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Abstract

This paper assesses the impacts of R&D, export and the presence of foreign direct investment (FDI) on Chinese manufacturing productivity based on a panel data on more than 10,000 indigenous and foreign-invested firms for the period 1998-2001. Indigenous Chinese firms are found to significantly benefit from their own export activities and R&D spillovers. Given some specific characteristics of China as a transition economy, OECD invested firms produce strong negative intra-industry spillovers on indigenous Chinese firms across regions but strong positive intra- and inter-industry spillovers within the same regions. Overseas Chinese firms from Hong Kong, Macao and Taiwan exert positive intra-industry productivity spillovers only. The robustness analysis suggests that different measures of FDI could lead to different results. Our findings have important implications for both business managers and policy makers.

Key words: FDI, Productivity, Spillovers, China

I. Introduction

Recent endogenous growth theory suggests that technological knowledge has an important influence on a country's productivity and is the main driving force of economic growth. Knowledge can be generated by an organisation's own research and development (R&D). In addition, given its non-rival nature, knowledge spills via various means, including R&D, international trade and foreign direct investment (FDI). There are respective strands of literature on knowledge spillovers from R&D, international trade and FDI, but few studies examine these channels within a single framework. Neglecting any of the sources would underestimate the total impact of knowledge spillovers.

There are only several studies on spillovers generated by FDI in China, including Li et al. (2001), Liu et al. (2001), Wei and Liu (2001), Hu and Jefferson (2002) and Buckley et al. (2002). There is only one study on spillovers by domestic R&D, i.e. Jefferson et al. (2003). No study, to our best knowledge, is on spillovers by exports.

As for productivity spillovers from FDI, a number of alternative measures of foreign presence have been applied in the literature, including capital, employment, R&D, exports, sales and output. However, apparently there is no clear recognition that each of these indicators may capture a different aspect of spillover effects. This may partially explain why mixed results have been produced in the literature (for a survey of the empirical literature, see Gorg and Strobl, 2001).

The principal aim of this paper is to assess the impacts of R&D, export and FDI on productivity in indigenous manufacturing firms in China. There are three specific features in this study. First, the three main channels of technological knowledge spillovers are incorporated into a single framework. That is, productivity in indigenous Chinese firms is modelled to be influenced not only by their own R&D efforts and exports, but also by knowledge spillovers from the presence of foreign-invested firms as well as R&D and export activities in Chinese manufacturing. Second, a number of alternative measures of foreign presence identified in the literature are compared and a robustness test is carried out to examine whether the productivity impacts of foreign presence depend on the way spillovers are proxied. Third, different from the majority of the existing studies for China, the current investigation uses a large and most recent firm-level data and is the most comprehensive investigation for China[1].

The rest of the paper is organised in the following way. The next section reviews the literature. Sections 3 and 4 describe methodology, and data and variables, respectively. Section 5 discusses the empirical results. Finally, section 6 summarises the findings and discusses policy implications.

II. Literature Review

II.1 R&D and Knowledge Spillover

R&D has long been seen as an important source of knowledge generation and productivity improvement (Shell, 1966). Recently, endogenous growth theory emphasises the importance

[1] Large-sample firm-level studies for China are very rare and Hu and Jefferson (2002) is an exception where firm-level data in the electronic and textile sectors for the period 1995-1999 are used.

of commercially oriented innovation efforts and R&D knowledge spillovers in explaining countries' productivity. R&D increases productivity by providing new products and processes or upgrading existing products and processes which will enhances profits or reduce costs.

R&D not only directly affects the productivity of the firm which conducts R&D, it may produce spillover effects which increase other firms' productivity. Given imperfect intellectual property rights and low marginal costs of reproducing results from R&D, technologies developed in one firm may spread to other firms through imitation, reverse engineering or recruitment of the investing firm's personnel (Braconier and Sjoholm, 1998).

Multinational enterprises (MNEs) from the developed world carry out much of the world's total R&D activities, and possess the bulk of the world's stock of advanced commercial technologies. Mansfield and Romeo (1980) find that technologies transferred from parent firms to their subsidiaries are of a later vintage than technologies sold to outsiders through licensing agreements. However, the technological knowledge transferred to the subsidiaries often leaks out to local firms. Thus R&D spillovers increase local firms' productivity.

II.2 Exports and Knowledge Spillover

Exports raise productivity by giving rise to various benefits, such as more efficient use of resources, greater capacity utilisation and gains of scale effects associated with large international markets (Bhagwati, 1978; Krueger, 1978; Obstfeld and Rogoff, 1996). Endogenous growth theory (Rivera-Batiz and Romer, 1991a, b; Coe and Helpman, 1995; Coe et al., 1997) suggests that international trade is an important means of facilitating technology creation, transfer and diffusion. For instance, when local goods are exported the foreign purchasing agents may suggest ways to improve the manufacturing process (Grossman and Helpman, 1991, p.166). Buyers want low-cost, better quality products from main suppliers. To obtain this, they transmit tacit and occasionally proprietary knowledge from their other, often OECD-economy suppliers (World Bank, 1993, P. 320). Participating in export markets brings firms into contact with international best practice and learning and productivity growth (World Bank, 1997). Exports may also raise productivity by spurring development of new technologies (Hejazi and Safarian, 1999). Positive relationships are often found between a firm's exporting and efficiency (e.g. Chen and Tang, 1987; Aw and Hwang 1995; Roberts et al. 1995).

Blostrom and Kokko (1998) argue that MNEs often have knowledge of, and experience in, international marketing, established international distribution networks and lobbying power in their home markets. This enables MNEs to possess strong competitive advantages in entering world markets. As a result of their own export activities, MNEs may pave the way for indigenous firms in host countries to enter the same export markets, because they either create transport infrastructure or disseminate information about foreign markets that can be used for these indigenous firms. In terms of empirical evidence for knowledge spillovers from exports, Clendides et al (1998) find some positive regional externalities.

II.3 FDI and Knowledge Spillovers

The most important reason why countries try to attract FDI is perhaps the prospect of acquiring modern technology, interpreted broadly to include product, process, and distribution technology, as well as management and marketing skills (Blomstrom and Kokko, 1998). FDI is a package of capital, technology and managerial skills, and has been viewed as an important source of both direct capital inputs and technology and knowledge spillovers. Balasubramanyam et al (1996) argue that developing countries can significantly benefit from FDI because it not only transfers production know-how and managerial skills but also produces externalities, or spillover effects.

Blomstrom and Kokko (1998) summarise the following means through which knowledge can spill over to indigenous firms in a host country. FDI contributes to efficiency by breaking supply bottlenecks, introduces new know-how by demonstrating new technologies and training workers who later take employment in local firms, breaks down monopolies and stimulates competition, transfers technologies to local suppliers, and forces local firms to increase their managerial efforts. However, there can be negative externalities from FDI. As Aitken and Harrison (1999) note, the entry of foreign firms producing for the local market can draw demand from local firms, causing them to cut production. Thus, the productivity of local firms would fall as they are forced back up their average cost curves. As a result, net local productivity can decline.

Some recent studies such as Kokko et al. (1996) for the Uruguayan manufacturing sector, Liu et al. (2000) for UK manufacturing, Li et al. (2001) and Wei and Liu (2001) for China find positive spillover effects. However, mixed results are reported in Aitken and Harrison (1999) for Venezuelan industry and in Hu and Jefferson (2002) and Buckley (2002) for China. Different results may be partially due to the use of different measures of foreign presence. Existing empirical studies tend to apply only one measure of foreign presence. One of the very few exceptions is Buckley et al. (2002) where capital, investment and employment shares are used as the alternative measures.

II.4 Inter-regional and Inter-industry Knowledge Spillovers

It is believed that spillover benefits from foreign firms would be received first by their neighbouring firms before they diffuse to other domestic firms (Aitken and Harrison, 1999). The benefits may then gradually spread to other, more distant domestic firms. If the spillover effects are received by neighbouring local firms only, spillovers are "local" in scale. If spillover benefits are received by firms in other regions in the host country, then the spillovers are "national" in scale.

In addition to the difference between local and national spillovers in geographical scale, there is a difference between intra- and inter-industry productivity spillovers. If technological benefits are received by indigenous firms in the same industries, there are intra-industry spillovers. However, if technological benefits are received by indigenous firms in other industries, there are inter-industry spillovers. In the current study, whether productivity spillovers are local or national, and whether they are intra- or inter-industry, will be examined.

II.5 Firm Ownership and Knowledge Spillovers

The effectiveness of knowledge or productivity spillovers depends largely on the technical capabilities of both foreign and local firms (Cantwell, 1993). In China, there are two main types of foreign investors: overseas Chinese investors from Hong Kong, Macao and Taiwan (HMT), and other investors mainly from OECD countries. It is recognised that OECD firms are superior to HMT firms in product and innovation and in technological development

(Yeung, 1997). Therefore, the magnitude of the effect of OECD firms on the productivity of indigenous Chinese firms should be greater than that of HMT firms (Buckley et al., 2002).

III. Methodology

In this paper, our estimations are confined to the impact of knowledge spillovers on productivity of indigenous Chinese firms only. This is different from such studies as Aitken and Haddison (1999) where domestically- and foreign-owned firms are pooled together. We argue that their model is restrictive because it imposes a condition of the same slope for domestically- and foreign-owned firms. As shown in Table 1 and discussed above, there are considerable differences between the two groups of firms. Therefore slope coefficients should vary and simple inclusion of a dummy variable in the estimation is not sufficient.

The most common approach found in the empirical literature of knowledge spillovers is to estimate a Cobb-Douglas production function.

$$Y_{it} = A_{it} K_{it}^{\alpha} L_{it}^{\beta} e^{\varepsilon_{it}} \qquad (1)$$

where Y, K and L denote output, physical capital and labour respectively. ε is the error term which reflects the effects of unknown factors, measurement errors and other disturbances. Subscripts i and t indicate the firm and time period under consideration. Usually, an assumption of constant returns to scale with respect to K and L is imposed ($\alpha + \beta = 1$). Here, instead, we let the estimation results to indicate whether the assumption applies at the firm level. Nevertheless, the estimation results are not much different when the assumption is imposed. A is total factor productivity (TFP) which is a function of a firm's own R&D and export activities and is dependant upon other firms' R&D, exports and the presence of FDI. Hence, we can write the expression for A_{it} as follows:

$$A_{it} = f(RD_{it}, EX_{it}, RDSP_{it}, EXSP_{it}, FDISP_{it}) \quad (2)$$

where RD and EX are the knowledge stock generated by firm i through its own R&D and export activities respectively. RDSP and EXSP are the knowledge stock spilled from other firms in firm i's industry. RDSP is the knowledge spillovers due to other firms' R&D activities. EXSP is the knowledge spillovers due to other firms' export activities. FDISP is knowledge spillovers emanating from foreign-owned firms in firm i's industry. The functional form for A_{it} is unknown, and we choose to use the following simple form.

$$\log(A_{it}) = \mu_1 RD_{it} + \mu_2 EX_{it} + \mu_3 RDSP_{it} + \mu_4 EXSP_{it} + \mu_5 FDISP_{it} \quad (3)$$

where μs capture contributions of the R&D, export, and spillover variables to TFP.

One important econometric issue is the possibility of endogeneity. Investment in R&D, exports and the presence of FDI might well be influenced by productivity. For example, productivity may be higher among those firms undertaking R&D or export activities because they are better able to do so after they increase productivity. Foreign firms may be attracted to high productivity sectors without generating spillovers. As is well known, it is very difficult to create an effective set of instruments. Among the list of candidates, few are likely to be truly exogenous. To keep the possible endogeneity problem to a minimum and take into account the lag between knowledge spillovers and productivity gains, we include all spillovers variables with a lag of one year into the estimations.

The logarithmic transformation of (1) after substituting for A_{it} from (3) and taking into account of the above argument gives us

$$\begin{aligned}\log(Y_{it}) = \alpha \log(K_{it}) + \beta \log(L_{it}) + \mu_1 RD_{it-1} + \mu_2 EX_{it-1} + \\ \mu_3 RDSP_{it-1} + \mu_4 EXSP_{it-1} + \mu_5 FDISP_{it-1} + \varepsilon_{it}\end{aligned} \quad (4)$$

Equation (4) is estimated with correction for heteroskedasticity and autocorrelation.

IV. Data and Variables

The data used are mainly from the *Annual Report of Industrial Enterprise Statistics* compiled by the State Statistical Bureau of China, covering firms in nine two-digit industries during the period 1998-2001. For each industry, the Bureau collects detailed data on each industrial firm in operation. The data include information on ownership classification, value added, output, capital stock, number of employees, costs of intermediate inputs, total sales, intangible assets, new product sales and exports. R&D expenditure and labour training expenditure are available for 2001 only. As for deflators, price indices for total manufacturing fixed assets and industrial output are obtained from *China Statistical Yearbook* 2002. This data set has at least two advantages. It covers a very recent period and it allows us to control for observable and unobservable firm-level characteristics in order to mitigate aggregation bias.

Due to entry and exit and ownership restructuring, the number of firms in operation is changing over time. In this study, the same firms have been identified based on their identifiers to produce a final balanced set of 15,761 firms for each year, of which 5861 are foreign-owned and 9900 are domestically-owned. A firm has been defined to be domestically-owned, if its foreign equity participation, if any, is below 25 per cent. In terms of employment, these firms altogether accounted for nearly 78 per cent over the sample period. The data are cleaned via extensive checks for nonsense observations, outliers, coding mistakes, and the like. In addition, only firms with at least three years of data for value added, output, capital stock, intangible assets, exports and total sales are kept. These finally leave us with a panel of 7697 domestically-owned firms. The data include 23 ownership classifications, as shown in Appendix I.

In this paper three sets of spillovers variables are used. FDISP, RDSP and EXSP represent the spillovers due to the presence of foreign-owned firms, R&D and exports respectively in the industry respectively.

Although several sources are identified, there is no consensus on the actual measurement of productivity spillovers from FDI due to their nature of being 'indirect'. Since Caves (1974) there have been a large number of empirical studies and various measures have been applied. Recent examples include the employment share of foreign-owned firms (Liu et al., 2000; Buckley et al., 2002), capital/investment share of foreign-owned enterprises (Liu et al., 2001; Wei and Liu, 2001; Buckley et al., 2002), output (or value added) share of foreign-owned firms (Kokko et al., 1996; Konings, 2001), the share of sales of foreign-owned firms (Kathuria, 2002), the share of assets held by foreign firms (Haddad and Harrison, 1993), the share of R&D stock held by foreign firms (Feinberg and Majumdar, 2001), the share of foreign equity participation weighted by employment (Aitken and Harrison, 1999), and the share of foreign equity participation weighted by sales (Hu and Jefferson, 2002), depending on data availability. Gorg and Strobl (2001) suggest that the choice of proxy variables for spillovers from FDI may be an important determinant of differences across studies, but they stop short of any explanation.

We propose that different measures capture different channels or aspects of productivity spillovers from foreign presence. If a single proxy such as foreign capital or fixed assets is applied, then the positive spillover effect simply indicates that the foreign presence produces a positive capital spillover effect. In this case, the positive externalities are closely related to the demonstration effect of the suitability of the project, or the superiority of machinery or equipment embodying updated technologies. Similarly, if employment in foreign firms is applied, then the spillover effect will be closely associated with employee turnovers or contagion between employees in foreign and local firms. This can be referred as to employment spillovers. In the same manner, we can have sales, output, R&D and export spillovers from foreign presence. Sales spillovers are linked with knowledge diffusion of the superior product and marketing skills. Output spillovers are concerned with the demonstration effects of not only the superior product but also such characteristics of scale or scope economies. They may also be linked with knowledge acquisition via reverse engineering of the product. R&D spillovers are the leakage of R&D activities from foreign-invested firms to local firms. Finally, export spillovers are related with international marketing knowledge diffusion.

Some of the measures are expected to be correlated, but this needs to be empirically confirmed. In the existing literature, it is a general rule that only one measure is applied in a particular study, but the results are interpreted as the existence or absence of productivity spillovers from foreign presence as a whole. It can be case that when alternative measures are applied, different results will be obtained. It follows that, when an individual measure (say, employment) is applied, then the research is actually examining the employment spillover effects rather than spillovers from foreign presence as a whole.

The measures of foreign presence in the current study include capital, employment, sales, output, R&D and exports. Our rich data set allows us to examine various channels and aspects of productivity spillovers from foreign presence in Chinese manufacturing.

In terms of measuring R&D, some studies use input-indicators of technology such as R&D expenditures and patents, while others use output-indicators such as intangible assets and new product sales. One disadvantage of input-indicators is that they can not measure the 'efficiency' of knowledge development. In this paper, we shall use output-indicators. R&D expenditure is only available for year 2001, and therefore is not used. The variable of R&D spillovers is measured as the unweighted sum of the R&D stocks of all other firms. In the literature of R&D spillovers, weights are used to take into account the different ability of firms to internalise other firms' knowledge (Kaiser, 2002). The weights are often assumed to be proportional to the similarity between two firms' 'technological space' which is determined by a vector containing the number of patents or the share of scientists per technology field or geographical distance. However, we have neither data for patents nor the number of scientists at the firm level. In addition, it is unclear to which extent those weighting schemes are appropriate for capturing knowledge spillovers. Therefore, we choose to use unweighted measures. A discussion about variables and their measurements is provided in Appendix II.

Table 1 provides a comparison of a range of firm-level characteristics between domestically-owned and foreign-owned firms. Overall, there are significant differences between domestically- and foreign-owned firms in terms of a number of statistics. Foreign-owned firms have higher capital intensity and labour productivity, and are more R&D intensive and export-oriented than domestically-owned firms. Summary statistics for the sample are reported in Table 2.

V. Empirical Results

Tables 3-7 present the empirical results. In all estimations, year dummies are included to capture the unobserved, year-specific effects. Output elasticities with respect to physical capital and labour appear to be highly stable across specifications. The assumption of constant returns to scale with respect to capital and labour is tested. In all specifications, it is rejected.

Table 3 reports the baseline estimates. Column 2 tabulates the estimation results without the spillover variables. Column 3 investigates industrial spillovers, columns 4 and 5 investigate regional spillovers and column 6 investigates industrial spillovers within specific regions respectively. The difference between columns 4 and 5 is that FDISP is dropped in column 5, due to the multicollinearity problem as reflected by the high correlation coefficient between FDISP and EXSP at the regional level in Table 2.

In all cases, firms' own R&D proxied by intangible assets appears to be an insignificant determinant of their productivity. On the other hand, the coefficients on RDSP are all statistically significant. These results are consistent with those of Raut (1995) who investigates the impact of R&D on productivity for private manufacturing firms in India. One possible explanation to the significant effect of R&D spillovers but insignificant effect of own R&D is that intangible assets as a proxy can only capture part of productivity-enhancing R&D activities. Another tentative explanation is that an individual Chinese firm's R&D may not be significant enough to enhance its own productivity. Technological knowledge from its R&D activity spills over to create public domain knowledge. Then the industry- or region-wide knowledge contributes to private productivity gains.

The direct effect of firms' own exports is significant, indicating the importance of own export activities in learning and productivity enhancement in indigenous Chinese firms. However, export spillovers from other firms are only significant at the regional level after FDISP is dropped from the estimation. This suggests that there are inter-industry regional spillovers from exports.

The coefficient on FDISP is negative and insignificant in column 3 but positive and significant in columns 4 and 6. This indicates that intra-industry productivity spillovers from FDI as a whole do not seem to occur across regions, but there are inter-industry as well as intra-industry positive spillovers within a region. This fact may be due to the existence of barriers to the movement of factors of production and output across regions in China. The restrictions on factor mobility include constraints on local enterprises for hiring migrant labour and the sales of products across regions (Cai et al. 2002; Yang 2002). The contagion, demonstration and competition effects of FDI as a whole would be stronger without these barriers.

Table 4 reports the estimation results for domestically-owned firms without R&D activities. These firms still benefit from their own export activities, regional FDI spillovers, and inter-industry regional export spillovers. However, they no longer enjoy intra-industry R&D spillovers. The benefits from other firms' R&D activities are only confined at the inter-industry level across regions. Furthermore, they suffer from the competition from foreign invested firms at the same industry across regions. Our findings suggest that firms should conduct R&D in order to fully capitalise the public domain knowledge to enhance their productivity.

Table 5 reports the estimation results when foreign invested firms are grouped into Hong Kong, Macao and Taiwanese (HMT) firms and OECD firms. The FDISP_HMT variable shows some evidence of productivity spillovers from HMT firms, while the FDISP_OECD variable indicates productivity spillovers for firms whose parents are mainly from OECD countries. As in Table 3, RDSP is positive and significant, reconfirming the importance of R&D spillovers to domestic Chinese firms. EXSP in column 3 of Table 5 is positive and highly significant, indicating the existence of inter-industry productivity spillovers within a region.

It is interesting to note that FDISP_OECD has a highly significant negative intra-industry spillover effect across regions, but produces highly significant positive intra- and inter-industry spillovers within a region. The co-existence of negative cross-region but positive within-region spillover effects from OECD FDI may be caused by special behaviour of the local Chinese authorities. On one hand, the local authorities restrict flows of factors of production and finished products across regions in order to avoid competition. On the other hand, they attract FDI based on their own regional development interests without taking into account the national industrial development strategies laid down by the central government. As a result, there has been repetition of industrial projects by foreign as well as domestic investors across regions. Given that foreign invested firms from OECD countries have more advanced technologies, their competition tends to lower productivity in domestic Chinese firms in the same industry outside the regions where these foreign invested firms are located.

However, probably because of its complementarity, OECD FDI has positive impacts on productivity in domestic Chinese firms not only within but also outside the industries within the same regions.

The impact of FDI spillovers from HMT firms is not as strong as that from OECD firms, but it is always positive. This may suggest that, compared with OECD firms, the industrial projects launched by HMT firms, which are mainly labour intensive, are more compatible with mainland China's current resource endowments, and the technologies, managerial and marketing know-how transferred by HMT firms are crucial for the development of indigenous Chinese firms. In addition, HMT firms are more knowledgeable about the Chinese economy so that they are in a better position to avoid competition with indigenous Chinese firms.

Taking tables 3 and 5 together, it is interesting to note that total FDISP appears to be insignificant but FDISP_OECD and FDISP_HMT appear to be highly significant with the opposite sign at the industry level. The Wald test shows that the null hypothesis that the sum of the coefficients on FDISP_OECD and FDISP_HMT equals zero is accepted. This suggests that it is misleading to draw a conclusion that there are no intra-industry FDI spillovers across regions. Instead, the impact of FDI from different source countries is different. Firms from OECD countries exert negative impact, while those from HMT countries produce positive impact on the productivity of indigenous Chinese firms at the intra-industry level across regions. Regional FDI spillovers are mainly contributed by OECD investors. Our evidence here implies that previous finding of no FDI spillovers may not be as straightforward as suggested in the literature. It is important to distinguish sources of FDI.

Table 6 reports the results from a different measure of R&D, new product sales. The qualitative results are similar to those in Table 3. The only difference is that R&D spillovers from other firms are only significant at the industry level both within and across regions. This is probably because new product sales can only capture part of the productivity-enhancing R&D activities.

Finally, we look at different measures of FDI presence. Table 7 reports the results for spillovers at the intra-industry level within regions. As the results from other estimations are largely the same, they are not included in the paper. Different FDI presence measures are identified in row 1, and their estimated coefficients appear in the final row. Using unweighted measures, whether it is capital, employment, sales, output or R&D, FDI is consistently found to generate inter- and intra-industry productivity spillovers within a region. However, when weighted measures are used, e.g. weighted employment and sales, the results are inconsistent. From Table 7, the coefficient on FDISPEMW, i.e. the weight foreign equity share, is insignificant.

The findings from Table 7 suggest that different measures of FDI may capture different aspects of foreign presence, and can produce different results. Therefore, the findings in this paper cast doubts on previous studies based on only one measure of spillovers from foreign presence. In this study, the pairwise Spearman's rank correlation coefficients range from 0.999 to 0.512. This implies that these seven indicators should be introduced in separate regressions. However, by so doing much important information may be lost. To gain efficiency, we have adopted a principle components approach by combining some of the indicators into a 'grand' composite index. The first principle component is called FDISPPCS which has explained more than 66% of the variance of these seven indicators. Using this new index, the estimation results are produced in the last column of Table 7. It shows that, with other things being given, firms benefit from FDI spillovers.

VI. Conclusions

This paper aims to assess the impacts of R&D, export and FDI on Chinese manufacturing productivity. Our general findings are as follows. (1) Indigenous Chinese firms' own R&D activities measured by either intangible assets or new product output do not seem to have significant impacts on their productivity. (2) Indigenous Chinese firms' own exports have a significant impact on their productivity. This confirms the positive relationship between exporting activities and productivity enhancement. (3) Indigenous Chinese firms generally benefit from R&D activities in Chinese manufacturing. (4) Indigenous Chinese firms mainly learn from the export activities of those firms that locate in the same region but belong to different industries. (5) Productivity spillovers from total FDI are regional-mediated.

When dividing foreign invested firms into OECD and Hong Kong, Macao, and Taiwan (HMT) firms, we obtain further insights on productivity spillovers as follows. (1) OECD firms produce strong negative intra-industry spillover effects on indigenous Chinese firms across regions but strong positive intra- and inter-industry spillover effects within the same regions. The negative across-region, intra-industry effects may be due to the repetition of industrial projects different regional authorities have introduced. (2) HMT firms produce positive productivity spillovers, but they are mainly intra-industry, due to the low-tech and labour-intensive nature of their projects.

Our robustness test suggests that different measures of FDI can produce different results. Using unweighted measures, FDI is consistently found to generate productivity spillovers within a region. However, this is not the case when weighted measures are used. Using a principal component approach, we confirm our findings of positive regional FDI spillover effects on productivity of indigenous Chinese firms.

Our findings have important implications for managers as well as policy makers. For Chinese managers it is important to improve the quality of knowledge stock of their firms and learn from their own exporting activities as well as from foreign-invested firms in order to enhance productivity and competitiveness. For Chinese policy makers it may be important to co-ordinate the regional development strategies to avoid repetition of industrial projects so that the negative effects from OECD firms may turn to be positive. In addition, given that OECD firms generate much stronger positive spillover effects, more FDI should be attracted from OECD countries.

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Table 1. A Comparisons between Domestically-owned and Foreign-owned firms, 1998-2001

Sector	*Number of Firms*		*Employment*		*K/L*		*Y/L*		*Sales*	
	Domestic	Foreign	Domestic	Foreign	Domestic	Foreign	Domestic	Foreign	Domestic	Foreign
Food processing	2404	574	208	255	70.7	120.5	33.6	86.9	28374	107343
Food manufacturing	996	450	220	286	81.0	167.0	38.4	105.6	20889	82628
Beverage production	787	257	424	436	62.3	162.2	20.7	85.8	48717	158959
Garments and other fibre products	354	1367	445	378	80.9	302.6	32.3	126.9	29242	39786
Medical and pharmaceutical products	795	251	455	321	29.6	29.9	24.6	35.9	56491	103649
Ordinary machinery manufacturing	1543	523	716	414	99.6	151.7	87.5	145.8	43329	98297
Transport equipment manufacturing	1532	489	1128	598	54.2	137.4	17.6	85.1	127306	282721
Electric machines and apparatuses	875	844	606	429	60.8	200.8	25.4	105.2	59092	116761
Electronic and telecommunications equipment	614	1106	757	598	62.3	115.7	29.8	91.3	150154	319590
Total	9900	5861	549	430	95.6	103.4	37.4	107.4	59846	146945
	Intangible Assets		*New Product Sales*		*R&D Intensity*		*Exports*		*Export Intensity*	
	Domestic	Foreign	Domestic	Foreign	Domestic	Foreign	Domestic	Foreign	Domestic	Foreign
Food processing	852	2371	216	1296	5.65	19.38	1295	22800	3.23	37.26
Food manufacturing	1330	3083	303	1311	9.91	10.44	1939	8564	3.93	24.09
Beverage production	3058	13479	2121	16796	10.49	20.36	1100	6672	2.34	12.90
Garments and other fibre products	515	642	873	437	6.36	8.85	11293	29249	37.13	73.80
Medical and pharmaceutical products	4062	5264	8000	20431	21.00	36.88	5843	10048	4.11	16.18
Ordinary machinery manufacturing	3314	5651	10445	17138	11.48	17.62	3552	27412	5.11	33.61
Transport equipment manufacturing	5094	12023	33746	109930	10.55	19.26	10403	35999	3.57	24.94
Electric machines and apparatuses	3027	4046	14570	16366	13.34	14.10	5926	52765	5.72	48.60
Electronic and telecommunications equipment	5418	3830	69254	83006	11.28	39.41	20709	170438	9.34	60.31
Total	2861	4241	13564	30649	10.48	19.88	5507	55694	5.49	47.48

Table 2. Descriptive Statistics

	Mean	Standard Deviation	Spearman's Rank Correlation Coefficient Matrix						
			LK	LL	RD	EX	RDSP	EXSP	FDISP_HMT
LK	8.86	1.92							
LL	5.27	1.43	0.82						
RD	0.10	0.87	0.26	0.25					
EX	0.06	0.19	0.33	0.37	0.18				
Industry									
RDSP	0.08	0.04	0.07	0.08	0.12	0.00			
EXSP	0.17	0.22	0.04	0.13	0.04	0.32	0.04		
FDISP	0.35	0.22	-0.11	-0.13	0.00	0.07	-0.02	0.44	
FDISP_HMT	0.12	0.11	-0.16	-0.21	-0.04	0.02	-0.11	0.22	
FDISP_OECD	0.24	0.17	-0.05	-0.05	0.02	0.08	0.05	0.44	0.28
Region									
RDSP	0.08	0.03	0.04	0.04	0.11	0.12			
EXSP	0.16	0.15	0.01	-0.01	0.06	0.20	0.44		
FDISP	0.30	0.19	0.02	0.01	0.06	0.20	0.37	0.82	
FDISP_HMT	0.08	0.08	0.03	0.01	0.04	0.18	0.24	0.71	
FDISP_OECD	0.21	0.13	0.02	0.02	0.07	0.19	0.38	0.77	0.67
Industry within region									
RDSP	0.07	0.14	-0.02	-0.01	0.10	0.04			
EXSP	0.11	0.21	0.04	0.09	0.07	0.32	0.39		
FDISP	0.21	0.26	-0.05	-0.06	0.05	0.14	0.50	0.54	
FDISP_HMT	0.06	0.13	-0.03	-0.06	0.04	0.12	0.36	0.38	
FDISP_OECD	0.14	0.22	-0.02	-0.01	0.07	0.15	0.47	0.53	0.39

Table 3. Production Function Estimates, Baseline Specifications, All firms

		Industry	Region	Region	Industry within Region
LK	0.2927 (0.0083)***	0.2916 (0.0084)***	0.2920 (0.0083)***	0.2905 (0.0083)***	0.2958 (0.0083)***
LL	0.6309 (0.0111)***	0.6295 (0.0112)***	0.6364 (0.0110)***	0.6360 (0.0110)***	0.6373 (0.0111)***
RD	0.0066 (0.0108)	0.0055 (0.0108)	0.0059 (0.0107)	0.0061 0.0107	0.0062 (0.0108)
EX	0.3366 (0.0519)***	0.3740 (0.0542)***	0.2299 (0.0522)***	0.2372 (0.0523)***	0.2652 (0.0542)***
RDSP		0.9221 (0.2023)***	1.0550 (0.2834)***	1.2320 (0.2826)***	0.1112 (0.0594)*
EXSP		-0.0641 (0.0666)	0.0954 (0.1601)	0.9716 (0.0873)***	-0.0248 (0.0628)
FDISP		-0.0985 (0.0657)	0.8208 (0.1259)***		0.4525 (0.0524)***

Notes:
1. Intercept and coefficients on dummy variables are not reported.
2. Standard errors are in parentheses.
3. *** and * indicate that the coefficient is significantly different from zero at the 1% and 10% levels respectively.

Table 4. Production Function Estimates, Firms without R&D

	Industry	Region	Region	Industry within Region
LK	0.2573 (0.0109)***	0.2617 (0.0108)***	0.2584 (0.0108)***	0.2629 (0.0109)***
LL	0.5803 (0.0145)***	0.5874 (0.0143)***	0.5874 (0.0143)***	0.5866 (0.0144)***
EX	0.3819 (0.0758)***	0.2880 (0.0736)***	0.2926 (0.0737)***	0.2975 (0.0756)***
FDISP	-0.2599 (0.0857)***	0.7274 (0.1638)***		0.3226 (0.0688)***
RDSP	0.4044 (0.2706)	1.2364 (0.4003)***	1.3793 (0.3996)***	0.0396 (0.0782)
EXSP	0.0573 (0.0865)	-0.0700 (0.2074)	0.7004 (0.1140)***	0.0653 (0.0813)

Notes:
1. Intercept and coefficients on dummy variables are not reported.
2. Standard errors are in parentheses.
3. *** indicates that the coefficient is significantly different from zero at the 1% level.

Table 5. Production Function Estimates, Different Source Countries

	Industry	Region	Industry within Region
LK	0.2918 (0.0084)***	0.2932 (0.0083)***	0.2959 (0.0083)***
LL	0.6321 (0.0112)***	0.6347 (0.0110)***	0.6328 (0.0111)***
RD	0.0055 (0.0108)	0.0060 (0.0107)	0.0061 (0.0108)
EX	0.3680 (0.0542)***	0.2320 (0.0522)***	0.2778 (0.0542)***
RDSP	0.9188 (0.2022)***	0.9599 (0.2844)***	0.1196 (0.0595)**
EXSP	-0.0934 (0.0671)	0.3481 (0.1738)**	0.0738 (0.0610)
FDISP_HMT	0.2018 (0.1103)*	0.1032 (0.2299)	0.0645 (0.0402)#
FDISP_OECD	-0.2055 (0.0728)***	0.9519 (0.1306)***	0.3226 (0.0567)***

Notes:
1. Intercept and coefficients on dummy variables are not reported.
2. Standard errors are in parentheses.
3. ***, **, * and # indicate that the coefficient is significantly different from zero at the 1%, 5%, 10% and 11% levels respectively.

Table 6. Production Function Estimates, R&D = RDNPS

		Industry	Region	Region	Industry within Region
LK	0.2911 (0.0083)***	0.2888 (0.0083)***	0.2914 (0.0082)***	0.2900 (0.0082)***	0.2940 (0.0083)***
LL	0.6306 (0.0110)***	0.6258 (0.0112)***	0.6353 (0.0110)***	0.6348 (0.0110)***	0.6358 (0.0110)***
RDNPS	-0.0097 (0.0071)	-0.0104 (0.0071)	-0.0086 (0.0071)	-0.0087 (0.0071)	-0.0090 (0.0071)
EX	0.3435 (0.0521)***	0.3851 (0.0544)***	0.2402 (0.0524)***	0.2489 (0.0525)***	0.2735 (0.0543)***
RDNPSSP		0.2921 (0.1068)***	-0.0900 (0.1185)	-0.0213 (0.1182)	0.1573 (0.0729)**
EXSP		-0.0998 (0.0669)	0.0628 (0.1602)	1.0159 (0.0877)***	-0.0344 (0.0629)
FDISP		-0.0852 (0.0665)	0.8914 (0.1256)***		0.4589 (0.0522)***

Notes:
1. Intercept and coefficients on dummy variables are not reported.
2. Standard errors are in parentheses.
3. *** and ** indicate that the coefficient is significantly different from zero at the 1% and 5% levels respectively.

Table 7. Production Function Estimates, Different Measures of FDI Spillovers, Industry within Region

FDI Spillover Measure	FDISPEM	FDISPSALES	FDISPOUTPUT	FDISPRD	FDISPEMW	FDISPSALESW	FDISPPCS
LK	0.2959 (0.0083)***	0.2956 (0.0083)***	0.2953 (0.0083)***	0.2948 (0.0083)***	0.2946 (0.0084)***	0.2943 (0.0084)***	0.2951 (0.0083)***
LL	0.6398 (0.0111)***	0.6353 (0.0111)***	0.6363 (0.0111)***	0.6350 (0.0111)***	0.6299 (0.0111)***	0.6300 (0.0111)***	0.6392 (0.0111)***
RD	0.0057 (0.0108)	0.0061 (0.0108)	0.0062 (0.0108)	0.0095 (0.0108)	0.0062 (0.0108)	0.0062 (0.0108)	0.0072 (0.0108)
EX	0.2402 (0.0542)***	0.2714 (0.0542)***	0.2707 (0.0543)***	0.2734 (0.0542)***	0.2805 (0.0543)***	0.2833 (0.0543)***	0.2635 (0.0542)***
RDSP	0.0901 (0.0595)	0.1161 (0.0596)**	0.1149 (0.0596)**	0.2037 (0.0639)***	0.1442 (0.0594)**	0.1420 (0.0594)**	0.1000 (0.0595)*
EXSP	-0.1188 (0.0647)*	0.0396 (0.0644)	0.0345 (0.0643)	0.0840 (0.0593)	0.2027 (0.0572)***	0.1917 (0.0573)***	-0.0546 (0.0642)
FDISP	0.5867 (0.0560)***	0.2418 (0.0437)***	0.2532 (0.0439)***	0.2084 (0.0287)***	0.0000 (0.0000)	0.0381 (0.0132)***	0.0730 (0.0083)***

Notes:
1. Standard errors are in parentheses.
2. Intercept and coefficients on dummy variables are not reported.
3. ***, **, and * indicate that the coefficient is significantly different from zero at the 1%, 5% and 10% levels respectively.

Appendix I. Ownership Category

Domestically-owned enterprises	HMT-owned enterprises
110 State-owned enterprises 141 State-owned jointly operated enterprises 151 Wholly state-owned enterprises 120 Collectively-owned enterprises 130 Shareholding cooperative enterprises 142 Collectively jointly operated enterprises 159 Other limited liability enterprises 160 Shareholding limited enterprises 171 Private wholly owned enterprises 172 Private-cooperative enterprises 173 Private limited liability enterprises 174 Private shareholding enterprises 143 State-collective jointly operated enterprises 149 Other jointly operated enterprises 190 Other enterprises	210 Overseas joint ventures 220 Overseas cooperative enterprises 230 Overseas wholly owned enterprises 240 Overseas shareholding limited enterprises Other foreign-owned enterprises 310 Foreign joint ventures 320 Foreign cooperative enterprises 330 Foreign wholly owned enterprises 340 Foreign shareholding limited enterprises

Appendix II. Variables

Y	Value-added
K	Physical assets
L	The number of employees
RD	Intangible assets of a firm as a proportion of its fixed assets
RDNPS	Total new product sales of a firm as a proportion of its sales
EX	Exports of a firm as a proportion of its sales
RDSP	The share of intangible assets held by all other firms (the firm's own R&D is excluded) in an industry, in a region, or in an industry within a region.
RDNPSSP	The share of new product sales of all other firms (the firm's own R&D is excluded) in an industry, in a region, or in an industry within a region.
EXSP	The share of exports by all other firms (the firm's own exports are excluded) in an industry, in a region, or in an industry within a region.
FDISP	The share of foreign owned firms' capital in total capital in an industry, in a region, or in an industry within a region.
FDISPEM	The share of foreign owned firms' employment in total employment in an industry, in a region, or in an industry within a region.
FDISPSALES	The share of sales accounted for by foreign firms in total sales in an industry, in a region, or in an industry within a region.
FDISPOUTPUT	The share of output accounted for by foreign firms in total output in an industry, in a region, or in an industry within a region.

FDISPEMW	Foreign equity participation averaged over all firms in the level of industry (region, or industry within a region), weighted by each firm's share in employment. $FDI\_\sec tor_j = \frac{\sum_i FDI\_plant_i * Emp_i}{\sum_i Emp}$
FDISPSALESW	Foreign equity participation averaged over all firms in the level of industry (region, or industry within a region), weighted by each firms share in sales. $FDI\_\sec tor_j = \frac{\sum_i FDI\_plant_i * Sales_i}{\sum_i Sales}$
FDISPRD	The share of intangible assets held by foreign firms in an industry, in a region, or in an industry within a region.
FDISPEX	The share of exports by foreign firms in an industry, in a region, or in an industry within a region.