Firm-Level Productivity and Foreign Direct Investments in Taiwan

Bee-Yan Aw
Pennsylvania State University

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Abstract

This paper examines the changing trend and structure of FDI in Taiwan and the evolution of government policy towards inward FDI. In addition, firm-level data from the Census of Manufactures in Taiwan from 1986 to 1996 is used to examine the impact of foreign ownership on overall productivity. The findings of this paper are fourfold. First, from the firm's perspective, the benefit from FDI in terms of a higher level of total factor productivity (TFP) is very strongly linked with the export activity. In fact, there is little evidence to indicate that FDI on its own directly leads to higher levels of productivity. Second, the direct benefits from FDI accrue to firms with an export history, implying that conditional on being in the export market, firms with foreign ownership have higher productivity levels than firms that do not have any export history. Third, FDI has large and significant effects on the firm's TFP growth and future survival. Finally, there is also some evidence that the presence of foreign firms indirectly benefits other firms, especially small ones that are in close physical proximity.

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Table of Contents

List of Tables

1 Introduction

One of the hallmarks of the decade beginning in 1985 is the significant increase in the international flow of long-term private capital, particularly of foreign direct investments (FDI). Feenstra (1998) documents the surge of investment into developed countries in the second half of the 1980s, followed, since 1990, by a rapid increase of investments into developing countries, especially China. More than one-third of total inward flow of FDI has ended up in developing countries in recent years.

However, compared to international trade, the absolute magnitude of FDI in Taiwan has been small. This is clear from the performance indicators of the economy. Between 1975 and 1985, the share of exports in gross domestic product (GDP) grew from 38.4% to nearly 50% a decade later, figures that are significantly higher than those in other developing countries. In contrast, the share of FDI in GDP hovered around 1.1-1.2% during the same period. However, beginning in the mid to late 1980s, inflows of FDI surged. This surge reflected, in part, the rapid expansion of FDI into developing East Asia at a rate that exceeded that of world trade.

Formal FDI figures understate the importance of foreign firms in Taiwan. Many studies focusing on the industrial development of Taiwan conclude that FDI is one of the key sources of technology transfer. The transfer of new technologies, managerial skills, marketing networks and externalities associated with knowledge or technology spillover from the presence of FDI are of greater significance than the actual size of the capital inflow. Moreover, researchers have found that the extent these benefits are highly dependent on the institutional framework under which FDI occurs. In particular, the higher the level of human skills, the greater the degree of interaction between domestic and foreign firms, and the more outward-oriented the trade policy, the more likely are the growth-enhancing effects of FDI. All these features are clearly present in Taiwan, suggesting that the bulk of the benefits from FDI in Taiwan, especially if spillovers are important, are likely to be grossly underestimated.

This paper examines the changing trend and structure of inflows of FDI into Taiwan and its impact on overall productivity, using firm-level data from the Taiwanese Census of Manufactures. In particular, the paper will focus on the role of inward FDI in determining a) the productivity of firms with foreign ownership; b) the extent of export capability or establishing networks of subcontracting activities among Taiwan's manufacturing firms; and finally, c) the extent to which the presence of FDI generates benefits to other firms without any foreign ownership but are located in the same physical location or industry as those with FDI.

2 Trends in Foreign Direct Investment

In the decade of the 1970s, the growth in inward FDI lagged behind that of exports. Export growth was very rapid, averaging over 30% per year from 1970 to1979, before declining to 18% annually in the 1980s, and eventually falling to single digit growth rates in the 1990s.

Table 1 shows the contrasting pattern in the growth rates of FDI, GDP and exports. As export growth slowed down since 1970, so did GDP growth, indicating the tight link

between these two growth indicators. FDI growth was high in the decade of the 80s, slowed down significantly in early 1990s before reaching over 38% annually since the onset of the Asian crisis in 1997. This annual rate is over five times the rate of export growth over the same time period. FDI inflows into Taiwan peaked in the 1987-1989 and 1995-1997 periods and again in 2000, when the rate of growth was almost 80%. These patterns reflect the general surge in FDI into East Asia beginning in the mid-1980s, a development that contrasts with declining growth rates in both exports and GDP over the same period.

However, unlike exports, the absolute magnitude of FDI in Taiwan is small, with the actual flows increasing from only .43% of GDP in 1986 to just above 1% of GDP in 1999. Columns 2 and 4 of Table 2 present the absolute figures of actual and approved inward FDI and its share of GDP. Although approved inflows of FDI has been rising from an annual average of US$1 billion to a peak of US$4.9 billion in 2000, the inward stock of FDI has remained relatively low by regional standards, at around US$27.9 billion (or 9% of GDP) by the end of 2000.

Table 2 also provides yearly flows of outward FDI. Starting in 1988, following the rapid expansion of foreign trade, actual flows of outward investments exceeded inward FDI flows with the difference growing over time. In fact, since the early 1990s, Taiwan has become one of the leading exporters of capital. Outward FDI, the bulk of which are in mainland China, has grown from less than .1% of GDP annually in the 1980s to over ten times that magnitude in the decade of the 1990s. According to the International Financial Center's report in March 2002, the stock of outward FDI totaled US$49.2 billion in 2000, almost double the inward stock.

Nevertheless, statistics on the amount of inward FDI has displayed a strong pattern of resilience to the negative shock that hit many Asian countries following the 1997 financial crisis. FDI contributed about 2.5% of total domestic capital formation between 1984 and 1986, rising to around 3.5% between 1991 and 1996. This share rose to 6.3% in 1997, fell slightly to 5.1% in 1998 and rose again to 5.9% in 1999. As a share of GDP, statistics from the Investment Commission of the Ministry of Economic Activities indicate that approved FDI in Taiwan during 2000 reached almost 2.5 %, the highest share in history. While the growth has slowed down since then, inward FDI flow as a share of GDP remains at a level significantly higher than ever achieved in the 1990s.

This resilience of inward FDI even during the period of economic turmoil in the region stands in sharp contrast to growth rates in GDP and exports, suggesting that unlike other forms of capital flows such as portfolio investments, FDI are more sensitive to economic fundamentals in an economy.

Since the early 1950s, the environment for inward FDI in Taiwan has been increasingly hospitable. Coupled with good infrastructure and attractive fiscal incentives, inbound FDI took off in the early stages of export-oriented growth in the 1960s. The earliest inflow of FDI came from overseas Chinese investors, with the bulk of the funds channeled into export processing zones set up by the government. This inflow had a significant impact on the subsequent economic development of Taiwan (Schive, 1990). Local manufacturers relied on the Chinese network to market their products in those countries throughout the 1970s. However, overseas Chinese investments in terms of their share in total value of

inward FDI diminished by the early 1980s. Part of the explanation for this is that the average size of overseas Chinese investments is typically much smaller than the average size of non-overseas Chinese investments.[1] Between the larger size of European and U.S. investments as well as their higher growth rate, foreign investments from non-overseas Chinese sources averaged 90% of Taiwan's total value of FDI from 1981 to 1996. This figure increased to over 95% since 1997.

Traditionally, most overseas Chinese investments have been in industries oriented towards the domestic market. In particular, the service sector, non-metallic minerals, construction and banking and insurance sectors were major recipients of overseas Chinese funds. However, as high-technology sectors have proven to be successful over time, the overseas Chinese have joined investors from U.S., Europe and Japan in the technology-intensive sectors.

Tables 3 show the principal source countries of FDI into Taiwan. From 1952 to 2000, about 25% of approved FDI in Taiwan originated from the US, 21% from Japan, 13% from Europe and 8% each from Hong Kong and Singapore. Since 1998, the share of FDI from both Europe and Singapore has increased significantly so that by the end of 2000, they overtook the U.S. and Japan as the top two foreign investors in Taiwan with a combined share of over 50% of total FDI. Just over 25% (US$9.4 billion) of the FDI coming into Taiwan in the past four decades has been channeled into the electric/electronics sector, with the highest growth in the mid to late 1990s, aided in part by liberalization and privatization of the financial service sector.

Table 4 displays the contribution of FDI in the manufacturing sector in terms of absolute and relative employment and sales in the sector. While the absolute and relative contribution of FDI to total manufacturing employment has fallen from 1986 to 1996, the contribution to total manufacturing sales has kept up with the tremendous growth of the sector over that time period.

Despite the emphasis on developing the system of intricate networks created through foreign investors and overseas Chinese, the crucial factor that fueled Taiwan's economic growth came primarily from the private sectors' engagement in the international market. In particular, small and large, foreign and domestic firms were drawn towards the rapidly expanding export market.

3 The Evolution of Policy towards FDI

Even though the growth of FDI did not take-off until the mid 1980s, the success of the country's export-oriented trade strategy is tightly linked with foreign investors since 1960 when the government announced three major reforms. Firstly, the Statute for the Encouragement of Investment became the foundation for investment incentives to both local and foreign investors. The statutes encouraged the growth of new enterprises backed with

[1] In 1987, the average overseas Chinese investment was $.74 million, much smaller than the average non-Chinese investment of $2.6 million. The smaller value of overseas Chinese investment was attributed to the investors' familiarity with the Taiwanese economy, their ethnic ties, and family connections with the local population which facilitated their participation in many small ventures (Dahlman and Sananinokone, 1990).

foreign capital by liberalizing ownership restrictions and granting various forms of tax credits. Secondly, the government dismantled the multiple exchange rate system and liberalized the foreign exchange allocation system that had limited imports during the earlier period. Finally, the effective rate of protection was lowered on various items so as to stimulate competition.

At first, foreign investment was slow in coming given its lack of natural resources, a small domestic market, limited industry, and a precarious political future. These factors were offset by a cheap and disciplined labor force as well as solid infrastructure, thanks to its Japanese colonial legacy. Gradually, as more and more foreign investors tested the Taiwanese market and were successful, word of their success spread, attracting U.S., Japanese and European electronics, textiles and other industries who were looking to move their operations to Taiwan because of lower production costs.

To make Taiwan more attractive to foreign investors, in 1965 the government enacted the Statute for the Establishment and management of Export- Processing Zone (EPZs), which started operation in 1966. Combining the advantages of an industrial estate with those of a free port, EPZs offered complete exemption from custom duties, commodity and sales taxes, and provided other incentives for export-oriented firms to set up in the zones. These EPZs had the effect of multiplying Taiwan's links with foreign firms through FDI and subcontracting. Typically, a large multinational corporation would invest in Taiwan, establish a large manufacturing plant and generate a market for a host of small local suppliers and assembly operations.

During the 1960s and early 1970s, industries such as consumer electronics, various electronic components, synthetic fibers and plastics were given priority in the zones. Through the 1970s, the Statute for the Encouragement of Investment was revised nine times to promote Taiwan as a destination for FDI. At the same time, the Statute for Investment by Foreign Nationals and Statute for Investment by Overseas Chinese also underwent revision in 1979. Between 1970 and 1980, FDI increased by 700 percent while FDI-financed firms accounted for 22 percent of exports (Ho, 2003).

Since 1981, keen competition from developing nations in the export of light industrial manufactures and increasing protectionism from developed countries made it imperative that Taiwan develop capital and technology-intensive industries in order to remain internationally competitive. In the Eighth Four-Year Development Plan of 1982, the government identified the four industries of electronics, general machinery, transport equipment, and precision instruments as the set of "strategic industries" deserving of increased domestic and foreign investments.

The Statute for the Encouragement of Investment was amended in 1984 and then again, in 1987. During this period, the government began a series of changes in policy to liberalize its goods and financial markets with the explicit goal of making Taiwan a more attractive destination for high technology FDI. These moves included significant tariff reductions and relaxation and abolition of non-tariff barriers so that by the end of the decade of the 1980s, these import restrictions were practically negligible in magnitude.

The most prominent government incentive for attracting FDI in high-tech industries was the establishment of science parks. As these parks hosted both foreign and domestic enterprises, the objective was, not only to attract more technologically sophisticated FDI, but also to broaden the industrial base and upgrade domestic skill development (Ho, 2003).

The most well-known of the science parks was the Hsinchu Science-Based Industrial Park in 1980. Apart from the physical infrastructure of a high-tech industrial city as well as the cooperation of two universities and the leading industrial technology research institute, Hsinchu offers foreign investors generous financial and fiscal incentives through low-interest government loans and tax deferments on R&D investments. To qualify, firms must be involved in sophisticated and advanced technology, contribute to the local economy through local sourcing of their inputs and have the export market as the destination of their output.

As Taiwan moved into the most sophisticated end of the technology sector in the 1990s, ethnic Chinese living in advanced industrialized countries have begun to invest in Taiwan and more importantly, become a source of technical manpower as they return to work in high-tech corporations in Taiwan. The government has been very successful in luring back overseas Chinese with fiscal and financial incentives. Many of these returning nationals have been educated and received degrees in science and engineering from U.S. and Japanese universities and assume positions of leadership in large Taiwanese corporations. Recognizing the critical role that these returnees can play in the development of Taiwan's high-technology industry, the government has been very active in luring these R&D managers back to Taiwan to upgrade local technology.

At the Hsinchu Science Industrial Park, the majority of computer corporations are owned by overseas Chinese or by Taiwanese who used to work overseas (Dahlman and Sananikone, 1990). In addition, a group of returning executives have formed the Overseas Chinese Entrepreneurs Advisory Network Program to help returnees adjust to life in Taiwan, find business partners, and discuss business plans (Dahlman and Sananikone, 1990).

In early 1988, the government replaced the "Positive Listing" of industries where FDI was permitted with a "Negative Listing Policy" for FDO applications. Under the "Positive Listing", industries permitted to welcome foreign shareholding were exceptions to the rule. With the "Negative Listing Policy", only pollution-causing industries and those in the banking and insurance industries as well as public administration were denied entry by FDI. In April 1989, the government lifted the ban on foreign participation in the banking sector.

In 1991, the SEI, which targeted specific "strategic industries", was replaced by the Statute for Upgrading Industries, designed to encourage both domestic and foreign investments in all industries. Similarly, the statutes for investments by foreign nationals and overseas Chinese were revised in 1997 to remove obstacles to and improve conditions for investors. Perhaps as a direct result of all these changes in policy towards foreign investors, total FDI in the 1990s nearly tripled the figures for the previous decade.

Taiwan's current policy towards FDI cannot be separated from its overall development policy that emphasizes the growth of high-technology industries in the decade of the 2000s. Preferential tax measures that included credits for R&D investments and five-

year exemptions or shareholder investment credits for companies in high-technology industries were extended to 2009.

Finally, Taiwan's entry into the WTO in 2002 and continuing liberalization of its domestic market are viewed as offering FDI increased opportunities to invest in its manufacturing and service sectors. For example, in 2003, The Negative List was further reduced to meet WTO rules. The List now contains only 10 (8) prohibited and 25 (22) restricted industries for investment by foreign nationals (overseas Chinese).

4 Factors Contributing to the Growth of FDI

The following factors are viewed as crucial in Taiwan's ability to use foreign investors as means to attain a high level of international competitiveness, boosting export production and enabling the economy to reach sustained economic growth.

Subcontractors

Multinational corporations were first attracted to Taiwan because of the cheap and disciplined labor force as well as well-developed economic infrastructure. Local small and medium investors entered rapidly growing industries, aggressively seeking out foreign partners or, with government assistance, entered into subcontracting arrangements with MNCs. Hobday (1995) documents that during the start-up phase, many Taiwanese companies learned the art of manufacture by relying heavily on foreign firms for training and licensing agreements. Over time, the relationship between foreign investors and small-scale local suppliers developed into a viable, efficient and dependable network of small subcontractors able and ready to act as local suppliers to foreign investors.

This pattern of the foreign investor generating a dense network of small-scale local suppliers became established over the years, providing an important channel for the transfer of technology through the FDI's specification requirements. A study by Schive (1990) indicates that the degree of foreign capital involvement in a local company is linked to the application of foreign technology by that company. In addition, nearly all foreign-majority-owned companies in the electric/electronics industry received foreign technology from their foreign partners.

In exchange for the expertise of the foreign investor, the government ensured an efficiently run subcontracting network, a ready supply of relatively inexpensive educated labor force and entrepreneurs with the strong potential to reduce the overall cost of production of the foreign enterprises. Most importantly, the creation of the Hsinchu Science and Industrial Park with its close proximity to major universities and the leading industrial technology research institute meant that FDI could benefit from the ready availability of skilled personnel in addition to the generous financial and fiscal incentives once located within the park.

Spillovers

Unlike other forms of capital inflows, FDI is strongly associated with simultaneous technology and manpower flows and therefore, is a potential source of spillovers due to their more advanced techniques of production, organizational practices, new management and marketing networks (Blomstrom and Sjoholm, 1998). Anecdotal and case study evidence

indicates that FDI in Taiwan has helped upgrade the technological capabilities of the manufacturing sector through subcontracting and technical cooperation agreements between foreign and local producers. A fundamental purpose of Hsinchu Science and Industrial Park is to capture the spillover from the presence FDI, leading to technological upgrading as well as the necessary backward linkages in the local economy (Schive, 1990).

Industry Associations

The foreign investors' links with local producers were further strengthened via the pro-active industry associations. For example, the electronics industry association, TEAMA (the Taiwan Electric Appliances Manufacturers' Association), aggressively recruited members from both foreign and local producers and, with the support of the government, actively promoted the local content program. This program was instrumental in establishing the link between local producers and FDIs (Kuo, 1995). Local producers wanted to take advantage of the technology, management skills and sales networks of the FDIs.

Local Content Requirements

Policies such as those related to local content requirements were used to generate backward linkages in the local economy and create a market for a host of small local suppliers and assembly operations. This pattern of the foreign investor generating a dense network of small-scale local suppliers took hold over the years boosting export production and acting as an important channel for the transfer of technology through specification requirements. In addition, the growing numbers of local SME investors constantly competed for orders with different foreign firms resulting in highly competitive market structure both in the domestic as well as the international markets.

Foreign producers stood to benefit from the local content program because it reduced labor and transportation costs as long as local supplies met their quality standards. Consequently, the response of FDIs was enthusiastic. They began to train local technicians, provide technical know-how and management skills to suppliers and cooperate with technical schools on internship programs. These links were further strengthened through the establishment of production satellite systems which formally connected local producers and FDIs as well as small producers of parts and components and large assemblers.

Dahlman and Sananikone (1990) provide evidence indicating that it is through subcontracting with foreign firms that local SMEs acquired the technology needed to produce goods of internationally competitive quality as well as have a ready market for their output. It is in this way that foreign firms fueled the development of the intricate network of permanent linkages between the local economy and the international economic system. This strategy became even more crucial as Taiwan's overall economic policies towards FDI shifted from a concentration on labor-intensive manufactures toward the promotion of more sophisticated, technology intensive products and processes after the mid-70s.

The Electronics Sector

The Taiwanese electronics and electrical appliance sector owes its early establishment and success to foreign multinational corporations such as RCA of America and Philips of Holland. As leading investors in the free trade zones in the late 1960s, the Taiwanese operations of both RCA and Philips changed with the growth of the export market. Both corporations upgraded their engineering facilities, engaged in the transfer of process and product technologies and trained local engineers, technicians and directors (Hobday, 1995). In 1976, RCA began one of the first ventures to transfer chip technology to local firms with Philips following suit in 1987. However, in either case, the major technology spillover from these ventures came from the exposure and on-the-job training received by engineers and managers in their workforce who later started their own businesses or moved to work in existing nationally owned firms. For instance, one of RCA's Taiwanese engineers later founded Winbond Corporation, which by 1992, became the second largest chip producer in Taiwan. The top executives of the local firm, GVC Corp, a manufacturer of modems and notebooks and later cellphones, came from RCA and Philips.

In a recent publication tracing the development technological capability of firms in the Taiwanese manufacturing sector, Amsden and Chu (2003) note that while the typical American investment in Taiwan, particularly those in the electronics industry, involve 100%-owned FDI oriented toward exports, those from Japan are generally joint ventures with Taiwanese firms. These are oriented toward the domestic market, utilizing local components in response to tariff protection policies and domestic content requirements.

Consequently, the Japanese investors have greater incentives than their American counterparts, to transfer know-how to their joint venture partners as well as to their local supplier of parts and components. For instance, in the case of TV manufacture, "..all local firms in Taiwan acquired their technology by proprietary transfer from foreign manufacturers, especially Japanese manufacturers, through the channel of joint ventures or technological contracts. Since TV manufacturers also produced other home electrical products, they chose their TV technology suppliers based on their cooperating experiences in manufacturing other products, or as sales agents of their technology suppliers. (e.g., Sampo was the sales agent in Taiwan for Sharp TVs, and when Sampo decided to enter into the manufacture of TVs, the technology was provided by Sharp). Finally, in the 1970s, exports of color TVs from Taiwan came under original equipment manufacture (or OEM) contracts which were mainly with Japanese firms." Accordingly, technological learning in the electronics industry was strongly influenced by Japanese FDI in TV production. When growth in the demand for TVs slowed, the knowledge and experience accumulated from TV production aided manufacturers in the switch to monitors and terminals (Amsden and Chu, 2003; Lin, 1986).

As wages in Taiwan soared with rapid economic growth, U.S. as well as Japanese firms in the labor-intensive end of the electronics sector ceased to expand and gradually relocated some production to other lower wage countries in Asia. In their place, local Taiwanese companies filled the gap left by exiting foreign firms. These local firms, often labeled as Taiwan's high-technology start-ups are owned and managed by individuals who were ex-employees of American DFI in Taiwan, dominated Taiwan's electronics industry by the late 1990s.

In the remaining sections of this paper, we examine the characteristics of firms with foreign ownership and productivity effects arising from the presence of FDI in the Taiwanese manufacturing sector. The analysis will be based on both Census of Manufactures data as well as Survey data. Information on foreign ownership of firms in the Census data was collected only in 1986 and 1996. Panel data is available for all three years (1986, 1991, and 1996) in the Survey of Manufactures, comprising of a random sample of larger firms in all the industries. This will be used to look at the productivity evolution of firms with FDI.

5 Incidence and Characteristics of Firms with FDI

Table 5 indicates the incidence of firms with FDI and exports across 6 of the principal industries in the manufacturing sector of Taiwan. In 1986 and 1996, the chemicals and electric/electronics industries have the highest share of firms with FDI, followed by the transportation industry. The remaining industries have less than 1% of firms with FDI. If we compare the first with the third column in each year, it is clear that almost all firms with foreign ownership also export. For example in 1986, every firm with FDI in the clothing industry also exports. This is very likely the result of government incentives encouraging all FDI firms to export. In contrast to the sparse presence of foreign ownership, a large fraction of firms in every industry are involved in the export market.

How do firms with foreign ownership differ from domestic firms? Table 6 lists mean sales revenue, mean employment and mean ratio of export to total sales figures for foreign-owned, non-FDI and exporting firms in six principal manufacturing industries. A couple of features about foreign-owned firms stand out in the table. First, while it is not surprising that firms with FDI are larger than domestic firms, the difference in the magnitude is quite startling. For all the six key industries in 1986, FDI firms are 7 (textiles) to 36 (transportation) times larger in sales revenue to 2 (plastics) to 5 (clothing) times in terms of employment. In three of the six industries, these size differences between FDI and non-FDI as well as FDI firms and exporting firms widen significantly ten years later.

Second, foreign-owned firms are, on average, many times more export-oriented than domestic firms, particularly those in the clothing and electric/electronics industries where the export to sales ratio in 1996 is .8 and .52, respectively. This feature is consistent with our earlier observation that, unlike domestic firms, the bulk of foreign firms engage in the export market.

6 Productivity of Firms with FDI

Table 7 summarizes the cross-sectional differences in average productivity of firms that have some foreign capital and those that are domestic-owned. Productivity is measured as total factor productivity (TFP).[2] The intercept is the average TFP of the firms that have no foreign capital and coefficients in the third and fifth columns represent the percentage difference in productivity between non-FDI firms and firms with FDI in 1986 and 1996 respectively.

[2] See the appendix for a description of how we measure TFP.

Except for the textile industry in 1996, the coefficients of the FDI variable in the regression are all positive implying that foreign firms are more productive than non-foreign firms. However, only half of the coefficients in 1986 and one-third in 1996 are significantly different than zero. These coefficients range from 6.3 (electric/electronics industry in 1996) to 18.4 percent (chemicals in 1986). One possible reason for the weak correlation between foreign-ownership and productivity, particularly in 1996, is that starting in 1991, the sample of domestic-owned firms includes Taiwanese MNCs with relatively high productivity. For evidence of this, see the large increase in outward FDI in the 1990s in Table 2.

Another indicator that these domestic MNCs are included in our sample of non-foreign firms is the significant increase, except in the transportation industry, in the magnitude of the intercept term in 1996 compared to 1986. For example, in the textile and electric/electronics industry where outward investments by Taiwanese firms have been particularly active, the productivity of non-FDI firms increased by about 19% and 23% respectively during the ten-year period under study.

Since the bulk of foreign firms are also export firms, the finding of higher productivity in foreign firms is likely to be highly correlated with the export activity. This feature implies that we need information on a distinguishing characteristic of the FDI activity to separately identify the productivity effect of FDI from that of exporting. A distinguishing characteristic of firms with FDI is the large size of these firms in terms of revenue from sales as well as employment relative to both non-FDI and exporting firms. Thus, we can use information on FDI intensity to see if the productivity differential between foreign and non-foreign firms is an increasing function of the share of a firm's total assets that is foreign-owned, a pattern that would allow us to attribute the observed higher productivity to foreign ownership.

Table 8 reports the results of regressions of firm productivity on year and FDI intensity dummies for each of the 6 industries. The intercept represents the average TFP of firms with no FDI in the base year (1986) and the remaining coefficients measure the percentage difference in productivity between these firms with no FDI and firms with low FDI intensity (less than 25 percent of total assets are foreign-owned), moderate FDI intensity (25 to 75 percent), and high FDI intensity (more than 75 percent).

The positive coefficients of all but two of the coefficient estimates clearly indicate higher levels of productivity for foreign firms relative to non-foreign firms. There is no consistent movement in the level of average productivity across the intensity categories. In three of the six industries, none of the FDI intensity coefficients are statistically significant. With the exception of electric/electronics where the coefficient of high FDI intensity is significantly positive, the coefficients for firms with low and high FDI intensity are not statistically different than zero in the remaining five industries. In three industries where the coefficients are statistically significant, the data indicates that firms with medium FDI intensity have average productivity levels that are between 6.6 percent (in electric and electronics) to 13.9 percent (in chemicals) higher than firms without any FDI.

Tests on the equality of the estimated coefficients suggest that with the exception of the electronics industry, we cannot reject the hypothesis that the low and medium FDI intensity and medium and high FDI intensity coefficients are equal. In the case of

electric/electronics, we cannot reject the hypothesis that average productivity of the medium and high FDI intensity groups has equal average productivity.

Overall, the cross-sectional results in tables 7 and 8 indicate that focusing only on the foreign-ownership of firms, foreign firms in some industries have higher productivity than firms without any FDI. However, in many industries, this productivity difference is not statistically significant. This may be due, particularly in the 1990s, to a large number of highly productive Taiwanese MNCs included in the firms that are classified as firms without any FDI. Finally, the degree of FDI intensity appears to have little systematic effect on productivity for most of the industries under consideration.

7 FDI and the Role of Exports

To analyze the joint effect of foreign-ownership and export activities on firm productivity, Table 11 reports the results of the regression of firm productivity on dummies representing the presence of FDI only, export only, or both FDI and exports. The intercept in the regression represents the productivity of baseline firms: those with no exports and no FDI. Three observations stand out from the table. First, across all six industries average productivity of exporting firms exceed that of firms without any FDI by between 4.6 to 15.6 percent. All of the differences in means are statistically significant. Second, only two of the six coefficients on the FDI dummy are statistically significant, with one of the two carrying a negative sign, suggesting that, in general, foreign ownership in firms have no significant impact on firm productivity. Finally, with the exception of the textile industry, firms in all the other industries that combine both export activity and FDI have significantly higher productivity than both the baseline group of firms as well as firms that only export. The productivity premium from foreign ownership relative to the export-only firms range from 1.6 percent in the clothing industry to 7.6 percent in transport equipment.

The simple comparisons of average productivity of firms with various combinations of export and FDI indicate that the higher productivity observed among foreign relative to non-foreign firms in Table 9 is clearly linked with the export activity. At the same time, our evidence also suggests that when coupled with exports, firms' productivity is further enhanced by the presence of FDI. In the next section of this paper, we exploit the time series aspects of the data from the surveys of the larger and more technologically advanced firms taken in 1986, 1991 and 1996 to show the importance of the export factor in the success of firms with FDI.

8 The Timing of FDI

We focus our attention on the electric/electronics industry because it has the highest share of FDI among all the two-digit industries in Taiwan. Between 1990 and 1997, 42.4 percent of the total FDI in the manufacturing sector was in electronics. The chemical industry is a far second at 20.3 percent during the same time period.

In Table 10, firms in Taiwan's electronics industry are viewed as those who participate (or not participate) in two activities: export and/or FDI. They are classified into

four separate categories: those with no exports and no FDI; those with only exports; those with only FDI; or those with both exports and FDI. The table reports the number of firms in each group in 1986, 1991 and 1996. In 1986, almost 20 percent of all firms in the survey had some foreign capital and over 74 percent participated in the export market. Over the period covered by the panel, between 12 and 18 percent participated in both activities and between 25 and 41 percent of the firms in each year did not participate in either activity. As observed in the cross-sectional data in Table 5, the export activity was more prevalent among firms than foreign ownership. While 46 to 56 percent of the firms in each year chose to only export, only 1.3 percent of firms have only FDI.

While Table 10 summarizes the different combinations of FDI and export activities in each cross section, it does not indicate how these combinations persist or change over time. To do this we focus on a balanced panel of firms that are observed in the all three years of the survey.

Table 11 summarizes information about *changes* in firms' FDI/export status and illustrates how the initial state is related to the start or cessation of each activity. The columns in Table 11 report the number and share of firms that initiate or cease each activity in period $t+1$, conditional on each firm's initial state in period t. For example, column 2 reports the number and proportion of firms in each of the four initial states that began exporting five years later.

Two general transition patterns emerge from Table 11. First, regardless of their initial state, a higher proportion of firms begin exporting than receive FDI. For example, of the 285 firms that did not participate in either activity in the initial period, 30 percent began exporting in the next period whereas less than 2 percent have FDI five years later. Second, the FDI activity is more likely to proceed rather than precede the export activity. Comparing the first and second rows of the table, 6.4 percent of firms with an export history receive FDI (row 1) compared to 1.8 percent without any export history (row 2). Of the total of 611 firms in the initial state, only 5 firms (less than 1 percent) are only-FDI firms.

Taken together, we find evidence from simple counts of various activities in the panel data that history matters substantially in determining current engagement in either the export or FDI activity. In particular, export participation demonstrates more persistence than FDI and more importantly, there is evidence that firms tend to engage in exports prior to receiving FDI. These observations are consistent with our previous findings that, relative to non-exporting and/or non-foreign firms, exporting firms have higher productivity. This observation is independent of the presence of FDI in the firm. In addition, firms that have an export history are also more likely to receive FDI relative to those without any export history.

9 Spillovers and FDI

It is very likely that taking the share of foreign ownership of a firm's total assets may not be a complete measure of the benefits generated by the presence of FDI. Indeed, some of the key benefits of FDI are likely to arise from agents external to the firm.

Studies that have addressed the potential spillovers from FDI have hypothesized that foreign firms import and demonstrate technologies that are useful to domestic firms.

More recent work on the nature of spillover suggests that physical location plays a significant role in the spread of ideas. However, the few studies that have examined location spillover in developing countries conclude that there is no evidence of any geographical spillover from FDI in Morocco (Haddad and Harrison, 1993) and Venezuela (Aitken and Harrison, 1999) and export experience in Colombia, Mexico and Morocco (Clerides, Lach and Tybout, 1998). This is not surprising with horizontal FDI since foreign-owned firms have every incentive to minimize technology spillover to competitors by restricting the mechanisms such as imitation and labor mobility. However, in the case of Taiwan, where inter-firm linkages made possible by strong subcontracting relationships dominate, the potential for spillover benefits may be greater than those in other developing countries. In their efforts to build efficient supply chains, foreign firms often share technical knowledge with their suppliers, enhancing their productivity in the process.[3]

A recent paper by Aw (2002) finds some evidence of indirect benefits generated by FDI firms in Taiwan's electronics industry for the period from 1986 to1991. In the following paragraphs, we summarize the key points of the paper.

Aw (2002) focuses on three sources of new knowledge: FDI, exports, and R&D activities. All these variables are measured at the firm-level using the same census data as in this paper. The empirical model answers two questions. First, do firms with positive investments in any one of these activities have higher productivity growth than other firms where these activities are absent? Second, do firms that are located in the same industry or geographical region or county with greater intensity of investments in FDI, R&D investments and exports benefit from the diffusion of new knowledge associated with these activities. This "spillover" of foreign technology is quantified by taking the ratio of the sum of FDI (or export, or R&D) of other firms to total revenue within each of the 193 counties or 4-digit industries. Table 12 reproduces the results that are relevant for this analysis.

The results indicate that the firm's own investments in the three activities are positive and statistically significant. Given Taiwan's status as a technology latecomer, it is not surprising that productivity growth rates are positively and significantly correlated with the firm's own investments in R&D, FDI participation and exports. However, only three of the six spillover variables are statistically significant. The coefficient of the variable measuring the degree of spillover benefits generated by export activities located in specific 4-digit industries is positive (.059) and statistically significant. In addition, there are positive externalities generated by firms with FDI to other firms located within the same county, although the magnitude of this coefficient is small at .015.[4] The coefficient of the variable measuring the degree of spillover benefits generated by R&D investments located in specific 4-digit industries is also statistically significant but negative in magnitude.

An interesting result from the study is found in the lower half of Table 12, which reports the determinants of survival rates of firms. Initial firm TFP has the biggest and most pervasive effect on firm survival into the next time period, a result that is consistent with the predictions of recent theory of industry evolution that more efficient firms have the highest

[3] Blalock and Gertler (2003) find evidence of spillovers from FDI among Indonesian factories in industries in regions with growing downstream FDI experiencing greater productivity growth.

[4] The same regression was run for small (<100 workers) and large firms. The result indicates that all the benefits reflected in the coefficient on the FDI spillover variable are those accruing to small firms.

probability of survival. Of the three investment activities, FDI has the highest impact on firm survival rate. Firms with FDI have a 31 percent higher survival rate than those without any FDI.

While the results in section 6 suggest that relationship between FDI and the level of TFP is mixed unless it is coupled with exports, the results from this section show that FDI in a firm has a large and significant effect (11.3 percent) on its TFP growth and a strong positive and significant effect on ensuring the firm's survival rate over time. More importantly, FDI firms appear to benefit neighboring firms, especially smaller firms (<100 workers).

10 Summary and Conclusions

Like many developing countries, the earliest and most common source of new technology for Taiwan was from foreign firms operating within its borders. In sheer volume, the direct contribution of FDI to Taiwan's economy has not been significant. Since the first inflows of FDI into Taiwan in the early 1960s, its share of gross investment in the manufacturing sector ranged from 5.56 percent from 1962-69 and 11 percent in the period from 1973 to 1994. The bulk of this investment (80-90 percent) came from foreign (non-Chinese) investors and went into electrical/electronic and machinery industries. The average annual rate of growth of FDI fell from 27.5 percent in the 1980s to 6.8 percent from 1990-1996, picking up again to reach a high of 38.5 percent from 1997 to 2000. With the development of Taiwan into a matured, advanced economy, it is not surprising to witness the rising importance of outward FDI as well as the increasing share of industrial output from domestically owned firms.

The small absolute magnitudes of FDI into Taiwan, compared to those of other countries like Hong Kong and Singapore, understate the contribution of FDI to the economy's industrial progress, technological capability and export success. Many FDI concentrated in leading export sectors, generating new export industries and facilitating the transfer of new technology. FDIs in Taiwan has helped foster the start-up of many of Taiwan's electronics makes as large numbers of local companies grew up to supply these foreign firms with parts, components, sub-systems and services, leading to a dense network of subcontractors and OEM system.

Empirical evidence in the literature on the role of FDI in Taiwan's economic development to date has been very mixed. There are two studies based specifically on more recent data on FDI in Taiwan's manufacturing sector. Chen, Hsu and Chen (1999), using cross-sectional 1986 and 1991 survey data find that the effect of FDI on labor productivity is not significantly different than zero. Using the standard Granger causality tests to prove causality among variables, Chan (2000) concludes that there is a causal relation from FDI to economic growth through technology improvement rather than through increasing total capital accumulation or exports.

The findings of this paper are fourfold. First, from the firm's perspective, the benefit from foreign ownership in Taiwanese firms, in terms of a higher level of TFP, is very strongly linked with the export activity. In fact, there is little evidence to indicate that FDI

on its own directly leads to higher levels of productivity. This may partly be due to the lack of any observations of firms that only have FDI and no exports. Second, the direct benefits from FDI accrue to firms with an export history, implying that conditional on being in the export market, firms with FDI have higher productivity levels than firms that do not have any export history. Third, FDI has large and significant effects on the firm's TFP growth and future survival. Finally, there is also some evidence that the presence of foreign firms indirectly benefits other firms, especially small ones that are in close physical proximity.

The first finding of this paper is consistent with the view that for Taiwan exports and FDI are complementary, the evidence of which was apparent as early as the 1970s and continued through the 1990s. During this period export-oriented foreign investors arrived in Taiwan in response to the well-developed economic infrastructure and an environment conducive to foreign investments. In the process, from the perspective of Taiwanese firms that were successful in attracting foreign investors, FDI became, not only an important source of superior management skills and new technology, but also already developed marketing links with the rest of the world. In a recent paper, Urata (2001) refers to this FDI-trade nexus in the countries of East Asia: " The economies that succeeded in expanding exports attracted FDI, because they were seen as capable of providing an environment conducive to competitive production. In this way, virtuous spirals of export expansion and FDI expansion, or the FDI-trade nexus, were formed." Micro-level evidence from Taiwan strongly supports this view of how the economy grew and developed over the ten-year period from 1986 to 1996.

The second finding that the benefits from FDI accrue to firms with an export history is interesting from a policy perspective in the sense that while there is no "magic" that comes from the export activity of firms, the evidence is very clear that once a firm is in the export market, the presence of FDI brings additional benefits that are not reaped by those with no export market penetration. This suggests that for Taiwanese manufacturing firms, the timing of investment activities may be crucial. This finding is consistent with empirical evidence in numerous studies using data, from both developed and developing countries, to date indicating that more productive firms self-select into the export market.[5] It follows that these firms are more likely to attract FDI or have incentives to invest in other activities (such as R&D) to improve their productivity in order to stay competitive in the international market place.

According to Levy (1991), the simultaneous proliferation in Taiwan of a sophisticated network of subcontractors and export traders imply that the transactions costs of entering the export market may be lower in Taiwan than in many other countries, enabling higher than average participation by small firms in the export market. In developing countries entry into the export market may require firms to establish marketing channels, learn bureaucratic procedures and develop new packaging or product varieties. Thus, lowering these barriers may be an important first step in encouraging productive firms to

[5] Clerides, Lach and Tybout (1998) use data from Colombia, Mexico and Morocco; Bernard and Jensen (1999) study U.S. manufacturing firms; Aw, Chung and Roberts (2000) use data from Taiwan and South Korea; Bernard and Wagner (1997) for Germany; Liu, Tsou, and Hammitt (1999) for Taiwan; Delgado, Farinas and Ruano (2002) use data from Spain. All the authors find evidence that more efficient producers self-select into the export market. Aw, Chung, and Roberts (2000) also find evidence of productivity improvements following entry into the export market for a few Taiwanese industries.

export, and potentially benefit from any transfer of new technology that is transmitted through their export contacts or FDI that may be attracted to invest in these firms.

Table 1: Average Annual Growth Rates of FDI, GDP, and Exports

Time Period	DFI Growth (%)	GDP Growth (%)	Export Growth (%)
1970 – 1979	16.7	10.2	31.7
1980 – 1989	27.5	8.1	18.3
1990-1996	6.8	6.7	8.0
1997 - 2000	38.5	5.7	7.5

Source: Taiwan Statistical Data Book, Council of Economic Planning and Development, Republic of China, 2001

Table 2: Trends in Flows of Inward and Outward FDI (% of GDP)

Unit: USD$ml.

Year	Balance of Payments		MOEA Approved	
	Inward FDI	Outward FDI	Inward FDI	Outward FDI
1959	3.8 (.22)	-	0.97 (.05)	0.10 (.01)
1965	10.5 (.37)	0.47 (.02)	41.61 (1.48)	0.72 (.03)
1970	61.9 (1.09)	0.53 (.01)	138.90 (2.45)	1.21 (.02)
1975	34 (.22)	-	118.18 (.76)	4.46 (.03)
1980	166 (.40)	42 (.10)	465.96 (1.13)	10.76 (.03)
1986	326 (.43)	65 (.09)	770.38 (1.02)	56.91 (.08)
1991	1,271 (.71)	2,055 (1.15)	1,778.42 (.99)	1,656.03 (.92)
1996	1,864 (.67)	3,843 (1.37)	2,460.84 (.88)	2,165.41 (.77)
1997	2,248 (.78)	5,243 (1.81)	4,266.63 (1.47)	2,893.83 (1.0)
1998	222 (.08)	3,836 (1.44)	3,788.76 (1.42)	3,296.30 (1.23)
1999	2,926 (1.02)	4,420 (1.54)	4,231.40 (1.47)	3,269.02 (1.14)
2000	-	-	7,607.7 (2.45)	5,077.06 (1.64)
2001	-	-	5,128.5 (1.78)	4,391.65 (1.53)

Source: Figures based on BOP are obtained from B. Lim (2000), "Taiwan at the Gate of Globalization", Table on Trends in Taiwan FDI. MOEA Approved and GDP figures are from Taiwan Statistical Data Book, 2002, CEPD, Republic of China.

Table 3: Principal Sources of Overseas Chinese and Foreign Investment in Taiwan

Unit : million

	1952 - Sept. 2000			Jan. - Sept. 2000		
	Cases	Amount	% of Total	Cases	Amount	% of Total
U.S.A	2,211	10,431	24.52%	105	1007	18.02%
Japan	3,674	8,981	21.11%	218	502	8.99%
Europe	964	5,446	12.80%	278	1,674	29.95%
Hong Kong	2.035	3,537	8.31%	-	-	-
Singapore	635	3,502	8.23	73	1,207	21.60%
Netherlands	-	-	-	13	269	4.81%

Source: Huang (2002); The Ministry of Economic Affairs Investment Commission, MOEA.

Table 4: Total employment and sales of FDI firms in the Manufacturing Sector

	1986	1996
Total Employment (no.)	279,658	227,413
Share of total manufacturing employment	11.0%	9.6%
Total sales	49,584,584	112,454,800
Share of total manufacturing sales	15.0%	14.9%

Source: Taiwanese Census of Manufactures, 1986 and 1996.

Table 5: Percentage of all firms by industry that are DFI firms, Exporting firms, and Firms with both DFI and Exports

Industry	1986			1996		
	FDI	Exports	FDI & Exports	FDI	Exports	FDI & Exports
Textiles	.74	34.0	.70	.68	20.1	.64
Clothing	.45	39.2	.45	.46	20.4	.40
Plastics	.59	28.4	.53	.52	13.7	.41
Chemicals	4.9	24.1	4.2	4.8	29.0	3.9
Electric/Electronics	4.2	41.9	4.1	3.1	30.4	2.6
Transportation Equipment	2.3	28.4	1.4	2.2	15.8	1.1

Source: Taiwanese Census of Manufactures, 1986 and 1996.

Table 6: Average characteristics of FDI, non-FDI and Exporting Firms

Industry	1986			1996		
	FDI	Non FDI	Export	FDI	Non FDI	Export
Textiles						
Sales (bl. NT$)	567	82	215	1,431	104	407
Workers (number)	333	57	137	461	36	123
Export-Sales ratio	.54	.23	--	.40	.09	--
Clothing						
Sales (bl. NT$)	386	38	84	356	43	120
Workers (number)	538	50	103	302	27	68
Export-Sales ratio	1.00	.34	--	.80	.16	--
Plastics						
Sales (bl. NT$)	412	40	120	3,219	33	225
Workers (number)	222	36	96	659	16	66
Export/Sales	.70	.22	--	.42	.08	--
Chemicals						
Sales (bl. NT$)	1,930	231	1,076	2,039	353	1,117
Workers (number)	207	60	222	170	53	148
Export-Sales ratio	.26	.07	--	.33	.08	--
Electronic						
Sales (bl. NT$)	1,132	58	226	1,493	200	654
Workers (number)	783	52	171	343	48	137
Export-Sales ratio	.77	.27	--	.52	.16	--
Transport						
Sales (bl. NT$)	1,754	48	245	3,734	86	655
Workers (number)	422	38	115	449	32	143
Export-Sales ratio	.21	.20	--	.17	.09	--

Source: Taiwanese Census of Manufactures, 1986 and 1996.

Table 7: Productivity Difference between FDI firms and non-FDI firms

	1986		1996	
	Intercept	FDI	Intercept	FDI
Textile	0.049*	0.083	0.237*	-0.113
	(0.006)	(0.065)	(0.006)	(0.075)
Clothing	-0.069*	0.091	0.043*	0.164
	(0.007)	(0.103)	(0.008)	(0.122)
Chemicals	0.041*	0.184*	0.251*	0.040
	(0.010)	(0.044)	(0.011)	(0.051)
Plastics	0.254*	0.094*	0.313*	0.070
	(0.003)	(0.045)	(0.004)	(0.054)
Electric and electronics	0.181*	0.020	0.407*	0.063*
	(0.004)	(0.019)	(0.003)	(0.020)
Transport equipment	0.056*	0.069**	-0.035*	0.134*
	(0.006)	(0.037)	(0.006)	(0.041)

* significant at the 5 percent level
** significant at the 10 percent level

Table 8: FDI intensity and Firm Productivity

		FDI intensity[a]			
Industry	Intercept	Low	Medium	High	Test results[b]
Textile	0.049*	0.008	0.013	-0.037	2,3
	(0.006)	(0.094)	(0.081)	(0.081)	
Clothing	-0.069*	0.154	0.117	0.123	2,3
	(0.008)	(0.172)	(0.133)	(0.121)	
Chemicals	0.044*	0.057	0.139*	0.039	2,3
	(0.011)	(0.090)	(0.043)	(0.072)	
Plastics	0.254*	0.003	0.108	0.120	2,3
	(0.004)	(0.066)	(0.064)	(0.057)	
Electric and electronics	0.180*	-0.029	0.066*	0.055*	3
	(0.004)	(0.034)	(0.025)	(0.019)	
Transport equipment	0.055*	0.101	0.116*	0.097	2,3
	(0.007)	(0.056)	(0.039)	(0.063)	

* Significant at the 5 percent level.
All regressions include year dummy variable taking 1 if the year is 1996 and 0 for 1986.
Standard errors are in parentheses.
a. FDI intensity is low if the FDI share of total asset is greater than 0 and less than or equal to 0.25, medium if the FDI share of total asset is greater than 0.25 and less than or equal to 0.75, and high if the FDI share of total asset is greater than 0.75.
b. Test results are coded as follows (all are for 5 percent level of significance): 1, do not reject the equality of all three FDI intensity coefficients; 2, do not reject the equality of the low and medium FDI intensity coefficients; and 3, do not reject the equality of the medium and high FDI intensity coefficients.

Table 9: Productivity of FDI and Exporting Firms

		Investment activity		
Industry	Intercept	Export	FDI	Both
Textile	0.010 (0.006)	0.118* (0.009)	-0.416* (0.196)	0.051 (0.051)
Clothing	-0.129* (0.009)	0.156* (0.012)	0.256 (0.289)	0.171* (0.084)
Chemicals	0.035* (0.012)	0.046* (0.018)	0.118 (0.084)	0.115* (0.038)
Plastics	0.226* (0.004)	0.100* (0.007)	0.004 (0.088)	0.121* (0.039)
Electric and electronics	0.150* (0.005)	0.075* (0.006)	-0.076 (0.042)	0.089* (0.015)
Transport equipment	0.038* (0.008)	0.061* (0.011)	0.102* (0.043)	0.137* (0.039)

* significant at the 5 percent level
All year dummy coefficients are significant at the 5 percent level.

Table 10: The incidence of FDI and Exports in the Electric/Electronics industry in the 1986, 1991 and 1996 Surveys (Percent of column total)

Combinations of Export and FDI	Year		
	1986	1991	1996
No Export, FDI	224 (24.6)	641 (41.2)	453 (34.9)
Only Export	507 (55.8)	717 (46.1)	677 (52.1)
Only FDI	12 (1.3)	19 (1.2)	20 (1.5)
Both Export and FDI	166 (18.3)	178 (11.5)	150 (11.5)

Source: Aw (2002)

Table 11: Transition Matrix for continuing firms in the electric/electronics industry: 1986~1996
(Number of firms, proportion of row total in parenthesis)

Investment Activity in year *t* (number of firms in year *t*)	Year *t+1*			
	Start Exporting	Stop Exporting	Start FDI	Stop FDI
No Export and No FDI (132 +153=285)	44+42=86 (30.18)	_	1+4=5 (1.75)	_
Only Export (390+373=763)	_	65+109=174 (22.80)	18+31=49 (6.42)	_
Only FDI (2+3=5)	0+1=1 (20)	_	_	0+2=2 (40)
Both Export and FDI (87+82=169)	_	1+7=8 (4.73)	_	23+24=47 (27.81)

Source: Aw (2002)

Table 12: Coefficient Estimates of TFP Growth Regression and Survival Regression in the Electronics Industry

Dependent variable:	TFP growth
Constant	-.965 (.311)**
RD	.094 (.029)**
Exports	.051 (.021)*
FDI	.113 (.044)*
County-Wide TFP	-.062 (.049)
County RD	-.014 (.013)
Industry RD	-.035 (.015)*
County Exports	.010 (.022)
2100.	.059 (.020)**
County FDI	.015 (.007)*
Industry FDI	-.005 (.013)
County-Industry RD	
County-Industry Exports	
County-Industry FDI	
Rho	.848 (.018)**
$\chi 2$ *a*	837.18**
Survival equation:	
TFP	1.162 (.076)**
RD	.280 (.071)**
Exports	.235 (.048)**
FDI	.307 (.118)**
Constant	-.470 (.031)**

Source: Aw (2002)

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Appendix I: The Measurement of Firm-Level Total Factor Productivity

Using the manufacturing data for Taiwan, we construct an index of total factor productivity (*TFP*) for each plant in each census year for which we have FDI information (1986, and 1996).[12]

A multilateral index which is useful for measuring *TFP* in firm-level panel data sets was developed by Caves, Christensen, and Diewert (1982). The *TFP* index is constructed as the log of the firm's output minus a revenue-share weighted sum of the log of the firm's inputs. In order to guarantee that comparisons between any two firm-year observations are transitive each firm's inputs and outputs are expressed as deviations from a single reference point. As the reference point the Caves, Christensen, and Diewert multilateral index uses a hypothetical firm with input revenue shares that equal the arithmetic mean revenue shares over all observations and output and input levels that equal the geometric mean of output and the inputs over all observations.

Therefore, each firm's output, inputs, and thus productivity in each year is measured relative to this hypothetical firm. Good, Nadiri, and Sickles (1996) discuss an extension of the multilateral index that uses a separate hypothetical-firm reference point for each cross-section of observations and then chain-links the reference points together over time in the same way as the conventional Tornqvist index of productivity growth. This productivity index is useful in our application because it provides a consistent way of summarizing the cross-sectional distribution of firm *TFP*, using only information specific to that time period, and how the distribution moves over time.

Let $Y_{f,t}$ be the value of the output of firm f in time t. Let $S_{f,t}$ be firm f's input share of input i and $X_{i,f,t}$ be firm f's use of input i. An upper bar demotes the average across all firms in the industry in a given period. The natural log of firm f's TFP in time t is calculated as,

$$\ln TFP = \left(\ln Y_{f,t} - \overline{\ln Y_t}\right) + \sum_{s=2}^{t}\left(\overline{\ln Y_s} - \overline{\ln Y_{s-1}}\right)$$
$$- \left[\sum_{i=1}^{n}\frac{1}{2}\left(S_{i,f,t} - \overline{S_{i,t}}\right)\left(\ln X_{i,f,t} - \overline{\ln X_{i,t}}\right)\right]$$
$$+ \left[\sum_{s=2}^{t}\sum_{i=1}^{n}\frac{1}{2}\left(\overline{S_{i,s}} - \overline{S_{i,s-1}}\right)\left(\overline{\ln X_{i,s}} - \overline{\ln X_{i,s-1}}\right)\right]$$

The first line of the formula measures plant output and consists of two parts. The first part expresses the firm's output in year *t* as a deviation from the reference point, the geometric mean output over all firms in year *t*, thus capturing information on the cross-sectional distribution in output. The second part sums the change in the output reference point across all years, effectively capturing information on the shift of the output distribution over time by chain-linking the movement in the reference point. The remaining two lines of the formula perform the same operation for each input X_i. The inputs are then summed using a combination of firm factor shares S_{ift} and average factor shares S_{it} in each year as weights. The index provides a measure of the proportional difference in *TFP* for plant f in year *t* relative to the hypothetical plant in the base year. In our application we use 1981 as the base year for Taiwan.

[12] Tybout (1996) discusses alternative productivity measures based on econometric estimation of production functions and summarizes the literature on the sources of productivity differences across producers.