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Faculty of Economics and Applied Economics

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Hongjun Guo and Reinhilde Veugelers

DEPARTMENT OF MANAGERIAL ECONOMICS, STRATEGY AND INNOVATION (MSI)

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MNEs, Internationalization of R&D and the Impact on Local Firms: Evidence from China's High-tech Industries

Hongjun Guo
(Katholieke Universiteit Leuven, Belgium)
Faculty of Economics & Applied Economics
Naamsestraat 69, B-3000 Leuven

and

Prof. Dr. Reinhilde Veugelers
(Katholieke Universiteit Leuven, EC-BEPA, Brussels & CEPR, London)

Abstract

This study examines the impact of FDI and foreign-owned Research and Development (R&D) on total factor productivity (TFP) of domestic firms in China's high-tech industries. Growth in local firm's TFP is modeled as being dependent on the local firm's distance in technology space to foreign affiliates in the same industry, along with R&D, both foreign-owned and domestic. This model is tested on small-sampled industry-level data for China for the period of 1997-2003, using a within estimator, panel data approach. The results show that the technology gap has a significantly positive relation to the improvement of domestic TFP growth productivity at the industry level. However, we do not find strong positive effect of foreign-owned R&D on improving local productivity. Domestic firms' own R&D, by contrast, is a significant determinant for local industry's productivity enhancement.

Keywords: multinational enterprises, foreign direct investment, foreign-owned research and development, technology spillovers, local total factor productivity

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1. Introduction

China has during the last three decades experienced a remarkable transformation. Since the comprehensive political and economic reforms initiated in the late 1970s, taking full speed since 1992, the economy has grown by more than 9 per cent per year on average and a large part of the economy is now in private hands. An important component of China's development is its integration in the global economy. Foreign Direct Investment was the catalyst to bring China's economy back to the global stage. Spurred by a supportive Chinese open-door policy, granting beneficial treatment for FDI, China has been the second largest FDI recipient in the world from 1994, only after the USA.

Initially, FDI was mostly aimed at developing export oriented activities. During this early stage, China benefited from the import of capital, employment creation and exports but also from the modern technology brought in by the foreign firms. During later stages of development, foreign investors became more motivated by market-access. Currently, China is trading access to the Chinese market against foreign investors' technological and organizational know-how. More recently, more and more multinationals have begun to shift their R&D activities to China, attracted by the large potential market, but also by the large and growing supply of Chinese S&T engineers. Some of them have even relocated their global or regional R&D centre to China.

With a more developed and growing internal market and having moved closer to the technology frontier in a number of sectors, most notably in ICT, China has embarked on a new phase of development, relying increasingly more on higher value added, technology intensive industries and own indigenous (innovative) capacity. As Chinese enterprises get closer to the world frontier, being globally competitive will require investing more in R&D, not only to scan for, acquire and adapt foreign technology, but also to develop their own R&D capabilities in core areas of activity.

Surprisingly, only a limited number of empirical studies have investigated the impact of FDI on the Chinese local economy. The studies that exist suggest that there exist positive technology spillovers on the Chinese economy, although the effects are far from robust (Hu *et al*, 2002; Buckley *et al*, 2002; Wei and Liu, 2003). To our knowledge, no study has yet examined the impact of R&D by foreign multinationals on the productivity growth of local firms in China.

This paper contributes to the growing literature on the Chinese development process by examining the impact of both foreign presence and foreign-owned R&D on the performance of local firms. We focus on China's high-tech industries, which attract the larger share of FDI and are the most active in international R&D. Using three-digit industry-level data from 1997 to 2003, we test the relationship between the total factor productivity of local firms on the one hand and the technology distance between local firms and foreign-invested enterprises on the other hand as well as multinationals' R&D activities in the host market.

The next section starts with a literature review of the impact of FDI on the local economy. Section 3 sketches the stylized facts about high-tech industries, FDI and R&D in China. The empirical model, methodology and data are discussed in the next sections. Section 6 presents our empirical findings, followed by the concluding remarks in Section 7.

2. Brief Literature Review: impact of FDI/R&D on the host economy

That openness of an economy towards FDI encourages growth in the host economies has been demonstrated already in the early macro-economic literature (*e.g*. Helpman (1997)). Eaton and Kortum (1997)). In this paper we will focus on how FDI at the industry level indirectly affects the host economy, namely through international spillovers to domestic firms.

The importance of international spillovers for the host economy

Caves (1974) in one of the early contributions, distinguishes between three benefits of the presence of multinational firms for the firms located in the host country. First, the increase in market competition due to the entry of a foreign subsidiary increases allocative efficiency. Second, domestic firms in monopolistic markets will increase their level of technical efficiency or X-efficiency. This benefit flows from either the competitive effect of the multinational entry or through a demonstration effect. Finally, the entry of the subsidiary of a multinational can speed up the transfer and diffusion of technology in the local market and hence increase the rate of innovation in the host country.

Transfers of technology occur through interactions with local suppliers and customers. These are the backward and forward linkages. However, internationally transferred know-how may also spill over to local firms, including competitors, through many informal channels such as imitation and reverse engineering, movement of personnel, conferences and meetings, patent applications among others. Especially the movement of personnel has been identified as an important source of technological spillovers (Veugelers and Cassiman (2004)).

Conditions for international spillovers in the host economy

A first important issue is whether foreign subsidiaries will transfer technology locally. Obvious motives for transferring technology are the monetary returns in case of licensing out or R&D contracting with local firms. But there is also a vast amount of involuntary spillovers. These involuntary spillovers are mostly considered to be exogeneous to the firm, reflecting the effectiveness of the IPR regime in appropriating the returns to innovation. A host country's IPR is an important policy variable in determining not only the amount of R&D-FDI undertaken, but also the technology content of the activities undertaken by the MNE (eg Mansfield et al (1982)).

But spillovers are also partly influenced by firms. MNEs may engage in strategies to prevent know-how from leaking out. While MNEs may have an incentive to improve the productivity of their local suppliers or customers in case of vertical spillovers, MNEs will try to *minimize technology leakage* to local competitors in case of horizontal spillovers. For instance, beyond building in secrecy, complexity or lead time, they can minimize the mobility of personnel through paying higher wages or select an entry mode that minimizes spillovers. Rather than inhibit informal flows of know-how, firms are nevertheless often found to actively *nurture* these flows, as the growing emphasis on the importance of networking suggests, providing reciprocal access to local know-how (von Hippel (1988)).

A second issue is whether the local firms are able to efficiently absorb and use the technology stock available through R&D-FDI. The relationship between the *technology gap* between the host and home economy and the incidence of the impact of R&D-FDI is not clearcut (Perez (1997) On the one hand, authors like Wang and Blömstrom (1992) argue that the larger the technology gap, the greater the scope for learning by the local economy. But Cantwell (1989) assumes that the lower the technology gap between domestic and foreign firms the higher the ability of the domestic firms to capture the benefits created y the MNE presence. Countries lagging too far behind may not be able to internalize efficiently these spillovers if they lack the necessary *absorptive capacity*. [1]

Empirical evidence on the impact of international R&D on the host economy

In the empirical macro-economic literature, FDI has been confirmed as a channel for international spillovers, enabling foreign R&D to contribute positively to host country productivity growth (eg Guellec and van Pottelsberghe (2001)).[2] We focus the discussion on the micro-economic studies

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[1] Dahlam and Nelson (1995) define national absorptive capacity as “the ability to learn and implement the technologies and associated practices of already developed countries”.

[2] The importance of FDI as a channel for technology transfer is tested using two related approaches. In the endogeneous growth approach, FDI, measured by the stock or flow of inward FDI, is one of the explanatory variables of the host country’s GDP or TFP growth rate. In the international R&D spillovers approach the TFP of a country is a

that examine the impact on the local productivity from the presence of MNEs in the host economy[3]. These studies assess technology transfers through FDI indirectly, by inferring them from their effect on local productivity.[4]

Reviewing the empirical evidence on spillovers to the host economy from inward FDI, Blomström and Kokko (1998) conclude that such spillover effects exist, but that both positive and negative effects on host economies can be occurring. The recent survey by Görg and Strobl (2001) shows that earlier studies based on industry level cross-sectional data find a statistically significant horizontal spillover effect both in host developed countries (Caves 1974, in Australia and Canada, Globerman 1979, in Canada) and developing countries (Blömstrom and Persson 1983, Blömstrom 1986, Kokko 1994 in Mexico). But cross-sectional studies typically overestimate the spillover effects of MNEs because they are not able to control for firm or sector specific fixed effects. Controlling for these unobservable and time-invariant factors is important because multinational companies are driven towards relatively high-productivity sectors which implies that the observed positive relationship between foreign presence and domestic productivity may not be related to the occurrence of spillovers, but simply to a selection of high productivity sectors. Once this identification problem is controlled for, eg with the use of panel data techniques, empirical findings seem to point towards a negative or non-significant impact of MNEs on domestic firms' productivity operating in the same industry. In a more recent survey of studies using panel data sets,

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function of domestic and foreign R&D investment. FDI flows are used as weights when summing the stock of foreign R&D, based on the notion that FDI increases the proximity between the home and host country and hence leads to higher spillovers. The magnitude of spillovers is asserted from the return on foreign R&D, *i.e.* by how much foreign R&D increases domestic output.

[3] These studies, generally involve regressing the domestic firms'productivity on a variable capturing the MNEs presence in the same sector, *e.g.* the share of employment in foreign-owned firms or the share of output produced by foreign subsidiaries, and a number of other variables controlling for host markets characteristics such as the level of host market competition, technology gap, absorptive capacity. These studies test for the impact on domestic firms' productivity in the same sector and hence for the presence of horizontal spillovers.

[4] There is also a growing empirical literature trying to measure technology transfers directly, either through patent citation information (see eg Branstetter (2004) or through survey level evidence (Mansfield (1987), Veugelers & Cassiman (2004)).

Görg and Greenaway (2003) find that only six studies for industrialized countries and none for developing countries report positive within-industry spillover effects.[5].

One explanation for the difficulty to find evidence of positive spillovers is that spillovers from FDI may not materialize, since a critical factor to exploit spillovers is the technological capability of indigeneous firms (Blomström and Kokko (1998)). Most of the empirical studies on developing countries have failed to find robust evidence of positive knowledge spillovers from multinational investment, accounted for by the lack of absorptive capacity in these host countries (*e.g*. Aitken and Harrison (1999)). Haskel et al. (2002) find a significant positive correlation, using firm level data from the UK, but this correlation is smaller for lagging domestic plants, again underscoring even for developed countries the need for absorptive capacity. Girma (2003) on a UK sample for the period 89-99, finds an inverted U-shaped relationship between absorptive capacity and foreign presence.

Another possible explanation for the lack of positive spillovers, is the reluctance of foreign firms to transfer technology to the host market. Particularly when multinational firms are technology leaders and affiliates are located in countries with an insufficiently developed intellectual property rights protection regime, maintaining control over core technologies is a key issue, discouraging firms from localizing R&D abroad or inciting MNEs to prevent know-how leakage to the local environment. A recent study by Branstetter et al (2003) provides evidence that R&D by US firms is very responsive to positive reforms in intellectual property rights protection regimes in host markets, but this applies primarily to technology leaders in the industry that are most active in patent applications. Zhao (2004) for instance, shows how foreign R&D labs in China mostly engage in R&D for technologies where the parent maintains control over key complementary

5 However, Keller and Yeaple (2003), estimating international technology spillovers via FDI to US manufacturing firms' productivity growth between 87 and 96, finds a significant productivity gain for US firms. They also discuss why their results are likely to generalize to other countries and periods. The main reason for the difference from previous work is the classification of foreign affiliates in the industries in which they operate in the US, rather than according to the main activity of the parent firm.

technologies. Other studies have also found that multinational firms adapt the type of activities located abroad in response to intellectual property rights concerns, with knowledge intensive and higher value added activities reserved for countries with stronger IPR regimes (Lee and Mansfield, 1996; Smarzynska, 2004).

In general, it is fair to conclude that the results on positive spillovers on host economies are not strong and robust, partly because of poor proxies and controls used for absorptive capacity and the technological position of the host economy as well as the technological activities undertaken by the MNE, which are all important conditions for the emergence of positive spillovers. In addition the recent studies that have examined the potential for vertical (inter-industry) spillovers find evidence suggesting that these types of externalities may be more important than intra-industry spillovers.

3. FDI, High-tech industries and R&D in China

It was not until China's strong commitment to a market economy in the early 1990s that the country was able to attract substantial amounts of FDI. The first "FDI-boom" began in 1992 and came to a halt in the turmoil of the Asian crisis (see Table 1). A short period of consolidation was quickly followed by the take-off of the second "FDI-boom" which finds its basis in China's accession to the WTO in late 2001. Currently, China has become the first destination for FDI in the developing world, absorbing 20-25% of all FDI directed towards these countries (UNCTAD).[6]

[6] The outstanding position of China remains unchallenged even if taking into account that part of the resources classified as inflowing FDI has in reality been "round-tripping" money, i.e., money that had been illegally brought out of the country in the first place and then brought back under the label "FDI" in order to benefit from special incentives reserved for foreign invested enterprises (cf infra).

Table 1: Trends in China's Share in World FDI flows

	1985-1995	1997	1998	1999	2000	2001	2002
China	11.7 (6.5%)	44.2 (9.3%)	43.8 (6.3%)	40.3 (3.7%)	40.8 (2.7%)	46.8 (8.7%)	63.0 (9.3%)
USA	44.4 (25.5%)	103.4 (21.6%)	174.4 (25.1%)	283.4 (26.0%)	300.9 (20.2%)	124.4 (19.4%)	63.0 (9.3%)
World	**181.1**	**478.1**	**694.5**	**1088.3**	**1491.9**	**818.0**	**681.0**

Source: United Nations Conference on Trade and Development (Unctad).

The bulk of China's massive FDI inflows have not originated in the world economy's centres of technological growth. The Triad economies of the EU, Japan and the USA each have accounted for only about 10% of all China-bound FDI (BEPA (2006)). Hong Kong, Taiwan and South-East Asia have been the most important investors in China.

Table 2 Hong Kong's Share in China's FDI Inflows

Year	85	90	91	92	93	94	95	96	97	98	99	00	01
Share	49	54	55	68	63	58	53	49	46	41	41	38	36

Source: Authors' calculation based on the data from the China Statistical Yearbook (various years)

Part of this investment is so-called "round-tripping" in search of preferential treatment[7], which puts in perspective the use of FDI as a mechanism to import technology. Nevertheless, a substantial and growing part of FDI into China even from Hong Kong & Taiwan is a source of technological know-how for the Chinese economy.

The distribution of China's FDI inflows to various sectors does not follow market parameters alone, but remains rather heavily regulated by the Chinese government. The "Foreign Investment Industrial Guidance Catalogue" outlines in which industries foreign investors are welcome, restricted or not permitted. Today, FDI excluded or restricted sectors include cars, pharmaceuticals, financial services, air transport, media and electricity (BEPA (2006)). FDI into China is strongly concentrated in

[7] Although it is difficult to measure exactly which part round tripping represents in China's FDI inflows, a large proportion of China's FDI inflows coming from Hong Kong or overseas tax havens such as the British Virgin Islands, Bermuda and Cayman Islands, incorporate round tripping. A 2002 report by the International Finance Corporation (IFC) of the World Bank put the estimates at 30-50% of the total in the year 2000. And the market's general assessment is that the ratio has declined from 30% to around 10-20% in recent years.

Manufacturing[8]. As documented in the following table, foreign firms have a strong presence in the production of electronic and telecommunication equipment, office machinery, leather and sports goods, furniture, as well as garments and plastic products. These goods are produced in predominantly labour-intensive production processes.

Table 3. Share of Foreign Enterprises in China's Industrial Production Gross Industrial Output Value by Sector 2003

	Share
Electronic and Telecommunications Equipment	73.4%
Instruments, Meters, Office Machinery	61.8%
Leather, Furs, and Related Products	53.2%
Furniture Manufacturing	47.3%
Garments and Other Fiber Products	45.3%
Plastic Products	41.9%
Food Manufacturing	39.6%
Rubber Products	36.6%
Metal Products	35.9%
Electric Equipment and Machinery	33.1%
Transport Equipment	31.8%
Beverage Manufacturing	30.2%
Textile Industry	22.1%
Raw Chemical Materials and Chemical Products	22.1%
Medical and Pharmaceutical Products	22.1%

Source: European Commission (2005).

China's economic policy makers are aware that China being the global centre for labour intensive, low skilled processing manufacturing will not be sufficient to sustain their growth performance in the longer run. The current focus of China's industrial policy is on the promotion and establishment of higher value added, technology intensive industries and own indigeneous innovative capacity. China's high-tech industries still lag behind those of developed countries, but they are growing rapidly, particularly in ICT, where China has become in 2004 the largest exporter

8 Although the inflows of foreign funds are beginning to shift into service sectors, in 2003 64% were nevertheless invested in manufacturing and only 23% in services, of which half is accounted for by real estate management.[8] This low share of services is mainly due to a policy bias that promoted foreign investment in traditional industries, while restricting foreign participation in services. Foreign ownership in banking is expected to increase after 2005, depending on the swiftness of lifting market access barriers. In other service sectors like telecommunications and securities, foreign participation is more likely to remain limited.

(BEPA (2006)). Gross expenditure on R&D (GERD) as a share of national income has increased substantially and is planned to increase to levels comparable to the West. Although private (local) investment in R&D is growing, the Chinese government remains an important financer of research. This public spending is highly focused on areas where China can spur its development: IT, energy, biotech, but also national security (aerospace and laser) and frontier research. An important component of S&T growth in China is its huge pool of human capital for R&D, especially scientists and engineers.

The growth in China's High-Tech has a strong international dimension. China has been a prolific importer of technology embodied in goods.[9] It has been less active as an importer of disembodied technology, which entails royalty or other licensing fees.[10] The most important mechanism used by the Chinese government to bring in foreign technological know-how is by encouraging foreign investment. As a consequence, foreign-owned firms now play an important role in Chinese high-tech industries, as Table 3 already showed. Nevertheless, there are substantial differences across the various High-Tech industries. Foreign presence is particularly high in computers and office equipment and in electronic and telecom equipment, not so much in pharmaceuticals.

Foreign firms from High-Tech industries, increasingly (have plans to) locate R&D in China. Although the exact number of these foreign R&D centres is not clear, the evidence suggests that they are increasing rapidly. For example, US outward R&D investment to China has grown by 25% annually since the mid 1990s (against 8% per year in EU-15), making it the fastest growing destination for outward R&D investment.[11] Chinese international patent applications are dominated

9 High-Tech imports accounted for about 30% of total Chinese imports in 2003 (BEPA (2006)).

10 China spends about 12% of what Korea spends as a share of GDP on licensing foreign technology (World Bank 2002)).

11 In addition, patents owned by US assignees but invented abroad, although only 12% of total USPTO patents, are the fastest growing component of US patents. In these foreign invented US patents, the EU is still the biggest destination part, but Asia (excl Japan) is the fastest growing component of foreign invented US patents (R&T Management (2005)).

by foreign companies. [12] Between 1999 and 2001, almost half of all Chinese inventions were foreign owned, while this is only around 10% for the US or EU25 (BEPA (2006)).

Survey data on FDI intentions further indicate that China is high on the list of planned R&D investments in the future. For example, a global survey conducted by the Economist Intelligence Unit in 2004 showed that top companies' favorite location for planned R&D investment was China followed by the US and India. UNCTAD (2005) has also found that while the US is the top destination in developed markets, China is a top destination among developing countries.

Due to recent WTO-related reforms, foreign high-tech enterprises are now in many cases allowed to establish wholly foreign-owned subsidiaries in China, which are more attractive than joint ventures for conducting R&D, since they are better modes for keeping core know-how proprietary. This is of particular relevance in China, given its weak enforcement of intellectual property rights. Hence, foreign firms are currently consolidating their previously established research related programs into whole-owned subsidiaries while simultaneously shifting toward more advanced R&D activities.

Locating R&D in China is motivated by the need to be closely aligned to and adapt products to the large (potential) Chinese market. But also the access to the local base of Science & Technology know-how, particularly, the large pool of engineers and scientists, is a major pull-factor for attracting foreign R&D investments.

4. Data

This study focuses on the Chinese high-tech industries using data published jointly by the National Bureau of Statistics, National Development and Reform Commission and the Ministry of Science and Technology. The data cover five high-tech industries with a total of 17 sub-sectors

[12] China accounts for 1.4% of all world patent applications (Triadic patents). In 2003 China has 370 patents granted in USPTO compared to for instance 35500 for Japan.

from 1997 to 2003. These five categories are then divided into 17 sub-sectors. Two sub-sectors, spacecraft and radar, are excluded in our analysis since there is little foreign investment in these two industries related to government restrictions.

The dataset has a number of limitations. First, although firm-level data may explore better the research questions of FDI, R&D and productivity growth, the data are only publicly available at industry level. Second, we have no information on the home countries or regions the foreign capital is from. This makes it difficult a.o. to sort out the round-tripping when local firms shift their capital out of the country and then repatriate back as foreign firms. Another limitation of the data is that it only focuses on high-tech industries. Spillovers may also occur between high-tech and non-high-tech sectors.

The National Bureau of Statistics of China (NBSC) issued in 2002 the guideline of statistic catalogue of high-tech industry classification , in which about 60 four-digit industries are identified as high-tech industries covering various sectors such as medicine, telecom, information technology, electronics, aircraft and radar. The published high-tech data by NBSC is based on the reconstruction of the listed guideline. These finally identified high-tech industries are listed in the Appendix.[13]

Calculated according to the classification standard of the OECD for new and high-tech industries, in 1993, the share of China's high-tech industries in manufacturing total value added amounted to 6.2% in 1995, which is much lower than the level in major developed countries and newly industrialized countries in the same period. For instance, that of the United States was 20.1 percent, Japan, 16 percent, the Republic of Korea, 18.6 percent. However, in the recent years, especially

[13] The published data concerning high-tech industries by the National Statistical Bureau excludes item 1, 2 and 8, due to claimed limitation of data sources. The final high-tech data are comparable to OECD statistics (see Appendix for OECD STAN classified High-tech industries).

during the late 1990s, Chinese high-tech industries have been growing rapidly. In 2000, China's total value added of high-tech industries reached 9.3% of the total manufacturing value added. Although there is still a somewhat large gap between China and most developed countries in terms of the value added generated by the high-tech industries, the distance is getting closer. Table 4 shows this trend for China, comparing with some selected countries.

Table 4: The Ratio of Value-added of High-tech Industries to Value-added of Manufacturing: China and Selected Countries

	1995	**1996**	**1997**	**1998**	**1999**	**2000**
China	**6.2**	**6.6**	**6.9**	**8.1**	**8.7**	**9.3**
USA	20.1	21.1	21.6	21.8	22.1	23.0
Japan	16.0	16.5	16.7	16.8	17.8	18.7
Germany	8.8	9.2	9.6	9.5	10.3	11.0
France	13.0	12.5	13.9	13.7	14.0	13.6
UK	14.5	14.3	15.0	15.5	16.3	17.0
Canada	9.3	9.3	9.6	9.0	10.4	-
Italy	8.2	8.7	8.5	8.6	9.0	-
Korea	18.6	17.2	17.2	17.5	19.3	20.9

Source: China Statistics Yearbook on High Technology Industries (2003) and OECD STAN Database .2004

As already indicated supra, the Chinese Government has been encouraging foreign investment in the country's high-tech industries, expecting these foreign firms to introduce new technologies to the country. Taking the year 2002 for example, foreign-funded firms exceed the domestic firms in terms of value added, with around 55% of the total value added coming from foreign firms. In computers, electronics and telecommunications sectors, foreign firms have more value added than domestic firms (Table 5).

Table 5 Value added of high-tech industries by ownership (2002) (100 million yuan)

	All firms	Foreign firms	SOE	Non-SOE domestic firms	Share of foreign firms in all firms
High-tech industries	**3769**	**2060**	**1234**	**475**	**55%**
Medical and pharmaceutical products	835	199	342	294	24%
Aircraft and spacecraft	149	12	145	-8	8%
Electronic and telecom equipment	1939	1268	594	77	65%

Computers and office equipments	604	484	91	29	80%
Medical equipments and meters	242	96	61	85	40%

Source: China Statistics Yearbook on High Technology Industries (2003)

The entry and presence of foreign firms bring into China not only production facilities but also R&D sources, as reflected in the R&D expenditures by foreign-owned firms. Foreign firms are quite active in R&D in some high-tech sectors, such as computers and electronics. Nevertheless, domestic firms are the major players in terms of R&D input in China's high-tech industries (see Figure 1).

Insert Figure 1 here

The R&D intensity (R&D expenditure to value-added ratio) of foreign firms is only about half of that of domestic firms (See figure 2). This low level of foreign R&D puts into perspective the use of FDI as a mechanism to get access to foreign technology for China. This can be correlated to a reluctance of American, European and Japanese firms to locate R&D in China. Under unclear IPR regimes, when it is difficult to keep know-how proprietary, foreign firms will prefer to leave most of their core R&D at home when locating in China.

Insert Figure 2 here

Overall, whether or not the presence of multinational firms and particularly their foreign R&D will be a source of positive spillovers on the local Chinese economy, remains to be investigated carefully, using the appropriate methodologies.

5. Model and methodology

Our basic model, to test for "local" productivity spillover effects from multinational subsidiaries in China on the performance of local firms, is derived from Griffith, Redding and Van Reenen (2000 and 2004).

According to the standard neoclassical production function, value added (Y) in each sector (i) at a certain time period (t) is modelled using labor (L) and physical capital (K), i. e.

$$Y_{it} = A_{it}F_t(L_{it}, K_{it}), \quad (1)$$

where A is an index of technical efficiency, or total factor productivity (TFP).

In the empirical literature on R&D and productivity growth (e.g. Griliches 1980, Griliches and Lichtenberg 1984) at firm and industry levels, TFP in equation (1) is assumed to be a function of the own R&D knowledge stock (G). Taking logarithms and differencing with respect to time, the rate of TFP growth depends on the rate of growth of R&D knowledge stock,

$$\Delta LnA_{it} = \beta \Delta lnG_{it} + \gamma X_{it-1} + u_{it}, \ (2)$$

where β= (dY/dG)(G/Y) is the elasticity of output with respect to the R&D knowledge stock, u is a stochastic error term, and X is a vector of control variables. For small rate of depreciation of R&D knowledge stock, equation (2) may be expressed as[14]

$$\Delta LnA_{it} = \rho (R/Y)_{it-1} + \gamma X_{it-1} + u_{it}, \ (3)$$

where ρ=dY/dG is the rate of return to R&D and R denotes real R&D expenditure.

[14] If an R&D depreciation rate is assumed, equation (2) can be estimated directly. We did this as a robustness test and found similar results.

The theoretical rational for equation (3) is provided by models of endogenous innovation and growth (e.g. Romer, 1990; Aghion and Howitt, 1992). Griffith *et al*. (2004) augment the specification in the equation in two ways: technological transfer as a source of productivity growth for the countries behind the technological frontier and the absorbing role of R&D in technological transfer. Thus the conventional model is augmented to allow the size of innovations (and hence R&D's rate of return) to be a function of the distance behind the technological frontier. An equation for TFP growth of the following form is derived:

$$\Delta LnA_{it} = \rho_1(R/Y)_{it-1} + \delta_1 ln(A_f/A_d)_{it-1}+\delta_2(R/Y)_{it-1}*ln(A_f/A_d)_{it-1}+\gamma X_{it-1} + u_{it}, \quad (4)$$

where A_f and A_d are the TFP of foreign firms and domestic firms, respectively, and the term A_f/A_d is thus defined as the technology gap between foreign and local firms. The second term on the right-hand side captures the scope for technology transfer. Foreign firms are taken to represent the technology frontier. The distance between local firm's productivity and foreign subsidiary's local productivity measures the technology gap. The third term in (4) is an interaction term that captures the absorptive capacity role of own R&D for catching up with the frontier.

As Griffith *et al* (2004) states, there will clearly be unobserved country or industry characteristics that affect rates of TFP growth and are not captured by the model. Moreover, it is likely that these unobserved country and/or industry characteristics will be correlated with the explanatory variables. For example, features of the production technology in particular sectors of a country may result in a high rate of TFP growth in precisely the industries characterized by high R&D intensity. We allow for unobserved heterogeneity that is correlated with the explanatory variables by including a full set of fixed effects (ψ_i) in the error term u_{it}. Furthermore, there are macroeconomic shocks which may raise TFP in all countries or industries - a full set of time dummies is therefore included to control for these (T_t). All other factors are consigned to a serially uncorrelated error term (ε_{it}),

$u_{it} = \psi_i + T_t + \varepsilon_{it}$.

The final econometric specification of TFP growth in sector j is given as

$$\Delta LnA_{it} = \rho_1 (R/Y)_{it-1} + \delta_1 ln(A_f/A_d)_{it-1} + \delta_2 (R/Y)_{it-1} * ln(A_f/A_d)_{it-1} + \gamma X_{it-1} + \psi_i + T_t + \varepsilon_{it}. \quad (5)$$

A positive δ_1 would indicate that there is potential technology transfer or spillovers from foreign affiliates to local firms and hence promote their productivity growth, and a positive δ_2 would indicate that R&D investment by local firms will better absorb the technology from their foreign peers and thus help to enhance their own productivity.[15]

Our model differs from that of Griffith *et al* (2004) mainly in the definition of the frontier and technology gap. Griffith et al (2004) examine cross-border spillovers in 12 OECD countries and measure TFP of an industry in a certain country relative to the geometric mean of that industry's TFP in all countries. The frontier is defined as the country with the highest value of TFP relative to the geometric mean in each industry during a certain time period. Subtracting the industry TFP of a country from that of the frontier, calculated as in the relative-term way, they obtain a superlative-index-number measure of a country's TFP distance from the frontier. Since we test within-country 'local' spillovers from foreign to local firms, we assume foreign subsidiaries to be the relevant frontier for local Chinese firms. This is supported by the TFP data in our sample. The industry-level TFP for foreign subsidiaries are always higher than those of local firms.

In order to examine further the role of the R&D activities of foreign affiliates, namely how foreign-owned R&D affect local firms' productivity and whether there is R&D spillovers from foreign affiliates to local firms, we augment the TFP-model to incorporate R&D done by foreign subsidiaries in the industry. This is in line with the econometric analysis of R&D spillovers in

[15] Some scholars also argue that there might be a non-linear form of productivity. We tested it and have not found significant non-linearity.

growth models (e.g. Keller 1998 and Lichtenberg and van Pottelsberghe 1998). We first simply test the role of R&D by foreign affiliates with the following simple model (6), without considering the productivity gap:

$$\Delta LnA_{it} = \rho_1 (R/Y)^d_{it-1} + \lambda_1 (R/Y)^f_{it-1} + \lambda_2 (R/Y)^d_{it-11} * (R/Y)^f_{it-1} + \gamma X_{it-1} + \psi_i + T_t + \varepsilon_{it}, \quad (6)$$

where $(R/Y)^f$ stands for the R&D intensity (R&D to value added ratio) of multinational affiliates. λ_1 captures the effect of foreign R&D on local firms and λ_2 captures the capacity of local firms in absorbing the R&D knowledge of multinationals.

Finally, we pool model (5) and (6) to investigate the effect of both productivity spillovers from catching up and spillovers from foreign R&D, which gives the following model (7):

$$\Delta LnA_{it} = \rho_1 (R/Y)^d_{it-1} + \delta_1 ln(A_f/A_d)_{it-1} + \delta_2 (R/Y)^d_{it-1} * ln(A_f/A_d)_{it-1} + \lambda_1 (R/Y)^f_{it-1} + \lambda_2 (R/Y)^d_{it-11} * (R/Y)^f_{it-1} + \gamma X_{it-1} + \psi_i + T_t + \varepsilon_{it}, \quad (7)$$

One important econometric issue is the possibility of endogeneity. There may be an endogeneity problem between own R&D and productivity growth with the concern that firms will invest heavily in R&D during periods when TFP grows more quickly. This concern should not be overstated, as the ratio of R&D to value added (unlike TFP) is not generally procyclical. Nevertheless, firms might be able to correctly predict future shocks one period ahead and immediately adjust their R&D. Following Griffith *et al* (2004), we examine the scale of the potential problem by assuming the weaker restriction $E[(R/Y)_{it-2}\ \varepsilon_{it}]=0$. Under this assumption, the use of R&D lagged two periods reduces endogeneity bias. We examine the specification of this form and find that the results are not qualitatively different.

A modified Wald test for heteroskedasticity is taken for the model of both Equation (5) and (6). The results show that there exists a heteroskedasticity problem. The Wooldridge test for autocorrelation indicates no serious presence of first-order autocorrelation (AR1) in our data set. We estimate fixed effect models with heteroskedasticity-robust standard errors

6. Empirical results

We first run the regression of Equation (5). The results are shown in Table 6.

[*Insert Table 6 here]*

The results show a positive and significant relation of the TFP gap to the TFP growth of local firms, indicating potential for technology transfer when catching up and a positive effect on the productivity growth of the host economy. Within each industry the local firms that are further behind the frontier experience higher rates of productivity growth.

The R&D undertaken by domestic firms (R/Y) shows a positive and significant relationship with the productivity of domestic firms, indicating the domestic firms own R&D enhances productivity. For enterprises in high-tech industries, R&D is an important driving force to improve firms' competitiveness and productivity. This finding is consistent with a number of studies investigating the relationship between R&D and productivity (e.g. Griliches and Mairesse, 1990; Liu et al, 2000). Wei and Liu (2003) find, however, using firm-level data, no significant effect of a firm's R&D on its productivity in China. Their explanations are that intangible assets as a proxy can only capture part of productivity-enhancing R&D activities. An individual firm's R&D may not be significant enough to enhance its own productivity, with technology spilling over to create public domain knowledge, an effect which would be picked up at the industry level. Furthermore, their results are on all industries, not restricted to high-tech sectors, like in our analysis.

Although there is indication for domestic growth to be enhanced by own investment in R&D and spillovers from foreign subsidiaries operating at the technology frontier, it is interesting to see that the interaction of the TFP gap and domestic R&D intensity has an insignificant sign, suggesting that there is no evidence for absorptive capacity of local firms. Costly absorption both raises the effectiveness of a firm's R&D and lowers the effective spillovers which it obtains from rival firms (Leahy and Neary 2004).

In the next part of our analysis, we first estimate Equation (6) to test the effect of R&D of foreign firms on the productivity of local firms. The results are presented in Table 7.

[Insert Table 7 here]

The results show that foreign-owned R&D, which is of particular interest for us, has a positive effect on productivity growth of domestic firms but it is not statistically significant in any specification. Foreign firms' activities in R&D may affect the local firms by transferring more advanced technology or by forcing them to improve their existing equipment and management skills and thus increase productivity. The insignificance of foreign-owned R&D found in our sample, may be caused by the insufficient input of core R&D from foreign firms, which was shown in the previous sections. Foreign firms may not be investing particularly large amounts in R&D in China and/or protecting their technology know-how from spilling over to local firms.

To gain know-how spillovers from foreign affiliates, domestic firms may need absorptive capacity. Only when domestic firms invest in R&D themselves can they have the capability to learn and absorb the technology from foreign firms. Similar to the technology-gap absorptive spillover story, this foreign technology absorptive capacity is reflected by the interaction term between $(R/Y)^d$ and $(R/Y)^f$ in the model. In line with the insignificant effect of foreign owned R&D, the interaction term turns out not to be statistically significant. The non-existence of local R&D spillovers may be caused by the insufficiency of absorbing activities of domestic firms on one hand and/or by the protection behavior of foreign firms on the other. Nevertheless, although own R&D does not seem to enhance the absorption of external know-how, domestic firms' own

R&D is shown as an important determinant for improving own productivity. Local firms seem to invest in R&D to compete with their rivals, rather than intending to learn and absorb technology.

Finally, we consider the role of both productivity spillovers and R&D in affecting the productivity growth of local firms. This is tested in model (7). The results are shown in Table 8.

[Insert Table 8 here]

The results from this more general model are similar to those in model (5) and (6). The local firms can benefit from productivity-spillovers from the foreign firms in the corresponding industries, shown by the significant positive coefficient of technology gap. However, the effect of R&D spillovers from foreign firms is not significant. Both indicators for the absorptive capacity (interaction terms) are insignificant. However, local firms' own R&D is always a significant driving force for local productivity growth in high-tech industries.

7. Conclusions

Multinational enterprises (MNEs) play an important part in transferring technology across national borders through foreign direct investment. Especially in China, FDI has been an important catalyst to bring China's economy back to the global stage. The current focus of China's industrial policy is on the promotion and establishment of higher value added, technology intensive industries, stimulating simultaneously the absorption of foreign technology through FDI and the development of local innovative capacities.

Numerous studies investigating the impact of FDI on the productivity of local firms for various countries, have failed to find strong evidence for positive effects. Few studies have examined the impact of R&D conducted by foreign firms in the local market, on the performance of domestic firms. This paper studies the impact of FDI and foreign-owned R&D on total factor productivity of domestic firms in China's high-tech industries. TFP growth of the local firms is modeled as dependent on the technology distance between local firms and foreign affiliates in the industries, along with the effect of R&D, both foreign-owned and domestic. A panel data model approach is used on industry-level data for the period of 1997-2003 in China's high-tech industries.

We find that the technology gap has a significantly positive effect on the improvement of domestic TFP growth at the industry level, indicating existence of productivity spillover effects from foreign to local firms. We do not find strong positive effect of foreign-owned R&D located in China on improving local productivity. Domestic firms' own R&D is a more important determinant for their productivity enhancement. However, the results show no evidence for the dual role of domestic R&D, serving as absorptive capacity for productivity and/or technology spillovers.

Caution must be taken when interpreting the results, given the limitation of the small sized data set, as discussed earlier. R&D spillovers might prevail more between vertically related firms. Focusing solely on intra-high-tech industries inevitably neglects the vertical spillover effects across these sectors. Moreover, industry-level data are not able to capture fully the channels through which spillover effects may materialize. Firm-level data would allow more detailed analysis of the spillover effects.

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Appendix

The Statistics Catalogue of the High-tech Industries in China

Industry	Sub-sectors
1. Nuclear Fuel Processing	
2. Manufacture of Information Chemical	
3. Manufacture of Medical and Pharmaceutical Products	3.1 Chemical Pharmaceutical Products
	3.2 Processing of Traditional Chinese Medicine
	3.3 Biology Products
4. Manufacture of Aircraft and Spacecraft	4.1 Manufacture and Repair of Aircraft
	4.2 Manufacture of Spacecraft
5. Electronic and Telecommunications Equipment	5.1 Telecommunication Equipment
	5.2 Radar and Peripheral Equipments
	5.3 Broadcast and Television Equipments
	5.4 Electronic Apparatus
	5.5 Electronic Components
	5.6 Household Audiovisual Equipments
	5.7 Other Electronic Equipments
6. Manufacture of Computers and Office Equipments	6.1Computers
	6.2 Peripheral Equipments of Computer
	6.3 Office Equipment
7. Manufacture of Medical Equipments and Meters	7.1 Medical Eqiupments and Instruments
	7.2 Instruments and Meters
8. Public Software Service	

Source: Reproduced from *China Statistics Yearbook on High Technology Industries (2003)*

OECD STAN (ANBERD) Database Hi-tech Classification

Sector	Sub-sector(s)
Aircraft and Spacecraft (353)	
	Manufacture of aircraft and spacecraft (3530)
Pharmaceuticals (2423)	N.A.
Office, accounting and computing machinery (30)	
	Manufacture of office, accounting and computing machinery (300)
Radio, TV and Communications equipment (32)	
	Manufacture of electronic valves and tubes and other electronic components (321)
	Manufacture of television and radio transmitters and apparatus for line telephony and line telegraphy (322)
	Manufacture of television and radio receivers, sound or video recording or reproducing apparatus, and associated goods(323)
Medical, precision and optical instruments (33)	
	Manufacture of medical appliances and instruments and appliances for measuring, checking, testing, navigating and other purposes, except optical instruments (331)
	Manufacture of optical instruments and photographic equipment (332)
	Manufacture of watches and clocks (333)

(Source: *OECD STAN Indicator Database 2004* and *UN Classification Registry*; numbers in the brackets are ISIC Rev.3 Classification Codes.)

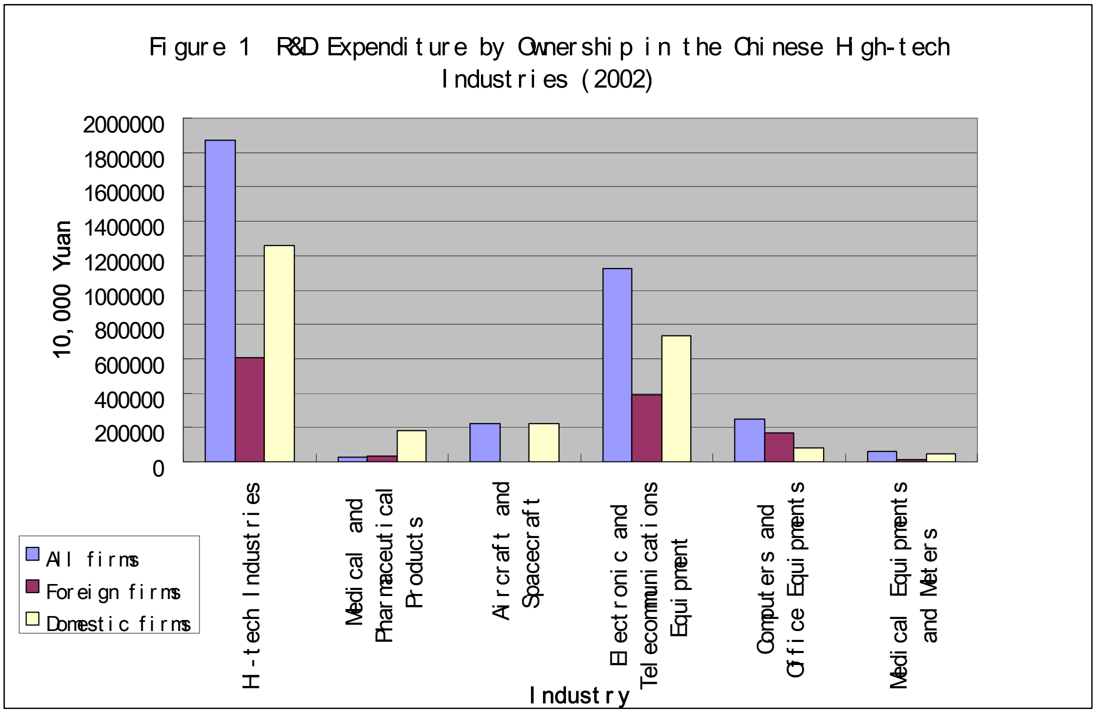
Figure 1 R&D Expenditure by Ownership in the Chinese High-tech Industries (2002)
10,000 Yuan
2000000
1800000
1600000
1400000
1200000
1000000
800000
600000
400000
200000
0
All firms
Foreign firms
Domestic firms
H-tech Industries
Medical and Pharmaceutical Products
Aircraft and Spacecraft
Electronic and Telecommunications Equipment
Computers and Office Equipments
Medical Equipments and Meters
Industry

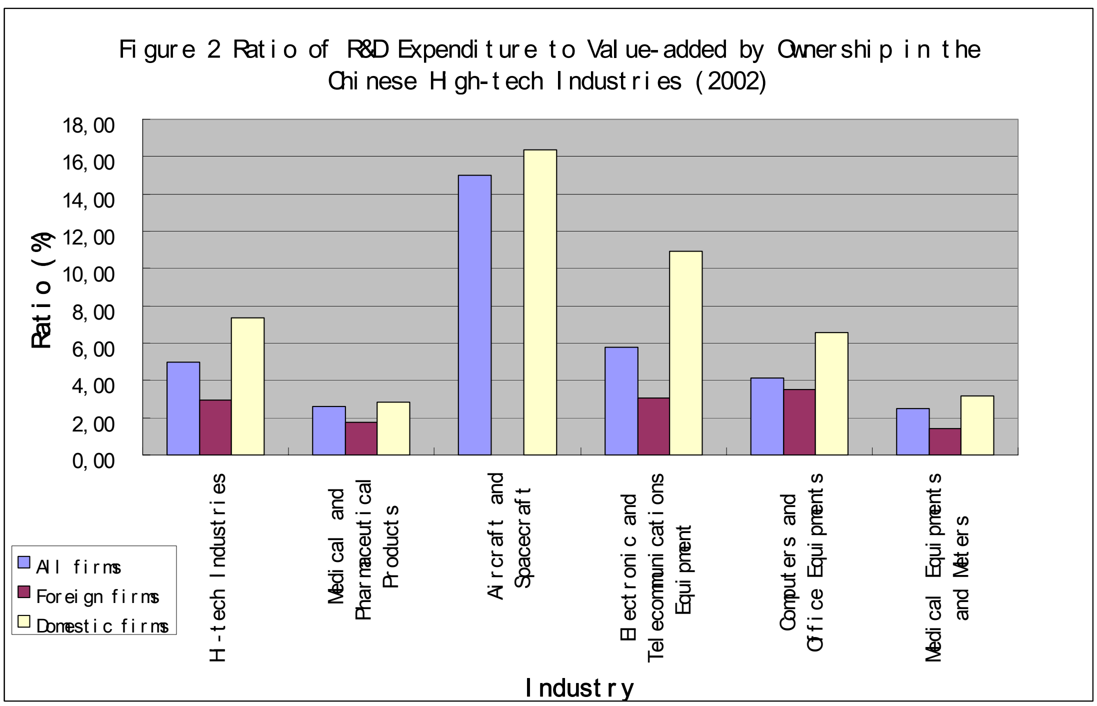
Figure 2 Ratio of R&D Expenditure to Value-added by Ownership in the Chinese High-tech Industries (2002)
Ratio (%)
18,00
16,00
14,00
12,00
10,00
8,00
6,00
4,00
2,00
0,00
All firms
Foreign firms
Domestic firms
H-tech Industries
Medical and Pharmaceutical Products
Aircraft and Spacecraft
Electronic and Telecommunications Equipment
Computers and Office Equipments
Medical Equipments and Meters
Industry

Table 6 Domestic R&D, Spillovers and Local Productivity

Dependent Varible: Total Factor Productivity Growth of Local firms (ΔTFP_{it})				
	(1)	(2)	(3)	(4)
$TFPGAP_{i\,t-1}$	0.428 (2.05)**		0.496 (2.63)***	0.599 (2.03)**
$R/Y_{i\,t-1}$ (Domestic R&D)		3.18 (1.44)	3.806 (1.76)*	5.66 (2.51)***
$(TFPGAP \times R/Y)_{i\,t-1}$				-2.280 (-0.67)
Year Dummy	Yes	Yes	Yes	Yes
No. of observations	90	90	90	90
Adjusted R^2	0.70	0.70	0.74	0.74

Note: 1. Heteroskedasticity-robust within estimation 2. Figures in parentheses are t statistics; *, **, *** denote significance at the 10%, 5% and 1% levels respectively.

Table 7 Foreign R&D and Local Productivity

Dependent Varible: Total Factor Productivity Growth of Local firms (ΔTFP_{it})			
	(2)	(3)	(4)
$(R/Y)^d_{i\,t-1}$ (Domestic R&D)	3.182 (1.44)	3.182 (1.43)	3.566 (1.64)*
$(R/Y)^f_{i\,t-1}$ (Foreign R&D)		0.077 (0.03)	4.356 (0.84)
$[(R/Y)^f \times (R/Y)^d]_{i\,t-1}$			-51.660 (-0.98)
Year Dummy	Yes	Yes	Yes
Number of observations	90	90	90
Adjusted R^2	0.70	0.70	0.70

Note: 1. Heteroskedasticity-robust within estimation 2. Figures in parentheses are t statistics; *, **, *** denote significance at the 10%, 5% and 1% levels respectively.

Table 8 Foreign-owned R&D, Domestic R&D and Local Productivity

Dependent Variable: Total Factor Productivity Growth of Local firms (ΔTFP_{it})		
	(1)	(2)
$TFPGAP_{i\ t-1}$	0.60 (2.08)**	0.61 (2.06)**
$R/Y_{i\ t-1}$ (Domestic R&D)	5.32 (2.37)**	5.80 (2.32)**
$(TFPGAP \times R/Y)_{i\ t-1}$	-1.81 (-0.55)	-2.07 (-0.61)
$(R/Y)^f_{i\ t-1}$ (Foreign R&D)	-2.57 (-0.83)	0.71 (0.15)
$[(R/Y)^f \times (R/Y)]_{i\ t-1}$		-38.97 (-0.74)
Year Dummy	Yes	Yes
No. of observations	90	90
Adjusted R^2	0.74	0.73

Note: 1. Heteroskedasticity-robust within estimation 2. Figures in parentheses are t statistics; *, **, *** denote significance at the 10%, 5% and 1% levels respectively.