International and Intranational Technological Spillovers and Productivity Growth in China

Xiaolan Fu, University of Oxford
Yundan Gong, University of Nottingham

Abstract

Technological spillovers from foreign direct investment have been regarded as a major source of technical progress and productivity growth. This paper explores the role of inter- and intra-national technological spillovers from foreign direct investment (FDI) in technical change, efficiency improvement and total factor productivity growth in Chinese manufacturing firms using a recent Chinese manufacturing firm-level panel dataset over the 2001-2005 period. International industry specific research and development (R&D) stock is linked to the Chinese firm-level data, international R&D spillovers from FDI and intra-national technological spillovers of R&D activities by foreign invested firms in China are examined. Policy implications are discussed.

Key Words: FDI, technological spillovers, R&D; productivity
JEL Codes: F2, O1, O3

Acknowledgement: The authors would like to thank Wing Thye Woo, V. N. Balasubramanayam, Shigeyuki Abe, Chul Chung, Bhanupong Nidhiprabha and conference participants at the Asian Economic Panel Annual Meeting, North America Productivity Workshop and the Chinese Economic Association (UK) Annual Conference for helpful comments.

I. Introduction

Three decades of fast economic growth of the Chinese economy has attracted substantial research interest. This impressive growth performance is found not only due to factor accumulation, but more importantly also due to productivity growth. As the largest FDI recipient in the developing world, how much has China benefited from the huge inflows of FDI? Technology transfer through foreign direct investment (FDI) has for long been regarded as a major engine of technological upgrading in developing countries. What are the roles of international and intra-national R&D spillovers in the technical progress and productivity growth in China? Can the developing countries reply on foreign technology to catch up with the industrialised countries?

Empirical evidence on the impact of FDI on the productivity growth of indigenous firms is mixed (Blomström and Kokko, 1998; Aitken and Harrison, 1999; Görg and Greenaway, 2001; Javorcik, 2004). It is found that intra-national knowledge spillovers are more important source of technological progress than the international spillovers for U.S and Japan (Branstetter, 2001). In the context of China, Hu and Jefferson (2002) find significant productivity depression rather than positive spillover effects of FDI on domestic firms. Using cross-section data for 1995, Buckley et al (2002) show that non-Chinese MNEs generate technological and international market access benefits for Chinese firms, while overseas Chinese investors confer only market access benefits. Spatial-wise, Chen et al (2008) suggest that in locations with strong clustering of innovative foreign firms, local firms benefit from knowledge spillovers, but not in locations where foreign concentration is measured by employment or capital. These studies provide useful insights. However, foreign knowledge and the spillover effects from FDI are often tested using output/employment/asset share of foreign invested firms or productivity or R&D activities of foreign firms in the same industry or region as measures. Although there are some studies that have tested directly the spillovers of international knowledge stock through international trade and FDI at country and industry level (eg., Coe and Helpman, 1995), no study at firm level so far has investigated directly the international knowledge spillovers.

This paper explores the role of inter- and intra-national technological spillovers from FDI in technical change, efficiency improvement and TFP growth in Chinese manufacturing firms using a recent Chinese manufacturing firm-level panel dataset of 56,125 firms over the 2001-2005 period. International industry specific R&D stock is linked to the Chinese firm-level data in corresponding industry and adjusted by industry- and firm-level degrees of openness. Therefore, we employ two sources of R&D spillovers from FDI: R&D spillovers from innovation activities by foreign invested firms in the same industry, and international R&D spillovers through FDI. We use the non-parametric frontier technique to decompose TFP growth of firms into technical change and efficiency improvement. Unlike most of the existing studies that estimate total factor productivity (TFP) using a single unchanging production function across industries, this study allows for the differences in production technology across industries and TFP is estimated for each industry separately.

This paper is organised as follows: Section II discusses the theoretical framework on international and intra-national R&D spillovers. Section III describes data, model and methodology. Section IV presents empirical evidence. Section V concludes.

II. Theoretical framework and innovation in China

The literature presents two alternative perspectives for the choice of technology development paths for developing countries. One perspective regards that FDI technology transferred from developed countries has positive effects on developing countries (Kokko, et al., 1997; Eden,1997), and therefore, the technology spillover effects of FDI may be more important than the effects of domestic investments (Borensztein, et al., 1995). The degree of technology diffusion from FDI increases with the increase in technology distance between the hosts and the foreign countries (Findlay, 1978). The greater the technology distance, the more difficult it becomes for developing countries to build up independent innovation.

Another outlook is that the introduction of FDI will make the competing domestic firms worse off (Aitken, Harrison, 1999) and will reduce the R&D efforts of local firms (OECD, 2002). Furthermore, the benefits of FDI technology spillovers are limited because most techniques transferred from foreign investment firms are usually mature techniques, not core techniques, and as the working conditions and rewards of overseas-funded firms are better than that of native firms, knowledge diffusion caused by turnover of native talented personnel is usually one-way from the native firms to overseas-funded firms. Moreover, technologies created in the industrialised countries are argued to be biased to the factor endowment of the countries where the technology is developed, and therefore, are capital and skilled-labour augments. (Basu and Weil, 1998; Acemoglu, 2002). Considering that technology progress has the characteristic of path dependence, a country which is dependent on the technology spillover of FDI for a long period of time, will later limit its independent innovation. Therefore, strengthening R&D and enhancing the independent creative abilities should be the main path for developing countries' technological advancement. Taking into account the pros and cons of the foreign and indigenous innovation, Lall (2003) argues that neither autonomous innovations nor FDI-reliant strategies can be used independently.

Theoretically, FDI contributes to technological upgrading in the host economy in several ways. Firstly, advanced technology embedded in the imported machinery and equipments can lift the level production technology of the host economy. Secondly, R&D and other forms of innovation generated by foreign firms and MNEs R&D labs increases the innovation outputs in the country directly (Athreye and Cantwell, 2007). Thirdly, FDI may contribute to the local innovation activities by bringing in advanced management practices and thus improve the innovation efficiency of local innovation system (Fu, 2008a). Finally, technological spillovers from foreign innovation activities may influence technical change and catch-up of the indigenous firms. Knowledge spillovers from foreign to local firms may take place through knowledge transfer within the supply chain; skilled labour turnovers; demonstration effects when local firms are learning by imitation; and competition effects when the competitive pressure caused by foreign presence forces the local firms to improve their production technology and management.

However, foreign R&D activities could also generate negative externalities to the domestic innovation activities. These could occur if foreign firms exploit their superior technology and marketing power to force local competitors to reduce their outputs or if they attract the most talented researchers and compete in the markets of innovation products which threaten local firms, SMEs in particular (Aghion et al., 2005; Fu, 2004 and 2007; UNCTAD, 2005; Aitken and Harrison, 1999). Moveover, there are several reasons that local firms might not be able to enjoy the FDI spillover effects efficiently. Firstly, knowledge transfer via supply chain requires effective linkages between foreign firms and local suppliers and customers (Balasubramanayam, et al., 1996; Fu, 2004). Secondly, significant spillovers from FDI on local firms are also subject to sufficient absorptive capacity of the local firms and organisations (Cohen and Levinthal, 1989; Girma, 2005; Fu, 2008a). Thirdly, the appropriateness of the technology embedded in FDI affects the sign and significance of the productivity effects of FDI spillovers. Technologies created in the industrialised countries are argued to be biased to the factor endowment of the country where the technology is developed (Basu and Weil, 1998; Acemoglu, 2002). Finally, different types of FDI have markedly different productivity spillover effects (Driffield and Love, 2003).

Since it launched the economic reforms and invited foreign capital participation in its economy in 1979, China has received a large volume of international direct investment flows and stands as the second largest FDI recipient in the world. In 2004 FDI inflows into China reached a historical peak of US60.63 billion (Figure 1). The sources of inward FDI in China have also evolved over time. While investment from overseas Chinese in Hong Kong, Macao and Taiwan were the major sources of inward FDI in the 1980s, the 1990s has seen increasing inward FDI from the major industrialised countries and other OECD countries.

Innovation efforts in China have grown rapidly during the past two decades. The total R&D expenditure in China has grown from 7.4 billion Yuan in 1987 to 300.3 billion Yuan in 2006, with an average annual growth rate of 15 percent (Figure 2). Since late 1990s, innovation and R&D activities of foreign firms in China have been increasing, at a faster pace than that of the domestic firms. The average annual growth rate of R&D expenditure over the 1998 to 2004 period was 38 and 33 percent in foreign invested enterprises and Ethnic Chinese invested firms[1], respectively. This is much higher than that in indigenous firms at 25 percent over the same time period.

Given the fact that foreign investors in China are mostly market- or resource- or cheap labour-seeking processing types, R&D spillovers from foreign invested firms are likely to be limited. Moreover, motivations, technology levels and endowments, and access to advanced technological and managerial knowledge all are different between foreign and ethnic investments. The productivity effects of foreign and ethnic investments are likely to be different. Therefore, we look at the impacts from these two different types of firms separately.

III. Data and Methodology

Data

The empirical work is based on two datasets: Chinese manufacturing firm level dataset and International industry specific R&D stock dataset. The Chinese firm level dataset is from the Annual Report of Industrial Enterprise Statistics compiled by the State Statistical Bureau of China, covering all state-owned firms and other type of

1 Ethnic Chinese invested firms refer to firms that there are more than 25 percent share of capital invested by Hong Kong, Macao and Taiwan investors.

firms with annual turnover of over five million Renminbi (about $0.6 million). The dataset includes all the variables we are interested in, such as firm ownership structure, industry affiliation, establishment year, employment, gross output, exports, R&D and employee training expenditures etc.[2] The data covers the period 2001 to 2005. It is broadly classified under five ownership categories: (i) state-owned (ii) collectively-owned (iii) privately-owned (iv) foreign-owned and (v) others. Foreign-owned firms are further divided into firms that with investments from Hong Kong, Taiwan and Macro investors (so-called Ethnic firms) and from other foreign sources (FIEs). "Other" firms are mainly shareholding enterprises.

As we are interested in the technology spillover effects from foreign firms on the domestic firms, the econometric work is confined to domestic-owned enterprises only. We, however, use the full sample to construct various variables of interest, for example the share of foreign firms in an industry-region or the Herfindahl index of market concentration. The final data set consists of 269,905 observations from 53,981 firms, we include only those firms with the full set of observations during the sample period as estimation of TFP growth and its components using DEA analysis requires balanced datasets. Table 1 reports the ownership structure of firms for each industry. Of the total 29 SIC 2-digit manufacturing industries under study, 7 of them are dominated by foreign invested firms (FIEs) who produce more than 50% of the total outputs. In Cultural, educational and sports goods (24), electronic and telecommunications (40) and instruments and meters (41), foreign firms produce even 70 to 80 percent of the country's total output. This is phenomenal given the size of the Chinese industry. In these three and the apparel industries, more than 20% of the

[2] Nominal values are deflated using industry-specific ex-factory price indices obtained from China Statistical Yearbook 2006.

firms are invested by foreign capital, mainly from OECD countries. Table 2 sees a steady modest growth in the proportion of firms invest in research and development (R&D) across all the industries over the sample period. The medical and pharmaceutical (27), tobacco (16) and electronic and telecommunications (40) industries top the chart with 50, 45 and 33 percent innovative firms, respectively.

International industry specific R&D stock is linked explicitly to the Chinese firm-level data. The estimates of international R&D capital stocks are based on R&D expenditure data from the OECD's *Main Science and Technology Indicators.* Real R&D expenditure are nominal expenditures deflated by an R&D price index (PR)[3]. Following Coe and Helpman (1995), R&D capital stocks (S), which are defined here as beginning of period stocks, were calculated from R&D expenditure (R) based on the perpetual inventory model as $S_t = (1-\delta) S_{t-1} + R_{t-1}$. Here δ is the depreciation rate, which was assumed to be 5, 10 and 15 percent alternatively. The benchmark for S was calculated following the procedure suggested by Griliches (1979), as $S_0 = R_0 / (g + \delta)$, where g is the average annual logarithmic growth of R&D expenditures over the period for which published R&D data was available, R_0 is the first year for which the data was available, and S_0 is the benchmark for the beginning of the year. The domestic R&D capital stocks were converted into Euros at 2000 constant price. The R&D stocks of the 22 OECD countries are then summed to proxy the world R&D stock.

[3] PR is defined as PR = 0.5 P + 0.5W, where P is the implicit deflator for business sector output and W is index of average business sector wages. This definition of PR implies that, half of R & D expenditures are labor costs, which is broadly consistent with available data on the composition of R & D expenditures.

Methodology

For the empirical investigation, we first estimate total factor productivity (TFP) growth using the Malmquist index, and decompose it into technical progress and efficiency change. Secondly, we use econometric techniques to estimate the impact of technological spillovers of FDI on TFP gowth, technical change and efficiency improvement. TFP is estimated for each industry separately allowing for different technology and production function for different industries.

Due to the limitations of the traditional parametric approach, this paper estimates TFP growth by using a non-parametric programming method developed by Fare et al. (1994). Following Fare's approach, a production frontier is constructed based on all the existing observations. The distance of each of the observations from the frontier is estimated. Technical efficiency is defined as the distance of each observation relative to the frontier. TFP growth is defined as a geometric mean of two Malmquist productivity indexes, which is to be estimated as the ratios of distance functions of observations from the frontier. This approach has the advantage in that it allows for the decomposition of productivity growth into two mutually exclusive and exhaustive components: (1) efficiency change in movements towards (or away from) the frontier, which is a measurement of catching-up; and (2) technical change measured by shifts in technological frontier (Fare, et al., 1994). This decomposition of TFP growth enables us to investigate the impact of foreign and indigenous innovation efforts on technical progress and technological catch-up.

Assuming a production technology which produces a vector of outputs, $y^t \in R_+^M$, by using a vector of inputs, $x^t \in R_+^N$, for each time period t=1,…, T, the output-based

Malmquist productivity change index is defined as the geometric mean of two Malmquist productivity index as follows:

$$M_0\left(x^{t+1}, y^{t+1}, x^t, y^t\right) = \left[\left(\frac{D_0^t\left(x^{t+1}, y^{t+1}\right)}{D_0^t\left(x^t, y^t\right)}\right)\left(\frac{D_0^{t+1}\left(x^{t+1}, y^{t+1}\right)}{D_0^{t+1}\left(x^t, y^t\right)}\right)\right]^{\frac{1}{2}} \qquad (1)$$

A value greater than 1 indicates positive TFP growth in period t+1. When performance deteriorates over time, the Malmquist index will be less than 1. Rewriting equation (1), we have

$$M_0\left(x^{t+1}, y^{t+1}, x^t, y^t\right) = \frac{D_0^{t+1}\left(x^{t+1}, y^{t+1}\right)}{D_0^t\left(x^t, y^t\right)} \times \left[\left(\frac{D_0^t\left(x^{t+1}, y^{t+1}\right)}{D_0^{t+1}\left(x^{t+1}, y^{t+1}\right)}\right)\left(\frac{D_0^t\left(x^t, y^t\right)}{D_0^{t+1}\left(x^t, y^t\right)}\right)\right]^{\frac{1}{2}} \qquad (2)$$

where efficiency change (EFFCH) = $\frac{D_0^{t+1}\left(x^{t+1}, y^{t+1}\right)}{D_0^t\left(x^t, y^t\right)}$ (3)

technical change (TECHCH) = $\left[\left(\frac{D_0^t\left(x^{t+1}, y^{t+1}\right)}{D_0^{t+1}\left(x^{t+1}, y^{t+1}\right)}\right)\left(\frac{D_0^t\left(x^t, y^t\right)}{D_0^{t+1}\left(x^t, y^t\right)}\right)\right]^{\frac{1}{2}}$ (4)

TFP change is thus decomposed into two components: efficiency change and technical change. Efficiency change measures whether production is getting closer to or farther away from the frontier, reflecting the changes in X-efficiency. Technical change captures the shift in technology between the two periods. A value of greater than 1 indicates catch-up with the frontier or technical progress. A value of less than 1 indicates deterioration in performance. Scale efficiency is defined as the ratio of technical efficiency calculated under the assumption of constant returns to scale (CRS) to technical efficiency calculated under the assumption of variable returns to scale (VRS) (Fare et al., 1994). It measures how close a firm is to the most productive scale size. In this paper, output is measured by total output of firm, inputs includes capital (net fixed assets), labour (number of employees), and intermediate inputs (variable costs). We use the output-oriented model under variable returns to scale for estimation.

Following the decomposition of productivity growth, the next step is to estimate the determinants of TFP growth, technical change and efficiency improvement and to investigate the impact of indigenous innovation efforts and foreign R&D spillover effects on productivity growth and its components. There are two sets of variables that are of our interests: the sets of R&D variables and FDI variables. In our specification, there are three types of innovation efforts: innovation at the firm level, at the industry level and at the international level. We construct the variables as follows: (1) at the firm level R&D intensity is used as the direct effect of innovation on firm's growth performance; (2) the industry level innovation effect in each of the 171 three-digit industries and 31 provinces are constructed as the proportion of R&D expenditure accounted for by different ownership types in the same industry and region; (3) the interaction terms of international industry specific R&D stock and FDI share at both firm and industry level are adopted to measure the international innovation effect through FDI spillover effects. FDI is represented by two variables, the share of foreign and ethnic capital at the firm level. Therefore, the empirical analysis of the indigenous and foreign technology spillovers on the technology upgrading of indigenous firms are based on the model as follows,

$$\Delta p_{it} = \alpha + \varphi r_{it}^{f} + \chi r_{it}^{s} + \lambda_1 r_{it}^{w} * f_{it}^{s} + \lambda_2 r_{it}^{w} * f_{it}^{f} + \sigma X_{it} + \delta D_{it} + \varepsilon_{it} \qquad (8)$$

where the dependent variable p represents TFP growth, technical change and efficiency improvement respectively. r^f is firm R&D intensity, r^s is a vector of industry level R&D spillovers variables measured by industry average R&D intensity by different ownership types, r^w is world R&D stock constructed from OECD STAN database as discussed earlier, f^f and f^s are FDI intensity at firm and industry level, respectively. FDI intensity is further divided into foreign and ethnic capital intensity and enters the regression at the same time. X is a vector of control variables; D is the full set of time, sector and year dummies and ε is a random error term.

The choice of control variables is guided by the existing empirical literature on the determinants of TFP growth (e.g. Bernard and Jensen, 1999; Aw, et al., 2000; Girma and Gong, 2008; Fu, 2005 and 2008b). It includes initial level of technology efficiency, age, firm size, export, intangible assets, labour training and market concentration that are hypothesised to impact on the dependent variable. Smaller firms and firms with exports and more labour training are more likely to have faster TFP growth, technical change as well as efficiency improvement. Firms standing at the frontier are less likely to grow as fast as other firms. There is no conclusive relationship between firm age, intangible assets[4] and market concentration

There are good reasons to suspect that R&D, labour training, foreign capital participation are potentially endogenous, even after controlling for fixed effects. For example firms with relatively large number of R&D activities are more likely to have higher TFP growth and faster technical change than the others. However, it is possible that firms with higher growth rate might invest more in R&D activities to keep their technology advantages. Another example is the foreign share of a firm. Firms with a higher foreign share could have better access to more advanced foreign technologies

[4] According to *Accounting System for Business Enterprises*, costs to develop intangible assets are regarded as R&D costs of self-created products that are registered for a legal right to the asset, such as a patent (Pacter and Yuen, 2001).

and therefore have higher growth rates. There however also might be a “cherry-picking” effect (Huang, 2003) that foreign firms choose the faster growing firms to invest. Similar arguments can also be made in the case of export and ethnic capital participation.

We employ the fixed effects generalised method of moments regression technique (see, inter alia, Hansen, 1982 and Arellano and Bond, 1991) to deal with the endogeneity problem. Lagged values of the potentially endogenous variables are used as instruments. In addition, the shares of foreign and ethnic firms in the industry and region are used as extra instruments. We assume that a sector might be more efficient than others if there are more foreign firms or ethnic firms participating in it, given the low level of competition from state-owned firms. We test whether the assumption of endogeneity is borne out by the data at hand and whether our instruments are relevant in that they exhibit sufficiently strong correlation with the potential endogenous variables. We also test for the appropriateness of the instrumental variable candidates using Hansen J’s test for overidentifying restrictions and the validity of the instruments with Sargan test. Reassuringly we find that our instruments are appropriate on all counts.

IV. Results

Estimated TFP growth and its decomposed components for each industry are reported in table 3. From all industries, the Chinese firms have experienced considerable TFP growth over the 2001-2005 periods at an average annual rate of 4.5%. The growth is mainly due to technical change at an average annual growth rate of 4.3% rather than efficiency change. The average annual growth rate of efficiency improvement was only 0.7% over the sample period, which suggests limited catch-up process of the followers to the innovation leaders in the Chinese manufacturing sector.

It is also interesting to see, from table 3, that the industries that foreign firms produce more than 50% of the total outputs have higher efficiency change rate but lower technical change rate, as well as lower TFP growth rate than those industries dominated by indigenous firms. For example, among those industries dominated by FIE, the garments and other fiber products industry enjoys the highest efficiency rate 14.4% and the lowest technical change rate 10%. It might suggest that foreign firms are more likely to keep their technical advantage in their home countries and are more reluctant to improve their technical efficiency than their Chinese competitors. Meanwhile, they focus on adapting their technology to the local technological frontier, and therefore local market.

Determinants of productivity growth

Table 4 reports both the OLS and the GMM estimates of effects of technological spillover effects from foreign innovation efforts on the TFP of indigenous firms. As we discussed in section III, the test suggests significant endogeneity in the model. The GMM estimation results is therefore preferred to the OLS estimates. For robustness check, estimated results of the basic model, models with industrial and international R&D spillovers at three alternative depreciation rates are all carried out. The estimated coefficients from different model specification are consistent suggesting the robustness of the estimated results. We only report the results with a 10% R&D depreciation rate due to space limitation[5].

In terms of the coefficients of the control variables, we find that they all turn out as expected. Firms with better initial technical efficiency tend to grow slower. Smaller firms appear to be more productive. Firms with high export-intensity, high FDI-intensity, more training and greater intangible assets have higher TFP growth than those who lack these characteristics. These estimated results are robust and statistically significant across industry sectors and different model specifications. Firm age does not appear to be a significant factor. Interestingly, industry concentration and low levels of competition seem to increase firm productivity although the estimated coefficients lose its statistical significance when international R&D spillovers are controlled for.

The variables of most interest to us are, as we mentioned above, the sets of R&D and FDI variables. Indigenous R&D efforts have a significant positive impact on firm-level TFP growth. The estimated coefficients bear the expected positive sign and are statistically significant across different model specifications. R&D spillovers from domestic firms in the same industry exert a significant positive effect on the TFP growth of indigenous firms. However, it is interesting to see that innovation efforts from the FIEs in the same industry show a negative and significant impact on Chinese manufacturing firms and there is no significant impact from ethnic firms at the same industry. This is likely because of either the competition effects of foreign R&D on

[5] Results of all the estimations are available from the authors subject to request.

the indigenous firms, or the technologies developed by these sectors are not appropriate for the current technology frontier.

As we expected that both foreign and ethnic capital participations foster Chinese domestic firm's productivity growth. Foreign capital has bigger influence on firm's growth than ethnic capital and both magnitudes of the coefficients have been doubted when international R&D spillover effects are controlled. For example, the estimate result based on industrial level indicate that a 10 percentage points increase in the share of foreign capital leads to a 2.5 percentage increase in the rate of productivity growth, while a 10 percentage points increase in the share of ethnic capital only leads to a 1.7 percentage growth. However, both growth rates increase to 5.6 and 4.9 percentages respectively at the specification with international R&D spillovers. It might suggest that domestic firms with foreign capitals have better channels to foreign advanced technical and management knowledge compared to their competitors with only ethnic capital participations.

The estimated coefficients on international R&D spillovers variables are statistically negatively significant for firms with foreign and ethnic capitals at firm level, but insignificant for firms with ethnic capitals at the industry level. It is likely to be explained by their inappropriate nature in the developing country context and the strong intellectual property rights protection in the high-technology industries. Also we should bear in mind that the international R&D spillover data is from the OECD countries which might has a limited knowledge transfer through the ethnic channel.

Determinants of technical change and scale efficiency improvement

Tables 5 reports the estimated result on the impact of indigenous innovation efforts and foreign R&D spillovers on technical change and efficiency improvements of the indigenous firms. We find no systematic relationship between the age of the firm and both technical change and efficiency improvement. Bigger firms appear to have experienced faster rates of technical change across all the specifications. However, the effort of size is not statistically significant to efficiency improvement. Exports contribute to efficiency change and catch-up, but not the shift of the technology frontier. This result is consistent with the findings in Fu (2005) using Chinese industry-level panel data suggesting the focus on low-cost competitiveness based on cheap un-skilled labour and the dominance of process trading in the export structure provide no effective incentive for firms to innovate.

The estimated coefficients on the intangible assets variable are negative and statistically significant in the technical change equation. This is likely because intangible assets include, according to Chinese accounting practices, R&D investment in the development stage but not the research stage. For firms in the technology intensive industries, novel research activities may play a more important role in keeping them on the frontier and promoting TFP growth in these industries. The second reason may be that intangible assets are correlated with the fixed assets that we used for the TFP estimation. Therefore, technically there is a negative association between TFP and intangible assets. Training exerts a significant positive impact on efficiency improvement as expected, but surprisingly, bears a significant negative impact on technical change. Further investigation is needed with regard to the accounting definition of training expenditure in China, the purposes and contents of training, how they are expended and who are trained. They are likely to be conducted for teaching new or advanced practices but not for the creation of frontier technology. The estimated coefficients of market concentration are mostly insignificant.

Indigenous R&D of individual firms has no significant impact on technical change. It has, however, contributed significantly to efficiency improvement which reflects the catch-up process. This is not surprising given the fact revealed from the First National Economic Census in 2004 that about 95% of total business R&D expenditure was spent on development and only 5% was spent on basic scientific research. Interesting, R&D activities in the domestic firms at the industry level have shown significant and robust positive spillovers on the technical progress of indigenous firms. This evidence suggests that it is collective indigenous R&D activities, i.e. R&D at industry level, that push up the technology frontier and drives technology upgrading of indigenous firms. R&D activities of foreign invested firms at the industry level have shown a negative spillover effect on technical change of indigenous firms but a positive spillover effect on technological catch-up. This may be explained by the competition effects from the foreign R&D activities and the findings of recent studies that the core technology development of MNEs still remain at the head quarters, while the applied research and adaptation are the main tasks of its affiliates in foreign countries. Therefore, these R&D activities may not contribute to technical change but their impact on catching-up. The spillover effects of R&D investment in ethnic firms, however, only show significances when international R&D spillover effects are considered and have opposite signs from those of FIEs. It suggests that the R&D activities from ethnic firms at the industry can help to foster technical upgrading, but not technological catch-up.

In terms of FDI spillover effects, there is no direct FDI impact on efficiency change, but a significant negative impact is detected on technical change. This is likely, again, firms with foreign capital might tend to keep their core technology research at their mother countries. Another explanation may be due to the small share of foreign capitals in the indigenous firms, which is no more than 25 percent. There is also no indirect FDI R&D spillover effect on efficiency change, but the impacts for indigenous firms with foreign capitals are positively significant at both firm and industry level. This suggests the importance of intra-firm technology transfer of the frontier technology through FDI. Foreign investors may transfer the most advanced technology when they have more control of the firm.

V. Conclusions

This paper explores the role of inter- and intra-national technological spillovers from FDI in technical change, efficiency improvement and TFP growth in China. It finds that, firstly, over the 2001 to 2005 period, the Chinese firms have experienced considerable TFP growth at an average annual rate of 4.8%. This growth spreads widely across the board and is mainly due to technical change rather than efficiency improvement. Most of the FDI dominated industries did not grow as fast as the other industries in terms of TFP growth and technical change. A considerable proportion of rapid technical change took place in industries where the indigenous firms enjoyed a lead. All this suggests a turning point in China's post reform era that indigenous industries started to take off in terms of technological progress and productivity growth, and reveals a period with TFP growth driven by technical change benefited from internal and external technological spillovers.

Moreover, contrary to the normal expectations, R&D activities of foreign firms in China have exerted a significant productivity depression rather than positive spillover effects on indigenous firms. Collective indigenous R&D activities at industry level are found to be the major driver of technology upgrading of indigenous firms that push up the technology frontier. However, firms with high FDI-intensity are likely to have high TFP growth reflecting the benefits from FDI in non-technological aspects, such as managerial and marketing knowledge.

Finally, foreign direct investment, especially FDI from non-ethnic Chinese investors, is proved to serve as an effective vehicle and facilitator of international transfer of technological knowledge. Interactions of international R&D stock and FDI openness at the firm and industry level both show significant positive effect on the technical change of indigenous firms. However, the role of ethnic Chinese investment is rather controversial in this respect. Ethnic Chinese investors appear to confer only benefits in market access and managerial knowledge that hybrid the advantages of western and eastern management philosophy.

Findings from this research have important policy implications. Developing countries should not simply reply on FDI for indigenous technological upgrading. In the increasingly globalising world when countries, regions and firms adopting increasingly open innovation system, they can use both internal and external knowledge source for technology upgrading and productivity growth. The role of indigenous innovation, especially collective indigenous innovation efforts shall not be over looked. Science and technology policies should be introduced to encourage innovation by indigenous firms so as to build up dynamic indigenous technological capabilities. On the other hand, foreign direct investment, especially FDI from industrialised countries should be encouraged as this type of investment does serve as an effective conduit of advanced foreign technological knowledge. This gives the role for the trade and industry policies in developing countries to distinguish different sources of FDI and attract more FDI from industrialised countries.

References

Acemoglu, Daron, (2002), "Directed Technical Change", *Review of Economic Studies*, Vol. 69, p781-810.

Aghion, Philippe, Nick Bloom, Richard Blundell, Rachel Griffith and Peter Howitt (2005), Competition and innovation: An inverted U relationship, *Quarterly Journal of Economics*, May 2005, pp. 701-728.

Aitken, Brian J., Harrison, Ann E., (1999) "Do domestic firms benefit from direct foreign investment? Evidence from Venezuela", *American Economic Review*, 89(3): 605–618.

Arellano, Manuel, Bond, Stefan (1991) 'Some tests of specification for panel data: Monte Carlo evidence and application to employment equations'. *Review of Economic Studies* 58, 277-297.

Athreye, Suma and Cantwell, John, 2007. 'Globalisation and the emergence of new technology producers', *Research Policy*, v. 36, no. 2, 209-226.

Aw, Bee Yan, Chuang, Sukkyun and Roberts, Mark J. (2000) Productivity and turnover in the export market: micro-level evidence from the Republic of Korea and Taiwan (China), *The World Bank Economic Review*, 14 (1), 65-90.

Balasubramanyam, Vudayagi N., Salisu, Mohammed and Sapsford, David, 1996. 'Foreign direct investment and growth in EP and IS countries', *Economic Journal*, 106, 92-105.

Basu, Susanto and Weil, David, (1998) Appropriate technology and growth. *Quarterly Journal of Economics* 113, 1025–1054.

Bernard, Andrew and Jensen, Bbradford J. (1999) Exceptional exporter performance: cause, effect, or both? *Journal of International Economics*, 47 (1), 1-25.

Blomström, Magnus and Ari Kokko (1998): "Multinational Corporations and Spillovers". *Journal of Economic Surveys*, Vol. 12, pp. 247-277.

Branstetter, Lee G. (2001). "Are knowledge spillovers are international or intranational in scope? Microeconometric evidence from the U.S. and Japan". Journal of International Economics, 53(1), 53–79.

Borensztein, Eduardo, Gregorio, Jose De, Lee, Jong-Wha, 1995,"How does foreign direct investment affect economic growth ?", NBER Working Papers, No. 5057.

Buckley, Peter J; Clegg, Jeremy; Wang, Chenqi,_2002. The Impact of Inward FDI on the Performance of Chinese Manufacturing Firms. *Journal of International Business Studies*, 4th Quarter, Vol. 33 Issue 4, p637-655.

Chen, Dong, Li, Jing and Shapiro, Daneil (2008). "FDI knowledge spillovers and product innovations of Chinese firms", paper presented at the SLPTMD conference, University of Oxford.

Coe, David and Helpman, Elhanan (1995) International R&D spillovers, *European Economic Review*, 39, 859-887.

Cohen, Wesley, and Daniel Levinthal,(1989) "Innovation and learning: Two faces of R&D", *Economic Journal* (99):569-596

Driffield, Nigel and James H Love, 2003. Foreign direct investment, technology sourcing and reverse spillovers, *The Manchester School*. Vol. 71, Iss. 6, p. 659-672 (14 pp.)

Eden, Lorraine, Lecitas, Edward, and Martinez, Richard J., 1997. "The production, transfer and spillover of technology: Comparing large and small multinational as technology producers", Small Business Economics, (9) Fare, Ralf, Grosskopf, Shawna, Norris, Mary and Zhang, Zhongyang (1994) Productivity growth, technical progress, and efficiency change in industrialized countries, *The American Economic Review*, 84 (1), 66-83.

Findlay, Ronald, (1978) "Relative backwardness, direct foreign investment and the transfer of technology : A simple dynamic model", *Quarterly of Journal of Economics* , February , pp. 1 -16.

Fu, Xiaolan, (2004) 'Limited Linkages from Growth Engines and Regional Disparities in China', *Journal of Comparative Economics*, 2004, vol 32, no. 1, 148-164.

Fu, Xiaolan, (2005) "Exports, technical progress and productivity growth in Chinese manufacturing industries", *Applied Economics*, Vol 37, no7, 725-739.

Fu, Xiaolan, 2007. 'Trade-cum-FDI, human capital inequality and the dual economy in China: the Signer perspective', *Journal of Economic Change and Restructuring*, v.

Fu, Xiaolan, (2008a) "Foreign direct investment, absorptive capacity and regional innovation capabilities: Evidence from China", *Oxford Development Studies*, vol 36, no. 1, 89-110.

Fu, Xiaolan, (2008b) "Managerial knowledge spillovers from FDI: evidences from UK survey data", paper presented at the Academy of International Business Annual Conference, Milan, Italy.

Girma, Sourafel, 2005. 'Absorptive capacity and productivity spillovers from FDI: a threshold regression analysis', Oxford Bulletin of Economics and Statistics, 67, 3 281-306.

Girma, Sourafel and Gong, Yundan, 2008, "Putting people first? Chinese state-owned enterprises' adjustment to globalisation", International Journal of Industrial Organization, 26, 2, 573-585.

Görg, Holg and Greenaway David (2001): "Foreign direct investment and intra-industry spillovers: a review of the literature". GEP Research Paper 2001/37, University of Nottingham.

Griliches, Zvi (1979). 'Issues in assessing the contribution of R&D to productivity growth', *Bell Journal of Economics*, 10, 92-116.

Hansen, Lars Peter, (1982) Large sample properties of generalized method of moments estimators. *Econometrica* 50, 1029-1054.

Huang, Yasheng, (2003) *Selling China*. Cambridge University Press.

Hu, Guangzhou and Jefferson, Gary (2002) FDI impact and spillover: evidence from China's electronic and textile industries*. World Economy 38 (4), 1063-1076.*

Javorcik, Beata Smarzynska (2004): "Does foreign direct investment increase the productivity of domestic firms? In search of spillovers through backward linkages", American Economic Review, 94 (3), 605-627.

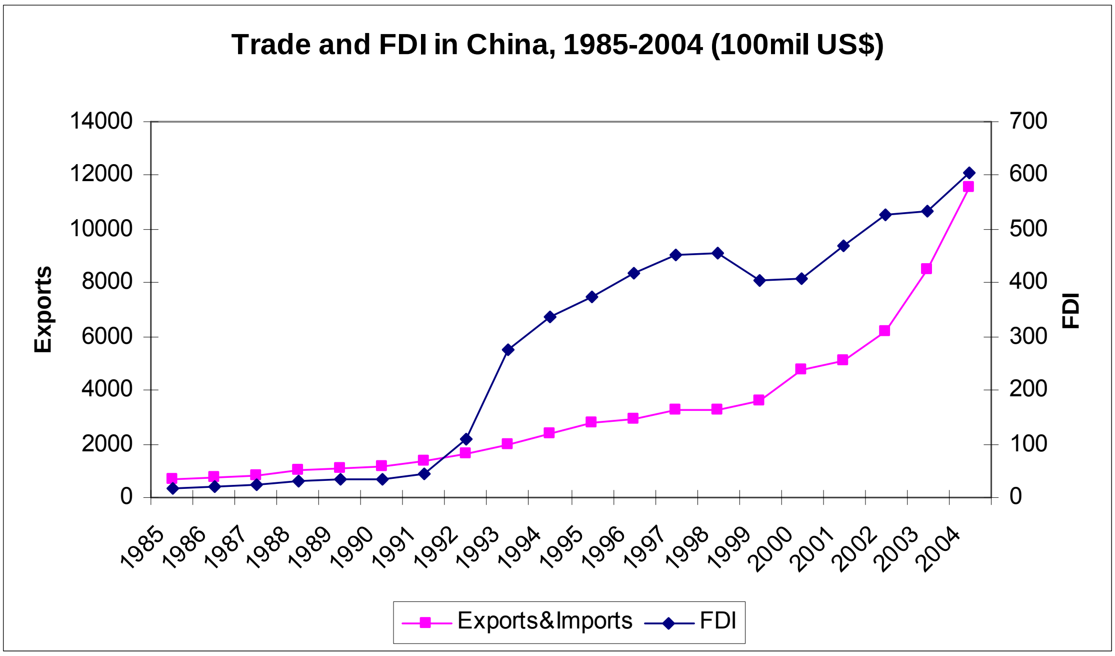
Kokko, Ari, Tansini, Ruben, & Zejan, Mario, 1997, "Trade regimes and spillover effects of FDI: Evidence from Uruguay" (Manuscript), Stockholm School of Economics, Stockholm.

Lall, Sanjaya, (2003), "Foreign Direct Investment, Technology Development and Competitiveness: Issues and Evidence", in: S. Lall and S. Urata (eds), *Competitiveness, FDI and Technological Activity in East Asia*, published in association with the World Bank, Edward Elgar, Cheltenham, UK.

Organization for Economic Cooperation and Development, 2002, "Science and technology industry outlook", Paris: OECD.

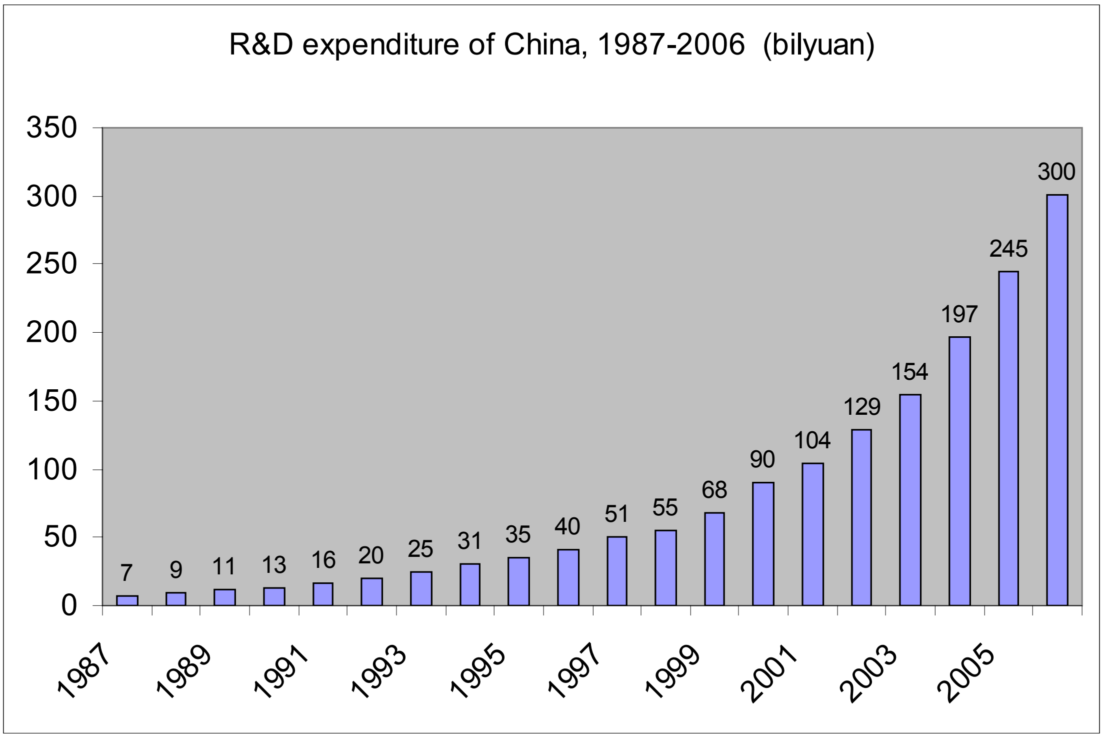
Pacter, Pual, and Yuen, Joseph, 2001, New comprehensive accounting system adopted in China, China Financial Reporting Update, issue 02/2001
UNCTAD, 2005. Globalisation of R&D and Developing Countries: Proceedings of an Expert Meeting, United Nations, New York and Geneva.

Figure 1.



Trade and FDI in China, 1985-2004 (100mil US$)
Exports
FDI
14000
12000
10000
8000
6000
4000
2000
0
700
600
500
400
300
200
100
0
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
Exports&Imports
FDI

Figure 2



R&D expenditure of China, 1987-2006 (bilyuan)
350
300
250
200
150
100
50
0
7
9
11
13
16
20
25
31
35
40
51
55
68
90
104
129
154
197
245
300
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005

Table 1 Ownership structure in each industry group

SIC 2-digit industry	Indigenous firms: % by number of firms	Indigenous firms: % by turnover	foreign firms: % by number of firms: all foreign firms	foreign firms: % by number of firms: ethnic firms	foreign firms: % by number of firms: non-ethnic foreign firms	foreign firms: % by turnover
13-Food Processing	79%	72%	21%	9%	12%	28%
14-Food Production	68%	52%	33%	16%	17%	48%
15-Beverage Industry	78%	60%	22%	10%	13%	40%
16-Tobacco Processing	97%	100%	3%	3%	0%	0%
17-Textile Industry	74%	74%	26%	17%	9%	26%
18-Garments and Other Fiber Products	48%	48%	52%	30%	21%	52%
19-Leather, Furs, Down and Related Products	48%	38%	52%	33%	19%	63%
20-Timber Processing	70%	66%	30%	17%	14%	35%
21-Furniture Manufacturing	55%	38%	46%	27%	18%	62%
22-Papermaking and Paper Products	80%	64%	20%	13%	7%	36%
23-Printing and Record Medium Reproduction	82%	63%	18%	13%	5%	37%
24-Cultural, Educational and Sports Goods	42%	30%	58%	39%	20%	70%
25-Petroleum Refining and Coking	87%	98%	13%	5%	8%	2%
26-Raw Chemical Materials and Chemical Products	81%	81%	20%	10%	10%	20%
27-Medical and Pharmaceutical Products	80%	73%	21%	10%	11%	27%
28-Chemical Fiber	73%	72%	27%	16%	10%	28%
29-Rubber Products	74%	58%	27%	16%	11%	42%
30-Plastic Products	61%	52%	39%	27%	13%	48%
31-Nonmetal Mineral Products	86%	79%	14%	8%	6%	21%
32-Smelting and Pressing of Ferrous Metals	91%	93%	9%	5%	4%	7%
33-Smelting & Pressing of Nonferrous Metals	87%	87%	13%	7%	6%	13%
34-Metal Products	70%	54%	30%	17%	13%	46%
35-Ordinary Machinery	84%	72%	16%	6%	10%	28%
36-Special Purposes Equipment	84%	82%	16%	8%	8%	18%
37-Transport Equipment	81%	75%	19%	9%	10%	25%
39-Electric Equipment and Machinery	73%	61%	27%	16%	12%	39%
40-Electronic and Telecommunications	40%	22%	60%	32%	28%	79%
41-Instruments and meters	58%	23%	42%	22%	20%	77%
42-Artifact and Other Manufacturing	55%	46%	46%	30%	15%	54%
Total	73%	67%	27%	15%	12%	33%
Total number of firms	39639		14342			

Notes: industries dominated by foreign invested firms (FIEs) who produce more than 50% of the total outputs are highlighted in shade.

Table 2 Proportion of firms investing in R&D

SIC 2-digit industry	2001	2002	2003	2004	2005
13-Food Processing	0.1022	0.1080	0.1169	0.0786	0.0786
14-Food Production	0.1711	0.1940	0.1743	0.1680	0.1680
15-Beverage Industry	0.1692	0.1897	0.1888	0.1645	0.1645
16-Tobacco Processing	0.4271	0.4583	0.5000	0.4479	0.4479
17-Textile Industry	0.0857	0.0909	0.0962	0.0769	0.0769
18-Garments and Other Fiber Products	0.0494	0.0589	0.0631	0.0536	0.0536
19-Leather, Furs, Down and Related Products	0.1049	0.1258	0.1096	0.0841	0.0841
20-Timber Processing	0.0756	0.0913	0.1041	0.0628	0.0628
21-Furniture Manufacturing	0.0930	0.1027	0.0969	0.1008	0.1008
22-Papermaking and Paper Products	0.0748	0.0834	0.0753	0.0601	0.0601
23-Printing and Record Medium Reproduction	0.0654	0.0592	0.0724	0.0675	0.0675
24-Cultural, Educational and Sports Goods	0.1143	0.1212	0.1322	0.1006	0.1006
25-Petroleum Refining and Coking	0.1818	0.2102	0.2216	0.1875	0.1875
26-Raw Chemical Materials and Chemical Products	0.2126	0.2285	0.2294	0.1848	0.1848
27-Medical and Pharmaceutical Products	0.4451	0.4819	0.5092	0.5016	0.5016
28-Chemical Fiber	0.2189	0.2090	0.2239	0.1791	0.1791
29-Rubber Products	0.1921	0.1952	0.2127	0.1746	0.1746
30-Plastic Products	0.0991	0.1071	0.1100	0.0832	0.0832
31-Nonmetal Mineral Products	0.1131	0.1304	0.1215	0.0822	0.0822
32-Smelting and Pressing of Ferrous Metals	0.1388	0.1490	0.1521	0.0976	0.0976
33-Smelting and Pressing of Nonferrous Metals	0.1683	0.1707	0.1851	0.1599	0.1599
34-Metal Products	0.1092	0.1221	0.1178	0.0892	0.0892
35-Ordinary Machinery	0.2168	0.2365	0.2514	0.1950	0.1950
36-Special Purposes Equipment	0.3237	0.3323	0.3253	0.2856	0.2856
37-Transport Equipment	0.2738	0.2855	0.3035	0.2646	0.2646
39-Electric Equipment and Machinery	0.2476	0.2604	0.2671	0.2218	0.2218
40-Electronic and Telecommunications	0.3114	0.3293	0.3332	0.3266	0.3266
41-Instruments and meters	0.3159	0.3368	0.3851	0.3133	0.3133
42-Artifact and Other Manufacturing	0.0926	0.1157	0.1278	0.0775	0.0775

Table 3 Technical change, efficiency improvement and productivity change, 2001-05

SIC 2-digit industry	Malmquist index (tfpch)	Technical Change (techch)	Efficiency change (effch)	Scale Change (sech)
13-Food Processing	1.0542	0.9698	1.0879	1.0347
14-Food Production	1.0321	0.9787	1.0604	1.0156
15-Beverage Industry	1.0510	1.0828	0.9723	0.9864
16-Tobacco Processing	1.0507	1.0432	1.0074	0.9963
17-Textile Industry	1.0438	1.1728	0.8916	0.9476
18-Garments and Other Fiber Products	1.0370	0.9074	1.1440	1.0040
19-Leather, Furs, Down and Related Products	1.0379	1.1274	0.9273	0.9378
20-Timber Processing	1.0427	1.0584	0.9885	0.9951
21-Furniture Manufacturing	1.0275	0.9247	1.1135	1.0160
22-Papermaking and Paper Products	1.0535	1.0664	0.9899	0.9902
23-Printing and Record Medium Reproduction	1.0213	1.0440	0.9793	0.9831
24-Cultural, Educational and Sports Goods	1.0277	0.9890	1.0393	1.0206
25-Petroleum Refining and Coking	1.0461	1.1272	0.9302	0.9824
26-Raw Chemical Materials and Chemical Products	1.0486	1.1372	0.9272	0.9825
27-Medical and Pharmaceutical Products	1.0339	1.0634	0.9735	0.9871
28-Chemical Fiber	1.0450	1.0510	0.9934	1.0011
29-Rubber Products	1.0514	1.0094	1.0411	1.0773
30-Plastic Products	1.0380	0.9891	1.0529	0.9848
31-Nonmetal Mineral Products	1.0698	1.0005	1.0693	1.0368
32-Smelting and Pressing of Ferrous Metals	1.0566	1.0646	0.9992	1.0177
33-Smelting and Pressing of Nonferrous Metals	1.0358	0.9690	1.0807	1.0838
34-Metal Products	1.0420	0.9536	1.0958	1.0043
35-Ordinary Machinery	1.0732	1.0207	1.0519	1.0189
36-Special Purposes Equipment	1.0555	1.1878	0.8895	0.9838
37-Transport Equipment	1.0578	1.2346	0.8622	0.9215
39-Electric Equipment and Machinery	1.0541	1.0149	1.0438	1.0343
40-Electronic and Telecommunications	1.0460	1.1088	0.9446	0.9737
41-Instruments and meters	1.0262	0.9497	1.0849	0.9947
42-Artifact and Other Manufacturing	1.0257	0.9667	1.0661	1.0374
Total	1.0450	1.0432	1.0074	0.9963

Notes: industries dominated by foreign invested firms (FIEs) who produce more than 50% of the total outputs are highlighted in shade.

Table 4 Determinants of the TFP growth

	OLS			GMM		
COEFFICIENT	firm level	Intranational spillovers	international spillovers	firm level	Intranational spillovers	international spillovers
Initial Technical efficiency	-0.164***	-0.164***	-0.160***	-0.203***	-0.203***	-0.193***
	(0.00470	(0.0047)	(0.0047)	(0.0071)	(0.0071)	(0.0072)
Age	0.0013	0.0010	0.0012	0.0006	0.0004	0.0015
	(0.0011)	(0.0011)	(0.0011)	(0.0018)	(0.0018)	(0.0018)
Employment	-0.0179***	-0.0184***	-0.0190***	-0.0215***	-0.0220***	-0.0216***
	(0.0009)	(0.0009)	(0.0009)	(0.0013)	(0.0013)	(0.0013)
Market Competition	0.160***	0.148***	0.121***	0.187***	0.161***	0.135**
	(0.039)	(0.041)	(0.042)	(0.054)	(0.056)	(0.058)
Intangible Asset	0.0043***	0.0043***	0.0043***	0.0047***	0.0047***	0.0051***
	(0.0007)	(0.0007)	(0.0007)	(0.0009)	(0.0009)	(0.0009)
Training Expenditure	0.0682***	0.0677***	0.0682***	0.0731***	0.0727***	0.0726***
	(0.0067)	(0.0067)	(0.0069)	(0.0083)	(0.0083)	(0.0084)
Export Intensity	0.0024***	0.0024***	0.0025***	0.0010***	0.0011***	0.0014***
	(0.0002)	(0.0002)	(0.0002)	(0.0004)	(0.0004)	(0.0004)
R&D Intensity	-0.437***	-0.444***	-0.459***	0.936***	0.937***	0.943***
	(0.075)	(0.075)	(0.08)	(0.28)	(0.28)	(0.29)
Foreign Share	0.0366*	0.0376*	0.0191	0.243***	0.246***	0.561***
	(0.022)	(0.022)	(0.035)	(0.073)	(0.073)	(0.2)
Ethnic Share	0.0021	0.0028	0.0071	0.161**	0.171**	0.491**
	(0.016)	(0.016)	(0.023)	(0.075)	(0.075)	(0.22)
Domestic R&D share		0.0039***	0.0031***		0.0042***	0.0034***
		(0.0007)	(0.0008)		(0.001)	(0.0011)
Ethnic R&D share		-0.0008*	-0.0001		-0.0007	-0.0000
		(0.0004)	(0.0005)		(0.0005)	(0.0006)
Foreign R&D share		-0.0014**	-0.0009**		-0.0024***	-0.0019***
		(0.0004)	(0.0005)		(0.0007)	(0.0007)
Internation R&D_Foreign_Firm			0.0008			-0.0145**
			(0.0011)			(0.0069)
Internation R&D_Ethnic_Firm			-0.0003			-0.0198**
			(0.001)			(0.0095)
Internation R&D_Foreign_Industry			-0.0053**			-0.0053***
			(0.0013)			(0.0018)
Internation R&D_Ethnic_Industry			-0.0005			-0.0006
			(0.0013)			(0.0018)
Constant	0.153***	0.134***	0.189***	1.295***	1.277***	1.325***
	(0.0054)	(0.0073)	(0.014)	(0.0088)	(0.011)	(0.022)
Observations	197908	197908	193135	158272	158272	155885
R(squared)	0.57	0.57	0.56	0.01	0.01	0.01
Exogenous test				0	0	0
Hansen J test				0.6792	0.5962	0.6451

Note: 1. Robust standard errors in parentheses
2. *significant at 10%; ** significant at 5%; *** significant at 1%
3. All specification include the full set of time and two-digit industry dummies

Table 5 Determinants of the technical change and efficiency improvement

	TECH		EFFCH	
COEFFICIENT	Intranational spillovers	international spillovers	Intranational spillovers	international spillovers
Initial Technical efficiency	-0.183***	-0.189***	-0.493***	-0.482***
	(0.0076)	(0.0077)	(0.011)	(0.011)
Age	0.0029	0.0019	0.0029	0.0048*
	(0.002)	(0.002)	(0.0027)	(0.0027)
Employment	0.0161***	0.0154***	0.0009	0.0020
	(0.0014)	(0.0015)	(0.0019)	(0.0019)
Market Competition	-0.0951	-0.199***	0.0472	0.153
	(0.064)	(0.068)	(0.094)	(0.097)
Intangible Asset	-0.0039***	-0.0046***	-0.0007	0.0002
	(0.001)	(0.001)	(0.0013)	(0.0014)
Training Expenditure	-0.0414***	-0.0447***	0.0532***	0.0559***
	(0.008)	(0.0081)	(0.012)	(0.012)
Export Intensity	-0.0001	-0.0001	0.0011*	0.0009*
	(0.0004)	(0.0004)	(0.0006)	(0.0006)
R&D Intensity	-0.223	-0.239	1.395***	1.445***
	(0.17)	(0.17)	(0.33)	(0.34)
Foreign Share	-0.0957	-0.369*	0.139	0.46
	(0.075)	(0.2)	(0.11)	(0.29)
Ethnic Share	-0.124*	-0.2760	0.0086	0.0887
	(0.071)	(0.2)	(0.091)	(0.26)
Domestic R&D share	0.0064***	0.0029**	-0.00551**	-0.0017
	(0.0013)	(0.0014)	(0.0016)	(0.0018)
Ethnic R&D share	-0.0005	0.0031***	0.0000	-0.0038***
	(0.0007)	(0.0008)	(0.0009)	(0.001)
Foreign R&D share	-0.0085***	-0.0083***	0.0031***	0.0027**
	(0.0008)	(0.0009)	(0.0011)	(0.0011)
Internation R&D_Foreign_Firm		0.0125*		-0.016
		(0.007)		(0.0098)
Internation R&D_Ethnic_Firm		0.0112		-0.0051
		(0.0088)		(0.011)
Internation R&D_Foreign_Industry		0.0064***		-0.0031
		(0.0022)		(0.003)
Internation R&D_Ethnic_Industry		-0.0193***		0.0182***
		(0.0021)		(0.0027)
Constant	0.958***	1.096***	1.545***	1.375***
	(0.013)	(0.025)	(0.018)	(0.035)
Observations	158272	155885	158272	155885
R(squared)	0.69	0.69	0.41	0.41
Exogenous test	0	0	0	0
Hansen J test	0.9587	0.3326	0.4248	0.4048

Note:

1. Robust standard errors in parentheses
2. *significant at 10%; ** significant at 5%; *** significant at 1%
3. All specification include the full set of time and two-digit industry dummies