.6	32.9	7.9	12.3
1989	-16,668.04	42.4	30.7	3.6	23.6

Note: (i) Direct balance-of-payment effect is derived as:

$$B_d = X - (C_k + C_r + R + D)$$

where X is the value of exports; C_k represents the value of capital goods imported; C_r is the value of raw materials and intermediate goods imported; R is royalties and technical fees paid abroad after tax; and D is net after-tax profits and interest accruing abroad.

(ii) The contribution of components is calculated as percentage to sales to exclude the scale difference across firms.

Source: Calculated from the survey data of Investment Commission, Ministry of Economic Affairs, 1975-1989, Taipei, Taiwan.

Table 3.7 shows that the balance-of-payment effect remained positive until 1987. Total foreign direct investment earned close to NT$3 billion in 1975 and reached a peak of NT$49 billion in 1984. Thus, foreign direct investment appears to have contributed to the accumulation of foreign exchange in Taiwan. over the past few decades. Furthermore, the components show that the role of exports was the dominant factor determining this positive effect on foreign exchange, the average of the ratio of exports to sales being over 40 per cent. At the same time, imports of foreign material and machinery had an important negative effect, accounting for around 30 per cent of sales. Remittance of profits and other factors had a relatively low negative impact on the balance of payment. Overall, foreign direct investment has had a positive contribution to foreign reserves in Taiwan, particularly before 1985.

The positive direct balance-of-payment effects are entirely expected, since Taiwan has succeeded in export-oriented industrialisation since the mid-1970s, and since most foreign direct investment tends to be export-led. The statistical data show that the export share to GNP in Taiwan rose from 8.5 per cent during the 1950s, to 20 per cent in the 1960s and further to 40-52 per cent from the mid-1970s, with only a few years recording an increase of less than 40 per cent (from Table 3.6). Export growth has been a leading factor in determining the economic growth of Taiwan. Furthermore, most foreign investment has maintained relatively high export ratios in their sales. As noted in Table 3.6, the nature of this trade-oriented investment led to Taiwan's balanced trade and foreign exchange accounts. This phenomenon is more significant in those investments in the export processing zones, which averaged export ratios as high as 98-99 per cent until the late 1980s.

The direct balance-of-payment effects are calculated using the export effect, the import effect and the remission effect of foreign investment. Another major effect which may influence the foreign exchange situation in the host country is the import-substitution effect. Although this effect is generally considered to have a positive impact on balance of payments, its influence remains uncertain because of measurement difficulties. It is impossible to estimate what Taiwan's balance of payments circumstances might be without foreign capital inflow.

Indirect effects may be more significant. For instance, Schive (1979) points out that one of the major contributions of foreign direct investment to Taiwan's exports was the dispersal of information about foreign markets to indigenous firms. Again, there is difficulty in measuring this indirect effect. Since Taiwan's surplus can partly be attributed to the positive direct balance-of-payment effects, it is undisputed that foreign investment served to fill the foreign exchange gap, particularly during the country's development period.

Apart from these contributions by foreign direct investment, there are other effects which are often discussed in the literature, such as the contribution to governmental tax revenues and foreign exchange. By taxing foreign firms' profits and participating financially in their local operations, the host government is thought to be better able to mobilise public financial resources for development projects. On the other hand, some studies suggest that foreign direct investment can also diminish tax revenue as a result of liberal tax concessions, excessive investment allowance, public subsidies and tariff protection provided by the host government.

In Taiwan, most foreign investments were eligible for benefits under the Statute for Investment by Foreign Nationals. This allowed them to enjoy a tax holiday, an investment allowance, and other preferential treatment. While there could be a loss of government revenues in the short run, considering their linkage effect to the development of industries, there could be a compensating expansion of the tax base in the long run. According to the survey data, corporate income tax paid by foreign firms is around 20 per cent of the whole country's yearly revenues. In addition, foreign firms also raised governmental tax revenues by paying tariffs, and commodity, stamp and other taxes. Foreign firms therefore contributed to filling the Taiwanese government's budgetary gap.

On average, the penetration of foreign direct investment into the Taiwanese economy had favourable effects, particularly before 1980. Strategic responses by foreign firms to economic changes began from 1980, when the Taiwanese economy matured and stabilised. Domestic firms had also developed the capacity to accept the challenge from the world market. Foreign direct investment had succeeded in playing the role of 'tutor' in dispersing technology, marketing, management and other techniques.

Conclusion

Government policy directed specifically towards supporting foreign firms appears to have had little influence on the location decisions of foreign firms. The belief that government policy can influence location and other decisions in foreign direct investment has led some host countries' governments to enact preferential and favourable policies towards foreign direct investment. A variety of incentives is included in these policies, such as tax holidays, tax allowances, accelerated depreciation, and other preferential treatment. In the case of Taiwan, government policy directed towards supporting foreign firms appears to have had little influence on the location decisions of foreign firms. Policy has, however, had an impact on the magnitude, pattern and form of foreign capital inflow.

It is possible that Taiwan's success in attracting foreign capital inflow was due to the establishment of export processing zones, where facilities were established for foreign investors to proceed with off-shore production. In addition, the establishment of a number of industrial districts around the island also induced some foreign direct investment by reducing search, plant and other pre-operational costs.

But the most important influence of government policy was the effort that the government put into providing a better investment environment for foreign firms, through simplifying application procedures for establishment, stabilising foreign currency exchange rates and the financial markets, and liberalising the trade market. Creating a good investment climate and a liberalised market appear to be the most important factors in inducing foreign capital inflow in Taiwan's case.

One of the major reasons that a host government wishes to attract foreign direct investment is to access advanced technology. However, foreign direct investment also provides capital, management know-how and other benefits to the host market, which can help in filling the savings gap, foreign exchange gap, and budgetary gap, as well as the management and the skilled labour gap in the host economy. Foreign direct investment may also assist in attaining macroeconomic policy objectives, such as creating job opportunities and improving terms of trade. Foreign direct investment can also generate positive effects upon firms and industries via linkages to the domestic market. Foreign firms may disseminate information on technology, marketing, and other matters, thus helping the domestic firms to access the world market.

Five major contributions of foreign direct investment on the Taiwanese economy have been examined: technology, capital formation, employment, linkages and balance of payments.

The impact of foreign direct investment on technology mainly depends on the appropriateness of the technology, the efficiency in adapting it and the continuity of technology transfer. The first of these is closely related to the factor endowment in the host economy because the technology transferred may not be most efficiently employed if domestic factor inputs are used. The technologies employed by foreign subsidiaries in Taiwan have usually passed through selection by the parent firms; most of them tend to be labour-intensive and thus easier to adapt, which also permits efficiency in adaptation. At the same time, the high flexibility of Taiwan's enterprises, the efficient training system and the high degree of labour mobility also ensure efficiency in adapting transferred technology. The speed of technology transfer is not easy to identify, but the continuous growth of the inflow of foreign direct investment provides, at least, some evidence. It also suggests the presence of spillover effects.

Compared with other factors, foreign direct investment did indeed play a major role in the transfer of new technology over the past three decades of Taiwan's economic development. However, with economic growth and industrial upgrading since the 1980s, technology licensing agreements have become more prominent than foreign direct investment.

Foreign direct investment provides the capital which can help the developing host country to break out of Nurkse's 'vicious circle of poverty' and to push through the growth process. Taiwan was pulled out of this low level equilibrium trap with the assistance of US aid, and economic development began to take off with the inflow of foreign capital in the 1960s. Foreign capital compensated for the shortage of domestic savings in the early stages of development, but became relatively less important when domestic savings grew and were directed to productive activities. Yet the contribution of foreign capital to capital formation is undisputed, particularly in the early stages of development and in the growth of the manufacturing sector.

The third role of foreign direct investment is its effect in creating job opportunities. A high unemployment rate or under-employment is always a crucial issue for developing countries, and utilising cheap labour is one major motivation for foreign direct investment in the host country. The establishment of foreign subsidiaries absorbs abundant labour in the market. The contribution of foreign direct investment in job creation depends on the characteristics of the foreign subsidiaries, such as firm size, production technology, foreignness and linkages to the domestic market. In Taiwan, the electronics industry has the largest foreign participation which, according to the ILO, created a considerable number of jobs in the labour market. Without foreign subsidiaries' employment, Taiwan's unemployment rate is likely to have remained above the full-equilibrium unemployment rate. Hence, foreign direct investment definitely mitigated the unemployment problem in Taiwan.

Another important issue related to foreign direct investment are linkages to domestic firms. These include purchases of domestic materials, introducing new intermediate inputs and marketing techniques and training workers. Linkage effects are usually measured by the ratio of local procurement in the foreign subsidiary, indicating backward linkage. The local procurement ratio of foreign subsidiaries in Taiwan remained steady for several decades, eventually following a slightly downward trend. Firms located in the EPZs have an increasing trend in local procurement which is partly attributable to the success of domestic firms in producing better quality substitutes. The declining ratio for foreign subsidiaries outside the export processing zones may be explained by their technological characteristics which lead to the import of new materials and intermediate inputs. These firms generally face much stronger competition from the indigenous firms than firms in the export processing zones, so they have to import new technology to keep their competitive advantage in production and thus generate technological change. Firms outside EPZs might create larger linkage effects with the domestic economy than those inside.

The last issue discussed was the effect on foreign exchange. A shortage of foreign exchange may act as a constraint to economic development, just as a deficiency of savings does. The effect on the balance of payments depends on the behaviour of foreign subsidiaries in three respects: the percentage of local content in products, the markets for the products, and the distribution of the profits. The effect of these factors on the balance of payments is channelled through the export, import-substitution, import and remission effects. The first two effects can improve the balance of payments, while the other two effects worsen it.

The calculation of the direct balance-of-payment effect, developed by Lall and Streeten (1977) and comprising the export, import and remission effects, shows that foreign subsidiaries in Taiwan generated a favourable impact on the balance of payments. There is no completely appropriate measure to estimate the magnitude of the import-substitution effect because the economic environment cannot be simulated by assuming no inflow of foreign capital, but this effect is commonly regarded as being positively correlated to the inflow of foreign capital via linkages to the domestic economy. Nonetheless, the impact of foreign direct investment on the balance of payments in Taiwan appears to have been positive.

In addition, foreign direct investment may also contribute to the host government's revenue through its payment of corporate income tax, tariffs, and commodity, stamp, and other taxes during its operations.

On average, the penetration of foreign direct investment into Taiwan could be seen as a positive factor in the country's economic development. The high economic growth and upgrading of the industrial structure which accompanied foreign direct investment suggest that a domestic economy benefits from foreign direct investment through both of these effects. However, domestic firms may also contribute to these effects, and it is therefore necessary to distinguish the differences between foreign and local firms before arriving at any final conclusion about the benefit of foreign direct investment to a host economy. Foreign and domestic firms in Taiwan are compared in several important aspects of firm behaviour in the following chapter.

4 The Comparative Performance of Foreign Firms and Indigenous Firms

Foreign direct investment had positive effects on Taiwan's economic development, yet it is possible that local firms may have generated similar benefits to the economy. The impact of foreign direct investment on development would be minimal if foreign subsidiaries and local firms behaved in a similar way. Comparison of the performance of foreign subsidiaries and local firms is employed in this chapter to distinguish their characteristics in terms of scale, technology, employment, sales strategy and so forth. The hypothesis is that, if foreign subsidiaries and local firms perform differently, then foreign subsidiaries may generate externalities over and above those generated by their local counterparts. Better performance by foreign subsidiaries, as mentioned in Chapter 2, suggests that there is a potential catch-up by local firms if local firms put effort into capturing spillovers, such as recruiting skilled workers from foreign firms. The assumption in this hypothesis is that foreign subsidiaries have superiority in all or some characteristics, because of their unique intangible assets, such as technology, management know-how, technical skills, and access to marketing and information networks.

There is little doubt that foreign subsidiaries and local firms perform differently—especially in developing countries—but it may be questioned whether this is due simply to the nationality of their ownership. Previous research such as Kojima (1973, 1985), Liu, Schive and Tsai (1990), and Chen and Wang (1992) has put much effort into comparative study of capital by origin of ownership.[1]

There are also many studies comparing the performance of foreign subsidiaries and domestic firms: Kumar (1989) in India, Blomstrom (1989) in Mexico, Willmore (1986) in Brazil, Riedel (1975) and Schive (1990) in Taiwan. On the basis of a survey of 445 Taiwanese manufacturing export firms in six industries, Riedel (1975) compared foreign subsidiaries and local firms' factor intensities, factor productivity, import content, degree of export orientation, and other indicators.

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1 Kojima posited that the market orientation of Japanese foreign direct investment is significantly different from that of other countries, especially American foreign direct investment, which leads to different performance by foreign subsidiaries of different national origin. Following Kojima, many studies have attempted to identify the features of Japanese subsidiaries distinct from those of US subsidiaries in various developing countries. For instance, Chou (1988) in Taiwan, Lee (1980) in Korea. Liu, Schive and Tsai (1990) and Chen and Wang (1992), in studying Taiwan, implicitly recognised differences in performance of different national origin, one being that US subsidiaries' are more export-oriented and use more foreign materials.

Schive (1990) compared the factor intensity of foreign firms and local firms across twelve highly aggregated industries. Riedel found that foreign subsidiaries differed significantly from local firms in scale of production, export performance and import dependence, but insignificantly in factor intensity. However, the absence of any significant difference in factor intensity might be because Riedel's study only examined export-oriented firms. Schive's study found that foreign subsidiaries, on average, used more capital-intensive technology than their local counterparts, but foreign investment tended to be concentrated in more labour-intensive industries. Foreign firms, on the whole, tended to use more labour-intensive technology. Both studies verified the difference between foreign-owned firms and local firms in Taiwan, but using highly aggregated levels of industrial data.

Since foreign subsidiaries in developing countries are often presumed to be different from their domestic counterparts in several important respects, the following study attempts to compare these characteristics by using the industrial census data of Taiwan in the year of 1986. The next section of this chapter presents the hypothesis and variables. The third part reports the results of tests of difference between matched pairs of firms by industry, followed by a description of the test results of matched pairs by size. The final section summarises the main findings.

Hypothesis and variables

In statistical analyses of the effect of foreign ownership and management on industrial performance, two approaches have often been used. One approach is to collect information for pairs of firms—one foreign-owned and one indigenous—carefully matched by industry or size. Any observed difference between the two types of firms is then ascribed to the effect of ownership rather than the effect of industry or scale of production, as has been done by Willmore (1986), Blomstrom (1989, ch. 2), Kumar (1989, ch. 4). This approach has the advantage of simplicity in assumptions, but the disadvantage of not making full use of the available data.

The other approach, such as that by Chou (1988), is to specify and estimate a regression model in which ownership characteristics are included as one of the explanatory variable. This makes better use of existing information, and observations are not wasted for lack of comparable firms, but the method is quite demanding in terms of the strong assumptions underlying a complicated theoretical model. If the two categories of firms (foreign and domestic) are poorly matched by size or by industry, fitting a common regression model to the sample amounts to extrapolation beyond the range of the available data, with all the pitfalls inherent in this procedure.

The 'matched pairs' approach is employed here. This approach has been used very little in comparative studies of foreign and domestic firms. The few studies that do exist are based on a very small number of observations[2] or a highly aggregated industry level,[3] which make it difficult to reject the null hypothesis of no difference between the two types of firms at any reasonable level of statistical significance. The statistical information for Taiwan on the activities of firms of different ownership is among the most comprehensive data sets available at present. Data at a four-digit industrial level are matched in this section, followed by data matched by size of firm in the next section.

According to foreign direct investment theory, the specific advantages which foreign firms may possess are of two broad types: first, those based on the generation of new technologies, managerial skills, marketing know-how and product differentiation; and, second, those derived from scale economies. In order to find out whether multinationals have advantages that are specific to ownership, the advantages of foreign firms are compared in respect of scale economies, superior technology and marketing, high skills and more capital-intensity. R&D activity, export performance and profitability are also discussed. Linkage to the domestic economy is another important issue in these performance comparisons. As there are no data available from Taiwan's census, this variable cannot be examined directly here.

Scale of production

Although there may be no *a priori* reason for expecting that foreign subsidiaries will set up a larger scale of production than local firms, many empirical studies find that foreign subsidiaries are on average larger than local firms, for example, Caves (1974) in the case of Canada and Australia, Blomstrom (1989) in Mexico, Lall and Streeten (1977) in India, Malaysia and Colombia, and Kumar (1989) in India.

There are several reasons why foreign subsidiaries may set up a relatively larger scale of production:

(i) The production processes of many foreign subsidiaries are vertically integrated with their parent firms in order to internalise the market. Their production is intended to serve world markets (at least, the home and host country markets), rather than just regional or local markets.

(ii) Foreign subsidiaries may be able to access cheaper or more varied sources of capital than their local counterparts because of the financial network of the

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2 For instance, Mason's (1973) data consist of fourteen pairs of firms: five from Mexico and nine from the Philippines; Chung and Lee's (1980) data use only seventeen matched pairs in South Korea.

3 As in Schive (1990). He analyses data for twelve industries in Taiwan.

parent firms. This advantage is particularly strong when foreign investment flows from developed countries to developing countries.

(iii) The products of foreign subsidiaries are differentiated products, which are often accompanied by extensive advertising and marketing campaigns. Since advertising activity usually enjoys significant economies of scale and is most cost effective if carried out on a large scale, the relative scale of production is thus likely to be larger.

Hence, the scale of production of foreign subsidiaries in Taiwan's manufacturing industry is hypothesised to be larger than that of their local counterparts and the scale of production is proxied through average sales per firm. Using the sales of a particular year as the proxy for size may be misleading, because of the different rates of capacity utilisation and the influence of the business cycle. The other proxy often used is fixed assets per firm. This scale measure is at the firm level rather than the plant level. The problem with this indicator is that it does not take into account the depreciation method and inflation, both of which may greatly affect a comparison of firms that have been operating for different lengths of time. Nevertheless, these indicators may be used to serve as crude proxies for scale.

R&D intensity

One of the most important advantages of foreign firms is technological superiority based on their R&D activities. If the intangible R&D output can be transferred among the network of multinationals, R&D expenditure will simply be put down in the world's most cost-minimising location. Decisions about locating R&D activities may be influenced by the need for close communication and exchange of information. Such activities are therefore most likely to be located in the headquarters of multinationals. Caves (1982, ch. 7) and Mansfield *et al* (1982) confirm that US multinationals concentrate their R&D activities at their corporate headquarters. The evidence also shows that overseas R&D activities tend to focus on development rather than on fundamental research; that is, on product and process adaptation and improvement, rather than on developing new products and processes. This implies a lower R&D expenditure made by subsidiaries. Nevertheless, Caves and Mansfield also find that there is an increasing tendency to decentralise R&D investment to subsidiaries' locations, partly in response to pressures from host governments.

At the same time, there are also reasons for a local firm to undertake R&D. For instance, the local firm that obtains technology from abroad via other channels may be forced to undertake R&D to absorb, adapt and improve the imported technology. Moreover, the technology transferred by the multinationals is 'know-how' (production engineering), not 'know-why' (design, research and development). They generally do not transfer to the host country the capability to generate new technology. By contrast, local firms which generate their own technology (by imitation) generally develop greater know-why. Therefore, they may wish, as a strategy, to develop technological autonomy over time. Schive (1983) finds that in Taiwan, foreign firms rely heavily on external sources compared with local firms.

Both groups have their own target for R&D investment, and there is no obvious relationship between foreign ownership and R&D intensity, although it is frequently suggested that foreign subsidiaries undertake a lower proportion of R&D locally. For this variable, the ratio of R&D expenditure plus technical fees and royalties to total sales will be compared.

Profitability

Since foreign firms possess technology, management, and other advantages, the rents from these advantages imply that they will generally be more profitable than local counterparts. The empirical studies of Lall and Streeten (1977, ch. 6), Willmore (1986), and Kumar (1989, ch. 4) find that multinationals in a developing country are more profitable than those in a developed country, and also that foreign firms are more profitable than local firms.

According to the theory of industrial organisation, a firm's profitability is determined by both industry and firm characteristics; for instance, the industrial concentration ratio, scale of production, industrial growth, and product differentiation. Since foreign control can only account for some of a firm's profitability and the observed difference in profitability from firm to firm may not remain statistically significant when neutralised for all of the above characteristics, the hypothesis that foreign subsidiaries are more profitable than their local counterparts will not necessarily hold.

It should be noted that reported profits may be lower than actual profits, especially in the case of a developing host country, because of the incentive to transfer pricing and regulations.

The proxy variable of profitability is defined as the profit margin (total revenue minus total expenditure) on sales (before taxes).

Labour quality

It is common to expect that foreign subsidiaries will be more prominent in sectors requiring both advanced managerial and organisational skills as well as high levels of production and technical skills, because foreign firms from developed countries will tend to transfer advanced techniques. Foreign subsidiaries usually attract talented workers in the labour market and train them. Workers in foreign subsidiaries can expect to accumulate skills or knowledge quicker than those in local firms and expect to be paid higher wages than the local going rate. Some empirical studies provide evidence of this, for example, Reuber (1973, p. 175-6) found that the majority of multinationals pay the prevailing wage rate, but an appreciable minority pay more. Lim (1977) found that foreign subsidiaries in Malaysia pay higher wages than indigenous firms. Kumar (1989) also found that the proportion of high-income employees in India is significantly larger in foreign subsidiaries than in local firms. Although paying higher wages may reflect the preference of foreign entrepreneurs for recruiting better 'quality' workers, who are relatively scarce in developing countries, part of the higher wages paid by foreign subsidiary may be accounted for by differences in skills.

According to the theory of human capital, a standard measure of labour quality is the average wage paid by the firm. Hence, the average wage per firm will be employed here as an index of labour quality. The hypothesis is that foreign subsidiaries are likely to pay higher wages.

On the other hand, training being a method to accumulate human capital, the training expenses of a firm can be regarded as a form of improving labour quality. There is some evidence to show that most of the productivity gains from introducing a new technology come from making cumulative small modifications to it, essentially through a learning-by-doing process. A trained worker copes with the production process and accumulates experience more quickly, and a more highly trained workforce increases the potential for invention, especially in modifications of the process. Since the training program of a firm improves the labour quality of its employees and so increases its productivity efficiency, the training expense per worker is also compared.

Another important difference between foreign firms and local firms is labour productivity. Many studies have attempted to compare differences in labour productivity between two groups of firms. Such comparisons raise complex issues and some studies find no significant difference between foreign firms and local firms, while others suggest that foreign firms enjoy higher residual productivity. In general, when all industries are lumped together, productivity between foreign and local firms is significantly different, but the differences are less significant on a disaggregated industrial level. Productivity difference has been interpreted in the literature as support for the existence of spillovers from foreign firms to domestic enterprises, and will be explored thoroughly in the analysis in the following chapters. Here, a crude proxy variable for labour productivity, output per employee will be compared.

Choice of technology

Foreign firms develop an advantage in capital-intensive technology for reasons similar to those which encourage their utilisation of scale economies. It may be easier for them to transfer highly capital-intensive technologies from the home country without adaptation, and there may be an association between advanced technologies, skills, scale and capital intensity. Hence, foreign subsidiaries tend to be more capital intensive than their local counterparts.

The appropriateness of the technology transferred by multinationals to host countries is a subject of intense discussion in the literature, such as Mason (1973) and Lall (1978), because technology is developed in advanced countries where factor prices are significantly different from those of developing countries. The argument about the appropriateness of technology concerns not only its adaptability to the relatively labour-abundant conditions in a developing country, but also the degree of adaptation by foreign subsidiaries and whether they adapt technology better than indigenous firms.

Some studies have investigated foreign firms' adaptation to the conditions of developing countries. Reuber (1973) reported that foreign firms make rather infrequent adaptations of technologies to the host developing country, and that the adaptations that occurred most were made to satisfy the smaller scale of the host market. Other studies, such as Wells (1973) in Indonesia and Willmore (1986) in Brazil, comparing factor proportions employed in firms, noted that operations of foreign firms were more capital-intensive than those of local firms. They explained this in terms of the tendency for foreign firms to predominate in capital-intensive industries. Schive (1990) found that foreign firms and local firms' capital intensities differ in Taiwan when the industries are compared at a high level of aggregation, but are more similar when industries are more narrowly defined. Some studies suggest that labour-intensive production processes increase the cost of supervision and coordination (Strassmann, 1968) for foreign subsidiaries, and that they face different factor prices from local firms, such as higher wages (Wells 1973; Mason, 1973).

On the other hand, Cohen (1975, ch. 3), Riedel (1975), and Chung and Lee (1980) found that export-oriented investments tend to employ labour-intensive processes. When production is mainly directed to local markets, foreign firms tend to employ relatively capital-intensive technology, but they are not significantly different from their local counterparts when most output is directed to world markets. Since most foreign investments in Taiwan are export-oriented, according to other studies, the expected sign of this variable is ambiguous and depends on whether activities are domestic or export-oriented.

A direct measure of choice of technique is the capital-labour ratio. The relationship between capital and labour is shown by the ratio of total workers per firm as a percentage of the net value of assets. Non-wage employees are also included as the data are available. The measure of labour input would be more accurate if working hours per firm could be accounted for. Unfortunately, such data are unavailable.

Some studies use fixed assets as a measure of capital input; however, this measure may underestimate capital input in Taiwan, especially for the EPZs' foreign firms, because of the misreporting of equity value, and because firms in the EPZs usually rent buildings and plant. Schive (1990) suggests using machinery and equipment per worker as the capital-labour ratio to avoid this deficiency. Therefore, machinery plus equipment is used as another measure of capital input here.

Export performance

The theory of international investment suggests that foreign firms will be a vehicle for a host country's export growth. Foreign firms directly access world market information networks, and foreign firms are generally world leaders in innovation and product differentiation. Therefore, many developing host countries turn to foreign investors to lead them into the international market.

Foreign firms may not, however, have a higher export ratio than local firms. The export performance of foreign firms can be expected to vary greatly among developing host countries, because of differences in industrial structure, level of technology, closeness to export markets, the global strategy of multinationals and other factors. For instance, Wu (1989) finds that the high export ratio in Taiwan's electronics industry was due to export-oriented strategies, but the low export ratio in chemical industry was mainly local market oriented.

Findings based on comparisons of the export performance of foreign subsidiaries and local firms in different countries are rather controversial. Cohen (1975) concludes that local firms are more likely to export than foreign firms, whereas Lall (1985) finds that foreign firms in India have better export performance than their local counterparts. Riedel (1975) finds no significant difference in export propensity between the two groups of firms in Taiwan. Lall and Streeten (1977) also find no evidence for foreign subsidiaries' promoting exports.

This section examines whether foreign subsidiaries in Taiwan's manufacturing industries export a higher proportion of their sales than their local counterparts. Since a high proportion of investments in Taiwan are export oriented, it is expected that foreign firms will export more than their local counterparts.

Other strategies which foreign subsidiaries may adopt are different from those of their local counterparts; for instance, local procurement, advertising expenditure and financing strategy. Foreign firms are good at differentiating products; their entry may promote non-price competition in the host market through their advertising strategy. Kumar (1989) finds that foreign subsidiaries in India spend a higher proportion of sales revenue on advertising than their local counterparts. Unfortunately, as there are no available data for Taiwan, the advertising variable is not analysed in this study.

Linkages are a good indicator of the contribution of foreign direct investment, and local procurement is one index reflecting the extent of linkages. In general, foreign subsidiaries can be expected to import a higher proportion of their raw materials or intermediate goods than local firms, because of their familiarity with foreign suppliers and because of the unavailability of some local inputs, as well as to provide markets for their global production network. The empirical studies of Cohen (1975), Riedel (1975) and Mason (1973) all find that foreign subsidiaries make few local purchases of inputs. Riedel finds that import dependence (imported raw material and intermediate inputs as a percentage of total output value) is consistently higher for all foreign firms in Taiwan than for local firms. Similarly, Cohen indicates that Korean firms tend to import less than foreign subsidiaries. It is often hypothesised that foreign subsidiaries will have a higher dependence on imported raw materials; however, the lack of data on Taiwan's census prevents a test of performance in this respect.

Although financial management relates to firms' production costs, and some data are obtainable, it will not be analysed in this context. The major reason for this is that firms' financial reports in Taiwan are incomplete and unreliable, especially those of small local firms, because of the incomplete tax and bank loan systems.

Empirical analysis—matched by industry

The empirical analysis compares foreign subsidiaries and local firms in Taiwan in terms of the variables defined above.

According to the census data of 1986 in Taiwan, there are 169 manufacturing industries at four digit level. However, only 111 pairs of foreign subsidiaries and local firms can be matched. A foreign subsidiary is defined here as a firm with foreign capital, regardless of the proportion of foreign capital. There is no foreign involvement in 38 of the four-digit industries, and only one observation for 20 industries. These industries were excluded from the analysis. In addition, as there are no foreign firms with fewer than ten employees but over 30,000 domestic firms of this scale, a comparison will be misleading if it tries to account for all observations, therefore, these small scale firms are also excluded. Total observations turned out to comprise 932 foreign subsidiaries and 32,352 domestic firms. A number of firms which did not report some variables were deleted from the estimation, and the number of observations for those variables is stated in the lower bracket under the coefficients. A simple comparsion of the performance obetween foreign subsidiaries and local firms are presented in Table 4.1.

Table 4.1 shows that foreign firms had a larger scale of production, a higher export propensity, and created more job opportunities than their local counterparts. Foreign subsidiaries also had a higher wage expenditure, for which there may be two explanations. One is that foreign subsidiaries pay higher wages than the ongoing market wage rate; the other is that foreign subsidiaries hire more skilled labour or a higher quality of labour. The average wage rate paid by local firms was NT$140,000 per year which accounted for only two-thirds of payments made by foreign subsidiaries (NT$222,000). As for the labour quality measure, no data on skilled workers and unskilled workers are available, instead 'staff' data is used as the proxy for skilled or higher quality labour, whereas 'worker' represents unskilled or lower quality labour. In this way, the two indicators can be used to compare the labour quality of the two groups: the ratio of wages paid to staff and workers, as well as the ratio of number of staff to number of workers. From the table, both indices show that foreign subsidiaries have nearly twice the mean values of local firms, suggesting that foreign subsidiaries use more skilled labour than their local counterparts.

The means of the variables measuring choice of technique indicate that foreign subsidiaries use more capital-intensive technology, either measured by net asset value per employee or by machinery and equipment per employee.

All three measures of R&D intensity revealed that foreign subsidiaries paid close attention to adapting new technology. These results seem to contradict Schive's (1990) findings in Taiwan. The variable of training per worker is contrary to the prediction, showing that local firms put more effort into increasing workers' skills than foreign firms. The results relating to these variables might not accord with the prediction; however, it should be noted that the mean difference of these variables might not represent the population, because many firms provided no data. The percentage of local firms reporting these variables was much lower than the percentage of foreign subsidiaries, so there is a strong possibility that biased estimation results were obtained. On the whole, the results of most of the variables concord with many other studies and with the main hypothesis. But it can be seen that the main differences in the parameters are not entirely in accordance with the prediction.

Table 4.1 Parameters for discriminating between foreign and local firms in Taiwan manufacturing (matched by industry)

	Prediction Foreign subsidiary (FS) vs Local firms (LF)	Mean (standard deviation) FS	LF
Scale of production (NT$1,000)			
(a) sale	FS greater than LF	702981 (2233354)	67916 (1084944)
(b) net value of assets (nasset)	FS greater than LF	344000 (3230650)	24718 (566376)
Profitability (profit) (%) ((total revenue-total expenditure) *age/sale)	ambiguous	1.95 (33.08)	4.45(66.20)
Export ratio (exp) (%) (export/sale)	FS greater than LF	53.97 (43.42)	29.44 (42.09)
Employment and labour quality			
(a) employee (emp) (persons)	FS greater than LF	385 (935)	55 (200)
(b) wage + fringe benefit (wage) (NT$1,000)	FS greater than LF	85006 (245185)	9254 (55568)
wage rate (wage/emp) (NT$1,000)	FS greater than LF	222 (108)	140 (74)
(c) wage of staff/ wage of workers (wlb) (%)	FS greater than LF	1.22 (3.76)	0.56 (4.93)
(d) number of staff/number of workers (lb) (%)	FS greater than LF	0.675 (1.957)	0.376 (1.823)
(e) train/emp (train) (NT$1,000)	FS greater than LF	2.57 (7.67) (obs=352)	2.92 (5.71) (obs=2918)
(f) labour productivity (lp) (NT$1,000) (output/emp)	FS greater than LF	1911 (3951)	909 (1042)
Choice of technique			
(a) nasset/emp (kl1) (NT$1,000)	FS greater than LF	795 (1983)	308 (457)
(b) (machinery+equipment)/emp (kl2) (NT$1,000)	FS greater than LF	694 (2641)	188 (736)
R&D intensity (%)			
(a) (R&D+royalties)/sale (rnd1)	ambiguous	0.052 (0.342) (obs=119)	0.020 (0.040) (obs=294)
(b) R&D/sale (rnd2)	ambiguous	0.022 (0.157) (obs=436)	0.013 (0.087) (obs=2930)
(c) royalties/sale (rnd3)	ambiguous	0.013 (0.049) (obs=140)	0.009 (0.031) (obs=347)

Note: obs = number of observations.

Source: Directorate-General of Budget, Accounting and Statistics, Executive Yuan, Republic of China, *The report on 1986 industrial and commercial census, Taiwan-Fukien Area, ROC, manufacturing sector*, Taipei.

The standard deviations of all variables are rather large, leading to the conclusion that differences between two groups are insignificant. Therefore, further inspection of the statistical significance of these mean differences is needed. Two statistical tests are conducted to examine the statistical significance of these mean differences: first, the univariate test of the significance of each variable is performed; and, second, because this test does not take into account interaction among the variables, a multivariate test is used to analyse the variables simultaneously.

Univariate analysis

The univariate test applied here is a non-parametric test. Non-parametric statistical methods are useful where directional differences are available and they have the advantage of not assuming any specific distribution of the population under analysis. Hence, the statistical hypothesis of the univariate tests does not involve population parameters but is concerned with the form of the population frequency distribution. One popularly used non-parametric test in empirical studies is the Wilcoxon Matched Pairs Signed-Ranks Test (for instance, see Mason (1973), Willmore (1986), Chung and Lee (1980) and Kumar (1989)). The Wilcoxon Rank Sum Test is used to analyse the paired differences by considering the paired difference of the two populations. The Wilcoxon Rank Sum Test can utilise information both on directions and on the magnitude of the difference within pairs because it gives more weight to a pair which shows a large difference between the two conditions than to a pair which shows a small difference. The null hypothesis for this test is that the two population relative frequency distributions are identical. One benefit of using this test is that the test statistic for more than 25 observations is approximately normally distributed, with a mean and a variance of

$$Mean = \frac{n(n+1)}{4} \qquad Variance = \frac{n(n+1)(2n+1)}{24}$$

and the Z statistic is

$$Z = \frac{T - [n(n+1)/4]}{\sqrt{n(n+1)(2n+1)/24)}}$$

where T is the smaller of the rank sum for positive difference and the rank sum for negative difference, and n is the number of non-zero differences.

The Wilcoxon test is applied to test the 111 matched pairs of industries. The test can be either one- or two-tailed. Since the null hypothesis is that there is no difference between foreign and local firms, the two-tailed test is applied. The alternative hypothesis is, therefore, that the performance of foreign subsidiaries is different from that of local firms. The decision rule for the two-tailed test is: reject H_0 at the level of significance α if Z exceeds $\omega_{1-\alpha/2}$ or Z is less than $\omega_{-\alpha/2}$, where $\omega_{1-\alpha/2}$ and $\omega_{-\alpha/2}$ are the critical values for α significant level. The results of Wilcoxon's Rank Sum Test are presented in Table 4.2.

Table 4.2 Analysis of discriminating characteristics: Wilcoxon's Signed Rank Test (matched by industry)

Terms*	Z statistics	Foreign subsidiaries (FS) versus Local firms (LF)
sale	8.54	greater than
nasset	8.48	greater than
profit	3.14	less than
exp	7.32	greater than
emp	8.23	greater than
wage	8.48	greater than
wlb	4.48	greater than
lb	3.77	greater than
train	4.60	greater than
lp	9.14	greater than
kl1	8.13	greater than
kl2	8.19	greater than
rnd1	7.21	greater than
rnd2	6.91	greater than
rnd3	3.43	greater than

Note: (i) * the abbreviation of each term follows the definition in Table 4.1
(ii) 5 % significant level for two-tailed Z statistic is 1.96.
(iii) greater than = foreign firms, on average, are greater than local firms.
(iv) less than = foreign firms, on average, are less than local firms.

Source: Directorate-General of Budget, Accounting and Statistics, Executive Yuan, Republic of China, *The report on 1986 industrial and commercial census, Taiwan-Fukien Area, ROC, manufacturing sector,* Taipei.

It is apparent that all the variables suggest statistically significant differences between foreign subsidiaries and local firms. The direction of differences indicates that foreign subsidiaries have a significantly larger scale of production, stronger export orientation, higher wage expenditure and labour quality, and more capital-intensive technology, but lower profit margins than their local counterparts. This result is in line with the simple analysis reported in Table 4.1, but is more definitive.

That foreign subsidiaries possess a larger scale of operation than local firms in Taiwan is often taken for granted because, under the policies of The Three Principles of the People,[4] the Taiwanese government basically discourages the formation of large firms. This has led to over 95 per cent of Taiwan's firms being small and medium sized. Apart from the effect of such policies, local firms are also relatively uneasy about raising large amounts of capital locally because of the rigidity and restrictions of the domestic financial market. The restriction on local enterprises' access to international financial markets has also constrained the expansion of firms.[5]

Foreign subsidiaries had a significantly different sales strategy from their local counterparts. They tended to be export oriented when compared with their local counterparts. This result was to be expected on *a priori* grounds, for the costs of exporting are much lower for foreign firms, which have access to international market information and sales organisations through their parent companies overseas. However, this result differs from Riedel's (1975), which concluded that there is no significant difference between the two groups of firms in this respect. One explanation lies in the different year being processed in the analysis. Riedel's data are for 1972, when Taiwan's economy was yet to take off and still had a trade deficit. Both local firms and foreign firms were pursuing gains from import substitution. However, the limitations of import substitution forced the government to shift industrial and trade policies towards export promotion. Export-oriented foreign investments were also encouraged. The impact of these policies began to be felt from that time. The trade account has been in surplus since 1975.

On the other hand, according to the survey data of the Investment Commission, Ministry of Economic Affairs (1992), foreign subsidiaries' exports rose to, and stayed above, 60 per cent of their sales,[6] yet their total exports accounted for nearly 20 per cent of Taiwan's total exports. The remaining 80 per cent of Taiwan's exports was produced by a relatively huge number of local firms. The average value of foreign subsidiaries' export is higher than that of local firms, which suggests foreign subsidiaries are export oriented when compared to local firms and thereby gives support to the Wilcoxon's test results.

Foreign firms are often criticised for transferring relatively capital-intensive technologies to less developed countries where labour-intensive techniques are preferred, because the manufacturing sector has to absorb abundant suppliers of

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4 The Three Principles of the People (nationalism, democracy and livelihood) written by Dr Sun Yat-sen who established the Republic of China, stress the equitable allocation of wealth and the equality of human beings, and hence the restriction of private capital.

5 The restriction on raising capital from international financial markets was removed in the 1990s. However, the high operative and distributive cost of issuing bonds in the international financial market is a big burden for Taiwanese firms because of their relatively small size, which prevents most of them taking such actions.

6 This percentage has been decreasing since 1986 when the Taiwanese economy changed dramatically, because of the quick appreciation of the NT dollar and rising labour costs.

labour in the domestic market. The relevant question, however, is how well do foreign subsidiaries do, compared to local firms, in absorbing labour? The variable for technology indicates that foreign subsidiaries performed quite poorly in Taiwan. Both measures of the capital-labour ratio suggested that foreign firms utilised techniques of production that were significantly more capital intensive than those of their local counterparts. This result confirms the study of Schive (1990), but contradicts the study of Riedel (1975) who concluded that export-oriented foreign investment tends to use more labour-intensive technology than domestically oriented foreign subsidiaries. However, in the case of Taiwan, the entry of foreign subsidiaries is encouraged because of their ability to provide new technologies rather than to absorb labour, which has become scarcer in Taiwan since the 1980s. Capital-intensive techniques are now preferred.

Do foreign firms in Taiwan pay higher wages for the same quality of labour? This question cannot be answered with the data available in this sample. What is evident is that foreign firms pay higher wages, which might imply that they prefer to hire skilled workers or quick learners who can cope with the production technology within a short period of time. The ratio of white-collar to blue-collar employees, a crude indicator of labour skills, is higher for foreign subsidiaries.

The technology and labour quality variables suggest that foreign subsidiaries indeed transfer new technology into Taiwan and thus produce spillover effects within the economy. The higher labour productivity of foreign subsidiaries also provides support for the possibility of spillovers from foreign firms to domestic firms.

However, one finding which differed from that of Table 4.1 relates to training expenditure per employee. The Wilcoxon's test suggests that foreign subsidiaries underwrote significantly larger training expenses per employee (train) than local firms. This result is in line with the general prediction noted in the second column of Table 4.1. Since foreign subsidiaries in Taiwan use more capital-intensive technology, some of which may be completely new to the local market, training is needed to improve the efficiency of production. The R&D intensity (R&D plus royalties (rnd1)) test suggests that foreign subsidiaries invested more in R&D, in accordance with Schive's conclusion. The other two measures (R&D (rnd2) and royalties (rnd3)) also indicate a higher expenditure on the part of foreign subsidiaries than that of local firms. The high expenditure on technical fees and royalties, accompanied by a low profit margin may imply, to some extent, that foreign subsidiaries manipulated the transfer of their profits via technical payments. Again, there are sampling problems. No data are reported on foreign subsidiaries' R&D plus royalties (rnd1) for twelve industries, nor for 56 industries for the R&D expenditure (rnd2), while the reports from local firms are relatively complete in respect of these variables. The differences between the two variables and ranks were obviously affected by missing data. The estimation of training expenditure per employee (train) also presented the same problem, with sixteen industries for foreign subsidiaries and only two industries for local firms giving no report on this variable.

The profit variable suggests that foreign firms' profits were lower than their local counterparts. However, as mentioned, reported profits do not necessarily reflect the true profits of the firm, since foreign firms are able to manipulate them, through transfer pricing. Unfortunately, there is no method nor any evidence for assessing the effect of foreign firms' transfer pricing on profits in Taiwan. No data were obtainable on material purchasing, destination of products sales, unit price of products and so on. In general, relatively high tariffs, which prevailed in Taiwan till 1986, might have induced foreign subsidiaries to under-report the value of materials imported if their products are mainly supplying the domestic market. Most foreign investments in Taiwan are export oriented, and foreign firms tend to manipulate transfer pricing by showing higher import prices for materials and a lower export prices for products in order to maximise global profits and suppress subsidiaries' profit margins in the host country.

With regard to the profit component, foreign subsidiaries in Taiwan were generally paying higher wages and employing more machinery and equipment in production. This might suggest that they were producing more differentiated products and with higher production costs, compared with their local counterparts. Taking into account transfer pricing strategies as well, it follows that the profit margins of foreign subsidiaries would be lower than their local counterparts, as predicted by the estimation.

Multivariate analysis

The univariate analysis gave rather explicit conclusions about differences in the performance of foreign subsidiaries and their local counterparts. However, the difference in respect of one variable might be attributed to the differences in respect of any of the other characteristics, or a combination of other additional characteristics. In order to take into account the interaction among variables, a multivariate analysis is used. One multivariate technique often used is the estimation of discriminant functions; for example Riedel (1975) and Kumar (1989). However, Press and Wilson (1978), comparing logistic regression and discriminant analysis, conclude that each method is unlikely to give substantially different estimations. Moreover, a logistic regression is preferable to the discriminant analysis because discriminant analysis is formulated on the assumption that the two groups are multivariate normal with a common covariance matrix and this assumption is unlikely to be satisfied in empirical applications. Wide applicability is one of the advantages of using a logistic function for discrimination. Therefore, a logit model is employed here. A logistic analysis is usually formulated mathematically by relating the probability of some events occurring, conditional on some explanatory variables. The logit model is based on the cumulative logistic probability function, which is similar to the cumulative normal function,[7] and is specified as:

$$P = \frac{1}{1 + e^{-(b_0 + b_1 X_{1i} + \cdots + bnX_{ni})}}$$

P is the probability that a choice is made, given X_{ni}. In order to estimate the probability function, the equation to be estimated is in the following form:

$$\ln \frac{P}{1-P} = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \cdots + \beta_n X_{ni}, \quad i = \text{foreign firms, local firms}$$

X_{ni} = the explanatory variable represents the behaviour of the *i*th firm in *n*th variable.

The dependent variable in this equation is the logarithm of the odds that a particular choice will be made, which is called the log-odds ratio and is a linear function of the explanatory variables. The estimated coefficients (β s) do not indicate the increase in the probability of the event occurring, given one unit increase in the corresponding independent variable. Rather, the coefficients reflect the effect of a change in an independent variable on the dependent variable.

The logit model posits that the establishment of a foreign subsidiary is associated with a set of strategic variables (such as export-orientation, scale, and other factors). These characteristics allow classification into one of several alternative groups. In a logit model in this context, P is the propensity to be a foreign firm, and 1-P is the propensity to be a local firm. X_{ni} are the characteristics of firms' behaviour defined in the previous section in terms of the comparative performance hypotheses.

However, since P and 1-P here are not observable, an alternative approach is to define a 'latent' variable for the dependent variable, that is, defining a dummy variable for the left hand side of the above equation. Therefore, it is convenient to classify the two groups of firms into binary grouping variables, such that, if it is a

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7 That is the reason why the logit model is often used as a substitute for the probit model.

foreign subsidiary, then the defining variable can be 1, with 0 being a domestic firm. Setting this 'latent' variable as the dependent variable, with the characteristics of firm behaviour as the explanatory variables, a logit model can be constructed as in the above equation. The estimated results of the logit model are shown in Table 4.3. It should be noted that all variables are defined in the same way as those in Table 4.1.

Table 4.3 The logit analysis (matched by industry)

	constant	sale	nasset	exp	lb	kl	kl1	rnd	rnd1	profit	train
(A)	-5.44	-0.0001		0.0614	1.17	0.004		146.57		-5.99	0.73
	-6.41	-0.69*		6.22	1.51*	4.84		3.48		-2.99	2.27
(B)	-5.36	-0.0001		0.0601	1.12	0.004			94.32	-3.81	0.84
	-6.44	-0.51*		6.25	1.49*	4.93			1.97	-1.75	2.28
(C)	-4.27	-0.0001		0.0518	1.72		0.0026	143.20		-5.73	0.85
	-5.82	-0.65*		5.79	2.32		3.55	3.44		-2.90	2.72
(D)	-5.50		-0.0004	0.0617	1.17	0.0041		143.70		-5.85	0.75
	-6.46		-0.87*	6.25	1.51*	4.83		3.40		-2.91	2.27
(E)	-4.34		-0.0002	0.0521	1.75		0.0027	138.97		-5.55	0.86
	-5.89		-1.09*	5.82	2.35		3.64	3.33		-2.80	2.72
(F)	-5.10		-0.0001	0.0580	1.21	0.0042		161.62		-6.58	
	-6.30		-0.45	6.18	1.59*	5.21		3.73		-3.05	
(G)	-5.14		-0.0003	0.0581	1.22	0.0043		160.44		-6.50	
	-6.33		-0.62*	6.19	1.59*	5.20		3.68		-2.98	

Note: (i) upper row of each equation is the estimated coefficients; lower row is the t-ratio.
(ii) * indicates the insignificance of the coefficients.
(iii) the significance of variable lb is always at 10% level.

Source: Directorate-General of Budget, Accounting and Statistics, Executive Yuan, Republic of China, *The report on 1986 industrial and commercial census, Taiwan-Fukien Area, ROC, manufacturing sector,* Taipei.

All variables were significant in the univariate analysis, yet the logit estimation indicated that some variables were insignificant across all experiments. These variables were excluded in this multivariate context. Several points can be made from the estimates in Table 4.3. The wage and employment variables were sometimes taken as a measure of scale of production which in turn might be highly correlated with the variables for sales and net value of assets, and thus lead to the biased estimation. These two variables were also excluded. The empirical test showed that sales were highly correlated with employment and wages; the correlation coefficients being 0.83 and 0.88. The correlation coefficient of net value of assets (nasset) and employment (emp) is also as high as 0.67, and nasset and wage is 0.81.

Secondly, the variable for labour productivity is not only highly correlated with the variable for the capital-labour ratio (the correlation coefficient is 0.96), it is also strongly correlated with the variables of training per worker (the correlation is 0.83) as well as the ratio of blue-collar and white-collar (a correlation of 0.53). The inclusion of this variable may produce a biased estimation and affect the sign and significance of other parameters, hence it is also deleted from the analysis. The estimation of labour productivity is discussed in other chapters.

Thirdly, the relatively few reports on royalties (rnd2) meant that this coefficient was always insignificant, so this variable was dropped too. As for the other two R&D intensity variables (rnd and rnd1), firms could theoretically choose both R&D investment and buying technology simultaneously (that is, rnd variable); however, the most common case was for a firm to choose either one (that is, rnd1 or rnd2). Therefore, rnd and rnd1 variables were included and estimated separately. Both of these coefficients were significant in explaining the difference in R&D intensity between the two groups of firms in Taiwan.

One finding in the logit analysis of Table 4.3 which is rather different from the univariate and simple statistical analysis is the negative sign for the scale of production, whether measured by sales or by net value of assets. The estimation result suggested that an increase in the scale of operation meant a decrease in the probability of a firm being a foreign subsidiary. This result seems to be counter intuitive. The difference might be due to the negative correlation of scale with other variables, such as export ratio, variables of R&D intensity, and profit. Since the coefficients for scale of production in all equations were insignificant, it could be concluded that this coefficient was indistinguishable from zero and had no explanatory power in distinguishing the behaviour of the two groups of firms. Hence, foreign subsidiaries were not significantly larger than Taiwan's enterprises.

The coefficient for R&D plus royalties is positive and significant whenever it appears in the equations. This suggests that foreign firms had higher R&D intensity than their local counterparts. The explanatory power of the R&D variables might, again, be affected by the unequal observations between the two groups of firms. Of the foreign subsidiaries, 15.1 per cent reported their royalties payments but only 1.1 per cent of local firms did so. The explanatory power of the coefficient for R&D plus royalties/sale (rnd) was strengthened by relatively more information obtained from both groups of firms.

Export (exp), employment (emp), labour quality (lb), and capital-labour ratio (both kl and kl2) had positive and significant estimated coefficients, suggesting that foreign subsidiaries preferred to sell to the international market, hired more employees, paid higher wages, and used more mechanised technology. The coefficient of the ratio of wages of staff and wages of workers (wlb) was insignificant but with the expected sign. As a whole, these estimation results were consistent with the univariate analysis.

The coefficient of profit was always negative and significant. This suggests that a unit increase in profit margins meant a higher propensity to be a local firm. Local firms tended to have higher profit margins than foreign subsidiaries. This result also accords with the univariate analysis. The variable representing training in firms had a positive and significant coefficient, similar to the univariate estimation. This suggests that foreign subsidiaries provide more training to their workers, on average, than do local firms.

Empirical analysis matched by firm size

The results of the previous section suggest that foreign-owned firms and local firms in Taiwan perform differently in terms of capital-labour ratio, export propensity, profitability, and employment strategies, even at the four digit industrial level. However, it is open to question as to whether this is due to ownership or other factors, such as scale differential, market conditions, and X-efficiency. As a large proportion of the local firms in Taiwan are small in size, either in terms of number of employees or scale of production, the deviation between the two groups of firms in terms of these variables may be exaggerated.

To add to this analysis, the size of firms can be matched at the four digit level of industrial classification. The analysis is based on data for 230 pairs of foreign-owned and local Taiwanese firms drawn from 67 manufacturing industries in the above sample sets. In general, two proxy variables can be used to represent the size of firm, number of employees or scale of production of a firm. Here, number of employees is chosen to determine the size of firm. The choice of employees as the proxy variable to match the two sets of firms is unavoidably arbitrary. The firms are matched by number of employees and in no case does the difference in number of employees exceed 10 persons. If there are two or more firms with the same number of employees, the mean of those firms in terms of all other variables has been taken as a representative firm.

The hypothesis in the following tests is that, if the different performance of foreign subsidiaries and local firms is due to the difference in size of firm rather than ownership, then the difference will be negligible with firms of the same size. If the results reveal that a significant difference between foreign firms and local firms still exists, it suggests that the difference may be attributed to difference in ownership.

As before, Table 4.4 reports the mean values for each type of firm. Comparing firms of the same size, foreign subsidiaries had the larger mean values for all variables.

The results were similar to those reported in Table 4.1 except for the profit parameter. Foreign firms enjoy a higher profit margin than local firms of the number of employee, a result contrary to that suggested in previous estimations.

Table 4.4 Parameters for discriminating between foreign and local firms in Taiwan manufacturing (matched by firm size)

	Mean (standard deviation)	
	FS	LF
Scale of production (NT$1,000)		
sale	363624 (467916)	327265 (498075)
net value of assets (nasset)	138255 (270242)	96391 (162267)
Profitability (profit) (%)	2.205 (5.436)	1.648 (5.872)
Export ratio (exp) (%)	66.43 (41.346)	58.39 (39.50)
Employment and labour quality		
wage+benefit fringe (wage) (NT$1,000)	52295 (47661)	44339 (51031)
wage of staff/ wage of workers (wlb) (%)	0.974 (2.654)	0.664 (1.194)
number of staff/number of workers (lb)	0.635 (2.223)	0.400 (0.924)
train/emp (train) (NT$1,000)	2.029 (3.182)	1.642 (3.114)
	(obs=82)	(obs=87)
Choice of technique (NT$1,000)		
nasset/emp (kl1)	530.23 (784.105)	355.96 (411.56)
(machinery+equipment)/emp (kl2)	478.80 (762.237)	287.48 (388.57)
R&D intensity (%)		
(R&D+royalties)/sale (rnd1)	0.0134 (0.022)	0.0065 (0.0093)
	(obs=82)	(obs=87)
R&D/sale (rnd2)	0.0116 (0.0210)	0.006 (0.009)
	(obs=82)	(obs=87)
royalties/sale (rnd3)	0.0018 (0.0051)	0.0004 (0.002)
	(obs=82)	(obs=87)

Note: obs = observations.

Source: Directorate-General of Budget, Accounting and Statistics, Executive Yuan, Republic of China, *The report on 1986 industrial and commercial census, Taiwan-Fukien Area, ROC, manufacturing sector,* Taipei.

As in Table 4.1, the matched pairs of the same size are also drawn from a disaggregated level of industry (five digit level or above). The fluctuation among matched pairs for each variable has been minimised by controlling size, yet variance for each variable remained at a high level, as shown in Table 4.4. Comparison of the mean values for each industry or averaging of simple differences may still be misleading. Once again, to avoid this deficiency the univariate and multivariate analyses used in the previous section have been estimated.

The Wilcoxon's test of the matched pairs in Table 4.5 is consistent with the results in Table 4.2. All parameters suggest that foreign firms performed significantly differently from domestic firms in terms of scale of production, export ratio, wages, capital-labour ratio, and R&D expenditure, except for the profit variable. Foreign subsidiaries also had higher output, export, wages payment, R&D expenditure and used better technology than local firms after taking into account the number of employees. The Z statistic for the coefficient of profitability (profit) was 0.63, in the range of accepting the null hypotheses of no difference between the two groups of firms, which suggests that foreign subsidiaries' profitability is not significantly different from that of local counterparts if the size of firms was the same.

Table 4.5 Analysis of discriminating characteristics: Wilcoxon's Signed Rank Test (matched by firm size)

	Z statistics	Foreign firms versus Local firms
sale	1.98	greater than
nasset	3.75	greater than
profit	0.63*	greater than
exp	4.06	greater than
wage	4.94	greater than
wlb	2.89	greater than
lb	3.21	greater than
train	2.79	less than
kl1	4.34	greater than
kl2	4.99	greater than
value added	5.29	greater than
rnd1	3.24	greater than
rnd2	2.87	greater than
rnd3	10.32	greater than

Note: * coefficient insignificant.

Source: Directorate-General of Budget, Accounting and Statistics, Executive Yuan, Republic of China, *The report on 1986 industrial and commercial census, Taiwan-Fukien Area, ROC, manufacturing sector,* Taipei.

Moreover, the statistic of training per worker suggests that foreign firms put less effort into training than local firms. This might also imply that if domestic firms have the same scale and ability to compete with foreign counterparts, they make more effort to catch up with foreign firms in absorbing new techniques or knowledge by underwriting more training programs. Foreign subsidiaries stimulate a demonstration effect in their local counterparts. This result highlights the spillover effects of foreign subsidiaries.

The logit analysis for matched pairs by size in Table 4.6 reveals some different results from the full sample analysis above. The variables for export ratio, capital-labour ratio and R&D intensity remain significantly different between the two groups of firms, but the variables for labour quality, profit and training become insignificant. It appears that foreign subsidiaries and local firms employ similar strategies in respect to employment, profit and training.

Table 4.6 The logit analysis (matched by firm size)

	constant	exp	lb	kl	kl2	rnd1	rnd2	profit	train
(A)	-1.2907	0.0113	0.0753	0.0010		24.3424		0.0204	-0.0226
	-4.7103*	4.0308*	1.0133	3.6186*		2.2620*		1.1704	-0.4718
(B)	-1.2582	0.0110	0.0792	0.0010			19.6741	0.0211	-0.0178
	-4.6228*	3.9759*	1.0419	3.6626*			1.8184**	1.2135	-0.3743
(C)	-1.3685	0.0122	0.1040	0.0012		21.4273		0.0178	-0.0312
	-5.0479*	4.3243*	1.2513	4.1832*		1.9602*		1.0152	-0.6438
(D)	-1.3577	0.0122	0.1071		0.0012		18.0949	0.0183	-0.0285
	-5.0131*	4.3137*	1.2716		4.3017*		1.6404**	1.0428	-0.5891

Note: (i) upper row of each equation is the estimated coefficients; lower row is the t-ratio.
(ii) * indicates 5% significance level of the coefficients; ** indicates 10% significance of the coefficients.

Source: Directorate-General of Budget, Accounting and Statistics, Executive Yuan, Republic of China, *The report on 1986 industrial and commercial census, Taiwan-Fukien Area, ROC, manufacturing sector*, Taipei.

The expenditure and revenue structure of firms in this matched pair sample are statistically the same, with 56.5-57.5 per cent going to material costs, 18 per cent to wage payments, 0.7 per cent to tax charges, and 23 per cent to miscellaneous costs. This similarity in cost structure reflects the similarity in profit performance. Therefore, the level of profitability between the two groups of firms is not significantly different.

Conclusion

The empirical analyses in this chapter lead to a number of conclusions as well as to some unresolved questions about the characteristics of foreign firms in Taiwan when compared with their local counterparts of the same size operating in the same industry.

One finding is that foreign firms utilise more capital-intensive techniques of production than their local counterparts. The fact that they do so implies that they make less use of unskilled labour. This may be because they have to pay higher wages for labour of the same quality, or because they want to put more effort into quality control of products produced with more machinery and equipment.

There is strong evidence that foreign firms export a much larger proportion of their output than do domestic firms. R&D investment is also higher for foreign firms. These results are to be expected, since the advantages of the multinationals often stem from their possession of brand names, proprietary technology, and links to overseas markets.

The analysis also shows that ownership ties do affect performance. In a broad sense, foreign-owned firms are much larger in scale than local firms. In addition, ties to a parent company give the foreign subsidiary an advantage over local firms in export markets, enabling them to attract and retain highly-skilled employees, using capital-intensive and skill-intensive techniques of production.

There is also no doubt that foreign firms in Taiwan typically have high levels of labour productivity compared with local firms either in the same industry or of the same size. This could result from any one of the following factors:

(i) more machinery and equipment per worker;
(ii) employees with greater skills and training;
(iii) greater technical efficiency, in the sense that the same output is produced with fewer inputs; or
(iv) some combination of these possibilities.

The results in this chapter show very clearly that the first two factors play an important role in accounting for productivity. In the absence of a clearly specified production function, measuring technical efficiency is impossible, and nothing can be inferred about the importance of this factor at this stage.

In summary, this analysis shows that foreign subsidiaries indeed perform differently from domestic firms in Taiwan's manufacturing sector, the result strongly suggests that foreign subsidiaries may generate spillover effects in the domestic market. For instance, higher export ratios indicate that they may lead to linkage benefits to domestic firms by providing information on export channels and markets. Their higher labour productivity suggests that they raise productivity levels in the host market via training and labour turnover. The demonstration of the more capital intensive technology by foreign firms encourages domestic firms to gain knowledge of it and accelerate technology transfer. As a whole, the results imply the existence of the spillover effects in the Taiwan economy.

As the realisation of spillover effects can raise the productivity efficiency in the host market, the following chapters employ the concept of the growth of total factor productivity—the best indicator to measure productive efficiency—to test the existence of spillover effects in the presence of foreign direct investment.

5 Productive Efficiency Test of the Spillover Effect

There is much evidence that points to the important contribution made by foreign firms to the technological development of the Taiwanese economy. Chapter 2 set out the contributions that are potentially made by spillovers from foreign firms. Chapter 4 demonstrated some key differences between the behaviour of foreign subsidiaries and local firms, particularly in regard to the capital-labour ratio and R&D investment. In this chapter, an empirical test of foreign firms' contribution to technological change in Taiwan's manufacturing industries is carried out.

A proxy for technological change is total factor productivity improvement—an index representing improvement in productivity efficiency—and the stock of foreign capital in the market may be taken to represent the contribution of foreign direct investment via the spillover effect. If a positive correlation is detected in a correlation test between these two variables, it may suggest that an industry with a higher level of foreign investment can expect a higher level of productivity growth. Aside from the spillover effect, scale of operations has also been identified in the literature as one of the major contributors to the growth of total factor productivity. Decomposition of total factor productivity into a scale effect and a spillover effect from foreign investment allows examination of the impact of foreign entry after taking into account scale effect.

A brief description of the definition of total factor productivity and its measurement follows. An hypothesis to account for spillovers is outlined, and the methodology to test the spillovers generated by the inflow of foreign capital is described. The empirical study of the effect of foreign investment on Taiwan's manufacturing sector is undertaken, and then conclusions are drawn.

Introduction

The dynamic factor that drives technological change is knowledge, and there are many stages in the accumulation of knowledge that precede technological innovations. The elements of knowledge range from pure principles of science to applied science to technical knowledge and the specific embodiment of technical know-how in the form of better organisational structures, new equipment, and better skills. The main features that distinguish the accumulation of technical knowledge from other forms of capital accumulation are that it is highly durable, its potential impact is extremely uncertain, and it is subject to large external economies. Once it is produced, the cost of its transmission is almost zero; that is, it soon becomes a public good.

In most of the literature on factor productivity and the production function, it is assumed that technical change is autonomous, neutral and growing at a constant rate. However, it is doubtful whether it can be assumed that the level of technical knowledge is exogenously determined, because the level of technical knowledge may also be determined by the amount of resources allocated to the production of new, or modified existing, techniques (R&D investment). In this sense, foreign investment is a major source of technological change via technology transfer, particularly for developing countries.

Foreign direct investment theory suggests that intra-marginal gains from foreign investment to the host market lie in the effects of foreign investment on the productivity of resources owned by the host economy. The host country's private sector generally may not benefit directly from the entry of foreign firm because foreign firms are relatively efficient. However, as explained in Chapter 2, local firms can raise productivity from the spillovers that occur when foreign firms cannot capture all quasi-rents from their productive activities, such as training and the diffusion of information.

Many researchers claim that one of the most significant contributions of foreign investment is likely to come from these externalities, but they are normally difficult to measure. Only a few quantitative analyses of spillover effects appear in the literature: Caves (1974), focusing on Australia and Canada; Globerman (1979) on Canada; and Blomstrom (1989) on Mexico. All of these studies employ the improvement in productive efficiency as an indicator of the presence of externalities as defined by Caves (1974). Caves classifies the influence of spillovers on productive efficiency in the presence of foreign subsidiaries into three categories:

(i) Allocative efficiency: since foreign firms may provide a significant increase in competition in the host market, they may pare down monopolistic distortions and raise the productivity of the host country's resources by improving their allocation.
(ii) Technical efficiency: foreign subsidiaries might increase pressure on local firms to improve their technical efficiency, for several reasons. Foreign firms tend to operate in industries marked by product differentiation and high barriers to entry, where the threat of potential competition does not continuously enforce cost minimisation or production on an efficient scale. The foreign firms themselves tend to be efficient firms, because success in a domestic market is a precondition for attaining multinational status. Foreign subsidiaries may also

avoid the inefficiencies of small scale more often than their local rivals. In general, foreign firms may squeeze their rivals both through upward pressure on factor prices and downward pressure on product prices.

(iii) Technology transfer: foreign firms may speed up the transfer of technology and innovations, leading to faster dissemination of knowledge than would otherwise be the case among local firms that compete with them, supply them or otherwise enjoy some point of economic contact.

Following this classification, Caves (1974) and Globerman (1979) find weak support for the spillover benefit hypothesis, but Blomstrom confirms the significance of spillovers. Most of these studies attempt to test the effects of the spillovers from foreign firms on technical efficiency and technology transfer. The effect on allocative efficiency may be a part of the spillovers effect, but the difficulty in defining a proper indicator of allocative efficiency restricts its empirical testing. In general, allocative efficiency is assumed to be inversely related to the profit of local firms. If foreign investment has any special virtue in improving allocative efficiency, the profit rates of local firms generally should be inversely related to the competitive pressure caused by the entry of foreign firms. However, accounting profit rates are a notoriously unstable measure of industry performance, and inter-industry differences in profit rates may also vary substantially over the business cycle. There are limitations, therefore, in the use of profit rates as a measure of allocative efficiency. Profit rate at an industry level is a highly aggregated figure, and the appropriateness of its use as an indicator of allocative efficiency is extremely doubtful. These difficulties have restricted the study of the effect of foreign investment on allocative efficiency in the past.

Spillovers can be tested for their effect on technical efficiency and technology transfer. It can be assumed that there is a positive relationship between the labour productivity of local firms in an industry and the presence of foreign capital in the same industry. This methodology is often applied to the inter-industry analysis and focuses on testing the existence of spillovers, instead of testing the magnitude or sources of spillovers. The basic hypothesis behind this productivity efficiency analysis is that, from the observation of a positive relationship between the productivity level of local firms in an industry and foreign participation in the same industry, it can be inferred that foreign investment raises the productivity of local firms through spillover efficiency. The dependent variable in these models is commonly a productivity measure for local firms in an industry.

Theoretically, it is preferable to construct the productivity measure as a ratio of net output to an index of total factor inputs, but due to data constraints, all studies mentioned above use only a partial measure of productivity, namely labour productivity, which is usually constructed as the ratio of total value-added in local firms to total number of employees in the same firms. The labour productivity index represents the level of technical efficiency in these models. As is widely recognised, labour productivity is not an appropriate index for expressing differences in the amounts of inputs used. Furthermore, as foreign subsidiaries cluster around advanced technology and marketing activities, it is possible to argue that a labour productivity measure merely reflects some difference in industrial characteristics.

The specification and measurement of total factor productivity provides a more direct and general measure to evaluate the significance of economic externalities. Total factor productivity (TFP) growth, a residual concept in analysis of product growth, can be used as a proxy measure for efficiency. This chapter intends to deal with the spillover benefits of foreign entry on Taiwan's manufacturing industries by testing the relationship between total factor productivity and stock of foreign capital. The basic hypothesis is that an industry with higher foreign involvement is assumed to be able to raise productivity faster than others.

Methodology and hypothesis

Productivity is the relationship between outputs of goods and services and inputs of basic resources—labour, capital goods and natural resources. An increase in productivity can result from conservation of, or savings in, the use of scarce resources per unit of output; it helps to mitigate price increases by off-setting rising wage rates and other input prices; and it increases the international competitiveness of production. Productivity changes also contribute to the changing industrial structure of the economy and the reallocation of resources. Since firms from the same and different industries all compete in the factor market, average hourly earnings and the price of capital tend to rise at similar rates over the long run in various industries, hence relative changes in unit costs and prices are negatively correlated with relative changes in productivity, by industry.

Productivity differences across firms (or plants) in the same industry can have a number of sources. As noted by Salter (1960), firms may not use the same techniques to produce the same industrial commodities. Since new vintages of capital make use of the latest and best industrial techniques, it follows that a firm's productivity depends in part on the newness of its capital equipment. As noted by Jorgenson (1972; 1974) and Nadiri (1970), a second source of productivity difference related to production theory is the likelihood that firms are not employing the same relative quantity of other factor inputs in combination with their workforce. For example, there may be differences in their capital-labour ratios. A third source of productivity difference among firms can derive from any tendency they might have to hire production workers of various skills. Another source of difference may be size.

The fact that foreign subsidiaries are, on average, of larger scale, more capital intensive, and employ more skilled labour than their local competitors in Taiwan (as tested in Chapter 4) contributes to the productivity differentials between the two types of firms. Such ownership characteristics may not benefit local firms directly, but foreign firms' demonstration of new technology (capital intensive) and training (skilled labour) can encourage domestic firms to learn or recruit skills to raise their productive efficiency.

As productivity may be thought of as the degree of efficiency exhibited in the process of turning inputs into outputs, there are two methods which are commonly used in the literature to estimate productivity—measurement of total factor productivity and partial productivity measures.

Partial factor productivity measures a ratio of output to the amount of a single input used (usually labour). Caves (1974), Globerman (1979), and Blomstrom (1989) employ a partial labour productivity index as the measure of productivity. Labour productivity is generally defined as the ratio of total value-added in local firms to total number of employees in the same firms. The usage of this specification is mainly due to data limitations and to its simplicity. Use of labour productivity as a measure of firm's productivity has its problems, because labour is not the sole source of productivity improvement. Output per worker may rise as a result of the substitution of capital or other non-labour inputs for labour, not only as a result of increased productive efficiency; and labour efficiency as such is only one of the factors affecting output per worker. Only if output is related to all associated inputs can one determine the net saving of resource inputs and thus the increase in overall productive efficiency. A useful and meaningful productivity framework should be able to identify the process of productivity improvement and the interaction with other factors in the overall production process. As suggested by Globerman (1979), the ideal is to construct a productivity measure as the ratio of net output to an index of total factor input, such as total factor productivity.

Spillovers from foreign firms to local firms deliver their benefit only after a lag, as the entry of foreign capital entails the time-consuming relocation of indigenous firms, and the productivity-enhancing effects in the host market take time. Using data for productivity in one year and testing its relation to a number of factors, such as differences in factor proportions, quality of inputs, and scale economies, to explain the spillovers from foreign subsidiaries to domestic industries, as in previous studies, is unreliable. Moreover, spillovers are embodied in changes in input quality, management skills and know-how, scale economies and other factors, which are the source of total factor productivity rather than labour productivity. Total factor productivity measures the residual element in product growth (Domar 1961), or technological progress (Solow; 1957), because a change in total factor productivity is approximately equal to that part of the change in output that is not explained by changes in the inputs. This is why TFP growth is often identified with technological progress. Hence, TFP growth provides a better measure to evaluate spillover effects.

There are two approaches to measuring TFP growth, according to Kalirajan, Obwona and Zhao (1994), namely: (a) the deterministic approach, and (b) the stochastic approach. Furthermore, the deterministic approach may be subdivided into two categories: (i) the index number approach, in which no specification of production functions is required, and (ii) the growth accounting approach, which requires the specification of a production function before TFP growth can be measured. The latter approach can be further divided into two groups, based on the method of quantifying output growth. One method estimates the parameters of a production function as the shares of factor inputs by using given data. The other method, using programming techniques, estimates the specified production parameters. On the other hand, the stochastic approach may be subdivided into the neutral technological progress approach and the non-neutral technological progress approach (the random coefficient stochastic approach), based on different assumptions of technological progress across time and among observations. Two alternative approaches are used here. Due to data limitations, the index number approach is employed in this chapter to evaluate TFP growth during 1961-92 in seventeen industries in Taiwan's manufacturing sector, and the stochastic approach is used in Chapter 6 to evaluate TFP growth in Taiwan's electronic industry, based on firm-level data.

The deterministic approach was developed by Solow (1955), Kendrick (1961), Griliches and Jorgenson (1966), Jorgenson and Griliches (1967), Nadiri (1970), and Caves, Christensen and Diewert (1982). Solow was the first to posit an aggregate production function explicitly to measure TFP growth. His 'Divisia' or geometric index was based on the Cobb-Douglas production function written in terms of capital and labour, and was characterised by linear homogeneity and disembodied Hicks-neutral technological change. Since then, this residual measure of TFP growth has been extended to other specifications of production function and widely applied in empirical research, especially in those studies attempting to correlate TFP growth with investment in technology. Many of these studies have also attempted to account for the accuracy of input measures in measuring total factor productivity, such as Griliches and Jorgenson (1966), Jorgenson and Griliches (1967), Gollop and Jorgenson (1980), and others.

The analytical framework for most empirical research on TFP growth is premised on the neoclassical economic theory of production. In the terminology of theory of production, the rate of growth of TFP is the difference between the rate of growth of real output and the rate of growth of real factor input. The rate of growth of real output and real factor input are defined, in turn, as weighted averages of the rate of growth of individual outputs and factors; and the weights are relative shares of each product in the value of total output and of each factor in the value of total input. If a production function is characterised by constant returns to scale and if all marginal rates of substitution are equal to the corresponding price ratios, a change in total factor productivity may then be identified with a shift in the production function, but if changes in real product and real factor input are accompanied by no change in total factor productivity, this can only be identified as movements along a production function. Of course, changes in total factor productivity or shifts in a given production function may be accompanied by movements along a production function.

The conventional analytical framework for constructing an index of TFP growth is premised on the existence of a well-behaved production function. Suppose that the production function is accurately specified, and that inputs are properly measured, then the growth of total factor productivity may be attributed to external economies, scale economies, structural changes, technological progress and other factors. Since numerous forces are involved in the determination of total factor productivity growth, it is difficult to sort them into one or more categories. However, in the literature, two major elements are identified: the technological progress in production process, and the movement in relative factor prices; that is, technical efficiency changes. Therefore, technological progress broadly involves:

(i) improvement in the efficiency of production; that is, equal reductions in the unit cost of all factors of production by applying better techniques;
(ii) bias in technical change; where the nature of the new technique is such that it leads to a greater saving in one input than in the other;
(iii) the elasticity of substitution, which measures the ease of exchanging factors of production in the course of the production process;
(iv) the scale of operation of the production process; including economies (diseconomies) that arise due to changes in the scale of operation of the economic unit; and
(v) the homotheticity of the production function; or whether the returns to scale are evenly distributed among all factors of production.

Besides technological changes, movements in relative prices also influence factor productivity via the effect on the capital-labour ratio by increasing the employment of one factor of production (capital) at the expense of the other (labour). The response to changes in factor prices depends on the elasticity of factor substitution. Since these characteristics of technical progress are highly interdependent, the distinction between the influence of technological progress and technical change in TFP growth cannot be neatly separated either in theory or in practice, especially through applying the conventional measures of productivity, such as the growth accounting approach. Hence, all these influences are embraced in the rate of TFP growth in the analytical framework employed here. In this sense, the growth of TFP offers insight into factors that are the root of productivity growth.

Index of total factor productivity

The rate of TFP growth is measured, according to the definition of the deterministic approach, by taking the time derivative of a well-behaved production function. The observed factor shares are then used as proxies for the parameters of the production function. Constant returns to scale and Hicks-neutral technological progress are in general assumed. Imposing the constant returns to scale assumption matches cost and revenue accounting in national income in empirical studies, yet the impact of economies of scale on the growth of output should also be considered when the index of TFP growth is derived.

A production function denotes the relation between quantities of different inputs used and the quantities of different outputs produced at a given period of time. If there are two factor inputs in production, then a production function can be expressed as:

$$Q(t) = f(K, L; t) \tag{1}$$

which denotes that a relation exists between inputs L (labour), K (capital), and outputs Q (value-added)[1] in an industry. It is possible to reflect the changing nature of the relationship between inputs and outputs by incorporating time (t) into the production function, then t becomes one of the additional variables in the production function. Assuming this production function is homogenous[2] and conforms to certain differentiability and curvature characteristics, then the index of TFP growth can be expressed as rate of growth of output with respect to time, a function of time t, holding capital and labour input constant. The ranges of the upward shift of the

1 Since no intermediate inputs—materials or energy— are considered in this production function, instead of total output, value-added is used to represent the level of output for an industry.

2 That means the production function can be expressed as:

$$\lambda^{\theta} Q(t) = f(\lambda K(t), \lambda L(t); t)$$

isoquant line, due to input quality changes or technological progress, can then be defined as

$$\dot{A}(t) = \frac{\partial f / \partial t}{f} \qquad (2)$$

where $\dot{A}$ represents the rate of technical change or the rate of TFP growth. Differentiating production function (equation (1)) with respect to time t yields

$$\frac{dQ}{dt} = \frac{\partial f}{\partial L}\frac{dL}{dt} + \frac{\partial f}{\partial K}\frac{dK}{dt} + \frac{\partial f}{\partial t}$$

Under the Hicks-neutral technological progress assumption,[3] the above equation states that the rate of technical change can be expressed as the rate of growth of the corresponding output less a weighted average of the rates of growth of capital and labour input, where the weights are given by the corresponding factor shares. Dividing this equation by output Q yields

$$\frac{dQ/dt}{Q} = \frac{\partial f}{\partial L}\frac{1}{Q}\frac{dL}{dt} + \frac{\partial f}{\partial K}\frac{1}{Q}\frac{dK}{dt} + \frac{\partial f/\partial t}{Q(=f)} \qquad (3)$$

Assuming factor markets are perfectly competitive, then the conditions for yielding producers equilibrium and minimising production cost are that marginal productivity of labour is equivalent to real wage, and marginal productivity of capital is equivalent to real rent; these are,

$$\frac{\mathrm{W}}{\partial C/\partial Q} = \frac{\mathrm{W}}{\mathrm{P}} \text{ and } \frac{\mathrm{R}}{\partial C/\partial Q} = \frac{\mathrm{R}}{\mathrm{P}}$$

$$\text{Since } \frac{\partial f}{\partial L} = \frac{\mathrm{W}}{\partial C/\partial Q};\ \frac{\partial f}{\partial K} = \frac{\mathrm{R}}{\partial C/\partial Q} \qquad (4)$$

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3 This means that the production function can be written as

$$Q(t) = A(t) f(K, L)$$

where W represents the price of labour and R is the capital price; $\partial C/\partial Q$ is the marginal cost of production which is equal to P, product price. Substituting these two cost-minimising conditions into equation (3) and rearranging the equation, we obtain

$$\frac{\dot{Q}}{Q}=\frac{\text{WL}}{(\partial C/\partial Q)Q}\frac{\dot{L}}{L}+\frac{\text{RK}}{(\partial C/\partial Q)Q}\frac{\dot{K}}{K}+\dot{A} \tag{5}$$

On the other hand, according to the definition of elasticity, the elasticity of cost-output can be defined as the form

$$\varepsilon=\frac{\partial C}{\partial Q}\frac{Q}{C},$$ [4]

Substitution into equation (5) yields

$$\frac{\dot{Q}}{Q}=(1/\varepsilon)\frac{\text{WL}}{C}\frac{\dot{L}}{L}+(1/\varepsilon)\frac{\text{RK}}{C}\frac{\dot{K}}{K}+\dot{A} \tag{6}$$

or

$$\dot{A}=\frac{\dot{Q}}{Q}-(1/\varepsilon)\{S_l(\frac{\dot{L}}{L})+S_k(\frac{\dot{K}}{K})\} \tag{7}$$

where S_l and S_k are the cost share of labour and capital inputs in production. In accordance with the conventional definition of the total factor productivity index[5]

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4 $\varepsilon > 1$ implies decreasing return to scale in production, because the rise in production cost is greater than the increase in output.

$\varepsilon = 1$ implies constant return to scale in production.

$\varepsilon < 1$ implies increasing return to scale in production.

5 The traditional TFP index is defined as

$$\frac{d\ln Q}{dT}=s_k\frac{d\ln K}{dT}+s_l\frac{d\ln L}{dT}+s_T$$

where s_T is the rate of TFP growth, s_K and s_L are value shares of capital and labour respectively, Q, K and L represent output, capital and labour. This equation can be rewritten as

$$\frac{\dot{TFP}}{TFP}=\frac{\dot{Q}}{Q}-S_l(\frac{\dot{L}}{L})-S_k(\frac{\dot{K}}{K})$$

The derivation of the above equation is presented in Appendix 5.A.

which measures the residual of the changes in output levels controlling for input levels, the following equation can be derived:

$$\dot{A} = \frac{\dot{TFP}}{TFP} + [1-(1/\varepsilon)]\{S_l(\frac{\dot{L}}{L}) + S_k(\frac{\dot{K}}{K})\}$$

or

$$\frac{\dot{TFP}}{TFP} = \dot{A} + [(1/\varepsilon)-1]\{S_l(\frac{\dot{L}}{L}) + S_k(\frac{\dot{K}}{K})\} \qquad (8)$$

The term $\frac{\dot{TFP}}{TFP} = \frac{\dot{Q}}{Q} - S_K(\frac{\dot{K}}{K}) - S_L(\frac{\dot{L}}{L})$ is derived by imposing the assumption of constant returns to scale in production, while the term $[(1/\varepsilon)-1]\{S_l(\frac{\dot{L}}{L}) + S_k(\frac{\dot{K}}{K})\}$ in equation (8) expresses the scale effect on productivity growth. If the rate of technical progress expressed by changes in total factor productivity and shifts of production function is consistent, then $1/\varepsilon$ should be equal to 1 (ie. constant returns to scale). If production exhibits increasing returns to scale $(1/\varepsilon)>1$, change in total factor productivity is influenced by technical progress and the scale effect simultaneously, hence the growth rate of total factor productivity $(\dot{TFP}/TFP)$ is larger than the rate of technical progress estimated by the production function $(\dot{A})$. *Ceteris paribus*, when the production function is decreasing returns to scale, then $(\dot{TFP}/TFP)$ will be smaller than $(\dot{A})$.

Theoretically, both economies of scale and technological progress contribute to the growth of output; a biased growth rate of total factor productivity is induced if no account is taken of the effect of economies of scale. In order to compromise with the cost and revenue accounting requirements in national income, it is common to impose the constant returns to scale assumption in empirical studies, especially an aggregated analysis such as on a nation-wide or industry basis. Therefore, the rate of TFP growth is typically derived under the constant returns to scale assumption, that is,

$$\dot{A} = \frac{\dot{TFP}}{TFP} = \frac{\dot{Q}}{Q} - S_l(\frac{\dot{L}}{L}) - S_k(\frac{\dot{K}}{K}) \qquad (9)$$

Rearranging above equation produces

$$\frac{\dot{Q}}{Q}-\frac{\dot{L}}{L}=\dot{A}+S_k(\frac{\dot{K}}{K}-\frac{\dot{L}}{L}) \qquad (10)$$

The left-hand side of this equation is the rate of growth in labour productivity. The second term on the right-hand side is the rate of growth in the capital-labour ratio, weighted by the distributive share of capital, and the first term is TFP. Rearranging the above equation gives

$$\dot{A}=S_k(\frac{\dot{Q}}{Q}-\frac{\dot{K}}{K})+S_l(\frac{\dot{Q}}{Q}-\frac{\dot{L}}{L}) \qquad (11)$$

Equation (11) indicates that the rate of total factor productivity growth is defined as the summation of the productivity growth of all factor inputs.

The above index of technical change, being based on the primal model (equation (1)), is called the primal rate of total factor productivity growth. Instead of dealing with the production function, one might choose to deal with the cost function which is denoted by the dual model. The cost function can be defined as having the following form:

$C(Q,P_i,t)$: minimum total cost of producing output Q under prices P_i for the ith inputs.

Using duality, another index related to total factor productivity can be constructed. If the dual rate of total factor productivity is denoted by λ, then

$$\lambda=-\frac{\partial C/\partial t}{C}=-[\frac{d\ln C}{dT}-\frac{d\ln Q}{dT}-\sum_i S_i\frac{d\ln P_i}{dT}] \qquad (12)$$

λ is called the rate of cost diminution. This equation expresses TFP growth as the change in average cost after taking into account changes in input prices. It reflects the shift in the average cost curve over time. On the other hand, Ohta (1974) demonstrated that $\dot{A}$ is related to λ as follows:

$$\dot{A}=\frac{\lambda}{\varepsilon} \qquad (13)$$

which means that, whenever constant returns to scale is imposed ($\varepsilon = 1$), then $\dot{A} = \lambda$.

The above derivation of the rate of TFP growth assumes that the production function is continuous and differentiable, which is also called the Divisi index of TFP growth. However, the true variables are always observed in discrete form.

If two discrete points of time are considered, Gollop and Jorgenson (1980) define the average rate of technical change as the Tornqvist TFP index, which can be approximated as the difference between the successive logarithms of output induces a weighted average of the differences between the successive logarithms of inputs (capital and labour) with weights given by average value shares. That is,

$$\begin{aligned} \ln Q(t) - \ln Q(t-1) = \bar{S}_K[\ln K(t) - \ln K(t-1)] \\ + \bar{S}_L[\ln L(t) - \ln L(t-1)] \\ + [\ln TFP(T) - \ln TFP(t-1)] \end{aligned} \quad (14)$$

where $\bar{S}_K$ and $\bar{S}_L$ are the value shares of capital and labour inputs averaged over periods t and $t\text{-}1$.

$$\begin{aligned} \bar{S}_K = \frac{1}{2}[\bar{S}_K(t) + \bar{S}_K(t-1)] \\ \bar{S}_L = \frac{1}{2}[\bar{S}_L(t) + \bar{S}_L(t-1)] \end{aligned} \quad (15)$$

$\ln \frac{TFP(t)}{TFP(t-1)}$ is referred to as the Divisia-translog index of TFP growth, or the Tornqvist index of TFP growth. Rearranging and rewriting equation (14) gives

$$\begin{aligned} \ln TFP(t) - \ln TFP(t-1) = \ln \frac{Q(t)}{K(t)^{\bar{S}_K} \cdot L(t)^{\bar{S}_L}} \\ - \ln \frac{Q(t-1)}{K(t-1)^{\bar{S}_K} \cdot L(t-1)^{\bar{S}_L}} \end{aligned} \quad (16)$$

Let $I(t) = K(t)^{\bar{S}_K} \cdot L(t)^{\bar{S}_L}$. $I(t)$ is called the Tornqvist index of total factor input for time t. Substituting into equation (16) yields

$$\ln TFP(t) - \ln TFP(t-1) = \ln \frac{Q(t)}{I(t)} - \ln \frac{Q(t-1)}{I(t-1)} \tag{17}$$

where $\frac{Q(t)}{I(t)}$ represents the total factor productivity for time period t; and $\frac{Q(t-1)}{I(t-1)}$ for period t-1. If the indexes of total factor input and output are known, the index of total factor productivity is derived accordingly.

Test hypothesis

Thus far, measurement of the rate of change in TFP has been performed using two methods. One method calculates the rate of technical change on the basis of the data on output, input and cost shares of inputs directly without estimating the production function, such as Jorgenson and Nishimizu (1978), Wong and Wang (1994), as well as Denny and Fuss (1983); the other method performs the estimation of the production function and derives the rate of change in TFP from the estimated result, such as Kwon (1986) and Chen and Tang (1990). Since the data on cost shares for each factor input are calculated and published by the Taiwanese government, a direct measure of total factor productivity is possible. There is no need to specify and estimate the form of production function. Thus, the first approach is followed in this study.

The derived TFP index allows a test for the existence of spillover effects from the entry of foreign capital via technological progress or economies of scale. The basic hypothesis follows that of Caves (1974) and others; that is, productivity growth is a function of the presence of foreign capital. The higher the degree of foreign involvement, the higher the productivity growth of an industry. Direct testing of the relationship between productivity growth and foreign involvement by the level of variables probably introduces biased test results, for example, a simple correlation test is affected by the dispersion of the variables, a higher weight being given to a higher level of values. The Spearman rank correlation statistic, however, is a valid measure for testing independence between two variables by comparing the ranks between two variables. It is employed here to test the relationship between productivity growth and the impact of foreign firms. The test is not perfect but the presence of host country benefits from spillovers from the entry of foreign firms is suggested, if two series are positively correlated.

Next TFP growth was decomposed to identify the sources of productivity growth, particularly the contribution of foreign investment to productivity growth. The literature confirms that there are factors affecting TFP growth, such as business cycle, scale of operations, changes in government regulation and X-efficiency of firms. Increasing competition and technological progress can also affect the growth of TFP. Among these, spillover effects from foreign direct investment can encourage competition, improve the X-efficiency of firms and accelerate technological progress, and foreign direct investment can improve productivity growth via these factors. Foreign capital inflow may also enlarge the scale of operations due to the dissemination of marketing skill and information to domestic firms which enable them to increase their output and obtain scale economies. As indicated by equation (8), economies of scale can affect the rate of TFP growth. Christensen and Greene (1976), Kwon (1986), and Chen and Tang (1990) found that scale economies are one of the main factors influencing the growth of TFP.

The test here attempts to separate the scale effect from the other factors in the investigation of the relationship between foreign spillovers and productivity growth. In order to do so, a decomposition of the rate of TFP growth is necessary. A derivation of the decomposition is demonstrated below. Theoretically, it is possible to decompose the rate of TFP growth into three sources: the scale effect, the spillover effect from foreign firms, and the unexplained shift over time.

The index of TFP growth can either derive from production function or cost function. However, the dual approach is a more straightforward way to incorporate the scale factor, because cost function is a function of output level and factor prices. Therefore, it is necessary to define the rate of TFP growth by applying the duality theory if decomposition of TFP growth is needed. The dual rate of TFP growth was defined previously in equation (12).

A general form of the cost function by which the scale and spillover factor can be separated from other factors which contribute to productivity growth can be specified as:

$$C = C(P_i, Q, F; T)$$

where P_i is the factor price vector, which includes the prices of capital and labour; Q is the level of output; F is the level of foreign capital involvement, which represents the level of spillovers; and T is time.

Logarithmically differentiating the cost function with respect to time obtains,

$$\frac{d\ln C}{dT} = \sum S_i (d\ln P_i / dT) + V_q (d\ln Q/dT) - V_F (d\ln F/dT) - V_T \qquad (18)$$

where $S_i = d\ln C / d\ln P_i = \frac{P_i X_i}{C}$, represents the cost share of input i (with X_i standing for input i);[6] $V_q = \partial \ln C / \partial \ln Q$, measures the scale effect on costs; $V_F = -(\partial \ln C / \partial \ln F)$ measures the effect of foreign capital penetration on costs and $V_T = -(\partial \ln C / \partial \ln T)$ measures the shift in the cost function over time. If foreign penetration reduces (increases) production costs, V_F will be positive (negative); that is, foreign capital generates positive (negative) spillover effects on productivity.

Substituting the above equation into the definition of the dual rate of TFP growth in equation (12) yields:

$$\lambda = (1 - V_q)(\frac{d\ln Q}{dT}) + V_F(\frac{d\ln F}{dT}) + V_T \qquad (19)$$

The above equation decomposes TFP growth into three sources: the scale effect $(1 - V_q)$, the foreign capital effect (V_F), and the unexplained shift over time (V_T). This equation can then be transformed into a regression equation:

$$\lambda = \gamma_0 + \gamma_1(d\ln Q/dT) + \gamma_2(d\ln F/dT) + \gamma_3 T \qquad (20)$$

where the unexplained part of the productivity growth is captured by $\gamma_0 + \gamma_3 T$. The scale effect is represented by γ_1, where a positive γ_1 implies increasing returns to scale and the effect of foreign investment (V_F) is replaced by γ_2.

Before undertaking the empirical study, the link between λ (cost side) and A (production side) should be considered, because it is almost impossible to estimate the cost function at a highly aggregated level of industrial analysis, due to the vintage of capital and the difficulty in obtaining proper capital service prices, especially where there are no secondary capital markets. The rate of TFP growth is usually measured from the production side if a highly aggregated level of industrial analysis is considered, such as at the two-digit level used in this study. However, as noted in equation (13) by Ohta (1974), the two definitions of the rate of TFP growth are equivalent when the constant returns to scale assumption is imposed. His conclusion allows λ to be substituted for $\dot{A}$, and thus allows the regression analysis of the kind used in this study, since constant returns to scale are assumed in measuring TFP growth.

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6 This definition is obtained by Shepherd's lemma under the assumption of competitive markets.

Empirical results

The empirical study uses the two-digit industrial classification for Taiwan's manufacturing sector. The period of measurement is from 1961 to 1992, the choice of period being mainly dictated by the availability of data and no separation of foreign and local firms in an industry is available. Since there are slight changes in industrial classification over time, some industries have been consolidated to enable consistent sampling. As a result, there are data for sixteen industries available for measuring the index of total factor productivity. However, when testing the relationship between productivity growth and the presence of foreign direct investment later on, a further consolidation of the industrial classification is necessary to relate the industry data to the survey data of the Investment Commission, which uses a cruder classification with availability only from 1975 to 1992.

The data for the empirical study include the series of real value-added, real fixed capital stock (excluding land), working hours, and value shares of capital and labour for each industry in Taiwan's manufacturing sector.[7] Since data of material inputs and their share in production are not available at an aggregated level for parts of the sample period, this factor is eliminated and thus the level of output for each industry is replaced by value-added. The series of real value-added is derived from nominal value-added deflated by wholesale price index. In addition, for consistency in the unit of the measurement for each variable, a base year is chosen and the whole series normalised to this base year; the estimation is then based on these normalised data. In this study, the mid year of the data series (1976) is chosen as the base year.

First, the Tornqvist total factor productivity index is measured. Following equation (17), the Tornqvist TFP index is the index of total output divided by the index of total inputs; hence, it is necessary to derive the index of total factor input. The Tornqvist index of total input, $I(t)$, can be derived from the following definition:

$$\ln\frac{I(t)}{I(t-1)} = \bar{S}_K \ln\frac{K(t)}{K(t-1)} + \bar{S}_L \ln\frac{L(t)}{L(t-1)}$$

Since the right-hand side variables are all exogenously given, a series of total factor input indices is then obtainable. The series is then deflated to the base year chosen, which is assumed to be equal to 100. After deriving the index of total factor inputs, the index of total factor productivity is derived by dividing value-added by the index for total factor inputs.

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7 The data sources and construction are listed in Appendix 5.B.

The measured indices of TFP for each industry are listed in Table 5.1, and averaged for four periods: 1961-70, 1971-80, 1981-92 and 1961-1992. The last row in the table shows the average growth for the whole manufacturing sector across the whole period.

Table 5.1 The average growth of total factor productivity (%)

	1961-1970	1971-1980	1981-1992	1961-1992
Food and beverage	17.49	16.56	15.03	17.74
Textiles	24.51	17.10	20.02	40.98
Apparel	22.94	17.18	15.66	32.22
Leather & fur	19.09	13.25	18.26	27.94
Lumber & furniture	19.95	8.36	9.83	7.27
Pulp & paper	15.20	14.05	14.46	14.44
Chemical & plastic	18.20	16.09	23.14	28.80
Petroleum	26.44	4.79	18.12	8.38
Rubber	26.77	9.95	14.33	24.55
Non-metal	17.59	12.90	16.72	17.46
Metal	13.86	6.88	24.47	11.63
Fabricated metal product	30.58	15.51	13.76	33.28
Machinery	25.67	13.73	20.06	40.76
Electronics	34.07	16.77	21.53	58.34
Transportation	42.04	12.46	17.50	54.97
Miscellaneous	46.68	20.39	15.18	77.94
Whole manufacturing sector	25.07	13.50	17.38	31.04

Source: Derived as described in the text.

The average growth of productivity efficiency for the whole manufacturing sector appears to be faster during the 1960s than in the 1970s and 1980s. The particularly low growth of productivity during the 1970s for all industries could be attributable to the two oil crises in 1973 and 1978. The world commodity market fluctuated dramatically during the two oil crisis periods. This affected the Taiwanese economy directly, as Taiwan does not have abundant natural resources and has to rely heavily on importing raw materials to maintain economic growth. Furthermore, since the Taiwanese manufacturing sector was heavily export-oriented, the world market recession after the oil crises also affected Taiwan's manufacturing growth. The vulnerability of the Taiwanese economy in the oil crises, particularly affected the resource-consuming industries, such as the petroleum, rubber and metal industries.

The recession of the 1970s encouraged the restructuring of the Taiwanese manufacturing sector towards knowledge-intensive and high value-added industries, and the growth of the electronics, machinery and chemical industries began to outstrip the traditional industries, such as the apparel, rubber and miscellaneous industries. Restructuring led to higher productivity growth in these industries during the 1980s.

An examination of each industry reveals that miscellaneous industry (combined with the precision equipment industry) had the highest average growth in productivity for the whole period, as high as 77.9 per cent. This industry held its leadership in productivity growth during the 1960s (46.7 per cent) and the 1970s (20.39 per cent), but was then overtaken by the growth of the metal and chemical industries in the 1980s. Light industry was the strategic development industry in the early stages of Taiwan's development, one which not only could absorb abundant labour but which also encouraged workers to obtain skills. As a result, Taiwan became the kingdom of toys, umbrellas, shoes, bicycles and clocks, and exports of these light industrial products dominated the world market before the 1980s. The high productivity growth in this industry is readily understandable. The lumber and furniture industry grew the slowest, 7.3 per cent, due to its relatively low productivity growth during the 1980s. Taiwan's lumber and other products were famous for their high quality and craftsmanship in the world market during the 1950s and 1960s. However, after the economic take-off of the 1960s, this industry lost its comparative advantage, mainly due to the shortage of raw materials, which induced a long-term recession in the industry and the movement of skilled workers to other high-potential industries.

The textile industry maintained steady growth in productivity over time, compared with the related apparel industry. This reflects a typical industrial restructuring pattern which can be attributed to labour shortage; the labour-intensive downstream industries were driven out by the development of upstream industries, which are relatively capital- and skill-intensive. At the same time, the chemical, machinery, and particularly the electronics industries maintained a high level of productivity growth for over three decades. Some studies explain the high growth in the electronics industry in terms of the shorter life cycle of electronic products, but this does not explain how new products and technology were developed continuously in this industry with little expenditure on R&D in the early years, or how workers managed to absorb the new technology and know-how. One possible explanation is the demonstration and training effect of the continuous entry of foreign firms. Spillover effects from the entry of foreign firms may have contributed to productivity growth. It is possible to examine the relationship between foreign investment and productivity growth across industries over time.

Assuming that the entry of foreign capital contributes to productivity growth, the stock of foreign capital in an industry represents the potential benefit that an industry can obtain from foreign direct investment. Data on the actual stock of foreign capital in an industry are not available in Taiwan. It is necessary to define an appropriate index to express the impact of foreign capital inflow. A feasible proxy is the flow of foreign capital into an industry, expressed as the total the amount of foreign capital in firms in the survey data held by the Investment Commission of Taiwan. The survey began in 1975, but reliable data only exist from 1976. The sample period chosen in the following study is 1976-1992. To make data consistent, a reconsolidating of the classification of industries is required because there are only eleven industries in the manufacturing sector surveyed by the Investment Commission. The rubber industry is added to the chemical and plastic industry, primary metal combined with fabricated metal, and machinery with transportation, while the petroleum and miscellaneous industries are dropped because there is no suitable classification available in the survey.

There is another problem with this survey. Since the survey was designed for cross-sectional analysis, there is inconsistency in basic information for some firms when a time series is applied, such as different or missing industrial classifications. There is also problem with the code. Every foreign firm is registered under a code by the Investment Commission at the time of approval. Since the growth in the inflow of foreign direct investment exceeded the initial expectations of Taiwanese government, some new investments in later years were assigned the same codes, causing problems in the study of the series data over time. These have been adjusted and the direct line method has been used to extrapolate missing data for some years of a firm.

The stock of foreign capital in each industry is listed in Appendix 5.C. The electronics industry has received the highest volume of foreign investment. Other industries are ranked as follows: chemical, machinery, metal, and then textiles industry. Table 5.2 shows the average stock of foreign capital for each industry for 1975-1984, 1985-1992 and 1975-1992.

The year 1985 was as a turning point in Taiwan's economic growth in many respects, including the opening up of domestic commodity and financial markets, the relaxation of restrictions on holding and remitting foreign exchange, and the reform of the labour market by the enforcement of the Labour Standard Law. In addition to these policy changes, there was a rapid currency appreciation as well as a severe shortage of labour and industrial land. It was a period of dramatic change in the economic environment.

Table 5.2 Average stock of foreign capital by industry (1975-84, 1985-92, 1975-92) (NT$1,000)

	1975-1984	1985-1992	1975-1992
Food & beverage processing	938,746	3,360,313	1,998,182
Textiles	2,986,857	3,973,052	3,418,317
Apparel	718,588	792,842	751,074
Leather & fur products	80,620	173,194	121,121
Lumber & bamboo products	401,708	442,093	419,377
Pulp, paper & products	264,350	657,703	436,442
Plastic, rubber & chemicals	7,494,547	22,756,394	14,171,605
Non-metallic minerals	646,041	1,952,676	1,217,694
Metal products	1,777,014	7,421,279	4,246,380
Machinery	2,576,651	10,681,169	6,122,378
Electronic products	11,829,174	33,569,721	21,340,663

Source: Calculated from the survey data of Investment Commission.

The currency appreciation reduced the cost margin of firms. As most of Taiwan's firms are export oriented with low value-added in production, a shrinking of profits caused a crisis in their operations, particularly for marginal firms. The harsh Labour Standard Law,[8] labour shortages, and frequent strikes by workers reduced domestic investment. The harsh economic climate led many employers to begin to evaluate the potential of outward investment. At the same time, the liberalisation of foreign exchange controls became a catalyst for the realisation of investments abroad. Many heavily labour-intensive inward investors began to re-evaluate their investments. Some—particularly those in the EPZs—began to relocate to other cheaper labour cost regions, because the cost of relocation involved a relatively low sunk cost in establishing production sites in EPZs.

At the same time, there was also a continuous inflow of foreign capital. Because marginal firms or extremely low-end products had been relocated through outward investment, new capital inflow had to face rigorous competition from stronger local firms. In order to compete with local firms, new foreign direct investment had to embody advanced technology or other superior ownership-specific assets. These new investments would have raised productivity if there were externalities. On the other hand, if their technology or assets were far superior to those of local firms, there might have been less opportunity for spillovers. In this case, foreign direct investment might form an 'enclave' and thus create few, or a low level of, spillovers to the domestic market. The net benefits of externalities from foreign

8 This law has been criticised by many labour economists in Taiwan as leaning too much towards the labour side and damaging firms' operations.

direct investment is ambiguous after 1985. Hence, the sample period is divided at this year.

A correlation test is applied to examine the relationship between total factor productivity and the stock of foreign capital. First, the variables are analysed across industries. The correlation coefficients between these two variables were 0.314, 0.571 and 0.490 respectively for the above periods. The standard correlation revealed no strong direct relationship between total factor productivity and foreign investment. However, the Spearman rank-correlation coefficients were 0.682, 0.700 and 0.709 respectively for each period. Since the critical value of Spearman rank correlation coefficient for 95 per cent significance level with 11 observations is 0.623, the results reveal that the null hypothesis of no correlation between TFP and the stock of foreign capital cannot be rejected at the 5 per cent level of confidence.

These results imply that there was a higher productivity growth in industries which also had larger foreign involvement. These results are consistent with the hypothesis that there was a significant spillover effect in the presence of foreign direct investment. Foreign direct investments introduced advanced technology and techniques and aided the development of Taiwan's manufacturing industries. They did not form an enclave in Taiwan. It is conceivable that foreign direct investment played the role of 'tutor' in disseminating knowledge and technology in the Taiwanese manufacturing sector.

Next, a correlation test is applied across time for each industry. The results are set out in Table 5.3. The test results show that the null hypothesis of no correlation between these two variables is rejected for all industries except the lumber and bamboo products industry. As noted previously, this industry had traditionally developed its own techniques and skills. Inflow of foreign capital tended to be indifferent to the development of this industry.

However, most of them were rejected at 1 per cent significant level, except the clothing industry at 5 per cent, and the paper & products industry at 10 per cent level. The clothing industry was a labour-intensive industry in Taiwan's economic development; labour shortages and rising wages from the 1980s forced this industry to restructure towards upstream textile industries. The changed economic environment not only affected productivity growth, but also influenced the inflow of foreign capital into this industry. The pulp and paper products industry is a typical domestic market oriented industry and almost all materials, as well as equipment were imported. Indigenous firms grew independently and this resulted in a low correlation between productivity growth and the inflow of foreign capital in this industry.

From Table 5.3, the Spearman's rank test revealed that the no correlation null hypothesis can be rejected on a different level of confidence interval for most industries. The standard correlation test also confirmed a high correlation between productivity growth and the stock of foreign capital, except in the lumber and bamboo products industry. Both test results stated that an industry grew faster whenever there was a higher inflow of foreign capital. The results are consistent with the hypothesis.

Table 5.3 The correlation test for TFP and the stock of foreign capital, 1975-1992

	standard correlation coefficient	Spearman rank coefficient
Food & beverage processing	0.957	0.971***
Textiles	0.870	0.894***
Apparel	0.614	0.532**
Leather & fur products	0.908	0.918***
Lumber & bamboo products	0.320	0.288
Pulp, paper & products	0.895	0.900***
Plastic, rubber & chemicals	0.920	0.947***
Non-metallic minerals	0.966	0.944***
Metal products	0.969	0.968***
Machinery	0.977	0.997***
Electronic products	0.990	0.994***

Note: ** indicates 95% significant level of Spearman rank coefficient (critical value = 0.507);
*** indicates 99% significant level of Spearman rank coefficient (critical value = 0.666).

Both correlation analysis across industries and over time strongly suggest the existence of spillover effects by rejecting the null hypothesis that there is no correlation between productivity growth and foreign capital involvement. The relatively low level of significance in testing the relationship across industries can be attributed partly to the low productivity growth of raw material-consuming industries and the effects of the world recession. During those periods, the volume of foreign capital in the market might be an inaccurate measure of the contribution of foreign involvement, because export-oriented products, even those of foreign subsidiaries, were strongly and adversely affected by the recession. Their influence on the domestic market might also have been counteracted by the low incentives for domestic firms to adopt new knowledge or technology, because of low expected future profitability. The time series analysis for each industry is less subject to this disadvantage.

This analysis suggests that the hypothesis of 'no correlation' between TFP and the stock of foreign capital can be rejected. It reveals a possibility of the existence of spillover effects in the presence of foreign direct investment. The next step is to identify this externality through more systematic analysis. As shown in equation (20), the measured growth in total factor productivity can be decomposed into three parts related to changes in economies of scale by the expansion of operations, spillover effects from the entry of foreign capital, and the unexplained part which represents a shift of production function (or cost function).

It should be noted here that the level of total output for each industry replaces the variable of value-added in the previous measure of TFP, because the level of total output measures more directly the scale factor. However, modification is needed to equalise the primal and dual measurement of TFP growth, by adjusting the deviation between the level of output and value-added. Mathematically, these two measures maintain a proportional relationship. The proportion is equal to the share of value-added to total output.[9] Average TFP growth adjusted by the share of value-added is listed in Table 5.4. The rates of growth in total output and stock of foreign capital are also presented for comparison.

Table 5.4 The average growth of TFP, output and foreign capital stock (%)

	TFP			Output			Foreign capital stock		
	1977-84	1985-91	1977-91	1977-84	1985-91	1977-91	1977-84	1985-91	1977-91
Food	1.32	1.55	1.41	11.28	2.62	7.81	22.18	16.52	19.91
Textiles	2.83	2.65	2.76	10.48	3.02	7.49	5.18	4.68	4.98
Apparel	2.25	2.10	2.19	17.36	-1.62	9.77	6.12	5.42	5.84
Leather	2.01	2.71	2.29	25.39	3.42	16.60	15.47	6.60	11.92
Lumber	1.00	0.98	0.99	10.18	1.65	6.77	6.64	5.33	6.12
Pulp & paper	1.76	3.11	2.30	16.78	11.23	14.56	19.61	13.82	17.29
Chemicals	1.82	2.49	2.09	18.79	7.20	14.15	16.46	14.83	15.81
Non-metallic	1.27	3.25	2.06	16.21	5.58	11.96	20.60	22.10	21.20
Metal	1.61	2.11	1.81	19.68	8.10	15.05	13.20	16.68	14.59
Machinery	1.62	2.79	2.09	17.39	12.78	15.55	21.60	17.38	19.91
Electronics	2.38	2.93	2.60	19.71	11.65	16.49	17.58	24.22	20.23

Source: (i) Calculated from the survey data of Investment Commission
(ii) Derived as described in the text.
(iii) Directorate-General of Budget, Accounting and Statistics, Executive Yuan, *Gross Domestic Product and Factor Incomes by Kind of Activity*, each year, Taipei.

The table shows that total output and foreign capital inflow grew quite rapidly in the early period, but slowed down in later years, except for the metal industry into which foreign capital inflow continued to grow strongly. The apparel industry shifted to negative output growth after 1985. These two series reveal a rather similar growth pattern, suggesting that the entry of foreign firms resulted in the enlargement of scale of production. Secondly, the rate of growth in TFP is higher in the second period. There is inconsistency in the growth trend of TFP with the other two series, and this may imply that there is a lag before the effect of spillovers has its impact.[10]

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9 The derivation of this proportion is shown in Appendix 5.D.

10 In fact, the estimation results improve for some industries when one time lag of the stock of foreign capital is employed; but for some industries it worsens. Use of a time lag should take

Following equation (21), the regression analysis for decomposed TFP growth is estimated. The results of the regression analysis are shown in Table 5.5.

Table 5.5 Decomposition of TFP growth, the regression analysis
$\lambda = \gamma_0 + \gamma_1 (d \ln Q/dT) + \gamma_2 (d \ln F/dT) + \gamma_3 T$

Industry	γ_0	γ_1	γ_2	γ_3
Food & beverage processing	0.0124	0.0080	-0.0254	0.0008
	(0.724)	(0.080)	(-1.479)	(0.588)
Textiles	0.0088	0.1719**	-0.0290	0.0009
	(0.629)	(3.072)	(-0.648)	(0.736)
Apparel	-0.0031	0.1103*	0.0312	0.0016
	(-0.151)	(1.941)	(0.904)	(0.807)
Leather & fur products	-0.0326	0.1146**	-0.0059	0.0046**
	(-1.689)	(3.195)	(-0.279)	(2.725)
Lumber & bamboo products	-0.0313	0.2435**	-0.0241	0.0033**
	(-2.982)	(7.855)	(-1.329)	(3.043)
Pulp, paper & products	-0.0164	0.1290**	0.0170	0.0022
	(-0.837)	(2.434)	(0.588)	(1.424)
Plastic, rubber & chemicals	0.0075	0.0202	0.0143	0.0010
	(0.430)	(0.397)	(0.788)	(0.809)
Non-metallic minerals	-0.0005	0.0167	0.0136	0.0020
	(-0.019)	(0.215)	(0.300)	(0.904)
Metal products	-0.0031	0.0496	-0.0089	0.0019
	(-0.193)	(1.231)	(-0.357)	(1.470)
Machinery	-0.0059	0.1070**	-0.0290	0.0020
	(-0.317)	(1.926)	(-0.955)	(1.628)
Electronic products	0.0047	0.0063**	0.0197	0.0009
	(0.428)	(2.226)	(0.868)	(0.969)

Note: numbers in parentheses are t-statistics.
* significant at 90% level.
** significant at 95% level.

It should be noted that the regression analysis is based on the assumption that the levels of output and the stock of foreign capital are exogenous to contemporaneous productivity growth, because it is possible that productivity growth

account of the characteristics of each industry. It is conceivable that a larger establishment generally needs a longer time to operate and disseminate externally. Since this study is a preliminary to the overall analysis, an industry-by-industry analysis is left for further study.

will enhance the competitiveness of an industry and thus increase its output level, which in turn will attract the inflow of foreign direct investment. The exogeneity of output and the stock of foreign capital is thus assumed in the estimation of this regression. Moreover, it is assumed that the growth of foreign capital stock is uncorrelated with the time term, because foreign capital continues to enter and exit the host market.

The table reveals that the estimate of the scale effect (γ_1) is positive in every industry, and significant in 7 out of the 11 industries studied. Food and beverage, plastic, rubber and chemical, non-metallic and metal industries have positive but insignificant coefficients. It appears that the underlying technology exhibited substantial increasing returns to scale for all other industries. The results suggest that Taiwan's manufacturing sector, in most industries, has been exploiting scale economies through expansion in the size of operation over time.

The food processing industry is labour- and land-intensive. Since both of these factors became more and more scarce with economic development, an enlargement of operations could have raised marginal costs more than marginal productivity for these scarce inputs. Scale economies are therefore not a major source of productivity growth in this industry. In the plastic, rubber and chemicals industries, which encompass a very wide range of products, there appear to have been offsetting cost and productivity effects and no observable scale effect. The non-metallic minerals and the metal industries faced similar conditions to the food industry, but their higher costs resulted from the reduction in mine deposits, the imposition of a new environment law and protests from local residents against excavating. In addition, all of these industries, except the plastic products industry, are basically domestic market oriented. The relatively small size of the domestic market limited the expansion of production in these industries.

The estimates of the spillover effect (γ_2) vary in sign and are insignificant for all industries. The results clearly indicate that when both scale and spillover effects are taken into account, the scale effect is the dominant explanatory variable for productivity growth. The enlargement of scale appears to be the channel through which spillovers of direct foreign investment affect productivity growth. Aside from this indirect contribution to the scale of output, foreign capital appears to have a rather ambiguous and weak linkage to productivity growth in Taiwan. Productivity efficiency does not appear to have been achieved through an increase in the stock of foreign capital.

There are some qualifications to this conclusion. First, note that the regression results imply no causal relationship between stock of foreign capital and productivity growth. This type of study requires extensive time-series data, which are not available here. In particular, the most significant period in which foreign direct investment might have had a affect on the Taiwanese economy was conceivably from the 1960s to the mid-1970s. This study simply demonstrates that the scale factor has explanatory power in interpreting productivity growth compared with the spillover effect. Secondly, other forces that affect productivity growth have been important, yet excluded from this investigation. For instance, the contribution of export expansion and the capital utilisation rate to productivity growth may have been important. Some studies[11] suggest that these two factors are highly correlated with productivity growth.

Conclusion

This study demonstrates that the entry of foreign capital is correlated with productivity growth in Taiwan's manufacturing sector. Yet growth in the stock of foreign capital is not as important a factor in explaining productivity growth as output growth. If the competition effect of the entry of foreign firms could force indigenous firms to reduce managerial slack or to adopt more efficient production processes, they would operate in a more efficient manner. More efficient operation implies higher productivity growth. However, adjustment to foreign entry would also require some adjustment in indigenous firms' production processes or the exit of inefficient firms. This could impose some production costs and would be detrimental to productivity growth. These two effects might counteract each other and result in insignificant spillover effects.

There are a number of factors which might weaken the test results.

First, the spillover effect might not be contemporaneous with the inflow of foreign direct investment and might not be caught in the measure of TFP; for instance, foreign direct investment could raise labour productivity or change factor intensity in production, without growth in productivity. This can be seen in equation (10). Since the summation of input cost shares equals 1, this equation can be rewritten as,

$$\Delta \ln \frac{Q}{L} = S_K (\Delta \ln \frac{K}{L}) + \dot{A}$$

It is obvious that differences in the level of labour productivity can be attributed to two broad components. The first one is the difference in the level of

[11] Chen and Tang (1990), and Nishimizu and Robinson (1984), proved the significant relationship between export and productivity, whilst Kwon (1986) discussed the influence of capital utilisation.

TFP, and the second is the difference in the level of factor intensity $\Delta \ln(K/L)$. The growth in TFP can be attributed to the improvement in the use of resources by measuring the increase in the quantity of output given a fixed bundle of capital and labour, whereas a change in factor intensity assumes that if the ratio of capital to labour changes, then labour productivity will change. Increases in this ratio will raise labour productivity. There are reasons why factor intensity changes. Shifts in relative prices, new technologies and changes in the degree of processing are the major possibilities.

Although productivity growth and factor intensity change are two major components in labour productivity growth, they are correlated with each other. Changes in factor intensity may occur without any improvement in the ability to produce goods in a particular industry. They may occur without any increase in TFP.[12] The specific ownership advantages of foreign firms can enable the entry of foreign investment and a shift in the capital-labour ratio, thereby improving labour productivity without changing TFP. This benefit from foreign direct investment derives only from changing factor intensity or labour productivity.

Secondly, volume of foreign capital may not be the best index to reflect the magnitude of the impact of foreign direct investment or the stock of foreign capital in an industry. There are two reasons. The nominal book value of capital is a flow concept, representing the total amount of foreign capital in an industry, which may not be a proper indicator of the stock of foreign capital in an industry, because it does not account for the difference in capital utilisation rate across firms. In addition, the cumulative book value of foreign capital does not take into account depreciation for machinery and equipment and the age of machinery and equipment; the real value of foreign capital probably significantly deviates from the book value. This may induce bias.

The share of employment by foreign firms in each industry, listed in Appendix 5.E, was also tried as a proxy estimate for foreign capital penetration. The estimation results are similar to those reported here and therefore, no further report is provided on this variable. The spillover effect could still not be identified clearly. However, one interesting finding is that the share of foreign employment decreased continuously for many industries. The most dramatic instance is the electronics industry. The downward trend indicates the falling share of foreign investment and the growth of domestic firms in the market. These trends may indicate the contribution of foreign entrants via dissemination of technology and information, although there is no direct

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12 For instance, labour productivity is increased if a worker is provided with more capital. Unless there is improvement in capital, this will induce a change in factor intensity but not TFP.

evidence of this. A better index to represent the stock of foreign capital is desirable to provide a better estimate of spillover effects .

Thirdly, the time period chosen may not be ideal for measuring the effects of foreign direct investment. The Taiwanese economy had passed through a period of high growth and maintained relatively stable growth during the sample period. Domestic capital formation was expanding steadily and the importance of foreign capital in total capital formation was declining.

Finally, using highly aggregated industrial data may have hidden the significance of activities on productivity growth.

In summary, foreign direct investment is found here to have an ambiguous effect on productivity even though foreign direct investment and productivity are correlated. Scale economies appear to be a more important factor in explaining productivity growth in most industries. The underdevelopment of Taiwanese firms in technology and information, as well as the relatively small size of Taiwan's domestic market, means that links to the world market are critical if scale economies are to be exploited. On the other hand, foreign direct investment is one of the most efficient channels for obtaining production knowledge and access to world markets, and the inflow of foreign capital has conceivably contributed to achieving of economies of scale in Taiwan. Its contribution to productivity growth is mainly seen through a scale effect.

6 A Productive Efficiency Test of the Spillover Effect in Taiwan's Electronics Industry

Taiwan's electronics industry has been one of the engines driving the growth of the manufacturing sector since the 1960s, especially during the 1980s and 1990s. The share of electronic products in manufacturing output increased from 1.7 per cent in 1961 to 9.4 per cent in 1971, and from 10.8 per cent in 1981, to 19.5 per cent in 1993. Exports of electronics amounted to less than US$100 million in the 1960s, but grew rapidly in the 1970s, and even faster after the 1980s. The share of electronics in total exports also rose dramatically, from 0.5 per cent in 1961, to 12.9 per cent in 1971, to 18.4 per cent in 1981, and to 27.3 per cent in 1982. Taiwan's electronics industry surpassed textiles to become Taiwan's top industry in the 1980s.

Electronics also absorbed a huge amount of foreign investment. There were 896 foreign investments valued at US$4.03 billion in the electronics industry over the period 1952 to 1992. This accounted for 24.4 per cent of all foreign investment, far exceeding the second-highest invested industry, the chemical industry (which accounted for 15.3 per cent, valued at US$2.5 billion). In the beginning, foreign enterprises were mainly attracted by the low wage costs and high labour quality of domestic resources. Foreign investment provided not only capital and markets, but also played a major role in the development of Taiwan's electronics industry by transferring and demonstrating advanced technology, including management know-how and production techniques. Many studies suggest that Taiwan's electronics industry—through technological cooperation with foreign firms, labour turnover, and imitation—benefited from the spillover effects generated by foreign investment. However, no study has carefully quantified these externalities. This study attempts to ascertain whether there were spillovers in the electronics industry via channels other than size of operation; for instance, improvement in technical efficiency.

The structure of this chapter is as follows: a brief description of the role of foreign investment in the development of Taiwan's electronics industry is first given to provide the background to, and the reason for, this empirical study; the methodology and testing follow; and then the conclusions are presented.

Development of the electronics industry

The electronics and textile industries stand out among Taiwan's newly developed manufacturing industries. Both played their part as leading industries during the high growth period of Taiwan's economic development. Since the 1980s, the diversification of electronic products—from TVs, radios, and calculators, to integrated circuits (IC), computers and other information products—has led the electronics industry to become the largest industry in Taiwan's manufacturing sector, overtaking the textile industry. The fast growth of this industry provided an incentive for foreign enterprises to enter the domestic market, bringing new technology and further extending the production frontier, thus enhancing growth. The heavy foreign capital involvement accompanied by high growth suggests the presence of spillovers from foreign enterprises to the local market. The evolution of Taiwan's electronics industry and its interaction with foreign direct investment therefore presents an important case to examine.

After the import of the vacuum tube from Japan, Taiwan's electronics industry was able to produce vacuum tube radios from the 1950s, but the start of transistor radio production in 1961 was a milestone in the development of the electronics industry. Since then, the electronics industry has grown extremely quickly: transistor radios and monochrome televisions were the major products in the 1960s; colour televisions, calculators and tape recorders dominated during the 1970s; and integrated circuits (IC) and information equipment followed in the 1980s and 1990s. The chronology of the development of Taiwan's electronics industry is listed in Figure 6.1.

According to this chronology, the development of Taiwan's electronics industry can be roughly divided into three stages, according to the definition of Liu (1987): the beginning, growth, and expansion stages.

The beginning stage: the age of television and transistor radios

The first transistor radio factory in Taiwan was opened in 1961 by a Japanese multinational. Although most of the components had to be imported from Japan, this production line introduced a new field to Taiwan's electronics industry. However, the lack of technological information made the production of transistors impossible until 1964 when the first fully foreign-owned electronics subsidiary was set up by the American General Instrument Company to produce transistors and electronic components. Since then, Taiwan's electronics industry has played an active role in the world electronics market. This American subsidiary, and other companies that followed, created a market for local enterprises that produced low-end components while, at the same time. accumulating technical knowledge through learning-by-doing. The transistor radio became one of the major products in Taiwan's economy during the 1960s.

Figure 6.1 The chronology of Taiwan's electronics industry

1961	Establishment of the first transistor radio assembly plant
1962	Start of mono-television broadcasting
	Introduction of IBM-650 computer
	Commencement of joint ventures with Japanese electronic multinationals
1963	Beginning of production of mono-television
1964	Establishment of first fully foreign-owned investment, US General Instruments Co. (producing transistor and electronic components)
1966	Establishment of Kaoshiung Export Processing Zone and entry of foreign subsidiaries
1969	Start of broadcasting and production of colour television
	Export of electronic products exceeded US$100 million, recording trade surplus
	Establishment of Telecommunications Research Institute
1971	Beginning of calculator production
1974	Establishment of Electronic Research and Service Organisation (ERSO)
1975	Beginning of digital watch production
	Introduction of micro-computers
1976	Exports exceeded US$1 billion
1977	ERSO set up Integrated Circuit (IC) model factory
1978	Imports reached US$1 billion
1979	US imposed import quotas on colour televisions
1980	Establishment of Hsin-Chu Scientific-based Industrial Park (high-tech district)
	Ten Year Plan for the Development of Electronics Industry (1980-89)
1981	Identification of the electronics and information industry as the major strategic industry
	Acceleration of investments in the semiconductor industry
1982	Announcement of eight-year plan for industrial automation
	ERSO development of production technology for multipurpose macrocomputer
	Commencement of personal computer industry
1983	Export of electronics products reached US$ 4.2 billion—the top export industry
	Under technological support of ERSO, development of 16 bit personal computer begun
1984	Joint venture (Vitelic, Mosel, and Quasel) development of VLSI
	ERSO signed licensing agreement with Microsoft
1985	Success in developing digital TV chip set
1988	Testing ISDN (integrated service digital network)
1989	Open satellite and mobile phone communication
1990	Information and communication industry chosen as newly developing strategic industries
1991	Development of HDTV (high definition television)
1992	Establishment of scientific park for the development of computer software

Source: (i) Taiwan Electric Appliance Manufacturers' Association (TEAMA) *The Electronics Industry in Taiwan, Republic of China,* 1984, Taipei.
(ii) Taiwan Ching Chi Yen Chiu So, *Chung-Hua Min Kuo Tzu Hsun Tien Tsu Kung Yeh Nien Chien* [Electronics Industry Yearbook of the Republic of China], 1994, Taipei.

Another major electronic product at this period was monochrome television. The know-how for television (TV) production was introduced mainly by Japanese multinationals. Major Japanese electronic manufacturing companies, like Toshiba, Mitsubishi, Matsushita and Nihon Denki, rushed into the Taiwanese market in 1962. They brought in capital and TV technology. Unlike the export-oriented American multinationals, the domestic market oriented Japanese investments preferred to cooperate with local enterprises. This technical cooperation allowed the first Taiwan-made monochrome TV to appear in 1963. In the case of both TV and the transistor, foreign direct investment played the role of catalyst in the development of Taiwan's electronics industry. The establishment of the Kaoshiung Export Processing Zone in 1965 accelerated the inflow of foreign capital and, hence, the growth of the electronics industry.[1]

The statistics show that production in the electronics industry was a negligible proportion of the manufacturing sector in this period, yet the share of TV and radio output in total electronics production was 47 per cent and 34 per cent, respectively, by 1966, totalling 81 per cent. TV production exceeded one million sets in 1970 and reached a peak of 7 million sets in 1978. The production of transistor radios grew even faster, from one million sets in 1965 to a peak of 14.5 million sets in 1973. Furthermore, the proportion of electronics exports to total exports remained low before 1965, peaking at 2.7 per cent, but grew rapidly after that, from 4.9 per cent in 1966 to 12.3 per cent in 1970, and then to 17.2 per cent in 1973.

The growth stage: the age of colour television and the tape recorder

By 1969, colour television had been successfully produced and the spread of colour TV in the domestic market encouraged Taiwan's electronics industry to cover a wider spectrum. Colour TVs, tape recorders (produced from 1968), and calculators (from 1972) were the three major products, leading the growth of Taiwan's electronics industry in the 1970s. Exports of these products signalled the growth of the industry.

The shift from domestic market oriented to export oriented production in the electronics industry was not only attributable to changes in the government's industrial policy, as noted in Chapter 3. It was also a result of changes in sales and production strategies by foreign multinationals. For instance, American multinationals undertook overseas production mainly to take advantage of low local wages, and the production lines in subsidiaries were only part of their world-wide global production.[2] Almost 100 per cent of subsidiaries' products were shipped back to parent firms, especially from subsidiaries located in export processing zones. On the other hand, the small domestic market changed the strategy of Japanese subsidiaries to an export orientation. Unlike American multinationals, they tended to export to a third market. In fact, according to the Toyo Keizai (1985; 1992) survey, export to third markets

1 At this stage, foreign capital was mainly attracted by low labour costs. The facilities of the export processing zones provided an opportunity to lower management and other costs. For example, no tariff was levied on imports and exports (within the zone). Since most electronics firms relied on their parent firms to provide key components, many of them preferred to locate production in export processing zones.

2 This may have been one reason why most of the American multinationals were investing in the production of electronic components and parts instead of products.

(mainly the US market) was a major motivation, next to seeking low-cost labour, for Japanese multinationals to undertake production overseas. Regardless of the origin of foreign investment, a larger proportion of production was exported. Since American and Japanese multinationals were the two major foreign investors in Taiwan, their strategic behaviour certainly changed the market performance of the whole industry, as local firms were relatively underdeveloped.

The shift to export-oriented production widened the product market and the market for sub-contracting to local components firms, thereby accelerating the growth of this industry. The production of colour TVs reached one million sets in 1978. However, the rapid growth soon came to an end. The industry was heavily dependent on the US market, and this began to cause problems after the US government imposed import quotas for colour TVs from 1979. In conjunction with the extended depression in the world market caused by the oil crises, this let to a reduction in total electronics industry exports from Taiwan. The industry faced a recession for the first time since its establishment.

The expansion stage: development of the semiconductor and information industry

Taiwan's government realised the potential of the electronics industry in the development of the Taiwanese economy as early as the mid-1970s, and the industry—especially the semiconductor and information industry—was chosen as a strategic industry at that time.[3] As part of the industrial policy, the Electronic Research and Service Organisation (ERSO) was established in 1974 and its integrated circuits (IC) semiconductor model factory was set up in 1977. Both were intended to develop more advanced technology for the semiconductor industry.[4] The technology for producing computer chips was introduced by ERSO, as a result of technological cooperation with the American RCA Company. This technology provided the basis for the development of Taiwan's information and semiconductor industry during the 1980s and 1990s. Nowadays, ERSO possesses the ability to design and produce metal oxide semiconductors (MOS), a type of IC commonly used in digital watches, calculators, TV games and even toys. Because ERSO had an obligation to transfer technologies to private enterprises, its contribution in raising the technological level of the semiconductor industry has been extremely significant. Another contribution of

3 For instance, the first four-year plan (1975-79) specified the range of products, the technology to be imported, and partners for technological cooperation. The second four-year plan 1979-83, was followed by a five-years' very large scale integration (VLSI) development plan from 1983.

4 The semiconductor industry was developed in the early 1960s by the foreign investments of General Instruments Co., Texas Instruments Co., and Philips.

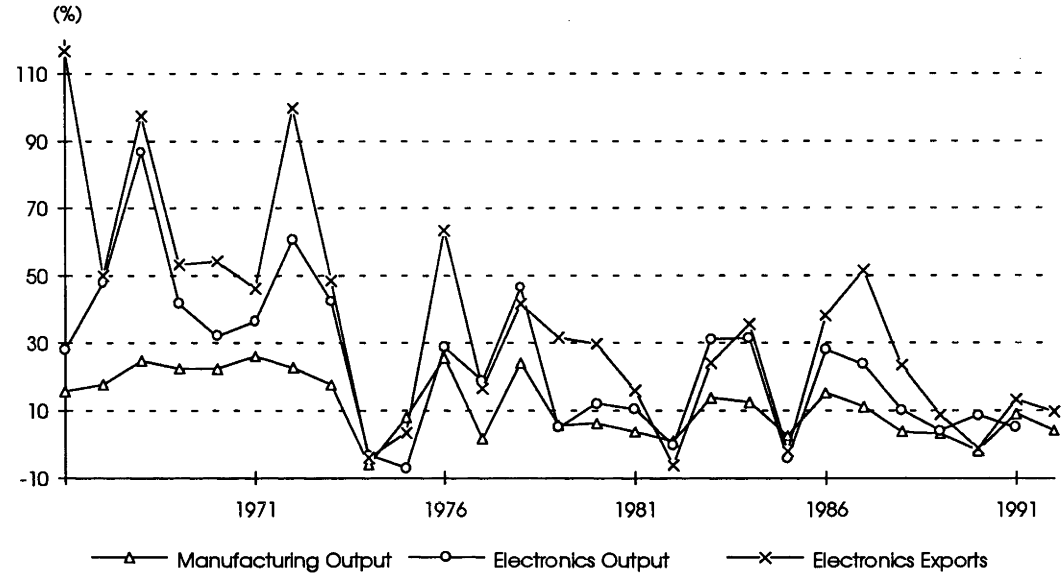
ERSO was to recruit technicians and experts from the United States. The government also attempted to develop Very Large Scale Integration (VLSI), a joint project with American Overseas Chinese computer companies—Vitellic, Mossel and Quasel—a task achieved successfully in 1984. The Taiwan Semiconductor Co. was established in 1986 to manufacture VLSI.

As well as the effort made to develop technology, the Hsin-Chu Scientific-based Industrial Park was established in 1980 to induce foreign investors to transfer advanced technology. Industrial policies were designed to provide preferential loans, tax deductions, tax holidays, or grants to develop new technology in this industry. Meanwhile, the growing demand for electronic products in the world market also played a role in encouraging local enterprises to enter the market one after another, even though their production was of a relatively small scale. According to the Taiwan Electric Appliance Manufacturers' Association (1987) survey, most of their technology came from ERSO, with only a small part from joint ventures with American Overseas Chinese. As a result of government efforts in raising the IC industry after 1980, the total output of semiconductor products increased from NT$31 billion in 1983 to NT$136 billion in 1993, growing at 15.6 per cent per annum. This sector is now the third biggest in the electronics industry, next to the information and electronics component industry.

The information industry is also a strategic industry. It was developed in 1980, growing from the production of terminal monitors and printed circuit boards to complete personal computers, to become the largest sector in Taiwan's electronics industry in the second half of the 1980s. Production in this industry captured over 3 per cent of the world market in 1990. Total output grew from NT$22 billion (6.5 per cent of total electronics output) in 1983 to NT$237 billion (24.5 per cent) in 1993, and the annual growth rate reached 27.1 per cent, which took this sector to the top of the electronics industry. The production of personal computers in 1993 reached 3.6 million sets (amounting to 10 per cent of world production), 13.3 million monitors (51 per cent), 6 million keyboards (49 per cent), 19.7 million mouses (80 per cent), 0.9 million scanners (55 per cent) and 14.1 million interface cards (83 per cent).

The output and exports growth trends in Taiwan's electronics industry as well as the output growth of manufacturing sector are summarised in Figure 6.2. It shows that the electronics industry grew faster, but with more fluctuations than manufacturing as a whole between 1962 and 1991. These fluctuations can be attributed to the influence of the world economy, especially the US economy, because the electronics industry is typically an export-oriented industry and is heavily influenced by disturbances in the international market. For instance, during the two oil crisis periods (1973-75; 1979-80), growth in this industry fell sharply. The fall in production in 1985, on the other hand, was due to the rapid appreciation of NT dollar. Figure 6.2 reveals the strongly trade-oriented growth in the electronics industry, reflected in the similar trend patterns of production and exports.

Figure 6.2 Output and exports growth of the electronics industry, 1966-1992



Source: Council for Economic Planning and Development, *Industry of Free China*, Monthly, Taipei.
Council for Economic Planning and Development, *Taiwan Statistical Data Book*, 1993, Taipei, p. 193

The US market is the most important export market for Taiwan's electronic products, accounting for over 60 per cent of exports in this industry during the 1970s and 48 per cent during the 1980s. In the 1990s, however, exports dropped to 30 per cent. These figures underscore the vulnerability of Taiwan's electronics industry to changes in the US economy. Nevertheless, the decrease in dependency on the US market suggests that the Taiwanese government's efforts in diversifying the export market for the electronics industry have had some success.[5]

In the import of electronic products, Taiwan became much more dependent on Japanese suppliers. The synchronous trend in import and export growth has been a critical problem in the development of Taiwan's electronics industry from the beginning. Export growth was accompanied by a growth in imports. This situation worsened in the mid-1980s, because of the rapid rise in import prices, mainly due to the rise in the price of key components from suppliers with a virtual monopoly. This

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5 Because of the huge trade surplus with the United States and the rise in protectionism in that country during the 1980s, the Taiwanese government campaigned for diversification of the export market to reduce the pressure. European and Japanese markets were promoted, but the unfamiliarity with the former and the closeness of the latter made Taiwan's producers hesitant.

implies that in Taiwan's electronics industry, there is a relatively small level of value-adding in products, and there is a technological gap with advanced countries.

A comparison of the performance of foreign subsidiaries and domestic firms

This chronology of Taiwan's electronics industry development indicates strongly that foreign capital functioned as a catalyst in promoting successive rounds of development, via its role in introducing and disseminating new technology, particularly before the establishment of ERSO.

The electronics industry has the largest foreign capital involvement of all Taiwan's industries, as shown in Table 3.2 of Chapter 3. It accounted for 27 per cent of total accumulated foreign capital inflow on an approvals basis between 1952 and 1992. It also has the highest number of investment projects; 896 cases. The 1986 census data on Taiwan's manufacturing sector showed that the average number of workers employed by foreign subsidiaries in the electronics industry was 709 persons, a much larger figure than in domestic firms (45 persons). They also had higher productivity, output per worker being NT$1.3 million higher than that of local firms (NT$0.8 million), and output per unit of capital was larger, at NT$6,380. The higher productivity indicates a higher gross return on capital for foreign subsidiaries, but not necessarily a higher net return, because they also paid higher wages. The high wage rate paid by foreign subsidiaries, according to human capital theory, implies higher accumulation of human capital among their workers. In addition, on-the-job training was a major activity of foreign subsidiaries, promoting the accumulation of human capital. The mobility of these trained workers potentially disseminated productive techniques and knowledge to local firms.

The higher export ratio of foreign firms was mainly due to intra-firm transactions. A higher export ratio might also suggest a lower local procurement ratio because of quality requirements. The survey data of the Investment Commission shows that foreign subsidiaries, on average, imported 60 per cent of their materials. A high export ratio with low local procurement illustrates foreign firms' strategy in international division of labour. This weak linkage to the domestic market might hinder the accumulation of skills and techniques. Liu (1987) found that the inflow of technology with multinationals—particularly in the case of Japanese multinationals—was usually accompanied by restrictions on key components or product market segregation in order to hinder the dissemination of technology. These factors might have constrained the externalities flowing from foreign firms in the development of Taiwan's electronics industry.

On the other hand, restrictions on components such as speakers, switches, transformers, rectifiers and resistors stimulated for domestic producers to develop them. This generated a backward linkage effect to the domestic market and encouraged the development of the import-substitution components industry in the 1960s and 1970s. This effort provided a solid basis for the development of the information and semiconductor industry in the 1980s. The production of components grew faster than other segments of the industry and on average accounted for over 50 per cent of total electronic products before the 1980s. It was the second largest sector in the electronics industry in 1983, valued at NT$56 billion with a share of 16.8 per cent in total electronics output. The fast growth of the information and IC industry after 1980 increased the demand for parts and accelerated its growth. Output of components increased to NT$211 billion and its share of output rose to 21.8 per cent in 1993. The major components produced since 1980 are printed circuit boards, electricity transformers, electric plugs, and colour tubes.

Table 6.1 A comparison of foreign firms and local firms (NT$1,000)

	Foreign Firms (251)	Local firms (5862)
productivity		
output per worker	1285.65	840.77
output per unit of capital	6.38	5.88
employees per firm (persons)	709	45
value-added per worker	355.03	247.48
wage rate	15.34	10.94
export ratio (%)	75.18	24.13

Source: Directorate-General of Budget, Accounting and Statistics, Executive Yuan, Republic of China, *The Report on 1986 Industrial and Commercial Census, Taiwan-Fukien Area, ROC, Manufacturing Sector*, Taipei.

In summary, foreign direct investment has made a contribution to the production of electronic products, by disseminating technology and knowledge and by stimulating the development of components and parts. On the other hand, limited linkages to the domestic market might have distorted resource allocation and thus deterred development. If the beneficial effects of foreign investment counterbalanced the negative effects, then domestic firms are likely to have improved in productive efficiency because of new information on production, management, or know-how originating from foreign firms. This conclusion can now be tested by undertaking a normal quantitative analysis of the productive efficiency effects of foreign investment on local firms in the electronics industry.

Stochastic approach to decomposing TFP growth

The empirical analysis in Chapter 5 decomposed TFP growth into a scale effect, a spillover effect and an unexplained residual (technological progress). The entry of foreign capital clearly increased the benefits from larger scale production in Taiwan's manufacturing sector. Apart from these effects, there are other channels by which foreign entry may contribute to the development of domestic industries, such as improving the technical efficiency of firms.

Examined from another angle, it is possible to decompose TFP growth further into technical progress and changes in technical efficiency. The decomposition of TFP in this way can provide more information on the nature of the production technology used by firms. As noted by Nishimizu and Page (1982), technical progress and technical efficiency are analytically distinct concepts. When there is innovation or adoption of new technology, firms make technical progress. A high rate of technical progress can accompany a deterioration in technical efficiency, if firms fail to achieve mastery of new technology, or they face a quasi-fixed vintage capital problem in their cost-minimising behaviour. On the other hand, relatively low rates of technical progress may coexist with rapidly improving technical efficiency, if firms put effort into learning-by-doing, improving managerial practice, or gaining from the diffusion of new technological knowledge. TFP growth might be misinterpreted if it takes no account of technical efficiency changes. Firm-level analysis allows closer examination of the impact of foreign firms on local firms by decomposing TFP growth to examine changes in technical efficiency.

The hypothesis assumes that foreign direct investment can improve productive efficiency in local firms, either through technical progress or technical efficiency via spillovers. When local firms adopt new knowledge in the market and improve their performance, their productive efficiency is raised, particularly through an improvement in technical efficiency. The methodology follows that set out in Chapter 5, except that here TFP growth is decomposed further to measure the technical efficiency of firms.

The first study which attempted to decompose TFP growth rate into technological progress and changes in technical efficiency was that of Nishimizu and Page (1982). They defined technological progress as the shift in the 'best practice' techniques production frontier function over time, and established its rate by direct estimation using the linear programming techniques of a deterministic translog frontier production function. Bauer (1990a), laid out an index number approach that explored the relationship between changes in total factor productivity and changes in technological progress and technical efficiency. Fan (1991), Lin (1992), and Kalirajan, Obwona and Zhao, (1994) examined the relative contributions of input growth, technological progress and technical efficiency changes in the mainland Chinese agricultural industry, using frontier production analysis. Following these studies, the stochastic frontier analysis is employed here, but the dual approach of estimating the cost function replaces the primal approach which is commonly used in the above studies.

Traditionally, the production function is estimated by regression analysis of the relationship between input and output. This kind of analysis represents only the 'average' output level of a given level of inputs for a production unit; intra-firm deviations in technical efficiency are excluded. Since technical efficiency generally refers to the firm's ability to produce the maximum possible output from a given combination of inputs and technology, regardless of market demand and prices, the production function should be able to measure the maximum possible output level under the existing technology. This type of production function is called the frontier production function.

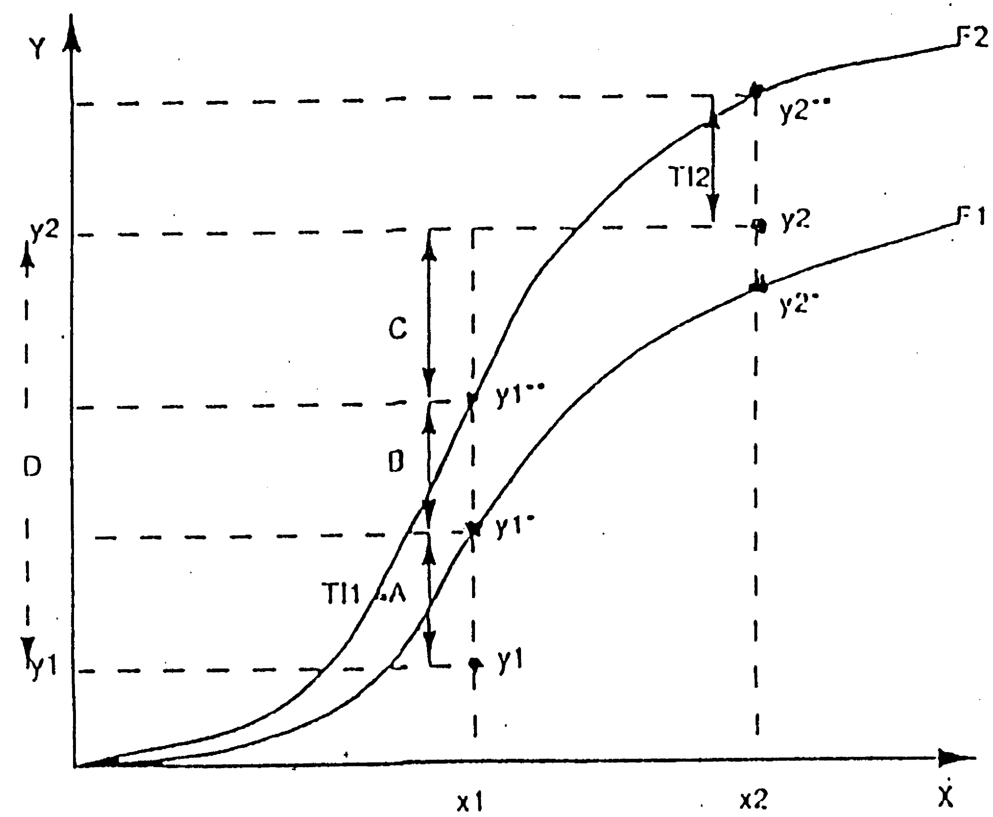
The frontier production function is commonly assumed and estimated in the literature when measuring technical efficiency, such as in Farrell (1957), Aigner, Lovell and Schmidt (1977), Meeusen and van den Broeck (1977), Schmidt and Lovell (1979), Pitt and Lee (1981), Nishimizu and Page (1982), Kalirajan and Flinn (1983), Fan (1991), Kalirajan, Obwona and Zhao (1994) and others. Bauer (1990b) thoroughly describes the development of and the approaches to the estimation of stochastic frontiers. The frontier model can interpret the deviations from a frontier as a measure of the efficiency with which economic units pursue their technical or behavioural objectives. It is consistent with the underlying economic theory of optimising behaviour. The relationship of TFP growth to output growth has been demonstrated by Kalirajan, Obwona and Zhao (1994, p. 7), as in Figure 6.3.

Assuming the firm faces production frontier F_1 and F_2 for periods 1 and 2, respectively, if a given firm was technically efficient, output would be y_1^* in period 1 and y_2^* in period 2. However, the firm can only produce y_1 in period 1 and y_2 in period 2 due to technical inefficiency in production, hence the output-based measure of technical efficiency can be defined, by Farrell's (1957) definition, as

$$TE = \frac{y}{y^*}, \text{where } 0 < \text{TE} \leq 1 \qquad (1)$$

From equation (1), technical efficiency can be expressed by the distance between the frontier output and the actual output of a given firm in the graph; that is TE1 in period 1 and TE2 in period 2. Change in technical efficiency over time is the difference between TE1 and TE2, and technical change is measured by the distance between frontier 2 and frontier 1; that is, $y_2^{*''} - y_2^*$ using x_2 input levels or $y_1^{*''} - y_1^*$ using x_1 input levels. The input growth between the two periods denotes as Δy_x, so the total output growth, $y_2 - y_1$ can be decomposed into three components, that is, input growth, technical change and change in technical efficiency.

Figure 6.3 Decomposition of output growth into technical efficiency change, technical change and input growth



Source: Kalirajan, K.P., M.B. Obwona and S. Zhao (1994) "On Decomposing Total Factor Productivity"

The decomposition can be mathematically expressed as follows

$$
\begin{aligned}
D &= y_2 - y_1 \\
&= A + B + C \\
&= \left[y_1^{*} - y_1\right] + \left[y_1^{*''} - y_1^{*}\right] + \left[y_2 - y_1^{*''}\right] \\
&= \left[y_1^{*} - y_1\right] + \left[y_1^{*''} - y_1^{*}\right] + \left[y_2 - y_1^{*''}\right] + \left[y_2^{*''} - y_2^{*''}\right] \qquad (2) \\
&= \left[y_1^{*} - y_1\right] + \left[y_1^{*''} - y_1^{*}\right] - \left[y_2^{*''} - y_2\right] + \left[y_2^{*''} - y_1^{*''}\right] \\
&= \left[(y_1^{*} - y_1) - (y_2^{*''} - y_2)\right] + (y_1^{*''} - y_1^{*}) + (y_2^{*''} - y_1^{*''}) \\
&= \dot{TE} + \dot{TP} + \dot{y}_x
\end{aligned}
$$

where $y_2 - y_1$ = production output growth between two periods

$\dot{TE}$ = technical efficiency change

$\dot{TP}$ = technical progress (shifts in the production frontier over time)

$\dot{y}_x$ = changes in output production due to input growth (shifts along the production function).

Total factor productivity growth measures output growth after taking into account input growth, that is, the changes in technical efficiency over time and shifts in technology over time, which can be expressed as follows,

$$
\begin{aligned}
\dot{TFP} &= D - \dot{y}_x \\
&= \dot{TE} + \dot{TP}
\end{aligned}
$$

Bauer (1990a) decomposed TFP growth into a change of technical efficiency, technical progress, and the scale effect. First, he logarithmically differentiated Farrell's definition of technical efficiency with respect to time to yield,

$$
\frac{d\ln TE}{dt} = \frac{d\ln y}{dt} - \left(\sum_i \frac{\partial \ln f(x,t)}{\partial x_i}\frac{dx_i}{dt} + \frac{\partial \ln f(x,t)}{\partial t}\right)
$$

rewritten as

$$\dot{TE} = \dot{y} - \dot{f}(x,t) - \sum_i \frac{\partial f(x,t)}{\partial x_i} \frac{x_i}{f(x,t)} \dot{x}_i \tag{3}$$

where $\dot{f}(x,t) = \dot{TP}$ is the time rate of change in technical progress by shifts in the production function, and x_i is the ith input. From Chapter 5, the conventional Divisia index of TFP growth is defined as

$$\dot{TFP} = \dot{y} - \dot{F}$$

$$\text{where} \quad \dot{F} = \sum_i \frac{w_i x_i}{C} \dot{x}_i \tag{4}$$

F is an aggregate measure of observed input usage, w_i is the price of the ith input, x_i is the use of the ith input, and C is the production cost.

Substituting equation (3) into the definition of TFP growth (equation (4)), then

$$\dot{TFP} = \dot{TE} + \dot{f}(x,t) + \sum_i \left(\frac{\partial f(x,t)}{\partial x_i} \frac{x_i}{f(x,t)} - \frac{w_i x_i}{C} \right) \dot{x}_i \tag{5}$$

Meanwhile, the output elasticity of the ith input and cost share of the ith input are defined as follows

$$\varepsilon_i(x,t) = \frac{\partial f(x,t)}{\partial x_i} \frac{x_i}{f(x,t)},$$

and

$$s_i = \frac{w_i x_i}{C}$$

Substituting the above definitions into equation (5) obtains

$$\dot{TFP} = \dot{TE} + \dot{f}(x,t) + \sum_i [\varepsilon_i(x,t) - s_i] \dot{x}_i \tag{6}$$

Equation (6) decomposes TFP growth into terms related to technical efficiency, technological progress, and a term that depends on the degree of the input-specific returns to scale and cost inefficiency. It is straightforward to conclude that improvement in technological progress and technical efficiency increases TFP growth from the first two terms in the equation. As for the last term, when the firm fails to produce at minimum cost, the aggregate measure of input usage is a biased measure of actual input usage since the observed input shares, not the cost-minimising input shares, are employed in the construction of this index. Therefore, the measure of TFP growth is shown to depend on changes in production efficiency, technological progress, and a residual term which represents the bias introduced in the aggregation of inputs using observed input shares.

The decomposition is consistent with the results in Chapter 5. When the production of a firm is cost efficient, its production satisfies the requirements of cost minimisation, that is the marginal product of *i*th input is equal to its marginal cost

$$\frac{\partial f}{\partial x_i} = \frac{w_i}{(\frac{\partial C}{\partial y})}, \text{ for all } i$$

then equation (5) can be transformed into

$$\dot{TFP} = f(x,\dot{t}) + \sum_i \left[\varepsilon_{cy}^{-1} - 1\right] \frac{w_i x_i}{C} \dot{x}_i$$

which is the same as equation (8) in Chapter 5. From this equation, when constant returns to scale and cost efficiency are assumed, TFP growth is equivalent to technological progress; but with non-constant returns to scale and cost inefficiency, TFP growth is equivalent to technological progress plus a term that adjusts for the degree of returns to scale.

A further decomposition of TFP growth into scale effect and cost inefficiency is possible when the firm is cost inefficient. As explained in Chapter 5, the use of the cost function is more straightforward when incorporating the scale factor, as it is a function of output level, rather than the production function. Thus the dual approach is employed and decomposed in the following.

In the dual approach, Farrell's (1957) input-based overall measure of cost efficiency is employed, defined as

$$E = \frac{C^*}{C}, \text{ where } 0 < \mathrm{E} \leq 1 \tag{7}$$

where C^* is the efficient cost given output level and factor prices at time t. Taking the logarithm of this efficient cost and differentiating with respect to time, with some substitutions yields

$$\dot{E} = \varepsilon_{cy}(y,w,t)\,\dot{y} + \sum_i \frac{\partial C^*}{\partial w_i}\frac{w_i}{C^*}\dot{w}_i + \dot{C}^* - \dot{C} \tag{8}$$

where ε_{cy} is the cost elasticity of output. Using the definition of TFP growth in equation (4), equation (8) is rewritten as

$$\begin{aligned} T\dot{F}P = &\left[1-\varepsilon_{cy}(y,w,t)\right]\dot{y} + \dot{E} - \dot{C}^* - \sum_i \frac{w_i x_i(y,w,t)}{C^*}\dot{w}_i \\ &- \sum_i \frac{w_i x_i}{C}\dot{x}_i + \dot{C} \end{aligned} \tag{9}$$

On the other hand, differentiating the cost function with respect to time derives the following equation[6]

$$\dot{C} = \sum_i \frac{w_i x_i}{C}\dot{x}_i + \sum_i \frac{w_i x_i}{C}\dot{w}_i$$

Substituting into equation (9) obtains

6 Since $C = \sum_i w_i x_i$

differentiating with respect to time derives

$$\frac{dC}{dt} = \sum_i w_i \frac{dx_i}{dt} + \sum_i x_i \frac{dw_i}{dt}$$

dividing the whole equation by C,

$$\frac{dC}{dt}\frac{1}{C} = \sum_i \frac{w_i}{C}\frac{dx_i}{dt}\frac{x_i}{x_i} + \sum_i \frac{x_i}{C}\frac{dw_i}{dt}\frac{w_i}{w_i}$$

rewriting as

$$\dot{C} = \sum_i \frac{w_i x_i}{C}\dot{x}_i + \sum_i \frac{w_i x_i}{C}\dot{w}_i$$

$$\dot{TFP} = \left[1 - \varepsilon_{cy}(y,w,t)\right]\dot{y} + \dot{E} - \dot{C}^{*} + \sum_{i}\left(\frac{w_i x_i}{C} - \frac{w_i x_i(y,w,t)}{C^{*}}\right)\dot{w}_i \tag{10}$$

On the other hand, Farrell defines input-based measures of technical inefficiency as the proportional overuse of all inputs, whereas allocative inefficiency is the failure to use the least-cost mix of inputs, which means that cost efficiency (equation (7)) can be decomposed as $E = T \bullet A$, a cross effect of technical efficiency and allocative efficiency, where T and A are the Farrell input-based measures of technical and allocative efficiency respectively. This implies $\dot{E} = \dot{T} + \dot{A}$. Substituting into equation (10) yields the decomposition of TFP growth as

$$\dot{TFP} = \left[1 - \varepsilon_{cy}(y,w,t)\right]\dot{y} + \dot{T} + \dot{A} - \dot{C}^{*} + \sum_{i}(s_i - s_i^{*})\,\dot{w}_i \tag{11}$$

Equation (11) decomposes TFP growth into terms related to the scale effect, changes in technical and allocative efficiency, technological progress, and a residual price effect term. The last term implies that, when the firm is allocatively efficient, then $s_i = s_i^{*}$, and the price effect term is equal to zero. This term is also equal to zero when input prices change at the same rate, since $\sum_{i}(s_i - s_i^{*}) = 0$. The presence of this residual is because TFP growth is defined as an observable quantity. It is biased by relying on observed input usage which is in turn biased by cost inefficiency.

The decomposition from the cost function is also consistent with expectations, in that increases in cost efficiency increase TFP growth. In short, the decomposition provides tools for assigning the observed changes in TFP growth to the various root sources. Furthermore, the decomposition shows that a more complete partitioning of the sources of observed TFP growth is derived when the duality is applied.

It should be noted from the above analytical framework that the decomposition of TFP growth is underpinned by the concept of the production frontier, which assumes that firms can maximise output or minimise costs if, and only if, their production is efficient. Alternatively, technical inefficiency is the failure to produce maximal output for a given level of inputs, which is generally assumed to be efficiency in neoclassical production analysis. In this sense, the neoclassical production functions are 'average' and unable to provide information on efficiency, because symmetric random disturbance is assumed in estimating production functions. The differences in interpreting production behaviour induce different specifications on production function in the frontier analysis. The development of frontier analysis is therefore briefly described in the following.

Farrell (1957) was the first to raise the idea of measuring a firm's technical efficiency by employing the production frontier. Since then, this approach has been widely accepted and applied empirically in the literature, but with different specifications for the disturbance term.

The earliest work on frontiers is called the deterministic frontier approach. This idea was developed by Farrell (1957), Farrell and Fieldhouse (1962) and Afriat (1972), and tested by Aigner and Chu (1968), Fφrsund and Jansen (1977) and others. The deterministic approach assumes that firms possess the same information on production and hence face the same production frontier, whilst technical efficiency can be measured by the deviations between actual output and the frontier. The production function in the deterministic frontier approach generally takes the following form:

$$y = f(x)e^{-u} \qquad\qquad u \geq 0$$

where y is actual output, x is the input vector, and u represents technical inefficiency. Deterministic approaches can be categorised as follows: deterministic nonparameter approach (Farrell 1957), deterministic parameter approach (Aigner and Chu 1968), and deterministic statistical frontier approach (Afrait 1972). The first two approaches use mathematical programming techniques to compute the parameters, and no assumptions are explicitly made about the properties of disturbance. The disadvantage of these methods is that the calculated frontier may be warped if the data are contaminated by statistical noise.

Unlike these approaches, the statistical frontier approach imposes a statistical relationship between observation and the estimated frontier by assuming a statistical distribution among those disturbance terms. The distribution of the one-sided disturbance has been assumed to have a particular form, for instance, two-parameter Beta distribution (Afriat 1972), one-parameter Gamma distribution (Richmond 1974), or exponential distribution (Schmidt 1976). The disadvantage of this specification is that the regularity conditions for application of maximum likelihood methods are violated during the estimation, because the range of the observed random variables depends on the parameter being estimated (Greene 1980b). The usual Cramer rule cannot be applied to determine the asymptotic distributions of parameter estimates and it is not clear how the asymptotic standard error for these estimators can be obtained. Under these circumstances, the frontier is not clear after estimation is undertaken. Estimates of the deterministic frontier model are not completely straightforward when applying maximum likelihood estimation. Another disadvantage of deterministic frontier approaches is that these models are extremely sensitive to outliers in the data.

In order to ameliorate the problems of deterministic frontier models, the stochastic production frontier was developed by Aigner, Lovell and Schmidt (1977), and Meeusen and van den Broeck (1977). This approach to estimating frontiers uses a parametric representation of technology along with a two-part composed error term. One part of the composed error term represents statistical noise and is generally assumed to follow a normal distribution. The other part represents inefficiency and is assumed to follow a particular one-sided distribution, for instance, a half-normal and exponential distribution (Aigner, Lovell, and Schmidt 1977), a truncated normal distribution (Stevenson 1980), a two-parameter Gamma distribution (Greene 1990), or a four-parameter Pearson family of distribution (Lee 1983).

The specification of this approach is that the output of each firm is bounded above by a frontier that is stochastic in the sense that its placement is allowed to vary randomly across firms. From an economic standpoint, the frontier itself can vary randomly across firms, or over time for the same firm. The one-sided disturbance reflects each firm's deviation from the optimal production. Any such deviation is the result of factors under the firm's control, such as technical and economic inefficiency, or the effort of the producer and employees. However, the frontier is stochastic in the sense that the frontier with random disturbances presumably captures the effects of exogenous shocks—favourable or unfavourable external events such as luck, climate, topography and machine performance—which are beyond the control of the firms.

To illustrate this approach, consider a stochastic cost function[7]

$$\ln C_i = \ln C(y_i, w_i) + \varepsilon_i \quad \text{where}$$

$$\varepsilon_i = u_i + v_i$$

where u_i is a one-sided disturbance (non-negative for cost frontier) capturing the effects of inefficiency, which reflects the fact that each firm's production cost must lie on or above its cost frontier ($C(y_i, w_i) + v_i$); and v_i is a two-sided disturbance capturing the effects of noise. If a firm uses best practice techniques, but there are either measurement errors or the influence of external factors, then the cost frontier is $C(y_i, w_i)\exp(v_i)$; that is, the stochastic cost frontier. Given distributional assumptions

7 The primal approach specifies the stochastic production function taking the following form,

$y = f(x)e^{-\varepsilon}$ where $\varepsilon = v - u$ and $u \geq 0$

for the two disturbance terms and assuming that they are mutually independent, the model can then be estimated by the maximum-likelihood method.[8]

Due to the unobservable random disturbance v_i and no way to identify the deviations among firms arising from the stochastic error or technical inefficiency,[9] this model can only estimate average technical inefficiency for the entire sample. In order to overcome this deficiency, Jondrow, Lovell, Materov and Schmidt (1982), and Kalirajan and Flinn (1983), independently suggest the use of either the expected value on the estimate of u_i given $u_i + v_i$, or the mode of this conditional distribution as an estimate of u_i, to calculate firm-specific technical efficiency. This statistical-type firm-specific technical efficiency measure is discussed and estimated later. The drawback of these estimates is that they are not consistent estimates of u_i, because ε_i contains only imperfect information about u_i.

A further development of this approach attempts to measure the allocative efficiency of the firm.[10] Following Farrell's definition, it is possible to decompose economic inefficiency into technical and allocative inefficiency; that is, to rewrite the cost frontier in the following form,

$$\ln C_i = \ln C(y_i, w_i) + \ln TE_i + \ln AE_i + v_i$$

where $\ln TE_i$ is a non-negative term reflecting the increase in costs due to technical inefficiency, $\ln AE_i$ is a non-negative term reflecting the increase in costs due to allocative inefficiency, and v_i represents statistical noise.

---

8 This model can also be estimated by corrected ordinary least squares (COLS), as in the estimation of Bagi and Huang (1983), which uses the moments of residual term in OLS estimations to derive the expected value of the residual and then adjusts the intercept term. This estimation is easier than maximum likelihood estimation (MLE), but may obtain inconsistent estimates.

9 Taking exponential of cost frontier,

$$C_i = e^{f(y_i, w_i)} \cdot e^{v_i} \cdot e^{u_i}$$

and firm-specific technical efficiency is measured by $e^{u_i} = \dfrac{C_i}{f(y_i, w_i) \cdot e^{v_i}}$.

Since v_i is unknown, only the average technical inefficiency of the entire observations can be obtained instead of an individual firm's technical inefficiency.

ie. $E(e^u) = 2(e^{\sigma\mu^2}/2)(1 - F(\sigma\mu))$.

10 Allocative efficiency can only be estimated by the cost frontier, because the production frontier provides no information on the influence of factor price changes on resource allocation.

In addition to the development of measuring technical efficiency and allocative efficiency, techniques to estimate panel data have also been developed to weaken the strong assumptions regarding disturbance terms.[11] In particular, as argued by Jondrow *et al.* (1982) and Kalirajan and Flinn (1983), the level of an individual firm's technical efficiency cannot be consistently estimated in a single cross-section, but this deficiency is essentially resolved with panel data because the statistical noise is being observed T times and averaged in the overall residual.

Furthermore, concerns about unrealistic assumptions of the time-invariant analysis in many potential applications, particularly over long periods, have led to the development of time-varying analysis, such as Sickles, Good and Johnson (1986) and Kumbhakar (1990). This is the stochastic coefficient frontier approach. The basic framework of this approach is that each firm may apply different methods in managing inputs, regardless of the levels of inputs, which lead to different levels of output. According to this model, an individual firm's decision-making leads to variations in production response coefficients, which are specific to each firm and to each time period for the same firm.

When applying maximum likelihood estimation, it is necessary to derive the likelihood function from the assumed distribution of the disturbance terms. Different assumptions lead to the estimation of different likelihood functions. However, there is a unique specification in this approach of the frontier analysis, that lies in the composite disturbances (u_i and v_i). The composite disturbance model is followed in the empirical analysis to derive firm-level TFP growth for Taiwan's electronics industry.

Empirical analysis

This section specifies the stochastic cost frontier to illustrate the use of the decomposition of TFP growth. The example is drawn from Taiwan census data on the electronics industry for the years 1981, 1986 and 1991.

Model specification

Before introducing frontier analysis, it is necessary to specify an appropriate functional form for the production function. This form depends on production technology. Some of the most popular functional forms in econometric analysis are Cobb-Douglas, Constant Elasticity of Substitution (CES), Leontief, and Transcendental Logarithmic (translog), among which the translog function is

[11] For instance, u_i is independent of factor inputs, or specific distributional specification of u_i.

characterised by a non-fixed substitution elasticity and is therefore subject to fewer constraints than a general logarithm linear model. Flexible functional forms impose relatively fewer *a priori* restrictions on the structure of production. The translog function has been frequently used in the empirical literature. Kopp and Smith (1980) found also that the more flexible functional form results in more generalised estimates.

Moreover, the various flexible models have been most useful in the indirect estimation of production structures through the use of cost functions. The cost function provides a preferable alternative to the production function for studying the structure of production. The cost function assumes that prices and output are exogenous, while input demands and total cost are endogenous. The costs model has been most frequently applied to regulated industries in which output prices are set by a regulatory body rather than the firms themselves (Greene (1980a); Kumbhakar (1991)). Alternatively, the behaviour of production indicates that producers minimise production costs subject to output, prices and production technology. On the other hand, Taiwan's electronics industry is a typical export-oriented industry with a relatively small scale of production, so that local firms are price-takers in the world market. It is appropriate then to specify the translog cost function in the study. The share equations are also added to form a system in the estimation. The use of a system estimation brings together a great amount of information and can provide estimates far more efficient than those obtained by the single equation methodology.

The translog system of cost and input share equations that was estimated is presented as equation (12) and equation (13). One feature that should be noted in this system is that the time variable was not interacted with input prices in order to reduce the number of parameters and to lessen the effects of multicollinearity.

$$\begin{aligned}\ln C &= \ln C(y, w_i, t) + \mu + \nu \\ &= \alpha_0 + \alpha_y \ln y + \sum_i \alpha_i \ln w_i + \alpha_t t \\ &+ \frac{1}{2}\beta_{yy}(\ln y)^2 + \frac{1}{2}\sum_i \beta_{ii}(\ln w_i)^2 \\ &+ \sum_i \gamma_{iy} \ln y \ln w_i + \sum_i \sum_j \gamma_{ij} \ln w_i \ln w_j + \varepsilon_i\end{aligned} \quad (12)$$

where C is total cost, y is the level of output, w_i is remuneration of factor i, t is the time variable, and α_i, β_{ii}, and γ_{ij} are parameters to be estimated.

By using Shephard's lemma, a set of factor share equations is derived as follows:

$$S_i = \alpha_i + \sum_j \beta_{ij} \ln w_i + \gamma_{iy} \ln y + \varpi_i \quad (13)$$

The share S_i of the ith input in total cost which ensures that the cost-minimising level of utilisation of any output is equal to the derivative of the cost function with respect to the price of that input.

In order to represent a well-behaved production function, the cost function in equation (12) must satisfy three properties: monotonicity; concavity, and homogeneity. Monotonicity requires that the estimated cost share in equation (13) be positive for each input. Concavity, that is, the cost function is concave in input prices, requires that the matrix of second order derivatives $(\partial^2 C / \partial w_i \partial w_j)$ be non-positive definite within the range of input prices. Homogeneity means that the cost function is homogeneous of degree one in input prices. The symmetry and linear homogeneity in input prices permit the following restrictions on the parameters of the cost function in equation (12). That is,

$$\sum_i \alpha_i = 1, \sum_i \gamma_{iy} = 0, \sum_i \gamma_{ij} = \sum_j \gamma_{ji} = \sum_i \gamma_{it} = \sum_i \sum_j \gamma_{ij} = 0$$

The factor cost shares always sum to unity, which implies that a covariance matrix is singular. Hence, to obtain a full-rank covariance matrix, one of the cost-share equations has to be dropped for joint estimation.

To specify the translog cost frontier, the estimation requires some assumptions about the distributions of error terms. First, the disturbance of cost frontier function has two components (ie. $\varepsilon_i = v_i + u_i$.): a symmetric component (v_i) and a one-sided component (u_i). The symmetric disturbance permits random variation of the frontier across firms, and captures the effects of measurement error, other statistical 'noise', and random shocks outside the firm's control. v_i is assumed to be independently and identically distributed as $N(0,\sigma_v^2)$, whereas the one-sided error term (u_i) captures the effects of inefficiency relative to the stochastic frontier. u_i is assumed to be distributed independently of v_i and to satisfy $u_i \geq 0$. u_i is derived from a $N(0,\sigma_u^2)$ distribution truncated with zero mode; that is, half-normal distribution is assumed here. For simplicity the statistical relationships among the disturbance of cost (ε) and the share equations (ϖ_i) are assumed to be independent.[12]

According to above specification, the density function of μ and ν can respectively be written as:

$$f(u) = \frac{2}{(\sqrt{2\pi})\sigma_u} \exp(-\frac{u^2}{2\sigma_u^2}), \quad u \geq 0$$

$$f(v) = \frac{1}{(\sqrt{2\pi})\sigma_v} \exp(-\frac{v^2}{2\sigma_v^2}), \quad -\infty \leq v \leq \infty$$

And the joint density function of $(\mu + \nu = \varepsilon)$ by convolution formula is given in equation (8) of Aigner, Lovell and Schmidt (1977):

$$f(\varepsilon) = \frac{2}{(2\pi)^{1/2}\sigma} \exp(-\frac{\varepsilon^2}{2\sigma^2})(1 - F^*(-\frac{\varepsilon\lambda}{\sigma})), -\infty < \varepsilon < \infty$$

where $\sigma^2 = \sigma_u^2 + \sigma_v^2, \lambda = \sigma_u / \sigma_v$, and $F^*(\cdot)$ is the cumulative distribution function of the standard normal random variable. Given the density function, the log-likelihood function of the observed random variable may be specified as

$$\ln(\ln C|\theta) = \frac{n}{2}\ln\frac{2}{\pi} - n\ln\sigma - \frac{\sum e_i^2}{2\sigma^2} + \sum_1^n[1 - F^*(-\frac{\varepsilon\lambda}{\sigma})]$$

where θ is the parameter to be estimated and is equal to the cost function parameters, σ^2 and λ. The above likelihood function uses only the information present in the cost function. Additional information is added by including the share equations.

Under the independence assumption, the joint probability density function (p.d.f.) of the three disturbances ($u, v,$ and ω) is

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[12] The relationship among the disturbance in share equations and the non-negative allocative inefficiency disturbance in the cost equation has been referred to as 'the Greene problem' in the frontier literature since it was first noted by Greene (1980a, pp. 104-5). However, as noted by Cowing et al. (1983, pp. 68-9), the extra information contained in the covariance between equations is small in contrast to the addition of the information changes, the magnitude and / or sign of the estimates by including cost shares. Therefore, it is acceptable to ignore the relationship among the disturbances in the cost and input share equations.

$$f(\varepsilon_i,\omega_{1i},\omega_{2i}) = f(\varepsilon_i)f(\omega_{1i},\omega_{2i})$$
$$= f(\varepsilon_i)(\frac{1}{(2\pi\Sigma)^{1/2}}\exp(-\frac{1}{2}[\omega_{1i}\ \omega_{2i}]\Sigma^{-1}[\frac{\omega_{1i}}{\omega_{2i}}])$$

where $\Sigma=\begin{bmatrix}\phi_{11} & \phi_{12}\\ \phi_{12} & \phi_{22}\end{bmatrix}$, the variance-covariance matrix for the share disturbances, and $f(\varepsilon_i)$ is the p.d.f. derived above. The likelihood function for the system can then be written as

$$\ln L(\ln C,S_1,S_2,\theta) = -n\ln\sigma + \frac{n}{2}\ln\frac{2}{\pi} - n\ln 2\pi - \frac{\sum\varepsilon_i^2}{2\sigma^2}$$

$$+\sum_1^n \ln[1-F^*(-\frac{\varepsilon_i\lambda}{\sigma})] - \frac{n\ln|\Sigma|}{2} - \frac{1}{2}\sum_1^n[\omega_{1i}\ \omega_{2i}]\Sigma^{-1}\begin{bmatrix}\omega_{1i}\\ \omega_{2i}\end{bmatrix}$$

Derivation of the likelihood function allows the model to be estimated by maximum likelihood techniques in which the estimators are asymptotically efficient. The maximum likelihood estimates are computed with GQOPT[13] which is a general purpose numerical optimisation computing package. The program employed the iterative Davidon-Fletcher-Powell algorithm, and also provides the inverse of the Hessian of the log-likelihood function, where the Hessian is calculated from analytical second derivatives, evaluated at the converged maximum. Asymptotically, the Hessian is equivalent to the information matrix, thus yielding asymptotical standard errors for each of the parameter estimates.

Estimation results

The defined translog cost model is estimated using cross-section and time series data on the establishment of firms in Taiwan's electronics industry. Data on 135 domestic electronics firms for the years 1981, 1986 and 1991 were obtained from manufacturing surveys conducted by the Directorate-General of Budget, Accounting and Statistics of the Republic of China. The sample size totals 405 observations.[14]

The whole system contains six variables: total costs, output, time, prices of energy, labour and capital. Time variables are set at 1 for 1981, 6 for 1986, and 11 for

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[13] GQOPT was developed by R. Quandt of Princeton University in USA.

[14] At first, there were 1110 observations with complete reports in all desired variables. Firms with less than five workers were omitted—these firms generally reported misleadingly, and with some outliers—and so 405 observations remained.

1991. Output is the value of the production of each firm for each year. Total costs are equal to the sum of expenditures for energy, labour and imputed expenditures for capital services. Fuel expenditures were obtained directly from the census data, while fuel prices were obtained from Taiwan's Commodity Price Statistics Monthly. The price of energy was weighted by the prices of fuel and electricity with their value shares as the weights. Labour expenditures are the annual sum of wage expenditure, pensions and benefits. Average yearly wage rates are defined as total labour expenditure divided by the number of employees. Capital price is calculated in the form of a Divisia index based on the book value of land, plant, machinery and equipment, and transportation equipment, with the imputed capital service price.[15] Total cost is the aggregation of total labour, capital and energy expenditure for each firm in each period. Shares of factor inputs are directly calculated as expenditure to total cost. The two share equations included in the system are capital and labour shares; the energy equation was dropped to obtain the non-singular matrix in estimation.

The maximum likelihood estimates of the parameters of the frontier function are summarised in Table 6.2.[16] All but three (β_{KL}, β_{YY}, and β_{YL}) of the parameter estimates are statistically significant at the 95 per cent confidence level. Note that the estimated parameter of technological progress, α_T, is positively and significantly different from zero which means that technological progress decreases at a rate of 0.1237 per sampling period (that is, every five years). This does not mean that there was no technological progress in Taiwan's electronics industry over the past fifteen years but that the sources of technological progress include adjustment costs in adapting or developing new technology, which raise the cost of production. Since electronic products are recognised as products with relatively short market cycles and the products of local firms generally embody popularised, non-frontier technology in the world market, these firms seek to accommodate increasingly competitive pressures in the world market by the establishment of a quick and flexible production line. This kind of production system obviously increases the firm's adjustment costs in production, partly due to the cost of holding extra stocks of materials. These adjustment costs probably dominate all other factors of the residual—technological

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15 Appendix 6.A describes the derivation of capital service price and expenditures.

16 The initial value of maximum likelihood estimation is derived as follows. First, assuming the residual of equation (13) is normally distributed and its parameters estimated by the Ordinary Least Square (OLS) method, these estimated coefficients are taken as the initial value for the non-linear equation (15). The error sum of squares in OLS is taken to be the initial value of σ. In addition, ϖ_{ii} takes the standard error of the estimates for the two share equations. λ is randomly assumed to be equal to 0.85 and ϖ_{ij}= -0.152 (a value approximately equal to the square root of the multiplication of ϖ_{ii}).

progress—and result in the negative parameter in estimation here. The rise of output quality may also induce the negative technological progress. Unfortunately, no price or quantity data is available for measuring output quality changes here.

Table 6.2 Maximum likelihood estimation parameter estimates

Parameters*	Estimates	Asymptotic T-ratio
intercept	8.5933	0.9742D+2
α_L	0.6015	0.7225D+2
β_{LL}	0.0516	0.2542D+1
α_K	0.3692	0.3960D+2
β_{KK}	0.0652	0.2227D+1
β_{KL}	0.0329	0.1700D+1
α_Y	0.6262	0.2452D+2
β_{YY}	-0.0216	-0.9882D+0
β_{YL}	-0.0084	-0.1409D+1
β_{YK}	-0.0346	-0.5307D+1
α_T	0.1237	0.2258D+2
λ	1.6050	0.5892D+1
σ^2	0.5870	0.1372D+2
ϖ_{11}	0.0058	0.1029D+4
ϖ_{22}	0.0202	0.1033D+4
ϖ_{12}	-0.0342	-0.4538D+7

Note: The parameters are stipulated by equation (12).

The coefficient of α_Y (= 0.6262) suggests that local electronics firms, on average, exhibit strong economies of scale. The estimates of α_L and α_K denote the extent to which the cost function varies with the two input prices. The positive estimates for these parameters imply that production cost increases with increases in input prices. The own-share elasticity is positive in β_{KK} and β_{LL}, and negative in β_{YY}. The former two estimates are significant for capital and labour elasticity respectively, but insignificant for output elasticity. The positive but insignificant estimate of β_{LK} (significant at the 90 per cent level) implies that the value share of labour (capital) increases with the price of capital (labour).

The decomposition of TFP for each firm is derived from the estimated cost frontier function, listed in Appendix 6.B. The calculation of scale, cost efficiency and the price effect follows the definition in the previous section, and the measure of TFP growth is constructed by summing the scale, cost efficiency, technological progress and price effect.

The TFP growth rate was different across firms. There was one more firm with negative TFP growth in 1986 (92) than in 1991 (91). The rate of TFP growth increased for 68 of 135 firms between 1986 and 1991, but decreased for 67 firms. Negative TFP growth can be mainly attributed to negative technological progress. The mean values of the decomposition of TFP for each period are reported in Table 6.3. Average TFP growth for 1986 was 0.1290, but -0.0518 in 1991 a result of larger fluctuations in the scale effect and price effect. The standard deviation for the scale effect and price effect in 1986 are 0.804 and 0.2128 respectively, but only 0.3779 and 0.0752 in 1991. In addition, a great deal of variation on TFP growth across firms is observed in 1986 when compared with 1991. The results reflect the fact that there was restructuring and upgrading in Taiwan's electronics industry during these years, due to the liberalisation of the market.

Table 6.3 TFP decomposition (mean value)

	TFP growth	Scale effect	Efficiency effect	Technological progress	Price effect
1986	0.1290	0.2300	0.0158	-0.1237	0.0068
1991	-0.0518	0.0589	0.0117	-0.1237	0.0013
Total	0.0386	0.1444	0.0138	-0.1237	0.0040

The electronics industry is the largest in Taiwan's manufacturing sector, so it is obvious that the dramatic changes in the economic environment in 1986, as mentioned in Chapter 5, would affect it significantly. In fact, rapid growth in labour costs encouraged lower end or labour-intensive production in the industry to relocate to other sites, such as Malaysia, Thailand and China in the mid 1980s. This led to a tremendous outward investment to these countries. Electronics dominates other industries in terms of outward investment, either by number of projects or value of investment.

From Table 6.3 the scale effect appears to be the most significant source of TFP gains, much of the increase in TFP being the result of expansion in the size of production. The relationship between these two variables was tested by applying Spearman's rank correlation statistics. The Spearman's rank correlation coefficient was applied to test the relation for 1986, 1991 and the whole sample. The coefficients were 0.9076, 0.9166 and 0.9109 respectively. All coefficients are highly significant suggesting that the hypothesised relationship between TFP growth and scale effect can be accepted. Firms with higher TFP growth generally enjoyed more expansion in the scale of their operations.

Although no clear evidence is available to prove the expansion of scale in operations is a result of the demonstration effect from the inflow of foreign capital, as described earlier, foreign subsidiaries tended to introduce new technology, broaden information channels, or enhance marketing to domestic firms. All of this seems to have helped domestic firms to accumulate knowledge about markets or products which they would not have acquired otherwise. Foreign capital inflow may have thereby played a role in encouraging domestic firms to enlarge their operations.

On the other hand, technological progress was the dominant negative factor in TFP growth for all firms. Negative TFP growth can be attributed mainly to the decrease in technological progress. This indicates that adjustment cost is a heavy burden on domestic firms. It also suggests that local firms faced competitive market pressures. The price effect is only a minor factor in TFP growth. The Spearman correlation coefficients suggest a weak relationship between TFP growth and the price effect (0.1950, 0.3197 and 0.2573 in each sample group, respectively). The hypothesis of no relationship between these two variables can be accepted.

The calculated efficiency effect varied rather more evenly across firms than did other factors.[17] The most efficient firm in 1986 gained 0.3649 of efficiency effect, and 0.3111 for 1991; the corresponding figures were -0.1717 for 1986 and -0.2042 for 1991 for the least efficient firms. The mean value of the efficiency effect for firms in 1991 was 0.0117, while it was 0.0158 for 1986. The downward trend indicates that, on average, firms in 1991 exhibited less efficiency in managing their production costs compared with 1986. A majority of firms (115) nonetheless improved efficiency growth between 1986 and 1991. These two results indicate that there was a large dispersion in efficiency across firms in 1986 compared with 1991. It seems that the more liberalised economic environment in 1991 created a better functioning market for both products and factors, for all firms, increasing market competitiveness and forcing firms to put effort into reducing unnecessary expenditures in production. Since cost efficiency measures an effect which is under the control of firms, the results indicate that firms can employ strategies to improve their performance, for instance, improving managerial techniques, reducing personnel expenditure, or allocating resources more efficiently. No matter what strategies firms adopt, this suggests a potential channel by which foreign firms' spillovers can be delivered, because foreign firms might bring new approaches to management and resource allocation. Through learning-by-watching or labour turnover, domestic firms can gain new information and techniques, thereby improving their efficiency.

The efficiency effect is also significantly correlated with TFP growth. The Spearman's rank correlation coefficients were 0.6075, 0.6263 and 0.6109 respectively. The results reveal that greater cost efficiency was achieved by firms with

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[17] There is a method other than Farrell's (1957), for defining cost efficiency. This statistical approach basically utilises the parameter estimates of the frontier function. This statistical analysis is summarised in Appendix 6.C.

higher TFP growth. This suggests that spillovers from foreign firms on TFP growth probably led to the improvement in cost efficiency.

In other works, Pitt and Lee (1981), and Chen and Tang (1987), identified three sources of technical efficiency—age, size and ownership, in the Indonesian weaving industry and in Taiwan's electronics industry. Since older firms have had more time to learn and become experienced in their operations, they become more efficient; and large firms are often considered more efficient than small firms because of economies of scale and the learning-by-doing effect. As for ownership, foreign firms adopting labour-intensive techniques in developing countries will operate at below maximum efficiency and thus local participation could improve efficiency via their knowledge of the domestic market. This earlier estimation examined only domestic firms in the electronics industry, so neither the testing of the ownership variable nor testing the correlation between foreign entry and local firms' performance is possible.

As for the other two factors, only the size factor is significantly correlated with cost efficiency in Taiwan's electronics industry. The Spearman's rank correlation between the efficiency effect and age of a firm was insignificant and negative for all three sample sets. That age of firm had no explanatory power in respect of cost efficiency can probably be attributed to the short product-cycle for electronics. The results illustrate that improvement in efficiency is closely related to the expansion of operations, but is unrelated to experience in production. Since firms could increase their output by either increasing the number of workers or by improving labour quality, determination of which factor affected efficiency needs further examination and more detailed data. However, the relationship between the growth of number of employees and the efficiency effect for each time period was not significantly correlated, suggesting that a higher productive efficiency could be gained with or without an increase in workers, and that an increase in cost efficiency might therefore be ascribed to an improvement in labour quality. The results emphasise the importance of labour mobility, because it is the most efficient and quickest way of recruiting skilled labour and increasing productivity in a short period.

The available data provide no information by which to measure labour quality changes, except labour productivity growth. Even though it is not satisfactory, as noted in Chapter 5, to use labour productivity growth as an index for labour quality changes, it is the only choice available here. When testing the correlation between labour productivity growth (defined as the growth of output per worker) and efficiency growth, the Spearman's rank correlation coefficients were 0.6996, 0.6936 and 0.6736, respectively. The significant coefficients suggests that the hypothesis of labour quality improvement can be accepted. Although no data were available to measure labour mobility among firms, the training activities and labour turnover of foreign subsidiaries has been recognised as one of the most effective means of quickly evening up the labour quality. The test results imply that there were spillovers via labour mobility which improved efficiency in production.

Technicians or workers in Taiwan's electronics industry formerly employed by foreign subsidiaries frequently exploited their entrepreneurship, beginning small businesses after a few years' learning and training. With minor modifications, they applied the technology acquired through their experience in foreign firms to develop local capacity to produce differentiated products and establish their own competitiveness in the market. In general, the size of these businesses was small at first, because it was difficult for them to access the financial market. Financial constraints limited their investment in R&D, and they had to acquire new technology from outside their firms to make progress. The most common and efficient way for them to acquire new technology was to recruit trained personnel from the market, mainly from foreign subsidiaries. These circumstances are consistent with the results, which reveal an insignificant age effect and significant economies of scale and labour quality effects in the improvement of cost efficiency.

In summary, the firm-level decomposition of TFP growth leads to conclusions similar to those in Chapter 5, namely, that the size of operation contributes significantly to TFP growth both in firm-level and for industrial level analysis. However, this analysis also demonstrates that the efficiency effect contributed to TFP growth in Taiwan's electronics industry. The examination of the sources of cost efficiency reveals strong correlation with scale factors and labour productivity growth, and no significant relationship with the age of a firm. The decomposition of TFP growth provides more evidence of the existence of spillovers in Taiwan's electronics industry beyond the scale factor—which was the principal source of productivity improvement identified in the previous chapter.

Conclusion

This review of the development of Taiwan's electronics industry reveals significant demonstration effects from the establishment of foreign subsidiaries. These effects accelerated the development of the electronics industry through technology diffusion, even though the industry attempted to pursue independence in technology development after its early rapid growth. The ability to pursue technological independence can also be attributed partly to the contribution of foreign direct investment in constructing a solid industrial foundation for this industry.

Decomposition of TFP growth provides evidence of the existence of spillovers resulting from the presence of foreign capital. Stochastic cost frontier analysis was used to measure the effect of technical efficiency and technological progress. Use of the frontier method is increasingly widespread, not only because of its ability to interpret the efficiency of firms, but also because it is consistent with economic theory that states that optimising behaviour is the objective of firms. A composite disturbance specification is assumed in the frontier model: a symmetric random specification caught those factors which firms cannot control and a truncated (half) normal disturbance which firms can try to improve.

The most flexible functional form, the translog cost function, was used in the empirical study. In addition, the share equations were also included to form the system estimation to provide additional information. The maximum likelihood technique was applied to estimate this non-linear translog cost system.

The empirical results provide evidence of the existence of spillovers through the effect of an improvement in labour quality on cost efficiency in production. Better labour quality can be achieved in many ways; for instance, though education, learning-by-doing, or labour turnover. Education has long-term effects which need a longer time series analysis to examine thoroughly. Learning-by-doing results in better technical efficiency, as can labour mobility, particularly when accompanied by a positive and significant scale effect. The opportunity of learning-by-doing comes from expansion of the market which, in turn, can be attributed to the beneficial effect of foreign direct investment—providing information and knowledge about relevant markets. An improvement in cost efficiency implies that local firms caught up to foreign firms, and their negative technological progress represents the effort they put into adjusting technology.

Here, as elsewhere in the literature, the existence of spillovers can only be indirectly identified. However, the firm-level analysis makes clear that local firms improved cost efficiency over time and there was a trend towards a shrinking of the technological gap between local and foreign firms. These results extend the conclusions from earlier studies based on cross sectional analysis. They suggest that foreign direct investment does indeed generate spillovers to the domestic market which were quite significant in the Taiwanese electronics industry.

7 Conclusion and Policy Implications

The spillover effects of foreign direct investment have been discussed extensively in the literature. When foreign firms undertake overseas investment, they not only provide capital that is scarce, especially in less developed countries; they also bring superior technology and information which are desired by host countries. Besides these direct contributions, the entry of foreign firms may also generate externalities, including increased competition, human capital accumulation, accelerated technology transfer, and linkages to domestic markets. Obviously these externalities can improve the productive efficiency of indigenous firms. Hence, the inflow of foreign capital can be considered as a source for upgrading technical know-how and narrowing the technological gap between local firms and foreign firms. It may be possible for local firms to catch up with foreign firms in terms of technological capabilities if the spillovers are strong enough. For these reasons, there has been a long history in many developing countries of stimulating foreign direct investment, for instance, by means of highly protective trade barriers and preferential financial treatment.

On the other hand, traditional economic models, such as the North-South model, the Heckscher-Ohlin trade model, and economic development models, tend to neglect these benefits. The explanation for this is twofold. First, it is almost impossible to quantify externalities because there are too many channels through which benefit is generated and no easily measurable economic phenomena whereby they can be accurately represented. The gains to the host country depend on the technological gap between foreign firms and local firms, labour quality, the degree of competitiveness in the market, and the capacity and willingness of indigenous firms to adapt new technology. In general, a narrower technological gap, higher labour quality, intense market competition, and aggressive adoption of new technology encourage larger spillovers to host countries. All these are highly qualitative factors and their character underlines the difficulty in empirically identifying the scale or importance of spillover effects.

Another reason for neglect of spillover effects in the literature is that most models concentrate on analysing the response of the host country to the benefits of spillovers. The reaction of foreign firms in the presence of spillovers has been ignored. The lack of consideration of this issue increases the difficulty of designing a model because part of the picture is missing. For instance, foreign firms facing the threat of technological catch-up are likely to behave strategically in transferring technology.

This thesis has attempted to rectify this deficiency in the literature by incorporating the responses of foreign firms to the spillover effects, and by empirically testing the existence of externalities via analysis of productivity. The major findings relating to the strategic behaviour of foreign firms are as follows.

First, protective tariff barriers may be ineffective in attracting the inflow of foreign capital if spillover effects are likely to be large. When there are spillover effects, foreign direct investment is always beneficial to the recipient country and host governments generally wish to attract foreign direct investment and extract the largest possible benefits in order to accelerate economic development. At the same time, the decision of foreign firms as to whether to undertake foreign investment or to export to a country depends not only on tariff policy in the host country; if foreign firms foresee that local firms might catch up with them, they may prefer to continue to export, instead of investing in the target market, to avoid losing the competitive advantage of technologies and information. High tariff policy alone may not be a sufficient inducement to attract foreign investment if spillover effects are large, and if alternative strategies are feasible.

Secondly, in the presence of spillovers, the best strategic response by foreign firms in maintaining their competitive power in a host market is to transfer technology continually. Since the profits of foreign firms are lower when benefits are leaked to local firms—and are even lower when local firms put effort into utilising externalities—dynamic technology transfer is likely to be the best way to maintain a competitive edge and avoid being overtaken by local firms in the host market.

The nature and prevalence of spillovers explains both the interest of developing countries in attracting foreign investment and the way in which the strategic behaviour of foreign firms multiplies those benefits.

The strategic behaviour of foreign firms outlined here is premised on the existence of spillover effects. But there are few studies of spillovers in the literature because of both conceptual and data problems in identifying them. Thus the second part of the thesis sought to test for the existence of spillovers. The tests use Taiwanese data to investigate the contribution of foreign direct investment to the Taiwanese economy, particularly through establishing the existence of spillovers.

The success of the Taiwanese government in attracting foreign capital during the past four decades can be attributed to the effort that the government put into establishing an attractive investment environment for foreigners, including stabilising the foreign currency and the financial market, liberalising trade, and establishing export processing zones in order to lessen search, plant and other pre-operational costs for overseas investments. Creating a good investment climate and a liberalised market appear to have been effective methods of inducing foreign direct investment in

Taiwan. Chapter 3 confirmed that the penetration of foreign direct investment, on average, contributed to Taiwan's economic development by providing technology, creating job opportunities, compensating for capital and foreign exchange shortages, and assisting in industrial restructuring. The argument in Chapter 3 provided some evidence that foreign subsidiaries adopted new strategies after 1980 in respect of employment, technology, material sourcing and marketing, in the face of growing competition by local firms.

The process of catching-up by local firms provides indirect evidence of the existence of spillovers as a result of foreign entry. If the performance of foreign subsidiaries is indistinguishable from that of local firms, the impact of foreign direct investment is likely to be limited. Chapter 4 detailed the significance of the differences in the performance of foreign firms over local firms.

Foreign ownership does influence performance. Foreign-owned firms are much larger in size, they are export-oriented, they have higher labour productivity, and they use more capital-intensive technology than their local counterparts. The higher level of their labour productivity might be attributable to the relatively capital- and skill-intensive technology they employ and their greater technical efficiency in production. The data in Chapter 4 demonstrated the potential for spillovers from foreign firms to Taiwan's economic development.

The effects of foreign direct investment on local firms were then analysed systematically. Spillovers arise from the fact foreign subsidiaries may serve as an effective force for competition; they impel higher technical efficiency, and they may speed the transfer of new technology in the host market. Total factor productivity therefore appears to be an appropriate index for representing the improvement in productive efficiency due to spillovers. TFP growth is measured by output changes after taking into account the changes in factors input. Alternatively, TFP growth emerges as a residual in measuring the contribution of factor inputs growth to output growth. The unexplained changes in output derive from technological progress, technical efficiency, labour quality changes and other qualitative changes in production processes. Since spillovers can improve the productive efficiency of local firms through improving labour quality changes, increased competitiveness, technological progress and technical efficiency, the measurement of TFP growth is probably the best index whereby to measure these externalities. The hypothesis of the empirical study is that the growth of total factor productivity is a function of the presence of foreign capital.

The empirical study set out in Chapter 5 led to four main conclusions. The entry of foreign capital is positively correlated with increased productive efficiency across industries in Taiwan's manufacturing sector. The growth in the stock of foreign capital is a relatively unimportant factor compared with output growth. The entry of foreign firms appears to push local firms to operate in a more efficient manner, technologically or technically, thereby raising productivity. The adjustment costs in adapting new technology or the costs of the exit of inefficient firms may be detrimental to productivity growth.

Two methods were employed to decompose TFP growth and examine its sources. One methodology included the stock of foreign capital, representing the scale of spillovers and the degree of penetration of foreign firms, as a dependent variable in the cost function in deriving the decomposition. TFP growth was decomposed into a scale effect and a foreign penetration effect. This method was applied in industrial level analysis of Taiwan's manufacturing sector.

The first methodology produced three main findings. Foreign direct investment has an ambiguous effect on productivity. Enlargement of the size of operation is a dominant factor in explaining productivity growth for the majority of Taiwan's industries. The results indicate that scale economies are associated with foreign direct investment in contributing to productivity growth. The stock of foreign capital in the host market, defined as the aggregation of foreign capital from each firm's book value, cannot alone explain productivity growth.

Two weaknesses in this analysis need to be underlined. Spillover effects are not contemporaneous with the stock of foreign capital in the market, and their diffusion across industries is varied. A longer time-series analysis of each industry is needed to obtain more accurate results. In addition, the variable of stock of foreign capital probably needs to be redefined as depreciation rates and capital utilisation rates could not be taken into account when the stock of foreign capital is defined as the accumulated book value of foreign capital, as in this study. Hence, a better indicator to represent the stock of foreign capital is necessary in future research.

The second methodology was developed by Bauer (1990). Production frontier analysis was employed to further decompose TFP growth into a scale effect, technological progress effect, technical efficiency effect and price effect. This method was applied to test the potential for catching-up by local firms in Taiwan's electronics industry.

There were three main findings from this firm-level analysis. Local firms improved their cost efficiency over time and there was a trend towards shrinking of the technological gap between local and foreign firms. Cost efficiency in local firms was the result of the improvement in labour quality. Labour quality changes were obtained through the learning-by-doing effect and the mobility of skilled labour, and foreign direct investment contributed importantly in both ways. Apart from this indirect evidence of spillovers, the study also found that indigenous firms put effort into adapting and learning new technologies, or know-how by high adjustment cost or potential output quality changes.

In summary, the thesis provides some evidence of spillover effects from foreign direct investment in the Taiwan economy, particularly in the electronics industry. There is also evidence of the way in which local firms catch-up to foreign firms in terms of technological and productive efficiency and pose a competitive threat to them through this process.

Policy implications

These findings indicate that foreign direct investment contributed to the development of Taiwan's manufacturing sector and particularly the electronics industry. This might suggest that developing countries should adopt preferential policies, such as tax advantages, subsidies or related financial inducements, to attract the inflow of foreign capital and extract maximal spillover effects. Preferential foreign direct investment policy is certainly welcomed by foreign firms, but it also leads to distortions in resource allocation and reductions in the national welfare of the host economy. If foreign firms were able to extract the entire value of techniques transferred to host markets, there would be no need for any intervention by the host government. The trade-off relation between distortions and spillovers is a crucial issue for policy makers, particularly in evaluating the magnitude of spillover effects. This may be one reason for the similarity of the preferential terms for foreign direct investment policy offered by many developing countries. An alternative policy concentrating on the creating of a favourable investment environment is, more generally, to be preferred.

Foreign direct investment policy in Taiwan has succeeded in attracting foreign capital inflow and utilising spillover effects in the past. The findings here suggest that Taiwan's success was not by chance, and can be attributed to the establishment of a favourable investment environment, in particular the effort put into raising labour quality.

Good labour quality has commonly been appraised as the most decisive factor in motivating foreign direct investment. In Taiwan, much effort was directed to accelerate the accumulation of human capital, especially through education and vocational training.

There was an effort by individuals to accumulate knowledge through schooling. This effort reduced the level of illiteracy in the population from 42 per cent in 1952 to 7 per cent in 1990. The ratio of the population in higher education increased from about 2 per cent in the 1960s to 11 per cent in 1990; the ratio of those in secondary education rose from 10 per cent in 1960 to 46 per cent in 1990. Formal schooling is an investment in human capital and is designed to satisfy long-term demands in the labour market.

Entrepreneurs exerted themselves in developing and exploiting entrepreneurship and training programs. Many Taiwanese started their own businesses. There was a rapid growth in the number of firms and a very high percentage of small firms in the manufacturing sector. The rush of indigenous firms into the market increased competition which in turn pushed firms to explore and absorb all sources of information, technology, know-how and marketing, and to improve efficiency. Foreign firms demonstrated the best ways to reduce information costs for those local firms willing to watch and learn. Enterprises also developed training programs. Many private enterprise training programs were incorporated into vocational schools, particularly before 1974, when training programs were sponsored by the National Vocational Training Fund and financed by a payroll tax of 1.5 per cent.

The Taiwanese government established an educational infrastructure and a favourable investment environment through education subsidies, vocational training, and preferential loans to businesses which developed training programs. The per capita cost of students below junior high school level was below NT$40,000 in 1990-91, and NT$66,000-78,000 for senior high school and vocational school, but up to NT$190,000 for university and college students. The greater per-capita investment for higher level of education provides incentives to pursue higher education, and shows that Taiwan has invested heavily in education. Investment in education is an investment for the economy. Vocational training, on the other hand, provides opportunities for unskilled labour to acquire skills, or re-training required for job-shifting.

Education and vocational training are two major sources of human capital accumulation. These investments are not only fundamental to the improvement of labour quality, their complementarity also accelerates human capital accumulation. The differences between vocational training and education are twofold: vocational training supplies the immediate needs of the labour market, while education satisfies labour demand in the long run. Vocational training includes general and specific training, but education involves only general training. The training provided by private enterprise is generally referred to as specific training, yet the dissemination of this knowledge diminishes its specificity. Labour mobility is then a major channel for transferring knowledge and increasing the productivity of the recruiting firm. Labour mobility from foreign to local firms is thus an important source of spillover effects.

It is not clear whether the amount and the allocation of investment in education in Taiwan provides an appropriate model for other developing countries, but it appears that there has not been a major deficiency of either high-level or manual skills during the course of Taiwan's development. More specifically, the pattern of vocational training adopted by Taiwan—a mixture of public and private enterprise sponsored training, and on-the-job training—seems to have worked well. A large increase in supply of professional, technical, and skilled labour was achieved within a short period. High labour quality improves efficiency in adapting technology from foreign firms, and thus encourages shrinkage of the technological gap between local and foreign firms, and with the other countries.

Since vocational training addresses more immediate changes in the labour markets, vocational training schemes need to keep pace with market demand. A crucial issue for policy makers is to manage and utilise sources of information on the labour market, such as distribution, kind of occupation, unemployment, size of firm, number of employees, wages, working hours and labour mobility in the labour market, otherwise a surplus of particular skills may be created. The establishment of a thorough information network related to the labour force and the labour market can reduce the search costs for either employers or employees and improve the efficiency of the allocation of workforce. In addition, the redundant investment in training can be avoided and even replace a new training program which accelerates human capital accumulation. As a consequence, a favourable labour market is established to reduce the risk of foreignness in the host country and to attract foreign direct investment.

As in the case of any research, the present work has limitations. The main limitations arise from gaps in the data. The current study does not clearly distinguish the sources of efficiency improvement in local firms. Labour quality changes should improve the cost efficiency of firms, but learning-by-doing and adapting new technology could also increase productive efficiency. Although all of these factors can be attributed to foreign firms' training, demonstrating and transferring activities, being able to quantify the statistical significance of each factor would help in obtaining a better understanding of the nature and magnitude of spillover effects and in constructing a more satisfactory variable for measuring such effects in empirical study. One method would be to conduct a survey of both local and foreign firms to obtain data on skilled labour turnover, the learning ability of the domestic firms, the technological gap between foreign and local firms, and the process of technology transfer from foreign firms, all of which would complement the findings of this study.

Taiwan has often been referred to as an example of successful economic development. The inflow of foreign direct investment certainly played a significant role in promoting the prosperity of the economy. Foreign firms created employment for the surplus labour force released from the traditional agricultural sector, and also introduced into Taiwan's economy new technologies, technical know-how and skills.

This thesis also provides evidence of the external benefits from the entry of foreign capital and the process whereby catching-up technologically is facilitated by foreign direct investment. Research on spillover effects from foreign direct investment is still only in its infancy and many important issues, of course, remain unexplored.

APPENDIXES

Appendix 5.A The derivation of conventional TFP index

Assuming the existence of a linear homogenous production function:

$$Q = F(K, L, T)$$

where Q refers to the output, K and L are the capital and labour inputs, and T is time, representing the technical changes. Assuming that technological progress is Hicks-neutral, then the above equation can be rewritten as:

$$Q = A(T)F(K, L)$$

Totally differentiating the logarithm of this equation with respect to time, and assuming conditions of producer equilibrium and constant returns to scale, then :

$$\frac{d\ln Q}{dT} = s_k \frac{d\ln K}{dT} + s_l \frac{d\ln L}{dT} + s_T$$

where $s_T = d\ln A(T)/dT$, and s_k and s_l are the value shares of capital and labour. s_T is referred to as the index of TFP growth.

Appendix 5.B Data sources

The data required for measuring total factor productivity for each industry in Taiwan's manufacturing sector 1961-86 are the values of the two inputs, capital and labour, value-added and total output for each industry.

The sources of time series data on relating variables for each industry are:

(1) Series of real net fixed capital stock (excluded land)

Source:

- Directorate-General of Budget, Accounting and Statistics, Executive Yuan, Republic of China, *The Trend in Multifactor Productivity of Industrial Sector, Taiwan Area, Republic of China*, 1992, Taipei.

Data construction:

- As some data vary in coverage for different industries, appropriate adjustment has been done. (For instance, the precision equipment industry and miscellaneous manufacturing industries are combined into one industry). In total, 17 industries are estimated.

(2) Working hours

Source:

- Directorate-General of Budget, Accounting and Statistics, Executive Yuan, Republic of China, *Yearbook of Earning and Productivity Statistics, Taiwan Area, Republic of China*, 1992, Taipei.

Data construction:

- In order to obtain consistent data series for each industry, the chemical materials, chemical products, and plastic products industries have been combined into one industry, and the precision equipment and miscellaneous manufacturing industries into one industry.
- Working hours = employees on payrolls of manufacturing establishments*average monthly working hours*12 (* = multiply)

(3) Value-added and total output (current price)

Source:

- Directorate-General of Budget, Accounting and Statistics, Executive Yuan, Republic of China, *Gross Domestic Product and Factor Incomes by Kind of Activity*, each year, Taipei.

Data construction:

- The chemical materials, chemical products and plastic products industries have been combined into one industry, and the precision equipment and miscellaneous manufacturing industries into one industry, to arrive at 17 manufacturing industries.
- Value-added = gross domestic product minus intermediate inputs

(4) Wholesale price index

Sources:

- Directorate-General of Budget, Accounting and Statistics, Executive Yuan, Republic of China, *Commodity Price Statistics Monthly in Taiwan Area of The Republic of China*, 1974, 1977, 1983, 1988 and 1992, Taipei.
- Directorate-General of Budget, Accounting and Statistics, Taiwan Provincial Government and Directorate-General of Budget, Accounting and Statistics, *Commodity Price Statistics Monthly in Taiwan Area of The Republic of China*. 1970, Taipei.
- Directorate-General of Budget, Accounting and Statistics, Taiwan Provincial Government, *Commodity Price Statistics Monthly of Taiwan Province*, 1967, Taipei.

Data construction:

- 1976 is the base year for all data series. Nominal value-added is deflated by whole price index to yield real value-added for each industry.

(5) Labour and capital shares of manufacturing

Sources:

- Directorate-General of Budget, Accounting and Statistics, Executive Yuan, Republic of China, *The Trend in Multifactor Productivity of Industrial Sector — Taiwan Area, Republic of China*, 1992, Taipei.
- Directorate-General of Budget, Accounting and Statistics, Executive Yuan, Republic of China, *Gross Domestic Product and Factor Incomes by Kind of Activity*, each year, Taipei.

Data construction:

- Labour and capital shares for 1978-86 are compiled from the first data source, whilst 1961-77 are compiled as follows:

  Since the total of capital and labour shares equals 1, the only calculation to the share is to calculate the percentage of labour. The percentage share for capital can be derived by 1 minus the percentage share of labour.

Based on above framework, the total cost can be defined as:

Total cost = Nominal Output (PQ)

= Gross Domestic Product (GDP) - Indirect Tax + Subsidy

For simplicity, the labour compensation refers to compensation for employees as shown in the national income account (the second data source). This definition modifies the calculation done in the first data source, where labour compensation is defined as the adjusted compensation for employment population, ie. compensation for employees plus the average compensation per person multiplied by the difference of number of employment population and number of employees.

The percentage share for labour is then derived by dividing the labour compensation into the total cost (nominal output).

- The precision equipment industry and miscellaneous manufacturing industries have been combined into one industry. A total of 17 industries is estimated.

Appendix 5.C Stock of foreign capital (NT$1,000)

	Food	Textile	Clothing & footwear	Timber	Pulp & paper	Leather & fur
1975	319316	1707001	466654	137308	124409	50321
1976	454378	2160108	528304	330337	120525	59163
1977	486309	2509544	564384	276097	183648	64619
1978	526526	2608844	614444	299024	222931	62196
1979	938084	2680917	712725	456833	260109	62146
1980	1010142	3003275	828133	427651	257875	75165
1981	930963	3231564	869949	433835	258211	108388
1982	1168537	3152510	802990	568152	273512	104743
1983	1340175	3631406	876959	409682	321742	82300
1984	2069172	3154683	904311	466523	459814	134650
1985	2275812	3317722	947401	492917	475583	186727
1986	2496816	4316244	958675	462206	637692	156894
1987	2528095	3920654	1208710	517176	823341	143524
1988	4058515	4816459	606828	478121	505351	156020
1989	4571023	5225832	779854	480586	624483	142500
1990	5714085	4102771	856571	393934	762275	208473
1991	5633564	4188455	941962	573681	1084799	213080
1992	5866563	4505189	614391	490263	1121036	123262

	Plastic & rubber	Chemical	Minerals	Metals	Machinery	Electronics
1975	554836	1582874	522983	701646	866239	5349239
1976	671347	2097745	499320	820603	1107951	6287604
1977	748695	2670335	561631	912946	1404658	7387519
1978	1022154	3997589	556150	1180029	1544024	8620400
1979	1111689	6280317	426626	1486119	1857899	10013902
1980	1426373	7144876	507716	1757690	2280326	11802320
1981	1689251	7824130	643538	2020962	2371879	13436160
1982	1925561	7307503	1167404	2116368	3774702	15086711
1983	2158243	6891157	1170085	2718197	3086946	17547468
1984	2182614	9250185	1368429	3226640	4731827	21555064
1985	2562725	10269363	1381653	4723365	4801154	24198771
1986	3077998	11274318	1873655	4043419	7211870	28205073
1987	3464841	13661840	1981788	6397305	11221707	35764878
1988	2578112	16512810	2422769	7154143	11783757	31052941
1989	4701832	24666975	2682483	9214598	13121630	38023185
1990	6231325	29526828	2860174	11053594	13608679	47465660
1991	4432255	33839287	3139536	13677262	16700784	48774882
1992	4115319	29750205	2884962	13634041	17231262	48379949

Note: industry classifications:

Food = food and beverage processing industry
Textile = textile industry
Clothing & footwear = garment and footwear industry
Timber = lumber and bamboo products industry
Pulp & paper = pulp and paper products industry
Leather & fur = leather and fur products industry
Plastic & rubber = plastic and rubber products industry
Chemical = chemical industry
Minerals = non-metallic minerals industry
Metals = basic metals and metal products industry
Machinery = machinery equipment and instrument industry
Electronics = electronics and electric appliances industry

Source: Calculated from the survey data of Investment Commission, Ministry of Economic Affairs, 1975-1989, Taipei, Taiwan.

Appendix 5.D Linkage of value-added to total output measured TFP growth

The relationship between total factor productivity measured by value-added and total output is as follows:

Suppose A represents the TFP measured by total output, A is defined as

$$d\ln A = d\ln Y - S_K d\ln K - S_L d\ln L - S_M d\ln M - S_E d\ln E \quad (1)$$

where Y is the level of total output, M is the material input and E is the energy input. On the other hand, let B represent the TFP measured by value-added (the factor inputs include only capital and labour), B is defined as

$$d\ln B = d\ln V - (1-\alpha)d\ln K - \alpha d\ln L \quad (2)$$

where V is the level of value-added, α is the value share of labour to value-added ($\alpha = W/V$), and $1-\alpha$ is the value share of capital to value-added ($1-\alpha = R/V$).

Since total output is value-added plus intermediate inputs, changes in level of output are thus equivalent to the weighted changes in value-added plus weighted changes in intermediate inputs. Therefore

$$Y = f(V, M, E)$$

$$d\ln Y = S_V d\ln V + S_M d\ln M + S_E d\ln E \quad (3)$$

where S_V is the share of value-added to total output ($S_V = V/Y$). Rearranging equation (3) and substituting into equation (2) yields

$$d\ln B = \frac{d\ln Y - S_M \ln M - S_E \ln E}{S_V} - (1-\alpha)d\ln K - \alpha d\ln L \quad (4)$$

Dividing equation (1) by equation (4),

$$\frac{d\ln A}{d\ln B} = \frac{d\ln Y - S_K d\ln K - S_L d\ln L - S_M d\ln M - S_E d\ln E}{\frac{d\ln Y - S_M d\ln M - S_E d\ln E}{S_V} - (1-\alpha)d\ln K - \alpha d\ln L} \quad (5)$$

Multiply S_V to denominator and numerator on left hand,

$$\frac{d\ln A}{d\ln B} = \frac{S_V[d\ln Y - S_K d\ln K - S_L d\ln L - S_M d\ln M - S_E d\ln E]}{d\ln Y - S_M d\ln M - S_E d\ln E - S_V(1-\alpha)d\ln K - S_V\alpha d\ln L} \quad (6)$$

As $S_V = V/Y; (1-\alpha) = R/V; \alpha = W/V$, it means

$S_V(1-\alpha) = R/Y = S_K$ and $S_V\alpha = W/Y = S_L$

Substituting into equation (6) derives

$$\frac{d\ln A}{d\ln B} = S_V < 1$$

TFP growth measured by level of output is proportionately smaller than that measured by value-added, and the proportion is equal to the share of value-added to level of output.

Appendix 5.E Share of foreign employment by industry

	Food	Textiles	Apparel	Leather	Lumber	Pulp & paper	Chemical products	Non-metallic	Metal	Machinery	Electronics
1976	4.69	8.79	21.82	16.48	7.36	1.93	13.81	11.70	9.09	14.06	60.13
1977	5.16	9.78	20.52	11.62	6.76	2.60	13.23	9.67	8.76	18.31	55.54
1978	5.11	9.51	18.79	12.10	6.29	3.36	13.10	9.26	8.23	19.41	51.56
1979	4.93	12.82	19.14	9.92	5.26	3.26	13.31	10.07	7.81	21.73	53.59
1980	4.57	12.14	18.97	8.43	3.78	3.47	12.64	10.17	7.50	20.19	49.08
1981	4.22	11.99	16.09	8.87	3.88	3.18	12.24	9.68	6.84	18.01	49.61
1982	3.87	9.79	13.05	7.45	2.25	2.74	11.17	7.98	5.33	17.69	46.98
1983	3.64	9.18	13.39	4.80	2.03	2.02	11.53	7.72	5.22	17.90	47.08
1984	3.73	8.85	12.14	4.95	2.32	1.93	10.30	8.24	5.04	18.57	38.74
1985	3.80	6.92	10.87	5.67	1.62	2.18	8.60	9.69	5.17	15.72	36.57
1986	4.20	7.00	9.22	4.74	1.64	2.92	7.96	7.23	4.91	18.48	35.82
1987	4.04	7.33	6.46	4.99	1.29	2.96	8.89	7.33	5.10	20.00	33.75
1988	4.96	7.79	7.02	4.19	1.04	2.70	8.34	8.65	5.44	20.21	29.28
1989	5.26	8.66	7.18	4.90	1.14	2.93	8.96	8.84	5.89	19.44	30.05
1990	6.48	8.59	6.71	4.53	1.26	6.36	13.41	8.84	6.65	19.63	29.21
1991	8.04	9.24	6.98	5.75	1.04	7.21	15.06	8.48	6.56	19.17	28.80

Source: (i) Calculated from the survey data of Investment Commission, Ministry of Economic Affairs, 1975-1989, Taipei, Taiwan.
(ii) Directorate-General of Budget, Accounting and Statistics, Executive Yuan, Republic of China, *Yearbook of Earning and Productivity Statistics, Taiwan Area, Republic of China*, 1986, 1992. Taipei.

Appendix 6.A The derivation of capital service prices and capital expenditure

The service price of capital is measured by using the method originally described by Christensen and Jorgenson (1969). In calculating the service price of capital, the rate of depreciation for plants is taken to be 0.513, and for machinery and equipment, 0.1325. Both figures are used by Jorgenson and Griliches (1967) in constructing capital data for the US manufacturing industry. The rate of depreciation for transportation vehicles is taken to be 0.2537, which is taken from Hulten and Wykoff's (1981) estimate of the rate of economic depreciation for trucks, buses and truck trailers. The rate of depreciation for land is assumed to be zero.

Appendix 6.B TFP decomposition

(1) TFP decomposition (1986)

Firm	TFP Growth	Scale Effect	Efficiency Effect	Technological Effect	Price Effect
1	0.0343	0.1071	0.0900	-0.1237	-0.0392
2	-0.3396	-0.1807	-0.0767	-0.1237	0.0415
3	-0.2024	-0.1854	0.0461	-0.1237	0.0606
4	0.0052	0.0808	0.0355	-0.1237	0.0126
5	-0.1212	0.0662	-0.0672	-0.1237	0.0035
6	-0.1669	-0.1038	0.0776	-0.1237	-0.0170
7	-0.1394	-0.0312	0.0198	-0.1237	-0.0044
8	-0.2706	-0.1553	-0.0461	-0.1237	0.0545
9	0.0477	0.1859	0.0434	-0.1237	-0.0579
10	0.0390	0.4547	0.0784	-0.1237	-0.3704
11	-0.3652	-0.1488	-0.0942	-0.1237	0.0016
12	-0.2533	-0.1113	0.0453	-0.1237	-0.0636
13	-0.0799	0.1007	-0.0743	-0.1237	0.0175
14	1.5501	1.4110	0.0655	-0.1237	0.1973
15	0.0489	0.1574	0.0136	-0.1237	0.0016
16	-0.2335	-0.1036	-0.0087	-0.1237	0.0025
17	-0.2529	-0.1383	0.0192	-0.1237	-0.0102
18	0.0183	0.1627	-0.0452	-0.1237	0.0245
19	-0.0933	-0.0075	-0.0287	-0.1237	0.0667
20	0.7367	0.7993	0.0797	-0.1237	-0.0186
21	0.0371	0.1828	-0.0283	-0.1237	0.0063
22	-0.1787	-0.0953	0.0074	-0.1237	0.0329
23	-0.3581	-0.1948	-0.0138	-0.1237	-0.0258
24	-0.1531	-0.1031	-0.0158	-0.1237	0.0895
25	0.0995	0.3059	-0.0520	-0.1237	-0.0307
26	0.1024	0.0090	0.1296	-0.1237	0.0875
27	-0.2170	-0.0932	-0.0401	-0.1237	0.0400
28	-0.6071	-0.2792	-0.1244	-0.1237	-0.0798
29	0.0247	0.1494	0.0020	-0.1237	-0.0029
30	-0.2074	0.0633	-0.0102	-0.1237	-0.1369
31	2.1811	2.2116	0.1636	-0.1237	-0.0703
32	-0.0124	0.1976	0.0055	-0.1237	-0.0917
33	-0.2736	-0.2158	-0.0186	-0.1237	0.0845
34	-0.0860	0.0605	-0.0821	-0.1237	0.0593
35	1.0600	1.1645	0.1550	-0.1237	-0.1358
36	-0.1821	-0.0424	0.0207	-0.1237	-0.0367
37	-0.4585	-0.2480	-0.1437	-0.1237	0.0569
38	1.0890	0.6875	0.0507	-0.1237	0.4745
39	-0.4763	-0.2859	-0.0490	-0.1237	-0.0177
40	-0.1765	-0.1304	0.0615	-0.1237	0.0162
41	-0.1266	-0.2049	0.1285	-0.1237	0.0735
42	-1.3093	-0.0594	0.0823	-0.1237	-1.2085
43	-0.3271	-0.1618	-0.1039	-0.1237	0.0623
44	0.6476	0.6697	0.1186	-0.1237	-0.0171
45	-0.4860	-0.2743	-0.0537	-0.1237	-0.0344
46	0.4582	0.4590	0.1857	-0.1237	-0.0629
47	-0.1783	-0.0165	0.0884	-0.1237	-0.1265

48	-0.2500	-0.1228	-0.0076	-0.1237	0.0041
49	-0.3185	-0.2074	0.0157	-0.1237	-0.0031
50	-0.3982	-0.2334	-0.0598	-0.1237	0.0187
51	0.3749	0.1341	0.0665	-0.1237	0.2980
52	0.0493	0.2226	-0.0334	-0.1237	-0.0162
53	0.5532	0.5995	0.0826	-0.1237	-0.0052
54	-0.4001	-0.0778	-0.1676	-0.1237	-0.0310
55	-0.2136	-0.0765	0.0705	-0.1237	-0.0839
56	1.9771	1.9827	0.1551	-0.1237	-0.0370
57	-0.0900	-0.0481	0.0681	-0.1237	0.0137
58	-0.1684	-0.1290	0.1255	-0.1237	-0.0411
59	0.1134	0.1108	0.0153	-0.1237	0.1110
60	-0.4864	-0.2762	-0.0190	-0.1237	-0.0675
61	-0.2879	-0.1036	-0.0767	-0.1237	0.0161
62	-0.5196	-0.2923	-0.1674	-0.1237	0.0638
63	0.0868	0.0955	0.1593	-0.1237	-0.0443
64	-0.1973	-0.0597	-0.0053	-0.1237	-0.0086
65	-0.2616	-0.1699	0.0540	-0.1237	-0.0220
66	-0.1839	-0.0237	0.0062	-0.1237	-0.0427
67	-0.0733	0.1520	0.0282	-0.1237	-0.1298
68	-0.0287	0.0839	0.0391	-0.1237	-0.0280
69	-0.0058	0.0458	0.0185	-0.1237	0.0537
70	0.0432	0.1173	0.0264	-0.1237	0.0232
71	-0.2988	-0.1246	-0.0435	-0.1237	-0.0071
72	0.0121	0.0615	0.0569	-0.1237	0.0175
73	0.2201	0.2910	0.0504	-0.1237	0.0024
74	-0.7701	-0.2813	-0.2042	-0.1237	-0.1609
75	0.7706	0.7446	0.0626	-0.1237	0.0872
76	-0.3029	-0.2069	0.0089	-0.1237	0.0188
77	0.3240	0.3732	-0.0201	-0.1237	0.0946
78	-0.3958	-0.2110	-0.0263	-0.1237	-0.0348
79	-0.3340	-0.1515	0.1248	-0.1237	-0.1836
80	0.0710	0.1789	0.0525	-0.1237	-0.0367
81	1.6049	1.6865	0.0499	-0.1237	-0.0077
82	-0.1609	-0.0800	0.0444	-0.1237	-0.0016
83	0.0071	0.0422	0.0938	-0.1237	-0.0053
84	-0.3998	-0.2082	0.0555	-0.1237	-0.1234
85	-0.2749	-0.1911	0.0324	-0.1237	0.0075
86	-0.2174	-0.0963	0.0367	-0.1237	-0.0342
87	-0.0662	-0.1269	0.0314	-0.1237	0.1531
88	0.1549	0.1409	0.0774	-0.1237	0.0603
89	-0.3072	-0.1656	0.0183	-0.1237	-0.0362
90	0.7598	0.7489	0.3111	-0.1237	-0.1765
91	-0.4488	-0.2617	-0.0589	-0.1237	-0.0045
92	0.7998	0.7509	0.0831	-0.1237	0.0894
93	-0.3127	-0.1326	-0.1175	-0.1237	0.0611
94	0.0153	0.1275	0.0263	-0.1237	-0.0148
95	0.5261	0.4552	0.0164	-0.1237	0.1782
96	-0.1356	-0.0199	-0.0676	-0.1237	0.0756
97	-0.1770	-0.1408	0.0855	-0.1237	0.0020
98	-0.3344	-0.0652	-0.1434	-0.1237	-0.0021
99	-0.1352	-0.0416	-0.0146	-0.1237	0.0447
100	0.7734	0.6432	0.1444	-0.1237	0.1095
101	-0.2580	-0.1558	0.0138	-0.1237	0.0078
102	1.2936	1.0643	0.1223	-0.1237	0.2307

103	-0.2980	-0.1949	0.0131	-0.1237	0.0075
104	-0.1128	-0.0330	0.0517	-0.1237	-0.0078
105	-0.2255	-0.1273	-0.0274	-0.1237	0.0529
106	-0.5049	-0.2214	-0.0978	-0.1237	-0.0620
107	-0.1634	-0.1173	0.0770	-0.1237	0.0006
108	-0.3255	-0.2712	-0.0012	-0.1237	0.0706
109	-0.3895	-0.1855	-0.0181	-0.1237	-0.0621
110	-0.2891	-0.0683	-0.1426	-0.1237	0.0455
111	-0.0699	0.0181	0.0113	-0.1237	0.0244
112	-0.3636	-0.2579	-0.0292	-0.1237	0.0472
113	-0.0486	-0.0843	0.0732	-0.1237	0.0862
114	-0.1151	-0.0136	0.0964	-0.1237	-0.0743
115	-0.1726	-0.2063	0.0152	-0.1237	0.1422
116	-0.1710	-0.1414	0.0263	-0.1237	0.0678
117	0.1489	0.1520	0.0527	-0.1237	0.0679
118	-0.2497	-0.1222	0.0164	-0.1237	-0.0202
119	-0.3505	-0.2243	-0.0126	-0.1237	0.0100
120	-0.1786	0.0073	-0.0372	-0.1237	-0.0250
121	-0.3341	-0.1866	0.0071	-0.1237	-0.0309
122	0.9213	1.0237	0.0383	-0.1237	-0.0171
123	-0.1605	-0.0896	0.0508	-0.1237	0.0020
124	-0.2655	-0.0994	0.0007	-0.1237	-0.0431
125	-0.2678	-0.2104	0.0112	-0.1237	0.0551
126	0.0467	0.4722	-0.1160	-0.1237	-0.1858
127	-0.0757	0.0630	0.1069	-0.1237	-0.1219
128	-0.1713	-0.0511	0.0155	-0.1237	-0.0120
129	-0.3301	-0.0726	-0.1154	-0.1237	-0.0183
130	-0.4108	-0.1078	-0.1468	-0.1237	-0.0326
131	-0.0429	0.0256	0.0244	-0.1237	0.0309
132	-0.0698	0.0262	0.0578	-0.1237	-0.0301
133	1.2835	1.2605	0.0274	-0.1237	0.1193
134	-0.2283	-0.1013	0.0056	-0.1237	-0.0089
135	0.0675	0.0831	0.0901	-0.1237	0.0181

—continued

(2) TFP decomposition (1991)

Firm	TFP Growth	Scale Effect	Efficiency Effect	Technological Effect	Price Effect
1	0.0151	0.1389	0.0127	-0.1237	-0.0127
2	-0.5956	-0.1493	-0.0266	-0.1237	-0.2959
3	-0.0631	-0.1812	0.0717	-0.1237	0.1702
4	-0.2369	-0.0888	-0.0109	-0.1237	-0.0135
5	-0.1087	-0.0077	0.0346	-0.1237	-0.0118
6	-0.0855	-0.0787	0.1461	-0.1237	-0.0292
7	-0.0897	0.1794	-0.1000	-0.1237	-0.0454
8	-0.3836	-0.2479	-0.0098	-0.1237	-0.0023
9	-0.0059	0.1029	-0.0038	-0.1237	0.0188
10	-0.1584	0.0357	-0.0898	-0.1237	0.0194
11	-0.1903	-0.0471	-0.0435	-0.1237	0.0240
12	-0.4907	-0.1916	-0.0919	-0.1237	-0.0835
13	0.6354	0.6032	0.1645	-0.1237	-0.0086
14	6.4273	6.2959	0.1564	-0.1237	0.0986
15	-0.2339	-0.0777	-0.0160	-0.1237	-0.0165
16	-0.4007	-0.2424	0.0090	-0.1237	-0.0435
17	-0.1344	0.0404	-0.0260	-0.1237	-0.0251
18	1.3755	1.5667	-0.0351	-0.1237	-0.0324
19	-0.1754	-0.0223	0.0528	-0.1237	-0.0823
20	0.6383	0.5426	-0.0047	-0.1237	0.2240
21	-0.3536	-0.1888	-0.0645	-0.1237	0.0234
22	-0.2667	-0.0148	-0.1717	-0.1237	0.0435
23	-0.0853	0.0567	-0.0103	-0.1237	-0.0080
24	-0.5912	-0.2306	-0.1468	-0.1237	-0.0901
25	0.2348	0.0439	0.1162	-0.1237	0.1985
26	0.0236	0.1716	-0.0916	-0.1237	0.0674
27	1.4590	0.3987	0.0626	-0.1237	1.1214
28	-0.4155	-0.2245	-0.0867	-0.1237	0.0194
29	0.1341	0.3111	-0.0421	-0.1237	-0.0113
30	-0.2352	-0.1261	0.0216	-0.1237	-0.0070
31	-0.2454	-0.0584	-0.0255	-0.1237	-0.0378
32	-0.6337	-0.2845	-0.0447	-0.1237	-0.1808
33	-0.4242	-0.2927	-0.0709	-0.1237	0.0631
34	1.2010	1.3294	0.0198	-0.1237	-0.0245
35	0.1565	0.2964	0.0000	-0.1237	-0.0163
36	1.4960	1.0456	0.3649	-0.1237	0.2092
37	-0.3856	-0.2066	-0.0714	-0.1237	0.0161
38	0.6867	0.1059	0.1488	-0.1237	0.5557
39	-0.2028	-0.1617	0.0355	-0.1237	0.0471
40	0.0874	0.3134	-0.0909	-0.1237	-0.0115
41	1.5561	1.6178	0.0872	-0.1237	-0.0252
42	-0.2906	-0.1508	-0.0393	-0.1237	0.0232
43	0.1414	-0.0112	0.1634	-0.1237	0.1129
44	-0.3888	0.0009	-0.0460	-0.1237	-0.2200
45	1.0872	1.1200	0.0166	-0.1237	0.0744
46	-0.2568	-0.0615	-0.0317	-0.1237	-0.0399
47	-0.7898	-0.0817	0.0238	-0.1237	-0.6082
48	-0.3588	0.0709	-0.1512	-0.1237	-0.1548
49	4.8256	4.9678	0.0953	-0.1237	-0.1138
50	-0.3279	-0.0860	-0.1526	-0.1237	0.0344

51	-0.4070	-0.1586	-0.1597	-0.1237	0.0350
52	-0.4349	-0.1229	0.0974	-0.1237	-0.2856
53	0.4998	0.5273	0.0965	-0.1237	-0.0003
54	0.0057	0.0395	-0.0316	-0.1237	0.1215
55	0.0032	0.1242	0.0110	-0.1237	-0.0082
56	-0.2584	-0.1770	0.0472	-0.1237	-0.0049
57	-0.0597	-0.0337	0.0954	-0.1237	0.0023
58	1.0178	1.0718	0.0540	-0.1237	0.0157
59	-0.0840	-0.0096	0.0743	-0.1237	-0.0251
60	-0.3836	-0.2273	-0.0214	-0.1237	-0.0112
61	1.1492	0.2056	0.2110	-0.1237	0.8563
62	1.6744	0.8549	0.2124	-0.1237	0.7308
63	0.4423	0.3686	0.1070	-0.1237	0.0904
64	-0.3674	-0.2487	0.0057	-0.1237	-0.0008
65	2.5350	2.7801	0.2757	-0.1237	-0.3971
66	0.0883	0.1666	0.0769	-0.1237	-0.0316
67	0.2994	0.3773	-0.0026	-0.1237	0.0484
68	0.0647	0.1341	0.0691	-0.1237	-0.0148
69	-0.2077	-0.1074	0.0663	-0.1237	-0.0430
70	-0.3024	-0.1566	-0.0131	-0.1237	-0.0090
71	0.2215	0.3224	0.0053	-0.1237	0.0175
72	-0.3932	-0.0790	0.0351	-0.1237	-0.2256
73	-0.1472	-0.0489	0.0533	-0.1237	-0.0280
74	-0.2458	-0.1526	0.0256	-0.1237	0.0050
75	0.5405	0.4440	0.0558	-0.1237	0.1645
76	0.3706	0.3592	-0.0310	-0.1237	0.1661
77	0.0717	0.1329	0.0097	-0.1237	0.0528
78	-0.0370	0.0777	-0.0012	-0.1237	0.0102
79	-0.3602	-0.2585	-0.1329	-0.1237	0.1550
80	-0.2227	-0.0835	0.0057	-0.1237	-0.0211
81	-0.4591	-0.2530	0.0420	-0.1237	-0.1244
82	-0.1721	-0.1039	0.0469	-0.1237	0.0086
83	0.4746	0.5465	0.0314	-0.1237	0.0204
84	-0.0875	-0.0013	0.0813	-0.1237	-0.0437
85	-0.0175	0.2731	0.0614	-0.1237	-0.2282
86	-0.0878	0.0226	0.0244	-0.1237	-0.0111
87	-0.1799	-0.0010	-0.0536	-0.1237	-0.0016
88	-0.5722	-0.2910	-0.1496	-0.1237	-0.0078
89	-0.4533	-0.1883	-0.1847	-0.1237	0.0435
90	0.0024	0.1878	0.0805	-0.1237	-0.1423
91	-0.3199	-0.1040	-0.1277	-0.1237	0.0356
92	-0.2135	0.0083	-0.0394	-0.1237	-0.0587
93	-0.4728	-0.1773	-0.1207	-0.1237	-0.0511
94	-0.1621	-0.0456	-0.0431	-0.1237	0.0503
95	1.8991	1.9985	0.0948	-0.1237	-0.0705
96	-0.1666	0.0243	-0.0346	-0.1237	-0.0326
97	-0.3170	-0.1219	-0.1057	-0.1237	0.0343
98	-0.1760	-0.0824	0.0330	-0.1237	-0.0030
99	-0.1163	0.0149	0.0414	-0.1237	-0.0489
100	0.1116	0.0687	0.1069	-0.1237	0.0597
101	-0.1648	-0.0517	0.0446	-0.1237	-0.0341
102	-0.2675	-0.0346	-0.0806	-0.1237	-0.0285
103	-0.2119	-0.0996	0.0294	-0.1237	-0.0180
104	-0.1656	-0.0911	0.0846	-0.1237	-0.0354
105	-0.5144	-0.2740	-0.0619	-0.1237	-0.0547

106	-0.3757	-0.1834	-0.0148	-0.1237	-0.0538
107	-0.0296	0.0342	0.0276	-0.1237	0.0323
108	-0.3539	-0.2075	-0.0090	-0.1237	-0.0137
109	-0.1832	-0.0765	-0.0314	-0.1237	0.0484
110	0.3599	0.3734	0.0912	-0.1237	0.0190
111	-0.4250	-0.2491	-0.0754	-0.1237	0.0233
112	-0.0323	0.1077	0.0204	-0.1237	-0.0368
113	-0.1151	-0.0548	0.0553	-0.1237	0.0081
114	-0.0835	0.0633	-0.0027	-0.1237	-0.0204
115	-0.0932	0.0004	0.0272	-0.1237	0.0030
116	-0.1023	-0.1753	-0.0245	-0.1237	0.2212
117	0.1112	0.1553	0.0928	-0.1237	-0.0131
118	0.0548	0.1181	0.0345	-0.1237	0.0259
119	-0.3114	-0.1386	-0.0306	-0.1237	-0.0185
120	-0.0666	0.0315	0.0287	-0.1237	-0.0031
121	-0.3452	-0.2706	-0.0571	-0.1237	0.1062
122	-0.3040	-0.1641	-0.0039	-0.1237	-0.0123
123	-0.4879	-0.1810	-0.0850	-0.1237	-0.0982
124	1.4661	1.4904	0.0815	-0.1237	0.0179
125	-0.2875	-0.0479	-0.0847	-0.1237	-0.0312
126	-0.0560	0.0812	-0.0053	-0.1237	-0.0082
127	-0.1478	-0.0933	0.0477	-0.1237	0.0216
128	0.0852	0.1842	0.0495	-0.1237	-0.0248
129	0.3231	0.3416	0.1268	-0.1237	-0.0216
130	-0.2684	-0.1141	-0.0351	-0.1237	0.0045
131	-0.1929	-0.2168	0.1425	-0.1237	0.0052
132	-0.1302	-0.0136	0.0328	-0.1237	-0.0257
133	-0.2685	-0.1089	0.0128	-0.1237	-0.0487
134	-0.2086	-0.1310	0.0674	-0.1237	-0.0213
135	0.8151	0.8365	0.0835	-0.1237	0.0188

Appendix 6.C Estimation of technical efficiency

From the studies of Aigner *et al.* (1977), Jondrow, Lovell, Materov, and Schmidt (1982) and Kalirajan and Flinn (1983), the following can be analysed by the estimates of the maximum-likelihood method.

First, the ratio of the two errors of u_i and v_i (ie. λ) is 1.6050, which implies that the one-sided error u_i, which represents technical inefficiency, dominates the symmetric error v_i, which represents pure randomness. If defining $\delta = \frac{\sigma_u^2}{\sigma_u^2 + \sigma_v^2}$, the value of δ is 0.7204. This variable means that about 72 per cent of the discrepancies between the observed cost and the maximal (frontier) cost are due to technical inefficiency. In other words, the extra expenditure of observed cost from the frontier cost is primarily due to factors which are beyond the control of the firms.

Secondly, the expected value of the inefficiency can be calculated from the estimates of λ and σ. The mean technical inefficiency is $\sigma_u \sqrt{(2/\pi)}$ as in Aigner, *et al.* (1977). The estimates of $\hat{\sigma}_u^2 = 0.4228$ and thus the estimated average technical inefficiency is 0.5299, indicating about 53 per cent technical inefficiency.

Thirdly, it is possible to measure firm-specific technical efficiency by using the estimate of the expected value of u_i conditional on $\varepsilon (= u + v)$ or the mode of the condition distribution as the point estimator for u. The conditional density of u_i given ε is the ratio of the joint density function of (u, ε) to density function of ε, which can be written as

$$f(u|\varepsilon) = \frac{1}{\sqrt{2\pi\sigma_*}} \frac{1}{1-F} \exp\left[\frac{-1}{2\sigma_*^2}(u^2 - \frac{\sigma_u^2 \varepsilon}{\sigma^2})^2\right],\ u \geq 0,$$

where $\sigma_*^2 = \sigma_u^2 \sigma_v^2 / \sigma^2$. This looks like the density of $N(u_*, \sigma_*^2)$ with $u_* = \sigma_u^2 \varepsilon / \sigma^2$. From this density function, the expected value of u condition on ε is derived,

$$E(u|\varepsilon) = u_* - \sigma_* \frac{f(-u_*/\sigma_*)}{1 - F(-u_*/\sigma_*)}$$

where f and F represent the standard normal density and cumulative density function respectively, while the mode of the conditional distribution is the minimum of u_* and zero, which can be written as

$$M(u|\varepsilon) = u_* \quad \text{if } \varepsilon > 0;$$
$$= 0 \quad \text{if } \varepsilon \leq 0$$

By substituting the estimated data into the above expected value equation, firm-specific technical efficiency can be measured. Instead of presenting the technical efficiency for every individual firm, the frequency distribution is presented below.

Efficiency interval	Frequency		
	1981	1986	1991
0.1 - 0.2	1	0	0
0.2 - 0.3	1	2	1
0.3 - 0.4	9	8	8
0.4 - 0.5	21	22	23
0.5 - 0.6	33	36	33
0.6 - 0.7	38	35	42
0.7 - 0.8	16	18	23
= 1.0	16	14	5
Total observations	135	135	135

The closer the efficiency level is to 1, the higher the technical efficiency of the firm. A quite high percentage of firms maintained their technical efficiency at about the 0.5 to 0.7 level. The efficiency level was dispersed across a wider range in the early years. As a whole, the results from the two methods are similar.

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