CENTRE D'ÉTUDES
ET DE RECHERCHES
SUR LE DÉVELOPPEMENT
INTERNATIONAL

Document de travail de la série
Etudes et Documents
Ec 2005.06

Pollution haven hypothesis and Environmental impacts of foreign direct investment: The Case of Industrial Emission of Sulfur Dioxide (SO_2) in Chinese provinces

Jie HE

CERDI
Université d'Auvergne
65 Boulevard de F. Mitterrand
63000 Clermont-Ferrand
France
Tel: 00.33.4.73.17.74.23
Fax: 00.33.4.73.17.74.28
Email: Jie.HE@u-clermont1.fr

(Feb 9th 2005)
38 p.

Abstract

Recognizing the complex inter-correlation between FDI, emission and the three economic determinants of emission, we constructed a simultaneous model to study the FDI-emission nexus in China by exploring both the dynamic recursive FDI entry decision and the linkage from FDI entry to final emission results under the intermediation of the scale, composition and technique effects. The model is then estimated on the panel data of China's 29 provinces' industrial SO_2 emission. Result shows that, exerting through different channels; the total impact of FDI on industrial SO_2 emission is very small. With 1% increase in FDI capital stock, industrial SO_2 emission will *increase* by 0.099%, in which the emission increase caused by impact of FDI on economic growth and composition transformation cancels out the emission reduction result due to FDI's role in reinforcement of environmental regulation. By introducing to the simultaneous system the recursive dynamism that supposes FDI entry decision to depend on last period's economic growth and environmental regulation stringency, our model also provides convincing supportive evidences for 'Pollution haven' hypothesis. Although FDI enterprises in China generally produce with higher pollution efficiency, the rise in environmental regulation stringency still has modest deterrent effect on FDI capital inflow. Furthermore, the composition transformation impact of FDI in China seems to be dominated by the inflow of foreign capital pursuing a 'production platform' that provides lower pollution regulation compliance cost.

Key words: foreign direct investment, industrial SO_2 emission, simultaneous system, scale effect, composition effect, income effect, and pollution haven hypothesis

Pollution haven hypothesis and Environmental impacts of foreign direct investment: The Case of Industrial Emission of Sulfur Dioxide (SO_2) in Chinese provinces

1. Introduction

The market-oriented economic reform has gradually turned China into one of the most attractive destinations for foreign direct investment (FDI) around the world. During most part of 1990s, China was the world second largest FDI recipient just behind the United States and the largest FDI recipient in the developing world. After entering into the new millennium, contrary to the decreasing tendency of FDI inflows in many OECD economics due to their sluggish macroeconomic performance, China experienced a steady FDI inflow increase. According to OECD (2004), China became world biggest FDI recipient in 2003 with an annual inflow of FDI amount to about 53.5 billions US dollars, largely higher than that to Germany (47 billions USD) and to the United State (40 billions USD) at the same year. During 25 years of economic reform, China has received in total almost 500 billions USD of foreign direct investment. (SSB, 2004) From the evolution of annual FDI actually utilized in China since 1978 illustrated in Figure 1, we observe a generally increasing trajectory with the most important rise happened after 1993. Besides the quantity, the nature of FDI inflow to China also experienced some changes during the last several years. OECD (2004) indicated that at the beginning years of China's economic reform, FDI choosing China as destination aimed at integrating its cheap labor resource into their global production chain, but recently, there is an increasing tendency for the foreign companies to invest in China as part of their strategies to service the local clients or to acquire a strategic position in China's enormous market.

(Insert Figure 1 about here)

However China's remarkable openness process during the last 25 years seemed to be accompanied by obvious environmental pollution problems. Air pollution situation in the urban area started deteriorating quickly since the first decade of economic reform in 1980's. Although some improvement came up during 1990's owing to the reinforcement of pollution control policies, 2/3 of Chinese cities still fail to meet the air quality standard established by China's Environment Protection Agency (EPA), which signifies that more than ¾ of the urban population are exposed in seriously polluted air.[1] What is the possible relationship between the rapid FDI inflow and the air pollution deterioration? Should the inflow of FDI be responsible for China's air pollution situation?

Aiming at obtaining a better understanding on the FDI-environment nexus, this paper constructs a five-equation simultaneous system to include both the FDI location decision with respect to host country's environmental regulation stringency and the impact of FDI on pollution through various underlying simultaneous mechanisms. This simultaneous system is then tested by the penal data of industrial sulfur dioxide (SO_2) emission of the 29 Chinese provinces during the period 1994-2001, during which FDI inflow experienced the most important increase. The time-constant specific effect for each province is captured by fixed effect parameters. To correct potential first-order serial correlation and heteroskedasticity in each estimation function, an instrumentation method inspired by both the GMM-system estimator of Blundell and Bond (1998) and Sevestre and Trognon (1996) for dynamic panel data is used on equation-level. Finally, to employ the full information imparted from the simultaneous system and to avoid inconsistency in estimation caused by the inter-equation residual correlation, we use Generalized method of Moment (GMM) estimator for simultaneous system to estimate the whole system.

The organization of the paper is the following. In the second section, we make a brief literature review to explain the necessity to investigate the relationship between FDI and environment through a structural simultaneous system by revealing the complexity in the FDI-pollution nexus. Section 3 gives a simple introduction on the current situation of FDI and industrial pollution in Chinese provinces. Then we introduce the simultaneous model in the fourth section. The econometric results are presented and discussed in Section 5. Finally, we conclude in Section 6.

[1] Calculated by author according to the available statistic information of population in the cities having serious pollution problems.

2. FDI-pollution nexus literature review

Most of the existing literatures did not directly treat the FDI-pollution nexus but based their analyses on the causality from environmental regulation stringency to firm's competitiveness as entry point. They supposed under globalization circumstance, the relatively lax environmental regulation in the developing countries becomes an attractive comparative advantage to the pollution-intensive foreign capital seeking for a 'pollution-haven' to avoid paying costly pollution control compliance expenditure domestically.[2] Though this 'pollution haven' hypothesis sounds reasonable, almost no empirical analysis has yet provided convincing supportive evidences revealing FDI's searching activity for the 'production platforms' permitting lower pollution abatement cost.[3]

Besides the potential explanation residing in measurement problems for both environmental regulation stringency and FDI flows, most of authors attributed the incapability in detecting a significant regulation-FDI flows nexus to the complexity of the relationship between them. Firstly, compared to the classical determinant factors in FDI location decision, as the conventional production factor cost, tax rate differential, the host country's market size, exchange rate risk, trade impediments and market power, etc., environmental regulation compliance cost is not a critical cost factor for most of private firms. Dasgupta, Wang and Wheeler (1997) find the control cost for sulfur dioxide pollution in large-scale Chinese industrial enterprises is just a few dollars per ton until the control rate rise above to 70%. Various studies based on developed country's firm-level data also found the total factor productivity decline caused by reinforced

[2] The related empirical studies are numerous. Bartik (1985, 1988,1989), Grossman and Krueger (1991), Friedman, Gerlowski and Silverman (1992), Levinson (1992, 1996), Bouman (1996), Keller and Levinson (2001), List and Co (2000), Smarzynska and Wei (2001), Xing and Kolstad (2002), Fredriksson, List and Millimet (2003), etc. Most of them used data from developed countries, especially those of the U.S. Their analyses investigated the impact of environmental regulation stringency differences on the capital outflow or inter-state location decision of firms. They used aggregate industry-, state- or detailed establishment-level data for capital flow measurement and the corresponding pollution abatement cost for environmental regulation measurement. Most of these studies focus their attention on the manufacturing industries and especially the most pollution-intensive sectors as chemical, metallic, non-metal materials industries, etc. The several papers based on the experiences of the developing countries, as Grossman and Krueger (1991) on Mexico, Wheeler (2002) on China, Brasil and Mexico, Eskeland and Harrison (2003) on Côté d'Ivoire, Morocco, Mexico and Venezuela, have neither found satisfactory examples of pollution haven from the side of FDI recipients.

[3] The only exception is Xing and Kolstad (2002) whose analysis was based on a very limited database of 22 observations concerning several selected US industries.

environmental regulations generally stays modest. (Denison, 1979, Gray, 1987, Haveman and Christiansen, 1981, etc) This suggests that pollution control cost differential does not provide OECD firms with strong incentive to move offshore. (Jaffe et al., 1995) Secondly, different from 'pollution haven' hypothesis—one classical economic reasoning based on the analogy of traditional static comparative advantage perspective, hypothesis of Porter asserts that from a dynamic point of view, environmental regulation stringency can encourage efficiency innovation and guide production procedure to be more environment-friendly (Porter and Linde, 1995; Xepapadeas and Zeeuw, 1999). This dynamic technical progress can further induce a 'negative cost', which will benefit productivity reinforcement owing to cleaned environment. (Jaffe, 1995) Following this point of view, firm's 'technology profiting' activities catalyzed by reinforcement of environmental control policy will be able to cancel off the differential in pollution abatement cost between countries, capital flight due to this differential is actually unnecessary in a long-run. Thirdly, the insignificance in using environmental regulation to explain capital flow might also due to the potentially reversed causality between these two phenomena. On one hand, for a developed economy, the 'racing-to-the-bottom' hypothesis emphasizes the possibility that the profit-driven capital outflow pursuing the lowest production cost might create pressures on the government to lower their environmental standard (Revesz, 1992). On the other hand, several 'pollution haven' studies based on the historical experiences of developing countries showed that as income increases with FDI inflow, the environmental regulation, strongly correlated with income level, will also increase with FDI inflow, therefore the "pollution-haven" should only be a transient phenomenon. (Mani and Wheeler, 1997) Given these two aspects, the cost gap in emission abatement between developed and developing countries should have the tendency to decrease with the inter-country movements of FDI. Finally, most of the "pollution haven" studies used the total pollution abatement cost as an approximation for the environmental regulation stringency. However, to some extent, this indicator can also be regarded as a measurement for the total technical efforts of the host economy on pollution abatement, in which we should not ignore the contribution from the technically more efficient FDI firms.[4]

Going a step further, even we can prove the causality from environmental regulation stringency to dirty FDI inflows to developing countries; this does not immediately mean pollution will increase in host country. As found in some studies (Eskeland and Harrison, 1997; etc.), the FDI enterprises specialized in pollution-intensive industries generally employ production and abatement technologies more environment-friendly than their domestic competitors in host developing countries. This might be due to the fact that heavy emission may signals to the investors that the FDI firms' production techniques are inefficient and hence reduces their expectation on the liability of these multinational corporations (Dasgupta, Laplante and Mamingi, 1997); or simply because investing in the developing countries is the global-scale production arrangement strategy of the multination enterprises, the adaptation of production technology to the local environmental standard is not necessary. If these FDI corporations replace the relatively less efficient domestic firms in the same production, we can expect a decline tendency in total pollution of the developing host country. Moreover, the presence of FDI enterprise may also reinforce competition and urge domestic firms to enhance research and development activity and to increase their production efficiency, which will in the long run, strengthen the technical efficiency of the whole host economy.

The FDI-pollution nexus is even more complicated if we relate our theoretical consideration to the often-mentioned three economic characteristics. They are economic growth (scale effect), industrial composition (composition effect) and environmental regulation stringency (technique effect), defined in Grossman (1995) as the three economic determinants of emission from production activities. On the first view, FDI entry is a decision partially depending on the environmental regulation stringency (technique effect) and the economic scale (scale effect) of the host country. At the same time, the structural linkage between FDI entry and final

[4] Eskeland and Harrison (1997) found the FDI enterprises in Côté d'Ivoire, Venezuela and Mexico are significantly more efficient in energy use.

emission results is also built on their intermediations. Once foreign capital enters the host country, it can in turn exert influences on all the three characteristics of the economy. For the case of China, firstly, FDI entry can accelerate economic growth, either through productivity reinforcement (Li et al, 2001; Chen and Demurgey, 2002 and Liu and Wang, 2003), or through technology diffusion (Thompson, 2002; Cheung and Lin, 2004 and Lemoine and Ünal-Kesenci, 2004), or through scale economy development (Tuan and Ng, 2004). Secondly, although the theories that predict the pattern of trade does not focus on ownership, given the similarity between the FDI location decision and trade specialization, most of the factors used in traditional theories to predict one country's trade patterns can be used to explain the composition impact of FDI. On one hand, 'pollution-haven' hypothesis suggests China's relatively lax environmental regulation attracts the inflow of polluting foreign capital, which will in turn increases the proportion of polluting sectors in industrial composition. On the other hand, given China's rich endowment in cheap labor force, traditional comparative advantage theory expects that some less polluting labor-intensive industries may also experience expansion with the inflow of FDI. Copeland and Taylor (1994,1997) and Anterweiler et al. (2001) combined these two aspects together and predicted the final composition transformation incurred by international trade depends on the force-contrast between these two comparative advantages in the host economy. The same conclusion is also valid for the case of FDI. Thirdly, FDI entry can also facilitate environmental regulation reinforcement, either by its direct contribution in pollution abatement capacity accumulation in host economy or indirectly by its income-growth impact that in turn reinforces public exigency for better environment. Finally, FDI-led variations in all of the three emission determinants can further lead final emission result to vary and to affect the future FDI entry decision.

Given these several aspects' consideration, Letchumanan and Kodama (2000) indicated the relationship between FDI and environment cannot be adequately understood by simply analyzing measurement of FDI flow in relation to environmental condition. We also need to consider the simultaneously occurring trends and underlying mechanisms that going through the changes in economic scale, industrial composition and technique effect.

3. Industrial SO_2 emission and foreign direct investment situation in Chinese provinces

The regional disparity in the aspects of openness degree, economic growth and environmental situation between Chinese provinces became more and more remarkable during the last 25 years economic reform. Figure 2 shows the detailed regional distribution of industrial SO_2 emission, accumulated FDI capital stock, economic growth and environmental regulation situation in year 2001.[5] Clearly, the rapid economic growth catalyzed by intensified FDI inflow does not benefit the 30 provinces in the homogenous way. The high ratio of FDI capital stock to GDP is remarkably concentrated in the richer eastern coastal province. While both the FDI capital stock and per capita GDP shows obvious decreasing tendency when we move from eastern coastal to western inland provinces, SO_2 emission does not follow the same geographical distribution pattern. The serious SO_2 emission problem seems to appear more frequently in the central northern provinces that had long tradition in heavy industrial production and some southern province as Guizhou, where the coal endowment contains high concentration of sulfur. Another reason to explain the serious SO_2 pollution problem is the lax environmental regulation applied in some provinces, such as Heilongjiang, Shangdong, Fujiang andQinghai, where we observe the co-existence of low average SO_2 levy rate and high per capita SO_2 emission.

(Insert Figure 2 about here)

Figure 3 further studies the correlation between economic growth, FDI stock, environmental regulation stringency and industrial SO_2 emission situation by plotting them by pair in same diagram. Except for the kind of inverted-U quadratic correlation between economic growth and FDI stock, concerning to the other three pair of correlation, we can not derive their clear correlation directions given the low significance in the estimation coefficients. Obviously,

[5] The provincial level FDI capital stock is constructed by the simple accumulation of the real annual FDI inflow on 1990 price since the beginning of economic reform.

The relationship between FDI and emission is more complicated than a simple positive or negative correlation.

(Insert Figure 3 about here)

4. The links between FDI and emission: The system of simultaneous equations

Considering the shortcomings of the existing empirical studies on the FDI-environment linkage mentioned above, the basic idea of this paper is to study the relationship between FDI and final industrial SO_2 emission in China by exploring both the relationship between environmental regulation stringency and FDI entry decision and the linkage from FDI entry to the final emission result by a structural framework.

A direct inspiration of the system constructed in this paper comes from Dean (1998). In her paper she studied the relationship between international trade and industrial wastewater emission in China by a simpler simultaneous system. Her model supposes that international trade increases pollution through "pollution haven" effect, but trade also contributes to economy growth, which in turn reduces emission since higher income strengthens public exigency for a better environment.

Following the same reasoning, we suppose the relationship between FDI and industrial SO_2 emission can be described by the following 5-equation simultaneous model.

$$E_{it}=e(Y_{it},\Omega_{it},\tau_{it}) \quad (1)$$

$$Y_{it}=y(K_{it},L_{it},E_{it},KF_{it},F_{it}/Y_{it}),\ where\ K_{it}=KH_{it}+KF_{it},\ L_{it}=LH_{it}+LF_{it},\ E_{it}=EH_{it}+EF_{it} \quad (2)$$

$$\Omega_{it}=z(\tau_{it},L_{it},KF_{it}) \quad (3)$$

$$\tau_{it}=t(E_{it-1},Y_{it},denpop_{it}) \quad (4)$$

$$KF_{it}=k(\tau_{it-1},L_{it},Y_{it-1}) \quad (5)$$

(i: indicator for different province, t: indicator for difference years)

E_{it}: *total emission.*

Y_{it}: *scale effect.*

Ω_{it}: *composition effect.*

τ_{it}: *technique effect.*

K_{it}: *total capital stock employed in production.*

$K_{H\,it}$: *domestic capital stock employed in production.*

$K_{F\,it}$: *foreign capital stock employed in production.*

L_{it}: total labor employed in production.

$L_{H\ it}$: total labor employed in domestic sector.

$L_{F\ it}$: total labor employed in foreign capital sector.

$denpop_{it}$: population density.

$E_{H\ it}$: total emission from domestic sector.

$E_{F\ it}$: total emission from foreign capital sector.

F_{it}: the total value added created by the foreign capital sector.

Equation (1) describes the economic determinants of emission. Following Grossman (1995), we include scale effect (Y_{it}), composition effect (Ω_{it}) and technique effect (τ_{it}) in to this equation. Other things kept unchanged, an economy with larger production scale emits more pollution, so we expect a positive coefficient for this term, which means $e_Y>0.$. Composition effect (Ω_{it}) reflects pollution performance of an economy's industrial composition. Given the same production scale, the industrial composition contains higher percentage of polluting sectors emits more pollution. Therefore, we anticipate a positive coefficient for composition effect, $e_\Omega > 0$. The original technique effect in Grossman (1995) is the average pollution intensity. As higher technique effort leads pollution intensity to reduce; most of the previous studies frequently used environmental regulation stringency as an approximation for this effect. Given the other two determinant factors stay unchanged; we expect higher environmental regulation stringency can reduce emission, which means $e_\tau < 0$.

The impact of FDI on emission is then captured through its influences on the scale, composition and technique characteristics of an economy.

Firstly, the impacts of FDI on economic scale are described by a Feder (1983) style production function as equation (2). In this function, similar to many growth theories including environment dimension, we include environment quality as a production factor by regarding emission as environmental service consumed by production activities. The original production function before transformation into equation (2) is the sum of the two separate production functions of domestic and foreign sectors as the equation (6).

$$Y_{it} = H(KH_{it}, LH_{it}, EH_{it}, KH_{it}) + F(KF_{it}, LF_{it}, EF_{it}) \qquad (6)$$

In this equation, we treat differently the factors employed in domestic and foreign sectors by supposing the latter to be more efficient than the former by a parameter δ. So the relationship in factor productivity between foreign and domestic sectors can be expressed as: $F_L=(1+\delta)H_L$, $F_K=(1+\delta)H_K$ and $F_E=(1+\delta)H_E$, where F_L, H_L, F_K, H_K, F_E and H_E are the productivity of labor, capital and environmental service in foreign capital and domestic sectors, respectively. As Feder (1983), we further allow the spillover effect of foreign capital's presence on domestic sector's productivity by directly including foreign capital stock into domestic sector's production function as an external productivity-promoting factor. The detailed mathematical transformation from equation (6) to equation (2) is given in Appendix. From the appendix we know the separated term $K_{F\ it}$ in equation (2) can be used to capture the potential spillover effect of FDI on domestic sectors' productivity. The coefficient for the term F/Y is actually equal to $\delta/(1+\delta)$, which can be used to detect the actually factor productivity differential between domestic and foreign sectors. From this production equation, the indirect impact of foreign capital on emission by the intermediation of scale effect can be captured from two channels: one is the direct participation of foreign capital as a production factor and another is its productivity promoting externality on domestic sector.

Indirect impact of FDI on emission can also be traced from its influences on the pollution performance of host economy's industrial composition. This channel is described in composition determination function (3). To capture the determinant roles of the two aspects of comparative advantages in the pollution performance of industrial composition described in comparative advantage theory and the "pollution haven" hypothesis, we include the environmental regulation stringency τ_{it} and labor force employment situation of economy L_{it} in this function. We expect an economy to have relatively less polluting industrial composition when it applies stronger pollution control efforts and its production mobilizes more labor forces, that means $z'_\tau<0$ and $z'_L<0$. Following, FDI is included to capture its impact on composition transformation, which is oriented by the force contrast between traditional comparative advantage and environmental comparative advantage. The sign of its coefficient will reveal the actual domination relationship between them.

The equation (4) describes the determination of technique effect as suggested in the neo-classical theories, in which we assume government to be a social planer seeking for maximizing social welfare. According to these theories, the optimal tax rate on emission should be equal to the marginal disutility caused by pollution to the population. (Lopèz , 1994; Selden and Song, 1995) We consider three potential determinants for the stringency of environmental regulation. If the emission tax is adjusted once annually, the first determinant is the last period's emission situation. The marginal disutility is supposed to increase with pollution deterioration, so we expect a positive correlation between environmental regulation stringency and last year's emission situation, $t_{E-1}>0$. The second determinant is economy growth (Y_{it}). People become more sensitive to pollution as getting richer, so faster economic growth facilitates increase of public demand for better environment; this in turn will result in the intensification of environmental regulation strictness, so $t_Y>0$. Given the same income and pollution level, higher population density intensifies the marginal damage of pollution, we also include population density as a determinant for environmental regulation stringency and anticipate $t_{denpop}>0$. Though FDI entry has not include directly into this technique effect determination function, its indirect impact on technique effect is embodied in environmental regulation reinforcement effect induced by the FDI-fueled economic growth.

Equation (5) expresses the determination of FDI entry decision. Following the reasoning of Copeland and Taylor (1995) and Anterweiler et al. (2001), everything else equal, we expect FDI will be attracted by both China's cheaper labor force and its lower pollution abatement cost. So we include both the lagged environmental regulation stringency τ_{it-1} and the labor force employed in industrial sector L_{it} into the FDI entry decision function. We regard a significantly negative coefficient before environmental regulation stringency τ_{it-1} as supportive evidence for the 'pollution haven' hypothesis for the case of China. As China's enormous market and her rapid economic growth rate has also become nowadays an important attractive factor to the foreign capital inflow aiming at serving domestic consumers, we also include the lagged scale effect, Y_{it-1} in to this function, we expect a positive coefficient for this variable.

Figure 4 summarizes the complex interactions between the five endogenous variables described by the simultaneous system. The numbers marked besides the arrows correspond to the equation numbers in the system. Compared to the previous empirical literatures discussing FDI-environment nexus, this interaction schema indicates the potential inconsistency of their analysis partially focusing on the uni-direction causality from environmental regulation to FDI location decision. Obviously, they ignored all kinds of potential correlations between these two variables through the intermediation of the other economic characteristics.

(Insert Figure 4 about here)

To facilitate the measurement of the overall environmental impact of FDI, we make total differentiation to all the five estimation functions and divide each of them by its corresponding dependant variable. Therefore, we get the following new simultaneous system. The positive and negative sign marked in bracket below each coefficient is its expected sign.

$$(1^*)\quad \frac{\dot{E}_{it}}{E_{it}} = e_Y \times \frac{Y_{it}}{E_{it}} \times \frac{\dot{Y}_{it}}{Y_{it}} + e_\Omega \times \frac{\Omega_{it}}{E_{it}} \times \frac{\dot{\Omega}_{it}}{\Omega_{it}} + e_\tau \times \frac{\tau_{it}}{E_{it}} \times \frac{\dot{\tau}_{it}}{\tau_{it}}$$

$$= \eta_{E,Y} \times \frac{\dot{Y}_{it}}{Y_{it}} + \eta_{E,\Omega} \times \frac{\dot{\Omega}_{it}}{\Omega_{it}} + \eta_{E,\tau} \times \frac{\dot{\tau}_{it}}{\tau_{it}}$$

(+) (+) (-)

$$(2^*)\quad \frac{\dot{Y}_{it}}{Y_{it}} = \eta_{Y,K} \times \frac{\dot{K}_{it}}{K_{it}} + \eta_{Y,L} \times \frac{\dot{L}_{it}}{L_{it}} + \eta_{Y,E} \times \frac{\dot{E}_{it}}{E_{it}} + \eta_{Y,K_F} \times \frac{\dot{KF}_{it}}{KF_{it}} + \frac{\delta}{1+\delta} \times \frac{\dot{F}_{it}}{Y_{it}}$$

(+) (+) (+) (+) (+)

$$(3^*)\quad \frac{\dot{\Omega}_{it}}{\Omega_{it}} = z_L \times \frac{L_{it}}{\Omega_{it}} \times \frac{\dot{L}_{it}}{L_{it}} + z_\tau \times \frac{\tau_{it}}{\Omega_{it}} \times \frac{\dot{\tau}_{it}}{\tau_{it}} + z_{K_F} \times \frac{KF_{it}}{\Omega_{it}} \times \frac{\dot{KF}_{it}}{KF_{it}}$$

$$= \eta_{\Omega,L} \times \frac{\dot{L}_{it}}{L_{it}} + \eta_{\Omega,\tau} \times \frac{\dot{\tau}_{it}}{\tau_{it}} + \eta_{\Omega,K_F} \times \frac{\dot{KF}_{it}}{KF_{it}}$$

(-) (-) (?)

$$(4^*)\quad \frac{\dot{\tau}_{it}}{\tau_{it}} = t_E \times \frac{E_{it-1}}{\tau_{it}} \times \frac{\dot{E}_{it-1}}{E_{it-1}} + t_y \times \frac{Y_{it}}{\tau_{it}} \times \frac{\dot{Y}_{it}}{Y_{it}} + t_{denpop} \times \frac{denpop_{it}}{\tau_{it}} \times \frac{\dot{denpop}_{it}}{denpop_{it}}$$

$$= \eta_{\tau,E} \times \frac{\dot{E}_{it-1}}{E_{it-1}} + \eta_{\tau,Y} \times \frac{\dot{Y}}{Y} + \eta_{Y,denpop} \times \frac{\dot{denpop}}{denpop}$$

(+) (+) (+)

$$(5^*)\quad \frac{\dot{KF}_{it}}{KF_{it}} = k_L \times \frac{L_{it}}{KF_{it}} \times \frac{\dot{L}_{it}}{L_{it}} + k_\tau \times \frac{\tau_{it-1}}{KF_{it}} \times \frac{\dot{\tau}_{it-1}}{\tau_{it-1}} + k_Y \times \frac{Y_{it-1}}{KF_{it}} \times \frac{\dot{Y}_{it-1}}{Y_{it-1}}$$

$$= \eta_{K_F,L} \times \frac{\dot{L}_{it}}{L_{it}} + \eta_{K_F,\tau} \times \frac{\dot{\tau}_{it-1}}{\tau_{it-1}} + \eta_{K_F,Y} \times \frac{\dot{Y}_{it-1}}{Y_{it-1}}$$

(+) (-) (+)

This mathematical adjustment transforms each variable of this simultaneous system into its growth rate. We distinguish five endogenous variables in this system: $\frac{\dot{E}_{it}}{E_{it}}$, $\frac{\dot{Y}_{it}}{Y_{it}}$, $\frac{\dot{\Omega}_{it}}{\Omega_{it}}$, $\frac{\dot{\tau}_{it}}{\tau_{it}}$ and $\frac{\dot{KF}_{it}}{KF_{it}}$. The four available exogenous variables are: $\frac{\dot{K}_{it}}{K_{it}}$, $\frac{\dot{L}_{it}}{L_{it}}$, $\frac{\dot{F}_{it}}{Y_{it}}$ and $\frac{\dot{DENPOR}_{t}}{DENPOR_{t}}$. We equally have three pre-determined variables $\frac{\dot{E}_{it-1}}{E_{it-1}}$, $\frac{\dot{\tau}_{it-1}}{\tau_{it-1}}$ and $\frac{\dot{Y}_{it-1}}{Y_{it-1}}$, so the system is identified. The coefficients estimated by the new functions can then be explained as elasticity of the dependant variables with respect to their independent variables. Owing to this arrangement, the indirect impact of FDI on emission going through the intermediation of one of the economic determinants can be simply calculated by multiplying the elasticity of emission with respect to the economic determinant with the elasticity of this determinant with respect to FDI. Based on the simultaneous system (1*) to (5*), we summarize in equation (7) the total relationship of FDI (K_F) with emission (*E*) into the 4 different channels categorized into the 3 aspects: scale enlargement (or economic growth), regulation reinforcement and composition transformation.

The first term called scale effect captures the emission increase due to economic growth catalyzed by FDI entry through both its direct participation into production as a factor and its positive externality on domestic sector's productivity. The second term reveals the pollution reduction benefiting from reinforcement of environmental regulation going through FDI-catalyzed income growth. The last term indicates the two channels through which FDI entry modifies emission by changing industrial composition. The first one is the industrial composition specialization directly caused by FDI entry, the second terms captures the indirect composition adjustment to environmental regulation stringency increase urged by FDI-fueled economic growth.

$$\frac{\partial E}{\partial K_F} = \underbrace{\eta_{E,Y} \times \Big(\underbrace{\eta_{Y,K} \times \frac{K_F}{K}}_{\substack{\text{Direct Participation} \\ (+)}} + \underbrace{\eta_{Y,K_F}}_{\substack{\text{Spillover effect} \\ (+)}} \Big)}_{\substack{\text{Scale effect} \\ (+)}} + \underbrace{\underset{(-)}{\eta_{E,\tau}} \times \underset{(+)}{\eta_{\tau,Y}} \times \Big(\underset{(+)}{\eta_{Y,K_F}} + \underset{(+)}{\eta_{Y,K} \times \frac{K_F}{K}} \Big)}_{\substack{\text{indirect technique effect} \\ \text{chained by} \\ \text{economic growth} \\ (-)}} \qquad (7)$$

$$+\underbrace{\underbrace{\underset{(+)}{\eta_{E,\Omega}}\times\underset{(?)}{\eta_{\Omega,K_F}}}_{\substack{\text{direct}\\ \text{Composition}\\ \text{transformation}\\ (?)}}+\underbrace{\underset{(+)}{\eta_{E,\Omega}}\times\underset{(-)}{\eta_{\Omega,\tau}}\times\underset{(+)}{\eta_{\tau,Y}}\times\left(\underset{(+)}{\eta_{Y,K_F}}+\underset{(+)}{\eta_{Y,K}}\times\frac{K_F}{K}\right)}_{\substack{\text{Indirect}\\ \text{composition transformation}\\ \text{chained by}\\ \text{indirect regulation reinforcement}\\ (-)}}}_{\substack{\text{total Composition effect}\\ (?)}}$$

We illustrate in Figure 5 the FDI-emission nexus into the first-, second- the third-level indirect channels. The gray-color cases are used to indicate all emission variations related to FDI change. The two first-level indirect channels reflect the emission variation caused by direct effect of FDI on host country's economic scale and industrial composition. The second- and third-level indirect channels trace the emission variations resulting from indirect composition and technique changes under the inter-determination between the three pollution determinants initiated by FDI entry. The total impact of FDI on emission should be measured by adding all these different aspects together.

(Insert Figure 5 about here)

5. Econometric analysis

a. Data choice

The choice of China's provincial level panel data on industrial emission during 1994-2001 to carry out our analysis is due to the following considerations. Firstly, being a big country, China's national-wide unified statistical system promises for our empirical study comparable and credible provincial-level economy and pollution data. These regional data will help to avoid the generally encountered critiques as data incoherence problems by those international experience studies. Secondly, the efficiency of our empirical analysis is also guaranteed by the remarkable regional disparity between provinces in both pollution and economic situation, which have been gradually formed during China's 25 years' economic reform. Thirdly, given the most important increase in the FDI inflow to China happened after 1992, focusing our analysis in the period of 1994-2001 will allow us to study principal influence of FDI on both Chinese economic and pollution situation. Finally, as China is under its industrialisation process, it is also more interesting for us to check the potential impact of FDI in China's industrial pollution situation, since the rapid expansion of

Chinese industrial production is the engine for both economic development and FDI inflow and the principal source of its air pollution problems.

(1) The data choice for the endogenous variables

The choice of industrial SO_2 emission as environmental quality variable is based on three reasons. Firstly, given its rich endowment in coal, SO_2 emission from coal combustion is always the most important air pollution source in China. The pollution phenomena as the acid rain and total suspending particulate (TSP) can both be linked to this pollutant. Aiming at monitoring and controlling, detailed statistic record for this pollutant becomes available since 1990s, especially for that emit from industrial production where the coal is intensively used. Secondly, among the available statistic data describing Chinese environment situation, industrial SO_2 emission is also the environmental index having the longest time dimension without interruptions. Thirdly, the theoretical foundations, such as "pollution haven" hypothesis, on which we construct the simultaneous system, are only applicable to local pollution case. Given China's geographical dimension, the pollution phenomena related to SO_2 emission are largely confined in the interior of each province. Therefore, industrial SO_2 emission is a local pollution case applicable to our simultaneous system.[6]

Corresponding to the environmental indicator, the three emission determinants are also measured in the scale of industrial sector. We use real industrial GDP to measure the scale effect. To capture the evolution of composition effect, in which we need to summarize the heterogeneous environmental performance of different industrial sectors in each province, we construct a synthetic indicator $\Omega_{it} = \sum_j (\frac{Y_{jit}}{Y_{it}} \times e_{j,0})$. Y_{jit} signifies the detailed value added of the 13 industrial sectors j in each province i and $e_{j,0}$ is the initial national average SO_2 emission intensity for each of the 13 sectors in year 1991.[7,8] Using this synthetic composition indicator instead of the frequently used capital

[6] Heil, M. K. and T. M. Selden (2000) also considered SO2 emission as a local pollution problem.
[7] The 13 industrial sectors are total mining industry, food and beverage, textile, paper, total power industry, chemical materials, pharmacy, fiber, non-metal products, metal processing and smelting, metal products, machinery and the other industry (source of data: China Industrial Economic Statistic Yearbook, 1989-2002)

abundance measured by the capital to labor ratio (K/L) as in Copeland and Taylor (1994, 1995), Antweiler et al. (2001), Cole et al. (2003) and Cole (2004) is based on the following consideration. Firstly, the simultaneous system used in this paper requires composition effect to be endogenous variable but the production factor capital and labor to be exogenous ones. Using capital abundance (K/L) to measure composition effect obviously does not meet this exigency. In addition, Dinda et al (2000) and He (2003) both indicated the potential ambiguity in using capital abundance as measurement for industrial composition's environmental performance, since some "capital intensive sectors could also be more clean technology owner" (Dinda et al, 2000), this is contrary to the underlying fundamental hypothesis of this measurement, which supposes pollution intensive sectors to be generally more capital-intensive. The synthetic indicator constructed on the detailed output ratio and emission characters of the 13 industrial sectors can help us to avoid these two problems. Furthermore, as the sum of value added of the 13 industrial sectors generally covers up to 98% of the total provincial-level industrial GDP each year, we are also confident in the capability of this synthetic indicator in reflecting the general environmental performance of the whole industrial composition.

As a determinant for FDI entry decision, the environmental regulation stringency was measured in most of the previous 'pollution-haven' hypothesis studies by the private sector's compliance expenditures in both capital investment and operation cost (Eskeland and Harrison, 1997; Keller and Levinson, 1999; Smarzynska and Wei, 2001 and List and Co, 2000, etc.). However, this measurement seems not to be suitable for China's case. The current pollution control system implemented in China is the so-called "Total Emission Quantity Control (TEQC)" system. Under this system, the polluters, principally industrial and commercial enterprises, are asked to pay only for their pollution emission *exceeding the relevant national or local pollution standard,* and "the original pollution levy rules also stipulated 80% of the levy revenue to be used to fund pollution prevention measures" (Cao et al, 1999). Although its strictness was reinforced during 1990's and its application

[8] Keller and Levinson (2002) also use the same expression to measure industry composition for each state in order to adjust the measurement for the state-level pollution abatement costs.

areas were enlarged, current TEQC system does not seem to be efficient enough to urge producers to exercise initiative emission abatement activities. Wang (2002) indicated the average levy rate for one unit of emission actually applied in China is only equal to half of the marginal cost for pollution abatement investment. From economic point of view, facing low pollution levy charge, polluters may prefer paying levy charge and polluting to taking more costly measures to abate their emission. In consequence, a large part of pollution reduction observed in the last ten years should be owed to the pollution abatement initiatives of Chinese environmental protection authority funded by over 80% of the revenue collected by pollution levy system. Considering this situation, the total investment on pollution abatement activities in a Chinese province is, to some extent, a policy-flavored intervention from the behalf of government. Therefore, we prefer to use the average emission levy rate with respect to industrial SO_2 emission to measure the actual pollution cost faced by a private producer, as this is an essential cost factor considered in FDI's location decision.

To investigate the actual impact of FDI in the scale, composition and technique effect of a host economy, we choose the accumulated FDI capital stock in constant 1990 price since the beginning of China's economic reform to measure FDI variable, because the annual FDI inflow can not reflect the total foreign capital's capacity in affecting scale, composition and technique effect in a host economy. As the FDI entry decision function will be estimated in growth rate form as in equation (5*), it is also more logic for us to use total foreign capital as FDI measurement, as the yearly growth rate of FDI capital stock reflects exactly the FDI inflow situation of each year.

(2) The data choice for the exogenous variables

The data choices for the five exogenous variables are simpler. The production factor as capital and labor are measured by capital stock of 1990 constant price and number of labor employed in industry separately. Population density is calculated by dividing provincial population with provincial surface. The variable $\dot{F}_{it}/Y_{it}$, used in the production function to capture the industrial production residual contributed by the higher production efficiency of the foreign capital sectors, is measured by the ratio of annual variation in FDI enterprises' output to the total industrial output of the same year.

Table 1 supplies the detailed statistical description for the data used in this model. All the variables are actually included into the estimation in their growth rate form except $\dot{F}_{it}/Y_{it}$ according to the function transformation result.

(Insert Table 1 about here)

b. The empirical method

Based on a simultaneous model and provincial level panel data, our empirical analysis need to take care of three potential estimation biases. The first and second come from the dynamic panel data characteristics of our database. On one hand, to capture the time-invariable specific effect, we need to employ fixed effect estimator for each province. On the other hand, we also need to take care of the potential serial correlation inside of each province. Both considerations require us to employ dynamic GMM estimator proposed by Blundell and Bond (1998) for each equation. It is a new development from Anderson and Hsiao (1982) and Arellano and Bond (1991). This method proposes to include to the right-hand side of each function the one-period lagged dependant variable to remove the first-order serial correlation in the residuals. At the same time, to deal with the time-invariable fixed effect, it uses first-difference transformation as suggested by Arellano and Bond (1991). Therefore the actual estimation function form for each equation becomes $y_{it}-y_{i,t-1}=\rho(y_{i,t-1}-y_{i,t-2})+(x'_{it}-x'_{i,t-1})\beta+(\varepsilon_{it}-\varepsilon_{i,t-1})$, where y_{it} signifies the dependant variable and x_{it} indicates the vector of independent variables. ε_{it} is the residual. While the serial-correlation and fixed effect are both cancelled out in this new estimation function, the difference of the lagged endogenous variable $(y_{i,t-1}-y_{i,t-2})$ is obviously correlated with the error term $(\varepsilon_{it}-\varepsilon_{i,t-1})$, since $y_{i,t-1}-y_{i,t-2}=\rho(y_{i,t-2}-y_{i,t-3})+(x'_{i,t-1}-x'_{i,t-2})\beta+(\varepsilon_{i,t-1}-\varepsilon_{i,t-2})$. Therefore $E(dy_{i,t-1}d\varepsilon_{it})\neq 0$, the estimator will be biased. The principal development of Blundell and Bond (1998) compared to Anderson and Hsiao (1982) and Arellano and Bond (1991) is their instrumentation method to the lagged endogenous variables $(y_{i,t-1}-y_{i,t-2})$. Besides of using the level instruments y_{it-2} as an instrument for the differenced lagged endogenous regressor $(y_{i,t-1}-y_{i,t-2})$ as Anderson and Hsiao (1982), Blundell-Bond further exploits all the available additional moments restrictions to enlarges the set of instruments as Arellano and Bond (1991), which means the instruments for the lagged endogenous variables $(y_{i,t-1}-y_{i,t-2})$ is enlarged to $y_{i,t-2}, y_{i,t-3}, y_{i,t-4},\ldots, y_{i1}$. Due to the low efficiency of Arellano-Bond estimator's instruments as only the information contained in difference is used, another innovation of Blundell and Bond (1998) is to make use of the additional level information besides the differences. "This combination of the moment restrictions for differences and levels results in the so-called GMM-system-estimator by Arellano and Bond." (Behr, 2003) Concretizing to the estimation functions in this paper, it means for each of the five equations in our system, we use both first difference and level function form in estimation by confining the coefficient for each variable to be the same in both the first difference and level function. The lagged endogenous variable $(y_{i,t-1}-y_{i,t-2})$ in first difference function is instrumented by the level moment $y_{i,t-2}, y_{i,t-3},\ldots,y_{i,2}, y_{i,1}$ and the lagged endogenous variable $y_{i,t-1}$ is instrumented by difference moments $(y_{i,t-2}-y_{i,t-3}), (y_{i,t-3}-y_{i,t-4}),\ldots, (y_{i,2}-y_{i,1})$.

The preoccupation for the third bias is related to the simultaneous system. As there exists potential correlation between the residuals of different functions due to the inter-correlation between the endogenous variables, which means $cov(\varepsilon i,\varepsilon j)\neq 0$, $i\neq j$, i and j indicate different equations in the system. We need to use the traditional Generalized Method of Moment (GMM) estimator for simultaneous system, which is able to control the covariance matrix of the five residuals of the system as a whole by instrumenting all the endogenous variables of the system by all the exogenous variables. However, there does not exist an already-made econometrical package that combines GMM estimator for simultaneous system with Blundell-Bond GMM-system estimator for dynamic panel data. Luckily, the instrumentation method developed by Balestra and Nerlove (1966) and Sevestre and Trognon (1996) indicates a compatible way to carry out the instrumentation step for the linear auto-regressive fixed-effect estimation function, which will allow us to exploit both the maximal availability of moments restriction in both level and first difference for each equation and to employ the GMM estimator for the whole simultaneous system.

The concrete estimation is actually carried out in two steps. In the first step, following Sevestre and Trognon (1996), we separately instrument each of the five lagged dependant variables of the simultaneous system in both the level and first difference forms, year by year on cross-province level by all of its available corresponding moments instruments. In the second step, we included the instrumented lagged dependent variables as exogenous variables into their corresponding estimation functions to carry out the GMM estimation for simultaneous system, where all the system endogenous variables are then instrumented by all the exogenous variable of the system. In practice, we actually estimate both the first difference and level function for each of the five equations by restricting the coefficients for the same variables in the two functions to be the same.

c. Estimation results

(Insert Table 2 about here)

Table 2 gives the system estimation results. The overall fit of the system is satisfactory. Most coefficients show expected signs and high significance. The specification test of Hausman (1978) and J-statistic proves the orthogonality conditions of the instruments used for the lagged endogenous variables on equation-level and the efficiency of the instrumentation used for the whole system. Adding the lagged dependant variables to the right side of the equation removes successfully the first-order serial correlation problem from most equations. The tiny inter-equation residual covariance shows the high efficiency of the GMM estimator for the simultaneous system.

The first column in Table 2 gives the estimation results for SO_2 determination. Confirming theoretical anticipation of Grossman decomposition, estimation obtains the positive and significant coefficients for both scale and composition effect. The significantly negative coefficient for environmental regulation stringency variable reveals the fact that although staying relatively low, the levy system on air pollution does have deterrent effect on industrial SO emission increase, at least as a financial source for the government-guided technique progress in pollution abatement activities.[9]

The both channels through which FDI capital stock increases production scale enlargement are confirmed in the estimation results for the production function. The significantly positive coefficient 0.693 before capital variable (K_{it}) reveals the direct participation of foreign capital stock in production as a production factor. Given the average foreign capita ratio to the total industrial capital (K_F/K) in our sample is 0.231, the estimation result expects a 0.231×0.693=0.16% industrial GDP growth to be catalyzed by 1% increase in FDI capital stock. In addition to the direct contribution to economy growth as a production factor, the 1% increase of FDI capital can induce another 0.345%'s industrial GDP expansion through its positive spillover effect on domestic sector's productivity. Overall, a 1% increase in the foreign directly invested capital stock will lead the industrial GDP to increase by 0.505%. This finding is coherent to the conclusion of some existing studies discussing the significant growth impact of FDI in China, as Chen et al. (1995), who found the elasticity of gross national production with respect to foreign direct investment amounts to 0.635. Though the significance is less convincing than the other variables, as expected, we obtain a positive coefficient for $\dot{F}/Y$. This actually indicates the productivity of foreign capital sectors is about 5% higher than that in the domestic sector.[10]

The expected negative coefficients for both labor forced and environmental regulation stringency variables are confirmed in the composition effect function. This confirms the decreasing tendency in pollution performance of industry composition with respect to the labor abundance increase and environmental regulation reinforcement. As the actual pollution performance of industrial composition is a final result of the force-contrast between these two aspects of comparative advantages, which guide industrial composition to transform in opposite directions. The unsatisfactory significance of these two coefficients could be interpreted as the temporary parity

[9] In estimation practice, we also tried to include FDI capital stock directly in the emission determination function, but we failed to find a significant coefficient.

[10] $\delta/(1+\delta)=0.049$, so $\delta=0.05$.

between their determinant roles in composition effect. However, the significantly positive coefficient before variable K_{Fit} reveals clearly that foreign capital inflow pursuing cheaper environmental regulation compliance cost actually dominates the capital pursuing low-wage labor forces in FDI's composition transformation impact. Overall, we expect 1% increase in FDI capital accumulation to induce a 0.131% deterioration in the pollution performance of China's industrial composition.

The fourth column in Table 2 shows the determination of China's environmental regulation stringency. We detect significant elasticities of pollution control effort with respect to economic growth (1.027) and to last period's emission (0.176). This finding actually provides an explanation for the relatively earlier appearance of EKC turning point in China's case with respects to the international cross-country experiences (He, 2003) and for the success in China's de-sulfur policies during 1990s discussed in Wang and Wheeler (1996) and World Bank (2000). Although expecting a higher population density to positively contribute to environmental regulation reinforcement, we were not able to find a coherent coefficient for this variable. One possible explanation resides in statistic aspect. The population data censored in China contains omission and errors. The rigid "hu-kou" registration system and "family-plan" policy reduces the credibility of China's population data, especially in the richer coastal provinces since they do not take care of the inter-province mobile population. We expect an underestimation for the population density in richer province and an overestimation for those in the poorer ones. This unavoidably flattens the correlation between population density and environmental regulation stringency. The second explanation is related to agglomeration and urbanization phenomenon. The agglomeration economy may accentuate the potential cost from pollution control.[11] If people attach more importance to economic growth, the concentration of economic activities and population in pursuit of faster economic growth may in their turn deter the progress in environmental regulation reinforcement.

Based on the strict econometrical definition of simultaneous system, FDI location decision described in the last estimation function is in fact totally determined by the exogenous or

[11] Verhoef and Nijkamp (2002).

predetermined variables. The reasons to include this equation to our simultaneous system are two-folds. Firstly, given complexity of the correlation between the determinants factors for emission and those for FDI entry decision, we believe using a partially recursive simultaneous system can help us to obtain more consistent estimation results on their relationship, as we can make use of the full-information and the dynamic characters of the model. Secondly, if the air pollution question is to be concerned from a long-run point of view, the one-period recursive model can also provide us a more stable description for the potential pollution impact of FDI, as it covers both the FDI entry decision, environmental regulation reinforcement, economic growth, composition transformation and finally SO_2 emission determination by a two-year-length cycle. The satisfactory estimation result of this equation confirms the fruits of using the full model in investigating FDI location decision. While the most attractive factor for FDI inflow is China's rapid economic growth prospective, the estimation results do confirm that FDI inflowing into China is also attracted by both her cheaper labor forces and her lax environmental regulation stringency. The small but significant environmental regulation elasticity (–0.012) in this equation actually provides a supportive evidence for the 'pollution haven' hypothesis from China's case.

(Insert Figure 6 about here)

In Figure 6 we calculate the total impact of FDI on industrial SO_2 emission by using the estimated coefficients. Totally speaking, with 1%'s increase in FDI capital stock, the total change in industrial SO_2 emission realized by all the four channels comes out to be a small positive number, 0.099%. The details show the overall emission increasing impact of FDI is actually owing to the domination of the emission increasing effect of FDI on economic growth and composition transformation over its emission reducing impact reflected in growth-induced environmental regulation reinforcement.

6. Conclusion

Recognizing the complex inter-correlation between FDI, emission and the three economic determinants of emission, in this paper, we constructed a simultaneous model to study the relationship between FDI and final industrial SO_2 emission in China by exploring both the relationship between environmental regulation stringency and FDI entry decision and the linkage from FDI entry to the final emission result. With the aid of this model, we get a structural and dynamic mechanism showing how the FDI, by exerting its impacts directly and/or indirectly on the three intermediary factors of the host country: scale, composition and technique effect, can finally change the pollution situation of the host country and how the changes in economic growth, environmental regulation stringency and pollution situation can then, in their turn affect new FDI inflow decision in the next period.

The model is estimated by the panel data of China's 29 provinces' industrial SO_2 emission. Corresponding to most of the similar analysis discussing the impact of openness on pollution, as Antweiler et al (2001), etc., our results find a small total impact of FDI on industrial SO_2 emission. With 1% increase in FDI capital stock, industrial SO_2 emission will *increase* by 0.099%, in which the emission increase caused by impact of FDI on economic growth and composition transformation totally cancels off the emission reduction results owing to FDI's role in environmental regulation reinforcement.

By introducing to the simultaneous system the recursive dynamism that supposes FDI entry decision to depend on last period's economic growth and environmental regulation stringency, our model also provided convincing evidences for the 'pollution haven" hypothesis. Although the overall impact of FDI on industrial SO_2 emission is relatively weak and the FDI enterprises in China generally produce with higher pollution efficiency, the rise in environmental regulation stringency does have modest deterrent effect on FDI capital inflow decision and final composition transformation impact of FDI in China is dominated by inflow of foreign capital pursuing the 'production platform' that provides lower pollution regulation compliance cost.

References

Anderson, T. and C. Hsiao, 1982. Formulation and estimation of dynamic models using panel data. Journal of Econometrics, 18: 67-82.

Antweiler, W., B. R. Copeland and M.S. Taylor, 2001. Is Free Trade Good for The Environment? American Economic Review, 91(4): 877-908.

Arellano, M. and O. Bover, 1995., Another Look at the Instrumental Variable Estimation of Error-Components Models. Journal of Econometrics, 68: 29-51.
Arellano, M. and S.R. Bond, 1991. Some Tests of Specification for panel Data: Monte Carlo Evidence and an Application to Employment Equations. Review of Economics Studies, 58: 277-297.
Balestra, P. and M. Nerlove, 1966. Pooling Cross Section and Time Series Data in the Estimation of a Dynamic Model: The Demand for Natural Gas. Econometrica, 34: 585-612.
Baltagi, B. H., 1995. Econometric Analysis of Panel Data. Wiley and Sons Ltd., West Sussex, England, 304pp.
Bartik, T. J., 1985. Business Location Decision in United States: Estimates of the Effects of Unionization, Taxes, and Other Characteristics of States. Journal of Business Economy and Statitisitcs, 3(1): 14-22.
Bartik, T.J., 1988. The effects of Environmental Regulation on Business Location in the United States. Growth Change, 19(3): 22-44.
Bartik; T.J., 1989. Small Business Start-Ups in the United States: Estimates of Effects of Characteristics of States. Southern Economic Journal, 55(4): 1004-1018.
Behr, A., 2003. A Comparison of Dynamic Panel Data Estimators: Monte Carlo Evidence and an Application to the Investment Function. Discussion paper 05/03, Economic Research Centre of the Deutsche Bundesbank.
Blundell, R. and S.R. Bond, 1998. Initial Conditions and Moment Restrictions in Dynamic Panel Data Models. Journal of Econometrics. 87:115-143.
Bouman, M., 1996. Do Pollution Abatement Costs Induce Direct Foreign Investment? Evidence for Germany. Mimeo, University of Amsterdam.
Cao, D., J. Yang and C. Ge, 1999. SO_2 Charge and Tax Policies in China: Experiment and Reform. In: OECD (Editor), Environmental Taxes: Recent Developments in China and OECD Countries, Paris: OECD, pp233-257.
Chen, C., L. Chang and Y. Zhang, 1995. The Role of Foreign Direct Investment in China's Post-1978 Economic Development. World Development, 23(4): 691-703.
Chen, Y. and S. Demurger, 2002. Croissance de la productivité dans l'industrie manufacturière chinoise : Le rôle de l'investissement direct étranger. Economie Internationale, 92: 131-164. (In french)
Cheung, K-Y, P. Lin, 2004. Spillover Effects of FDI on Innovation in China: Evidence from the Provincial Data. China Economic Review, 15: 25-44.
Cole, M.A., 2004. Trade, the pollution haven hypothesis and the environmental Kuznets curve: examining the linkages. Ecological Economics, 48(1): 71-81.
Cole. M.A. and R. J. R. Elliott, 2003. Determining the trade–environment composition effect: the role of capital, labor and environmental regulations. Journal of Environmental Economics and Management, 46(3): 363-383.
Copeland, B. and M. S. Taylor, 1994. North-South Trade and the Environment. The Quarterly Journal of Economics, 109(3): 755-787.
Copeland, B. and M. S. Taylor, 1997. A Simple Model of Trade, Capital Mobility and the Environment, NBER, Working paper No. 5898, Cambridge, MA.
Copeland, B.R. and M.S. Taylor, 2003. Trade and the Environment: Theory and Evidence. Princeton University Press, Princeton and Oxford, 304pp.
Dasgupata, S. and B. Laplante and N. Mamingi, 1997. Capital Market Responses to Environmental Performance in Developing Countries. Working Paper, No. 1909, World Bank, Washington, DC.
Dasgupta S., M. Huq, D. Wheeler and C. Zhang, 1996. Water Pollution abatement by Chinese industry: Cost Estimates and Policy ImplicationsWorking paper, No. 1630, World Bank, Washington, DC.
Dasgupta, S and D. Wheeler, 1997. Citizen Complaints as Environmental Indicators: Evidence From China. Policy Research Working Paper, No. 1704, World Bank, Washington, DC.
Dasgupta, S., A. Mody, S. Roy and D. Wheeler, 1995. Environmental Regulation and Development: A Cross-Country Empirical Analysis, Policy Research Working Paper, No. 1448, World Bank, Washington, DC.
Dasgupta, S., B. Laplante, N. Mamingi and H. Wang, 2000. Industrial Environmental Performance in China, Policy Research Working Paper, No. 2285, World Bank, Washington, DC.
Dasgupta, S., H. Wang and D. Wheeler, 1997. Surviving Success: Policy Reform and the Future of Industrial Pollution in China, PRDEI, World Bank, Washington, DC.
Dean, J. M., 1998. Testing the Impact of Trade Liberalisation on the Environment : theory and evidence. In Fredriksson, P. G. (Editor), Trade, Global Policy, and the Environment, Chapitre 4, pp.55-63.
Denison, E. F., 1979. Accounting for Slower Economic Growth: The U.S. in the 1970's. Brookings Institution, Washington, DC.
Dinda, S. and D. Coodoo and M.Pal, 2000. Air quality and economic growth: an empirical study. Ecological Economics, 34(3): 409-42.
Eskeland, G.S. and A.E. Harrison, 2003. Moving to Greener Pasture? Multinationals and the Pollution Haven Hypothesis. Journal of Development Economics, 70(1): 1-23.
Feder, G., 1983. On exports and economic growth. Journal of Development Economics, 12(1-2): 59-73.
Fredriksson, per G., J.A. List and D.L. Millimet, 2003. Bureaucratic corruption, Environmental Policy and Inbound U.S. FDI: Theory and Evidence. Journal of Public Economics, 87: 1407-1430.
Friedman, J., D. A. Gerlowski, and J. Silberman, 1992. What Attracts Foreign Multinational Corporations? Evidence from Branch Plant Location in the United States. Journal of Regional Science, 32(4): 403-18.

Greene, W. H., 2000, Econometric Analysis, International Edition, (Version IV), Prentice-Hall International Inc., New York University.
Grether, J-M and J. de Melo, 1995, Commerce, environnement et relations Nord-Sud : les enjeux et quelques tendances récentes, Revue de l'économie du développement, 1995(4) : 69-102. (In french)
Grossman, G. and A. Krueger, 1991. Environmental Impacts of A North American Free Trade Agreement, NBER, Working Paper No. 3914, Cambridge, MA.
Grossman, G. M. and A. B. Krueger, 1993. Environmental impacts of a North American Free Trade Agreement. In Carber P. (Editor), The U. S. –Mexico Free Trade Agreement, MIT Press, Cambridge, MA.
Grossman, G., 1995. Pollution and growth: What do we know? In: Goldin and Winter (Editors), The Economics of Sustainable Developmen, Cambridge University Press.
Hausman, J., 1978. Specification Tests in Econometrics. Econometrica, 46: 1251-1271.
Haveman, R.H. and G.B. Christiansen, 1981. Environmental Regulation and Productivity Growth. In H.M. Peskin, P.R. Portney and A.V.Kneese (Editors.), Environmental Regulation and U.S. Economy. Resource For the Future , Washington, DC, pp. 55-75.
He, J. (2003). Economic Determinants for China's Industrial SO_2 Emission: Reduced vs. Structural form and the role of international trade, Working Paper, CERDI, Université d'Auvergne, Clermont-Ferrand, France.
Heil, M. K. and T. M. Selden, 2000. Carbon Emission and Economic Development: Future Trajectories Based on Historical Experience. Environment and Development Economics, 6: 63-83.
Hettige, H., R. E. B. Lucas and D. Wheeler, 1992. The Toxic Intensity of Industrial Production: Global Patterns, Trends, and Trade Policy. American Economic Review, 82(2): 478-481.
Jaffe, A. B., S. R. Peterson, P. N. Portney and R. N. Stavins, 1995. Environmental Regulation and the Competitiveness of U.S. Manufacturing: What Does the Evidence Tell US? Journal of Economic Literature, XXXIII: 132-163.
Judson, R.A., and A.L. Owen, 1996. Estimating Dynamic Panel Data Models: A Practical Guide For Macroeconomists. Federal Reserves Board of Governors, Washington, DC.
Keller, W. and A. Levinson, 1999. Environmental compliance costs and foreign direct investment inflows to U. S. states. NEBR working paper No. 7369, Cambridge, MA.
Keller, W. and A. Levinson, 1999. Pollution Abatement Costs and Foreign Direct Investment Inflow to U.S. States. NBER. Working Paper no. 7369, Cambridge, MA.
Keller, W. and A. Levinson, 2001. Pollution Abatement Costs and Foreign Direct Investment Inflow to U.S. States. The Review of Economics and Statistics, LXXXIV (4): 691-703.
Lemoine, F. and D. Ünal-Kesenci, 2004. Assembly Trade and Technology Transfer: The Case of China. World Development, 32(5): 829-850.
Leonard, H. J., 1988. Pollution and Struggle for The World Product. Cambridge University Press, 272pp.
Letchumanan, R. and F. Kodama, 2000. Reconciling the conflict between the 'pollution-haven' hypothesis and an emerging trajectory of international technology transfer. Research Policy, 29: 59-79.
Levinson, A., 1992. Environmental Regulations and Manufacturers' location Choices: Evidence from the Census of Manufacturers. New York, Columbia University.
Levinson, A., 1996. Environmental Regulation and Manufacturers' Location Choices: Evidence from the Census of Manufacturers. Journal of Public Economics. 62: 5-29.
Li, X., X. Liu and D. Parker, 2001. Foreign Direct Investment and Productivity Spillover in the Chinese Manufacturing Sector. Economic Systems, 25: 305-321.
List, J.A. and C.Y. Co, 2000. The Effect of Environmental Regulations on Foreign Direct Investment. Journal of Environmental Economics and Management, 40: 1-20.
Liu, X. and C. Wang, 2003. Does Foreign Direct Investment Facilitate Technological Progress? Evidence from Chinese Industries. Research Policy, 32: 945-953.
Lopez, R., 1994. The Environment as a Factor of production: The Effects of Economic Growth and Trade Liberalisation. Journal of Environmental Economics and Management, 27: 163-184.
Lucas, R. E., B.D. Wheeler, and H. Hettige, 1992. Economic Development, Environmental Regulation and the International Migration of Toxic Industrial pollution : 1960-1988. In: P. Low (Editor), International Trade and the Environment, Discussion paper No. 159, World Bank, Washington, DC.
Mani, M. and D. Wheeler, 1997. In Search of Pollution Havens? Dirty Industries in the World Economy, 1965-1995, In: Proceedings of the OECD Conference on Foreign Investment and the Environment (1999). The hague, Netherland.
Matyas, L. and P. Sevestre, 1992. The Econometrics of Panel Data : Handbook of Theory and Applications. Kluwer Academic Publishers, 552pp.
OECD, 2004. Trends and Recent Developments in Foreign Direct Investment. June 2004. OECD, Paris.
Porter, M.E. and C. van der Linde, 1995. Toward A New Conception of the Environment-Competitiveness Relationship. Journal of Economic Perspective, 9: 97-118.
Revesz, R. L., 1992. Rehabilitating Interstate-Competition : Re-thinking the 'Race to the Bottom'. New York University Law Review, 67: 1210-1254.
Rogrigo, G. C., and E. Thorbecke, 1997. Sources of Growth: A Reconsideration and General Equilibrium Application to Indonesia. World Development, 25(10): 1609-1625.

Selden T. M. and D. Song, 1994. Environmental Quality and Development: Is there a Kuznets Curve for Air Pollution Emission? Journal of Environmental Economics and Management, 27: 147-162.
Selden, Thomas M. and D. Song, 1995. Neoclassical Growth, the J Curve for Abatement, and the Inverted U curve for Pollution. Journal of Environmental Economics and Management, 29: 162-168.
SEPA (State Environmental Protection Agency, PRC), 1998-2002. China Environmental Statistic Yearbook. China, Beijing.
SEPA (State Environmental Protection Agency, PRC), 1986-1997. China Environmental Yearbook. China Statistical Publishing House, Beijing.
Sevestre, Patrick and Alain Trognon, 1996. Dynamic Linear Models. In: L. Matyas and P. Sevestre (Editors), The Econometrics of Panel Data, Chapter 7, Kluwer Academic Publishers.
Smarzynska, B.K., and S-J., Wei, 2001. Pollution Havens and Foreign Direct Investment: Dirty Secret or Popular Myth? NBER Working Paper, No.8465, Cambridge, MA.
SSB (State Statistical Bureau, PRC), 1984-2004. China Statistical Yearbook, China Statistical Publishing house, Beijing.
SSB (State Statistical Bureau, PRC), 1986-1997. China Industrial Economic Statistics Yearbook. China Statistical Publishing House, Beijing.
Thompson, E.R., 2002. Clustering the Foreign Direct Investment and Enhanced Technology Transfer: Evidence from Hong Kong Garment Firms in China. World Development, 30(5): 873-889.
Tuan, C. and L.F.Y. Ng, 2004. Manufacturing agglomeration as incentives to Asian FDI in China after WTO. Journal of Asian Economics, 15: 673–693.
Verhoef, E.T. and P. Nijkamp, 2002. Externalities in urban sustainability: Environmental versus localization-type agglomeration externalities in a general spatial equilibrium model of a single-sector mono-centric industrial city. Ecological Economics, 40(2): 157-179.
Wang H., 2000. Pollution Charges, Community Pressure, and Abatement Cost of Industrial Pollution in China. Policy Research Working Paper, No. 2337, World Bank, Washington, DC.
Wang, H. and D. Wheeler, 1996. Pricing Industrial Pollution in China: An Econometric Analysis of the Levy System. Policy Research Working Paper, No. 1644, World Bank, Washington, DC.
Wang, J., 2002. Environmental pollution and legal controls during the Opening-up and reform in China: From the point of an Environmental law professor. In: Proceeding of Environment and our sustainability in the 21st Century: Understanding and cooperation between developed and developing countries, University de Nagoya, Japan.
Wheeler, D. and Mody, Ashoka, 1992. International Investment Location Decision: The Case of U. S. Firms, Journal of International Economics, 33(1-2): 57-76.
Wheeler, D., 2002. Racing to the Bottom? Foreign Investment Air Pollution in Development Countries. World Bank, Washington, DC.
Woodridge, J.M., 2002. Econometric Analysis of Cross-Section and Panel Data. MIT Press, Cambridge, 740pp.
World Bank, 2000. Greening Industry : New roles for communities, markets and governments. Oxford University Press, 150pp.
Wu, Y., 1999. Productivity and Efficiency in China's Regional Economics. In Tsu-Tan Fu et al. (Editors), Economic Efficiency and Productivity Growth in the Asian-Pacific Region, Edward Elgar Publishing, 351pp.
Xepapadeas, A. and A. de Zeeuw, 1999. Environmental Policy and Competitiveness: The Porter Hypothesis and the Composition of Capital. Journal of Environmental Economics and Management, 37: 165-182.
Xing, Y. and C.D. Kolstad, 2002. Do Lax Environmental Regulations Attract Foreign Investment? Environmental and Resource Economics, 22: 1-22.
Zarsky, L., 1997. Stuck in the Mud? Nation-States, Globalization and the Environment. In OECD (Editor), Globalization and Environment Study: OECD Economics Division, Paris, OECD.
Zarsky, L., 1999. Havens, halos and Spaghetti: Untangling the Evidence About Foreign Direct Investment and the Environment. In: Proceedings of the OECDConference on Foreign Investment and the Environment (1999), The hague, Netherland.

Table 1. Statistical description of the data

Variables	Corresponding Data	Obs.	Ave.	Sta. Dev.	Min.	Max.
Endogenous Variables (in level)						
E	Annual industrial SO_2 emission, 1000 tons	232	500.599	367.330	16.891	1760.057
Y	Real industrial GDP, 10^9 Yuan, 1990 price	232	73.900	68.100	2.970	353.000
Ω	Synthetic industrial composition indicator	232	24.800	5.428	14.368	44.248
τ	Average levy rate on industrial SO_2 emission	232	0.060	0.040	0.011	0.247
K_F	Simple accumulation of FDI capital stock, 10^9 Yuan, 1990 price	232	34.403	65.267	0.040	480.000
Endogenous Variables (in growth ratio)						
$\dot{E}/E$		203	0.019	0.151	-0.337	0.596
$\dot{Y}/Y$		203	0.111	0.034	-0.059	0.251
$\dot{\Omega}/\Omega$		203	0.041	0.130	-0.254	0.705
$\dot{\tau}/\tau$		203	0.096	0.703	-0.849	8.077
$\dot{K}_F/K_F$		203	0.342	0.375	0.000	4.593
Exogenous Variables (in level)						
K	Industrial Capital stock, 10^9 Yuan, 1990 price	232	129.000	123.000	13.100	754.000
L	Staffs and workers employed in industrial sector	232	343.444	250.428	19.603	1002.000
denpop	Population density per km^2	232	359.220	425.088	6.084	2700.196
$\dot{F}/Y$	Ratio of annual variation of output of foreign enterprises to the output of total industrial sector	232	0.032	0.045	-0.034	0.275
Exogenous Variables (in growth ratio)						
$\dot{K}/K$		203	0.046	0.042	-0.030	0.176
$\dot{L}/L$		203	-0.032	0.062	-0.300	0.086
$\dot{denpop}/denpop$		203	0.012	0.026	-0.099	0.189

Note:

(1)Due to lack of data, Tibet is excluded from the sample; all the other provinces have 8 observations (1994-2001) at the original database.

(2)The total industrial capital stock is calculated by the permanent inventory method by using real value of fixed investment data (on the constant price of 1990) of each province in each year deflated by the corresponding fixed investment price index. More details about the permanent inventory method are in Wu (1999).

(3) Due to data availability constraint, we use FDI data on the total provincial economy level instead of industrial sector level in the estimation. Considering most part of FDI aims at the industrial sectors. In year 2000, over 73% of the FDI inflow during 2000 is concentrated in industrial sector according to China Statistic Yearbook. We do not think using the total FDI capital stock will have important distortion in our estimation result. Furthermore, since we are interested in the spillover effect of FDI, to some extent we even believe to use the corresponding industrial level data is unnecessary for our objective.

(4) $\dot{F}/Y$, the ratio of annual production variation of foreign industrial sector to that of the total industrial sector is not calculated by using the industrial GDP data, but the output of the FDI industrial enterprises and that of all the state-owned and non-state-owned industrial enterprises of above designated size.

Table 2. The simultaneous system estimation results

GMM for simultaneous system, Fixed effect, 29 provinces during 8 years

Variables	$\dot{E}_{it}/E_{it}$	Scale	Composition	Technique	FDI location
		$\dot{Y}_{it}/Y_{it}$	$\dot{\Omega}_{it}/\Omega_{it}$	$\dot{\tau}_{it}/\tau_{it}$	$\dot{KF}_{it}/KF_{it}$
Lagged $\dot{E}_{it}/E_{it}$	-0.374*** (0.000)			-0.179 (0.175)	
Lagged $\dot{Y}_{it}/Y_{it}$		-0.021 (0.761)			1.618*** (0.000)
Lagged $\dot{\Omega}_{it}/\Omega_{it}$			-0.153*** (0.000)		
Lagged $\dot{\tau}_{it}/\tau_{it}$				-0.194*** (0.000)	**-0.012*** (0.001)**
Lagged $\dot{KF}_{it}/KF_{it}$					0.119*** (0.001)
$\dot{Y}_{it}/Y_{it}$	**0.242* (0.073)**			1.027*** (0.000)	
$\dot{\Omega}_{it}/\Omega_{it}$	**0.309*** (0.001)**				
$\dot{\tau}_{it}/\tau_{it}$	**-0.115*** (0.001)**		-0.021 (0.250)		
$\dot{E}_{it}/E_{it}$		0.135*** (0.000)			
$\dot{KF}_{it}/KF_{it}$		**0.345*** (0.000)**	**0.131*** (0.000)**		
$\dot{KF}_{it}/KF_{it}$		0.694*** (0.002)			
$\dot{L}_{it}/L_{it}$		0.171*** (0.000)	-0.072 (0.252)		0.125** (0.011)
$\dot{F}_{it}/Y_{it}$		0.049 (0.276)			
$\dot{denpop}_{it}/denpop_{it}$				-0.642 (0.255)	
Hausman (first-difference)	10.41 (0.038)	12.50 (0.052)	8.48 (0.075)	13.11 (0.011)	11.81 (0.019)
Hausman (level)	5.71 (0.222)	7.16 (0.307)	0.98 (0.913)	14.30 (0.006)	3.53 (0.473)
Autocorrelation ($\hat{\rho}$)	-0.572*** (0.000)	-0.4181*** (0.000)	-0.127* (0.062)	-0.445*** (0.000)	-0.522*** (0.000)
J-statistic (System identification)			0.718		
Residual covariance			2.04×10^{-17}		

Notes : 1. *** indicates the significance of 99%, ** indicates the significance of 95% and * means significance of 90%.

2. As the fixed effect of each province is removed by the first-difference transformation and the serial correlation between the observations for the same province is also controlled by the inclusion of instrumented lagged dependant variables to the right-hand side of the equations, the simultaneous system in this paper is estimated by the cross-section GMM estimator for system of equations, the heteroskedasticity is corrected by the White's heteroskedasticity consistent covariance matrix.

3. The equation-level specification test is the Hausman test, which verifies the orthogonality of the instruments for the lagged dependant variables with respect to equation residual.

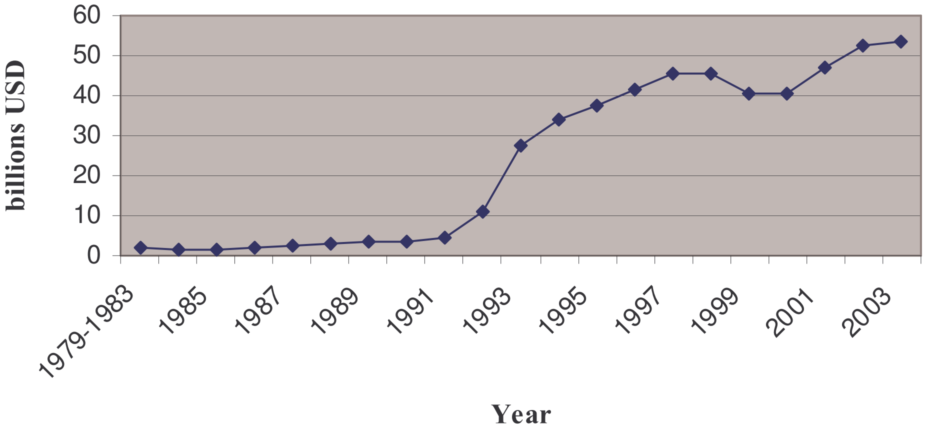
4. Autocorrelation test is from Woodridge (2002), P282-283. It is a simple test for potential serial correlation problem in first-difference fixed effect estimation based on the simple regression on T-2 time periods of the following equation: $\hat{e}_{it}=\hat{\rho}\hat{e}_{i,t-1}+error_{it}$, t=3,4,…,T; i=1,2,…,N. When the value of the coefficient $\hat{\rho}$ approaches to –0.5 will warrant computing the robust variance matrix for the first-difference estimator.

5. The J-statistic serves to verify the validity of all the instruments used in simultaneous system GMM estimator. Multiplying the J-statistic with observation number 124.93=0.718×174 derives an approximation for Chi-2 value, which can then be used in Sargan test. Given the number of the instruments used in this system counts up to 210 (the instruments for lagged dependant variables are also included), the probability for this Chi-2 value to be smaller than the critical value 160.97 is 1.000.

6.Reduction in the number of observation is due to the data transformation, such as growth rate and first difference.

7. In production function, we impose the restriction that the sum of the coefficient of capital, labor and SO_2 emission is equal to one according to the constant return to scale hypothesis.

Figure 1. Evolution of total foreign direct investment actually utilized in China



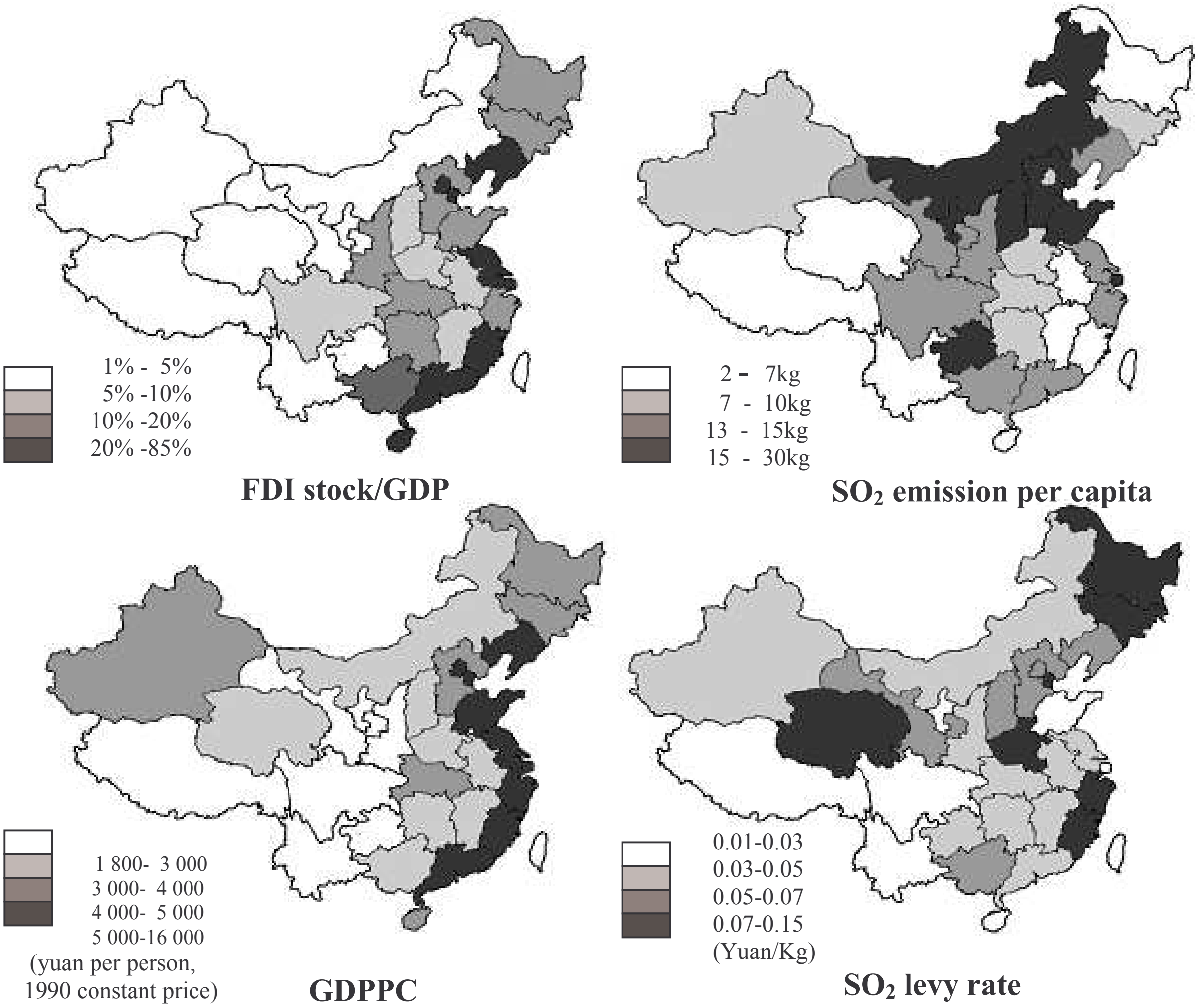


Figure 2. Geographical distribution of FDI, economic growth, industrial SO_2 emission and average SO_2 levy rate in 2001
(Data source: China Statistic Yearbook, 2002)

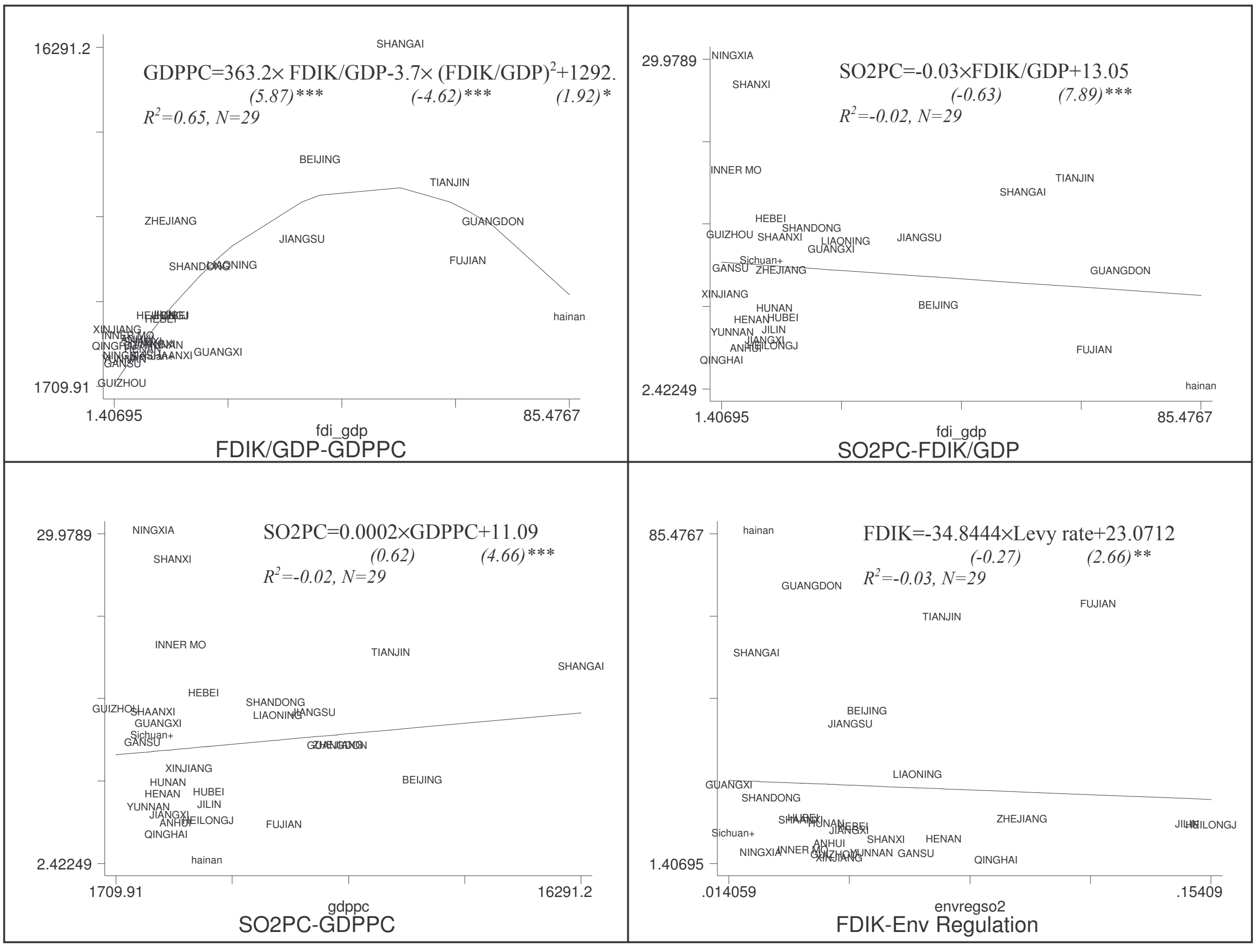


Figure 3. Correlation between economic growth, FDI, levy rate and SO_2 emission (2001)

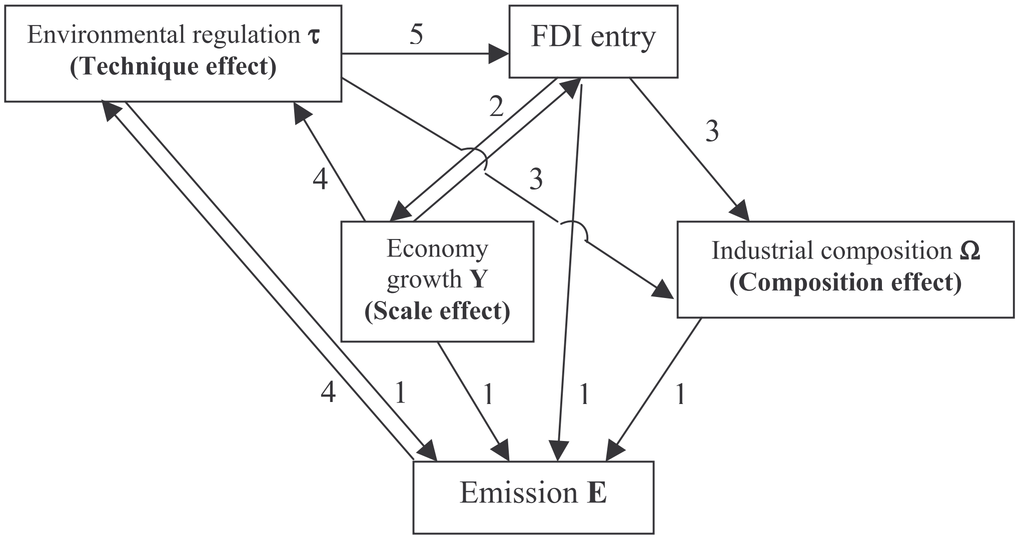


Figure 4. The schema for the FDI-emission relationship

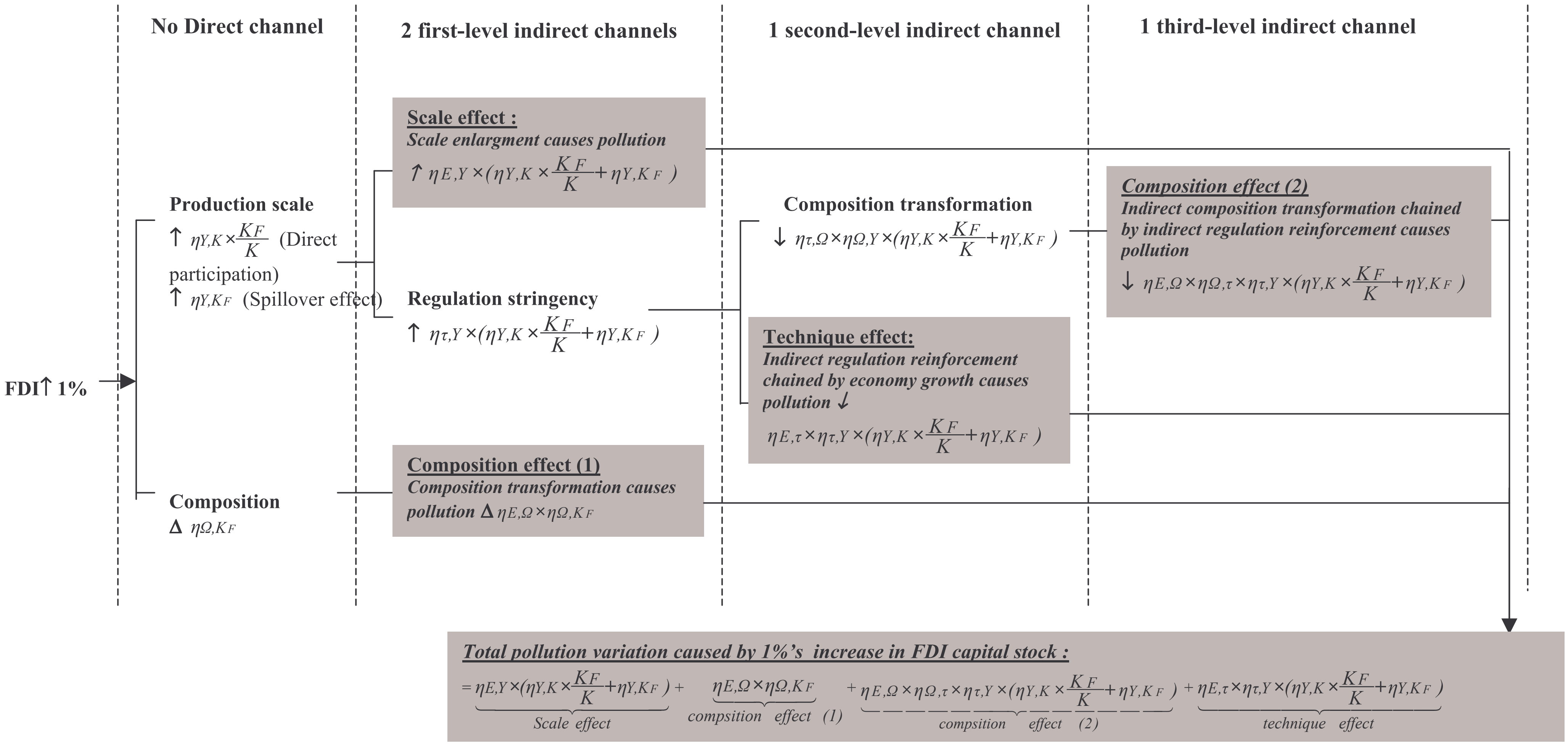


Figure 5. Illustration of the different Channels of the impacts of FDI on pollution

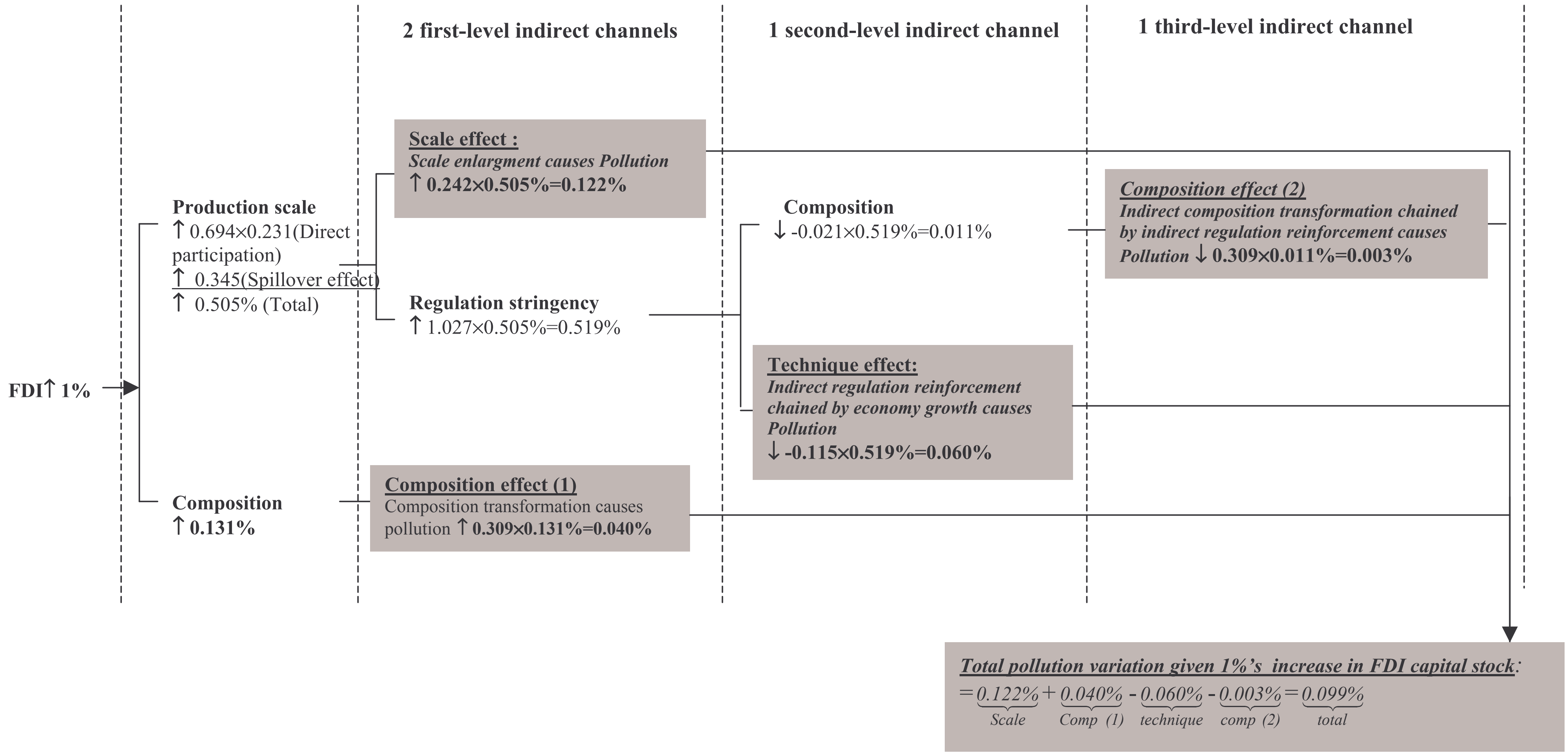


Figure 6. Different Channels of the impacts of FDI on pollution
(Based on estimation results of Table 2)

Appendix. The deduction for the production function based on Feder (1983)

Following to Feder (1983), we suppose host economy can be considers as consisting of two sectors, the domestic sector H and the foreign sector F, we have:

$$Y=F+H$$

In order to show the spillover effect coming from FDI on the domestic sector, we include the accumulated FDI stock to the production function of domestic sector H.

$$F=f(K_F,L_F,E_F)$$

$$H=h(K_H,L_H,E_H,K_F)$$

$$K=K_H+K_F$$

$$L=L_H+L_F$$

$$E=E_H+E_F$$

and the relationship in factor productivity between domestic and foreign capital sectors is,

$$\frac{F_K}{H_K}=\frac{F_L}{H_L}=\frac{F_E}{H_E}=1+\delta$$

Under the help of total differentiation:

$$\dot{Y}=\dot{H}+\dot{F}$$

$$\dot{H}=H_K\times\dot{K}_H+H_L\times\dot{L}_H+H_E\times\dot{E}_H+H_F\times\dot{K}_F$$

$$\dot{F}=F_K\times\dot{K}_F+F_L\times\dot{L}_F+F_E\times\dot{E}_F$$

So, we can get:

$$\dot{Y}=H_K\times\dot{K}+H_L\times\dot{L}+H_E\times\dot{E}+H_F\times\dot{K}_F+\frac{\delta}{1+\delta}\dot{F}$$

Where the $\dot{X}$ means the variation of the variable X, $X\in\{Y, K, E, K_F, F, K_H, L_H, L_F, E_h, E_F\}$

Divide the last function by Y:

$$\frac{\dot{Y}}{Y}=H_K\times\frac{K}{Y}\times\frac{\dot{K}}{K}+H_L\times\frac{L}{Y}\times\frac{\dot{L}}{L}+H_E\times\frac{E}{Y}\times\frac{\dot{E}}{E}+H_F\times\frac{K_F}{Y}\times\frac{\dot{K}_F}{K_F}+\frac{\delta}{1+\delta}\times\frac{\dot{F}}{Y}$$

$H_F\times\frac{K_F}{Y}$ is used to represent the coefficient of spillover effect of FDI in host economy, a positive $H_F\times\frac{K_F}{Y}$ means FDI plays a positive spillover effects on host economy's productivity.

The corresponding econometric production function is as follow.

$$\frac{\dot{Y}}{Y}=\eta_{Y,K}\times\frac{\dot{K}}{K}+\eta_{Y,L}\times\frac{\dot{L}}{L}+\eta_{Y,E}\times\frac{\dot{E}}{E}+\eta_{Y,K_F}\times\frac{\dot{K}_F}{K_F}+\frac{\delta}{1+\delta}\times\frac{\dot{F}}{Y} \quad (2^*)$$