

Outward Direct Investment and R&D Spillovers: the China's case

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Introduction

Spillover effect of foreign direct investment (FDI) has attracted a great deal of attention in economic research. As a matter of fact, the literature on the technological spillover effect largely emphasises uni-directional knowledge flows from multinational enterprises (MNEs) to host country domestic firms, and research on the impact of technological upgrading of investing country has been ignored for a long time. It was not until the early 1990s that scholars suggest that FDI not only leads to foreign knowledge flows for domestic players in host countries, but also serves as a channel (conduit) for international R&D spillovers to investing countries. However, in contrast to a plentiful supply of literature on international R&D spillovers by means of trade, the research about contribution of FDI to technology upgrading of investing country still remains fragmented and inconclusive. In the context of China, extensive research has been focused on the effect of FDI inflows and technology diffusion. This is not surprising given that China, in the past two decades, has implemented strategies of attracting foreign direct investment and export promotion, in the hope of technology as well as capital gains from the openness. It is only in recent years that along with the government's 'going out' strategy and accelerated internationalisation of Chinese firms, have scholars started to look into the role of outward FDI and its impact on domestic technology development and economic growth (e.g. Zhao, 2004, 2005). It is worth mentioning that as a late comer, one of the important objectives for the Chinese government's 'going out' strategies was to promote industrialisation and technological upgrading. The aim of this paper is to extend the existing models, to analyse the impact of outward FDI on technology development in China's context.

The remainder of the paper falls into four sections. First it provides a brief overview of technological spillovers related to outward foreign direct investments worldwide. Then it discusses four mechanisms of outward FDI and technological upgrading in China. The next section presents empirical analysis. The final section presents conclusions.

1. Outward FDI and R&D spillovers: the basic hypothesis and empirical model

The importance of international R&D spillovers has long been recognized and the search for R&D spillovers across countries received a boost in the 1990s with the development of new growth models by Romer (1990), Grossman and Helpman (1991), and Aghion and Howitt (1992), and by the application of the ideas from these models together with new empirical techniques to expanded data sets by Coe and Helpman (1995) and Coe, Helpman, and Hoffmaister (1997). (Coe, et al. 2008). To a large extent, the models are limited to trade and R&D spillovers and somehow neglect the impact role of foreign direct investment on spillovers of investing country in its economic growth. The shift toward outward FDI, linkages and channels of cross-border knowledge transfer had started in the 1990s, of which the paper on ‘The technological capability and Japan’s direct investment in the U.S.’ by Konut and Chang (1991) is of most significance. They developed the hypothesis of inverse technological spillovers, on the basis of the evidence that a large fraction of Japanese direct investment in the U.S. was restricted to industries where the Japanese companies lagged behind their U.S. counterparts. They found that Japanese companies inclined towards establishing joint ventures with local companies so as to enable them to acquire and/or share technology with their American partners. The above work inspired a large number of empirical studies. For example, Yarnawaki

(1993) find that there are positive association between entry decision, technological levels of Japanese companies and the technological gap against their competitors in host country. In other words, those Japanese firms with less technological advantages may choose joint venture or co-operation with local firms, whilst those who enjoy superior technological advantages over their local competitors in the host country, would likely choose greenfield investment, i.e. established wholly owned enterprises and independent branches. Also, the research further supports the strategic intention of protection or acquisition of technology by Japanese enterprises.

Given that knowledge spillovers are geographically localised (Jaffe, *et al.* 1993; Audretsch & Feldman, 1996; Branstetter, 2001; Keller, 2002), foreign direct investment can provide an important channel to facilitate the diffusion of knowledge by overcoming those geographic constraint (Caves, 1974; Aitken and Harrison, 1999; Branstetter, 2000). On the one hand, spillovers occur when local firms benefit from the foreign investor's superior knowledge of production technologies or markets, without having to incur a cost that exhausts the whole gain from the improvement (Blomström & Kokko, 1997). On the other hand, spillovers may also occur when foreign investors take advantage of local technological capital and human capital that would not exist or would obtain at a higher cost in home market. Utilised leverage and linkage of this is widely discussed in the literature of technology-seeking activities of firms from emerging markets (Peng, 2008; Matthew, 2008). Those technological less advanced enterprises may actively seek technological spillovers directly or indirectly, by locating close to the headquarters and production facilities of their more advanced competitors (Jaffe, *et al.*, 1993). Neven and Siotis (1993) examined FDI inflows to Western Europe and found that foreign capital investing in Europe was concentrated

in relatively innovative sectors. Head et al (1999) used regression to test correlation between geographical distribution and industrial cluster of Japanese manufacturing companies in the U.S., and they found the key element of location decision was industrial cluster effect, i.e. Japanese companies inclined towards locating in technological innovative areas. The research also indicates that the outward FDI has produced positive effect on technological upgrading in the home country. Branstetter (2000) examined performances of Japanese firms investing in the U.S. and found that technological levels have been improved by engaging in direct investment. This is consistent with previous work by Neven and Siotis (1996) and Siotis (1999) that FDI has inverse technological spillover effects. Fosfuri et al (2001) developed a more sophisticated model and concluded that companies with less advanced technology may achieve technological upgrading by means of learning from local firms in host countries.

The empirical evidence can be extended to a chain-type hypothesis, i.e. outward FDI – firm's technological upgrading – technology transfer and spillover effect of home country. Based on cross-sectional data about Swedish multinational enterprises and their outward FDI, Braconier and his colleagues (2001) assessed technological spillover effects of FDI inflows and outflows and concluded that there is positive association between the size of outward and inward FDI, R&D expenditure of host country and technological spillovers absorbed by home country. It indicates that the closer firms locate in countries with high R&D levels, the more likely firms may benefit from spillovers.

Empirical evidence shows that technological spillovers of Japanese investment have two directions (Branstetter, 2000). When Japanese firms invested in the U.S., they used outward FDI as a channel to acquire technology; while investing in East Asia, they tended not only to acquire but also to transfer technology. For example, Sony had 9 R&D centres in developing countries in Asia, including 3 in Singapore, engaging in research and development activities in digital memory, semiconductor design for hi-fi, CD-ROM drive and multi-media products. It had 4 centres in Malaysia and one each in South Korea and Taiwan, undertaking different R&D activities. Working closely with scientific institutes in the host countries, these R&D centres diffuse as well as absorb technology and know-how.

The positive association between international R&D spillover effects and FDI flows is now widely recognised by economists and policy makers, although estimates of their empirical significance at the macroeconomic level were often elusive. Several models have been developed based on empirical checking, though the outcomes are not very satisfactory. One model is based on the hypothesis of inverse technological spillovers of FDI (Braconier & Ekholm, 2002), to calculate possible spillovers of R&D capital stocks of FDI of one country.

$$OFDI^{kh} = \sum_j \frac{L_j^{kh}}{L_j^h} S_j^h \quad (1)$$

In the equation, OFDI represents foreign R&D capital stocks obtained from spillovers of

outward FDI, $\frac{L_j^{kh}}{L_j^h}$ represents rate of employees hired by company k in h sector in

country j against total employees working in h sector in country j . S_j^h represents R&D

capital stocks in h sector in country j . It attempts to control other sources of

technology, such as company's own R&D investment and R&D investment in sector h , and then to explore correlation between foreign R&D capital stock and productivity of parent company.

Another model, developed by Head and Ries (2002), from the perspective of industry features of outward investment, emphasises on effects of different types of FDI and their technological spillovers effect on home countries. The model is based on assumption of horizontal FDI arising for Horstmann-Markusen motive that Brainard (1997) describes as scale versus proximity. It argues that when a company confronts higher trade costs and relatively lower economies of scale, it would replace trade with horizontal FDI. Carr, Markusen and Maskus (1988) developed the 'knowledge-capital model' and included mobility or transferability of technology, collaboration and technological intensity in their analysis. The model hypothesises that an overseas subsidiary is relatively independent with little direct interaction with both parent company and home country. But its production may affect production output of the parent company; therefore it has indirect impact on technological intensity of home country. Since horizontal FDI may replace export, therefore the production in home country may be reduced.

It is worth mentioning that the outcomes of empirical checking of the two models are not satisfactory. For example, the empirical checking of the first model fails to find evidence of R&D led by technological spillovers, which is inconsistent with the observation. The second model suggests that FDI investing in a low-income country would lead to technological upgrading in home country, while FDI in a high-income country would lead to technological degrading in home country. This conclusion is

also inconsistent with the observation. In reality, it is observed that almost all multinational enterprises locate their R&D centres in developed countries in order to benefit from technological spillovers.

The technological spillovers effect of outward FDI has also inspired scholars to investigate the issues in China's context (e.g. Jiang, 2000; Ma & Zhang, 2003; Ru, 2004; Xian, 1998). Xian (2004) assesses various aspects of technological accumulation and competitive strategies of outward investment from developing country and developed the 'inverse investment learning FDI' model. Ru (2004) assesses systematic effects of 'technology-sourcing' or 'technology-acquisition' FDI. Jiang (2000) argues that domestic companies may benefit from spillovers by establishing R&D centres or high-tech companies in technologically advanced countries. This may help them to develop their own innovative products. Ma and Zhang (2003) use the uni- and bi-directional diffusion model, and demonstrate that firms in developing countries may upgrade their technology through investing directly in developed countries and absorbing technological spillovers. Based on the observation of xxx, Ruman and Li (2007) argue that Chinese MNEs are likely to become knowledge seekers as they go abroad given that they have few firm-specific advantages that their foreign competitors enjoy.

With the phenomena of increasing cross-border M&As undertaken by Chinese companies in recent years, the hypothesis of 'technology-sourcing FDI' by Chinese firms becomes an important topic. Empirical evidence suggests that outward FDI by means of M&As may help Chinese multinational companies acquire technology that is relevant to core technology, and thus could improve their R&D capability (Li,

2003). This is particular true for private owned companies in China, who consider acquisition of complementary technology as the top motive to undertake cross-border M&As (Zhao, *et al*, 2005).

2. China's Outward FDI and R&D upgrading: mechanisms driving spillover effect

FDI has positive technological spillover effects to investing countries; the question is how such effects take place? The survey of literature suggests that there are four main mechanisms. First, 'the sharing mechanism of R&D expenditures', i.e. outward investments may allow foreign companies in host countries take advantage of spillovers by domestic companies in host countries and thus lower their own R&D expenditures. It argues that the sharing of R&D expenditures may occur when firms invest in R&D intensive locations. On the other hand, firms may reduce unit R&D cost through market expansion and economies of scale. The survey of 30 American multinational enterprises shows that thanks to subsidiaries sharing large amounts of R&D expenditure, R&D expenditures at parent companies decreased by 15 per cent (Mansfield, 1982).

The second is 'feedback mechanism of R&D outcome, i.e. to influence technology of home country through sending new technology developed by overseas subsidiaries to parent companies. In some cases, foreign subsidiaries of an MNC serve as listening posts for the home base (Almeida, 1996; Florida, 1997; Frost, 2001); these subsidiaries should improve the absorptive capacity of the MNC *home base* for knowledge produced in the host countries. Dunning (1990) surveyed patent applications of big multinational enterprises and found that the rate of overseas

subsidiary patents against the total patent applications rose to 10.6 per cent during 1983 – 1986, from 9.8 per cent during 1969 – 1972. The research also suggests that new technologies developed by overseas subsidiaries may be better adapted to consumer preference of host countries, and thus strengthen competitive advantages of multinational enterprises. MNEs are as good at transferring knowledge from their subsidiaries to their home base as from the home base to the subsidiaries (Singh, 2004). Many researches demonstrate that R&D activities of overseas subsidiaries not only transfer technology to parent companies, but also have spillover effects to other subsidiaries within the same company.

The third is ‘mechanism of inverse technology transfer’, i.e. to acquire inverse technology transfer by means of direct investment in technological advanced countries (normally developed countries). This often occurs in the form of cross-border mergers and acquisitions. Through M&A or joint R&D, technologically less advanced firms may monitor new development trends and transfer new technology to home countries, and thus speed up inverse technology transfer and promote upgrading in home countries. Patel et al (1998) found that big British MNEs benefited greatly from their cross-border M&A activities, as the new patents applied by their overseas subsidiaries increased by 60 per cent during 1979 – 1990. It is not uncommon to observe multinational enterprises acquire successful companies so as to transform potential competitors into partners and to acquire research capabilities and outcomes, and hence strengthen its own competitive position.

The fourth is ‘mechanism of replacement of peripheral R&D activities’, i.e. parent companies may outsource peripheral R&D activities and/or relocate them overseas,

and to enable them to focus on key R&D projects, and thus strengthen core innovative capacity. This is somehow similar to the first mechanism. There has been much research in this area; for example, a survey of 104 senior managers suggested that it is important for firms with technology playing crucial roles in their sectors to invest in places close to pioneering R&D; 70 per cent of the senior managers considered labour availability and clusters of skilled labour an important factor; over half considered that low costs of overseas R&D as most attractive incentive (UNCTAD, 2005).

A framework may be developed on the basis of the four mechanisms discussed earlier (figure 1).

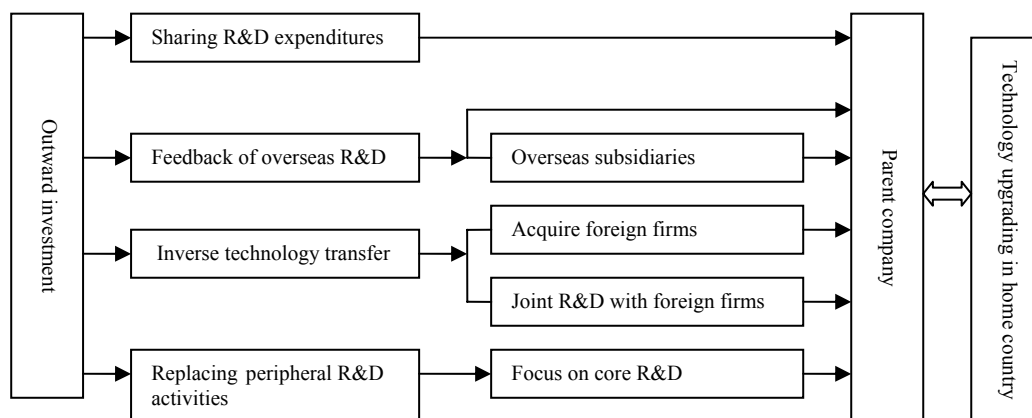


Figure 1. Mechanisms of outward FDI and technology upgrading of home countries

It is worth mentioning that the above mechanisms are all derived from empirical evidence of multinational enterprises originated in developed countries. The application to firms in developing countries is rather limited, especially when they are applied to emerging markets economies in the process of economic transition and accelerated industrialisation, including China. The direct investment of Chinese companies is directed to three groups of locations. The first one is industrialised

economies, especially the U.S. The recent statistics show that the outward FDI stock to the North America had reached to US\$1587 million by 2006, accounting for 2.1 per cent of total OFDI stock (MOF, 2007). Meanwhile, China's outward investment stock in the OECD was US\$ 4800 million, accounting for 6 per cent of the total in 2006¹. The second destination is newly industrialised economies and other transition economies. By 2006, China had invested US\$31.6 billion in these economies including Hong Kong and Macao. Along with overseas investments in Russia and Middle Asia, it accounted for more than 70 per cent of the total OFDI. The third destination is developing countries, especially South Asian economies (Vietnam, Cambodia, Laos) and African countries. By 2004, the FDI outflows to these economies were US\$1.99 billion, accounting for 4.5 per cent of the OFDI stock. Given that the significant technological gaps existing in the three destinations, it suggests that inverse technological spillover effects that Chinese companies may enjoy in these destinations are very different¹.

Empirical evidence suggests that in the developed countries, the following mechanisms be presented. 1. Mechanism of absorbing R&D factors, Chinese companies may absorb R&D outcomes through their direct investments in Europe and the U.S. Some famous cases include Shanghai Xiahua Company, Lenovo Group, Haier Group and Zhejiang Wanxiang Group. For example, Xiahua Company set up high-tech joint ventures in the U.S. and Japan to develop and produce UPS products and computer software; Lenovo set up its R&D centre in Silicon Valley in the U.S.,

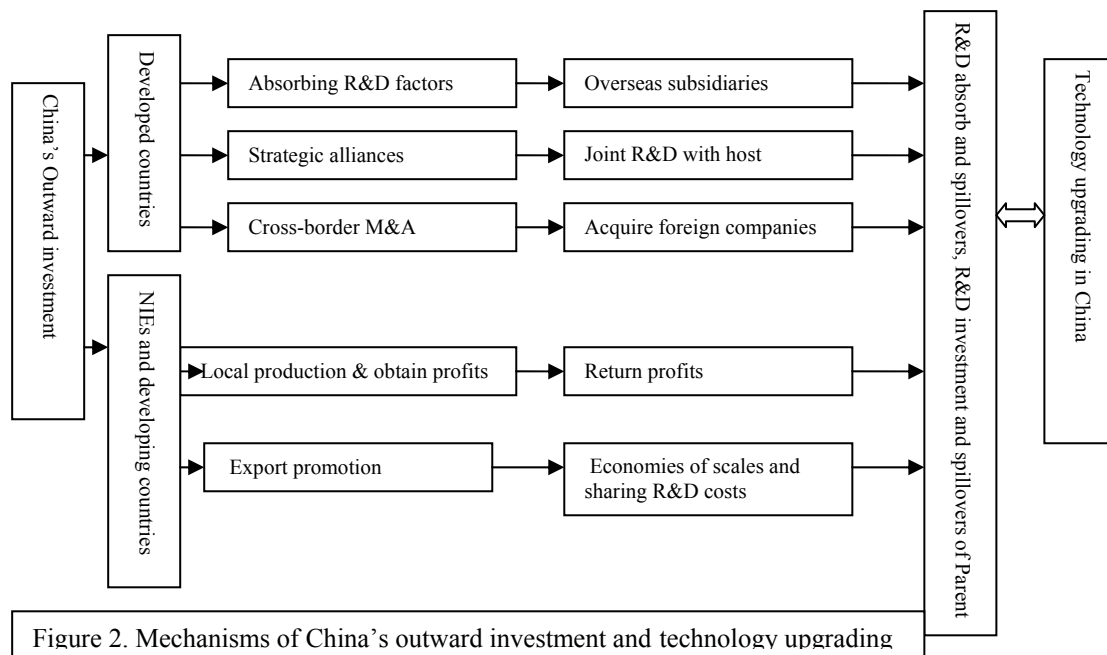
¹ A reasonable fraction of China's direct investment flowed via some offshore finance centres or tax havens, especially Cayman Islands and Britain Virgin Islands. By 2004, direct investment outflows to these two destinations reached US\$7.74 billion, accounting for 17.4 per cent of the total outflow stocks. It is very difficult to confirm the final destinations of such kind of investment. For a detailed survey, see 'Statistical Bulletin of China's outward foreign direct investment in 2004' (MOT, 2005).

this centre not only enables the company to take advantage of local infrastructure and local talents, but also helps the company to keep up to date with the latest trends in computer technology development. 2. Feedback mechanism of R&D outcomes. The cases include TCL's strategic alliance with Thomson in 2003, and Huawei 'joint lab' deals with world famous companies including Motorola, Microsoft, Agere, Sun, NEC, etc. It suggests that the parent companies benefit greatly from such collaborations. 3. Mechanism of acquiring foreign companies with suitable technology. There are some successful cases. For example, in 1988, Shougang Steel purchased a 70 per cent stake in Masta Engineering Designing Company in the U.S., and obtained the right to use 850 drawings and microfilms, 46 software packages, 41 patents and 2 trademarks. The acquisition made Shougang the first company in China with advanced steel rolling and continuous casting technology. The very recent case of Lenovo's acquisition of IBM's computer division also suggests that Lenovo benefited from acquiring some useful technologies.

In the second and third destinations or areas, most of China's investments went to East Asian NIEs and Latin American countries. There is insufficient evidence of inverse technological spillovers. Since China's investments in these regions are motivated by market expansion, there is little chance of spillovers in the short term. However, it may suggest that the market expansion would help companies to reduce R&D unit costs at home base through economies of scale. For example, with big investment in Russia and other transition economies, Huawei has made considerable profits from their market expansion; this actually supported their R&D activities back in China. Companies like TCL and Lifan set up large scale production bases in Asian countries (TCL has established a TV plant with an annual production output of

500,000 units in Vietnam). The investments helped export of upstream products and equipment from parent companies, and hence led to economies of scale effects and reduction of unit R&D costs.

The framework is developed on the basis of empirical evidence of outward investment from developed countries and technology upgrading at home countries. In the case of China, given that the mechanisms driving inverse technological spillover effects vary in different investing destinations, we need to make some modifications. The modified version of the framework is presented as follows (Figure 2).



3. Outward FDI and China's technology upgrading: empirical analysis

Although still in its early stages, China's outward investments have increased dramatically in the past decade. According to the latest report by the Ministry of Commerce and Trade and Chinese Statistics Bureau, by the end of 2006, China's accumulated outward investment stock was US\$90.63 billion, among which non-finance FDI reached US\$75.02 billion by 2006 (MOC, 2007). More than 5,000

domestic Chinese investment entities had established nearly over 10,000 overseas direct invested enterprises accommodating 268,000 foreign employees.

One of the objectives of the Chinese government in promoting the 'going out strategy' is to encourage companies to invest abroad to upgrade technology of domestic industries. This also includes obtaining inverse technological transfer and spillovers. Has the government achieved its targets or to which extent have such targets been realised? Answers to these types of questions need empirical checking. In principle, the process includes several aspects. First, select and develop core model; then define correlated variables and their measurement, and finally measure and calculate.

(1) Model selection and extension

It is hard to measure technological spillovers directly. In addition to patent citation approach, several studies have tried to use Total Factor Productivity (TFP) to measure technological spillovers in their models (Aitken & Harrison, 1999; Caves, 1974). This is because productivity changes are acting as critical signals of technological upgrading, though a challenge in doing so has been separating knowledge spillovers effects of FDI from its effects on competition (Cave, 1996; Chung, 2001; Chung et al, 2003). In an approach analogous to the original C-H model (Coe & Helpman, 1995, 1997) and L-P model (Lichtenberg & Potterie, 1996), we assess OFDI and R&D spillovers in China. As we know, C-H model is derived from empirical evidence of impact of trade on TFP, based on Grossman and Helpman's indigenous innovation growth model. Coe and Helpman (1995) use import share as weights to determine foreign R&D capital stocks, and for the first time, estimated the effects of a country's R&D capital stock and the R&D capital stocks of its trade partners on the country's

TFP. Two modifications are made to the L-P model, in order to assess the contribution of outward FDI to R&D spillovers in China.

$$\ln TFP_t = a_0 + a_1(RD_t^d / GDP_t) + a_2 \ln OFDI_t + \varepsilon_t \quad (5)$$

$$\ln TFP_t = a_0 + a_1(RD_t^d / GDP_t) + a_2 \ln S_t^f + \varepsilon_t \quad (6)$$

Where $t=1985, \dots, 2004$, $S_t^f = \sum_{j=1}^n \frac{OFDI_{jt}}{GDP_{jt}} S_{jt}^d$ is the overseas R&D capital stock transferred by outward FDI in year t ; n is the number of host countries of China's outward investments, $OFDI_{jt}$ is the outward investment stock that China invested in country j in year t , GDP_{jt} is the GDP of country j in year t , S_{jt}^d is the R&D capital stock of country j in year t , S_{jt}^d / GDP_{jt} is the degree of R&D intensity of a country, i.e. knowledge intensity of its product; $OFDI_t$ is China's outward direct investment stock in year t , RD_t^d is the domestic R&D expenditures of China in year t .

(2) Measure and calculate

As the performance measure, we use total factor productivityⁱⁱ, defined as the residual of a Cobb-Douglas production function. The TFP is normally measured by the production function, in particular the stochastic frontier production function. The Cobb-Douglas production function under two elements is: $Y = AK^\alpha L^\beta$, where A is equally defined as TFP. After taking the logarithms of the function, we get $\ln TFP = \ln Y - \alpha \ln K - \beta \ln L$, Where Y is the output, K is the capital stock, L is the labour output, α and β are the output elasticity of labour and capital respectively. To ease the computation, the output elasticity of labour and capital in China is 0.5.

There are three key variables to measure the TFP: domestic capital stock (K), output of labour representing as total employment, and output representing as GDP. The perpetual inventory approach is the basic approach to calculate the material capital stock, with the following formula: $K_t = (1 - \delta)K_{t-1} + I_t / P_t$, where δ is the depreciation rate of capital, estimated as 7%, P_t is the investment price index (1985=1), I_t is the annual fixed investment capital. The original data of Y, K and L can be obtained in China's Statistics Yearbooks of various years.

The R&D capital stock can also be computed by using the perpetual inventory approach, i.e. $S_t = (1 - \delta)S_{t-1} + R_t$, where R_t is the R&D expenditures based on unchanged prices, and the depreciation rate δ is estimated as 0.05. The OFDI stock can be obtained by relevant statistics dataset. Referring to various years' economic statistics yearbooks of China, we get that the top ten destinations that China has invested in between 1985 and 2004. They are Hong Kong, the U.S., Japan, Germany, Australia, Singapore, Canada, France, Italy and Great Britain.

(3) Results

The simple regression analysis is carried out on the basis of the above approach and the regression results of the model 5 and model 6 are reported in Table 1 (the detailed results are reported in the appendix).

Table 1: The results of regression analysis of model 5 and model 6

	a_0	a_1	a_2	F	R^2	$Adj.R^2$
Model (5)	-1.11* (0.13)	16.52 (20.2)	0.087** (0.04)	13.6	0.62	0.57
Model (6)	-0.91* (0.14)	8.8 (12.1)	0.14* (0.04)	21.6	0.72	0.69

Notes: values in the brackets are the estimated standard deviations of the variables, * significant at 1%, ** significant at 5%.

In model 5, the elastic coefficient a_2 of China's total direct investments is 0.087. The figure is relatively small, but the parameter estimation is significant. It implies that there is a 0.9% increase in Total Factor Productivity in the home country when China's nominal direct investment increases by 10%. Although the effect intensity of direct investment on productivity growth is relatively low, the results of such effect are significant. In model 6, the estimation coefficient of S_i^f is 0.14, with the significance level above 0.01. It implies that the China's outward direct investment may induce R&D spillovers from host countries, i.e. there is a 1.4 per cent increase of Total Factor Productivity when the foreign R&D capital stock transferred by China's OFDI increases 10 per cent. The effect intensity is significant. The combination of empirical analysis of the two models suggests that outward FDI greatly promotes productivity increase in China, and it is doing so through transferring of technological spillovers from host countries to home base.

4. Concluding remarks

The followings are four propositions we conclude:

1. The empirical evidence supports that inverse technological spillover effects exist when outward FDI takes place and home country benefits from such technological flows. The micro-level testing suggests that inverse technological spillovers occur when multinational enterprises engage in direct investments and transfer technology from overseas subsidiaries to parent companies. However, empirical testing at industrial levels and macro-levels is relatively limited. The spillover effects at these two levels are crucial to China's 'going out' strategy.
2. There are a number of transmission channels between outward FDI and technology upgrading of home countries. Empirical evidence of outward investments in developed countries suggests that there are at least four mechanisms driving such effects; they are mechanism of sharing R&D expenditures, feedback mechanism of R&D outcomes, inverse technology transfer mechanism and mechanism of replacement of peripheral R&D activities. It is helpful to view these mechanisms systematically and thus build a simple framework. However, due to the unique characteristics China is enjoying as a transitional developing country, the above mechanisms observed on the basis of developed countries' experience may not work well in China, and therefore modifications are necessary.
3. According to economic and technological development levels of destinations that Chinese firms are investing in, we classify the investing countries into three categories, i.e. developed or industrialised economies, newly industrialised economies (NIEs) and transitional economies and developing economies. Given that inverse technological spillover effects of China's

investments in the three types of designations are different, any modifications of the mechanisms and models should take the differences into consideration.

4. In contrast to direct investment outflows from developed countries, the scale of China's outward investment is still insignificant. However, the initial empirical analysis shows that the spillover effects and technological upgrading and productivity that China's outward investments have brought can be easily identified. Our research suggests that there is inverse technological spillover effect of China's outward FDI; this is particular true when capital is flowing to technologically advanced countries and regions.

Given that China's outward investments are still in their early stages, it is not feasible to provide an accurate assessment of the effects on technological upgrading in the home country. In particular, the insufficient dataset makes any empirical research even more difficult. Despite the difficulties, this paper attempts to shed some light for future research.

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Appendix: R&D capital stock in China 1985-2003

Year	R&D Expenditure (RMB billion)	R&D as percentage of GDP	China's OFDI stock (US\$ million, current prices)	S_t^f (US\$ million)
1985	5.69	0.65	47	72.57
1986	6.53	0.64	33	86.40
1987	7.42	0.63	410	99.99
1988	10.00	0.68	75	117.03
1989	11.33	0.70	236	127.75
1990	12.54	0.71	77	134.98
1991	15.03	0.72	368	150.19
1992	20.98	0.70	195	177.19
1993	25.62	0.62	96	188.42
1994	30.98	0.50	70	193.93
1995	34.98	0.60	101	216.18
1996	40.46	0.60	294	264.41
1997	50.92	0.64	196	279.56
1998	55.11	0.69	259	334.96
1999	67.89	0.83	591	385.10
2000	89.57	1.00	551	415.68
2001	108.48	1.07	708	559.85
2002	131.38	1.23	983	259.56
2003	159.11	1.31	2,087	13,317.79

ⁱ OFDI stock excludes finance part. Authors' calculation on the basis of '2006 Statistical Bulletin of China's Outward Foreign Direct Investment (2007).

ⁱⁱ They estimated equations explaining a country's total factor productivity (TFP) as a function of the domestic R&D capital stock and a measure of the foreign R&D capital stock, where all the measures of R&D capital were constructed from the business sectors' R&D activities.