FOREIGN DIRECT INVESTMENT AND AIR POLLUTION IN CHINA: EVIDENCE FROM CHINESE CITIES

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Abstract - *In order to gain deeper insight into the impacts of FDI on the air pollution situation in Chinese cities, I construct a simultaneous system. This system supposes the air pollution indicators to be determined by economic scale, industrial composition and technical characters of a city and in turn, FDI entry can affect the production scale, structure transformation and technical progress in pollution abatement activities. This system is tested for two air pollution cases in China: the annual average concentration of* SO_2 *and total suspended particles (TSP). Based on a panel database of 80 cities (1993-2001), the system is estimated by the Generalized Method of Moment (GMM) estimator for simultaneous system. The fixed effect estimator and the method of Anderson and Hsiao (1982) are included to take into account the city's specific effect and the potential first-order autocorrelation respectively. The results show that although there exist various channels through which FDI affects pollution, the impacts of FDI on pollution are mainly exerted through scale and technical effects. Corresponding to similar studies, the total environmental impacts of FDI in both pollution cases are proven to be very small.*

Keywords - CHINA, FDI, SO_2 CONCENTRATION, TSP CONCENTRATION, CITIES, SIMULTANEOUS SYSTEM, SCALE, COMPOSITION AND TECHNICAL EFFECT

JEL Classification : O53, Q53, Q56, C33

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1. INTRODUCTION

For a developing economy, the relationship between FDI and the environment can be explained differently. The hypothesis of “pollution haven” supposes that a developing economy has a comparative advantage in polluting sectors due to their less strict environmental regulation. While traditional international trade theories believe a labor abundant developing economy such as China will specialize in the labor-intensive sectors, which are generally believed to be less polluting. Following the reasoning of the hypothesis of Porter, FDI brings intensified competition to domestic producers, which in its turn may encourage domestic producers to adopt more advanced technologies and improve production and abatement efficiency at the same time. As Grossman (1995) decomposed the economic determinants of pollution into scale, composition and technical effects, FDI can actually exert an influence on all of the three economic aspects: enlarging the production scale, changing the industrial composition and increasing the income level, therefore reinforcing the technical requirement for pollution control; all these changes can in turn affect the pollution level in various ways. Therefore, the real relationship between FDI inflows and pollution can not be explained simply as positive or negative.

China, as the largest recipient of FDI in the world, is at the same time facing serious air pollution problems, especially in urban areas. What are the impacts of the inflows of FDI on China’s environmental situation? In order to answer this question, I have constructed a simultaneous model to capture the various channels through which FDI impacts on the environment. In this system, the air pollution situation, following Grossman (1995), results from the changes in the scale, composition and technical characters of the economy. In turn, the economic scale, industrial composition and pollution-abatement technical capacity of the host city are further considered to be endogenously affected by FDI inflows. Firstly, FDI inflows can enlarge the production scale, not only directly by participating in the foreign sector’s production as a production factor, but also indirectly, by its “spillover” effect on domestic sectors’ production efficiency.[1]

Secondly, as supposed by Copeland and Taylor (1994, 1997), FDI will also promote China’s industrial composition to transform according to its true comparative advantage. Thirdly, FDI inflows accelerate economic growth in the host economy, which will further encourage the transformation of industrial composition and reinforce the strictness of the environmental regulation through its income increase mechanism. With this system, I would like to trace the different channels conducting pollution impacts of FDI and to get a better understanding of the current general role of FDI on the air pollution situation in Chinese cities.

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[1] This effect can be positive or negative. FDI inflows can intensify the competition in domestic markets. If the domestic sector positively responds to competition by reinforcing their production efficiency, we may observe the positive spillover effect. If competition becomes too intense for the domestic sector, we may observe a contraction of the domestic sector, which will bring a negative spillover effect to the host economy.

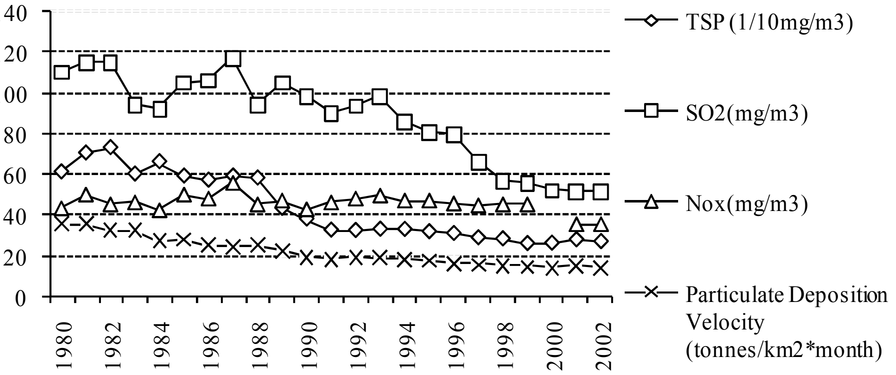
This paper is arranged as follows: Section 2 describes the current economic and environmental characteristics of Chinese cities. Then in Section 3, we introduce the simultaneous system, and the estimation results are provided in Section 4. Finally, Section 5 is made up of the conclusion.

2. A QUICK LOOK AT THE POSSIBLE RELATIONSHIP BETWEEN ENVIRONMENTAL AND OPENNESS SITUATION IN CHINESE CITIES IN THE 1990's

The openness policy since 1978 has brought a rapid integration process into the world economy to China. During the 1990s, FDI entry increased rapidly and the total accumulation reached 500 billions dollars.[2] Due to the geographical location and infrastructure facility advantages in the coastal urban area, most of FDI are concentrated in the urban areas and especially in the large cities located in the coastal provinces.

Figure 1. Ambiant Air Quality in Chinese Cities (Annual Average)

(Data source: China Energy Database, 6,0)



Although Figure 1 shows that, on average, the long-term general tendency for most of the air pollution concentration indicators in Chinese cities is decreasing, the uneven geographical distribution of economic, especially industrial, activities results in significant inter-city differences in these air quality indicators. According to SEPA (State Environmental Protection Agency) statistics, over one third of big cities still have their principal air pollution concentration indicators above the Class II standard (200$\mu g/m^3$ for TSP and 60$\mu g/m^3$ for SO_2).[3] Small, medium, and inland cities generally have more difficulties in respecting these standards than the bigger and eastern coastal ones.

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[2] Calculated by the author according to the data available in the China Statistical Yearbook, various issues.

[3] China Environmental Yearbook, various issues.

3. THE LINKS BETWEEN FDI AND THE ENVIRONMENT: THE SIMULTANEOUS SYSTEM

A direct inspiration for the system constructed in this paper comes from Dean (1998), in which he studied the relationship between international trade and Chinese industrial wastewater emissions by a simple simultaneous system. His model supposes that international trade increases pollution through the "pollution haven" effect, but at the same time, trade also contributes to economic growth, which in turn, will reduce pollution emissions through the effect according to which higher income is supposed to strengthen public demand for a better environment. In his paper, the total environmental effect of trade is considered as the results of the contrast of forces between these two aspects.

Following similar reasoning, we construct our 4-equation simultaneous system that captures the direct and indirect impact of FDI entry on the air pollution situation.

$$E_{it} = e(Y_{it}, \Omega_{it}, \tau_{it}, K_{F\,it}) \tag{1}$$

$$Y_{it} = H_{it} + F_{it} = A_{it}[h(K_{H\,it}, L_{H\,it}, E_{H\,it}, K_{F\,it}) + f(K_{F\,it}, L_{F\,it}, E_{F\,it})] \tag{2}$$

$$where: E_{it} = E_{H\,it} + E_{F\,it}$$

$$\Omega_{it} = z(K_{F\,it}, \tau_{it}) \tag{3}$$

$$\tau_{it} = t(Y_{it}, K_{Fit}) \tag{4}$$

(*i: indicator for different cities, t: indicator for different years)*

With:
E_{it}: *air pollution indicator of period t in city i.*
Y_{it} : *GDP of period t in city I (Scale effect)*
Ω_{it}: *the environmental performance indicator for the industrial composition of period t in city i (Composition effect)*
τ_{it} : *environmental regulation strictness on air pollution of period t in city I (Technical effect)*
A_{it}: *average productivity of city i during period t.*
K_{Fit}: *foreign direct investment capital stock of period t in city i.*
H_{it}: *the part of GDP produced by domestic sector of period t in city i.*
F_{it}: *the part of GDP produced by the foreign direct investment sector of period t in city i.*
K_{Hit}: *total capital stock employed in the domestic sector of period t in city i.*
L_{Hit}: *total labor employed in domestic sector of period t in city i.*
L_{Fit}: *total labor employed in foreign direct investment sector of period t in city i.*
E_{Hit}: *contribution of the domestic sector in the air pollution situation of period t in city i.*
E_{Fit}: *contribution of the foreign direct investment sector in the air pollution situation of period t in city i.*

Equation (1) describes the four economic determinants of air pollution. Firstly, scale effects (Y_{it}) represent the total production scale of the economy. With an unchanged pollution intensity, a larger economic scale means more pollution, so $e_y > 0$. Secondly, the composition effect (Ω_{it}) holds that, given the same quantity of production, the industrial composition contains a higher portion of polluting sectors will emit more pollution. Due to constraints in the data availability, we decided to use the capitalistic ratio (K/L) of the economy to measure the pollution performance character of the industrial composition. The same measurement has been widely used in openness-pollution theoretical analyses as those of Copeland and Taylor (1994, 1997, 2003) and Anterweiler, Copeland and Taylor (1998, 2001). Generally, we believe the industries with a high capitalistic ratio are also more pollution-intensive, so we anticipate $e_\Omega > 0$.[4] The third economic determinant for air pollution is the technical effect (τ_{it}). The original technical effect in the Grossman decomposition (1995) is represented by pollution intensity, given that stricter environmental regulation can encourage a producer to reduce his pollution intensity by investing in pollution abatement activities, we use environmental regulation strictness to measure this effect and we expect a negative sign for this determinant factor, $e_\tau < 0$. Finally, we also consider the direct pollution impact of FDI inflows in pollution reduction; we suppose FDI inflows reduce air pollution by introducing more competition in the domestic market and bringing domestic producers more access to advanced, clean production technology. Correspondingly, we anticipate $e_{FDI} < 0$.

However, the impact of FDI on pollution does not rest only on its technology-support role in pollution reduction. In the production function equation (2), we suppose the pollution determinant factor – the production scale – can also be enlarged by FDI inflows, either through direct participation of FDI as a capital factor in production $(f_{K_F} > 0)$, or through the so-called "spillover effect" that describes the way in which the existence of FDI encourages the domestic producers to improve production efficiency $(h_{K_F} > 0)$.[5]

Another indirect impact of FDI on pollution is through its influences on industrial composition transformation. This effect is captured by the composition determination function (3). On the one hand, China's less strict

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[4] Another consideration pushing us to choose the capitalistic ratio as pollution performance measurement is that the capitalistic ratio serves at the same time as an indicator for natural endowment comparative advantage of an economy. In our system we will also look into the possible industrial composition impacts of FDI entry, which in fact results from the force-contrast between the traditional comparative advantage theory and the "pollution haven" hypothesis. Therefore, using the capitalistic ratio as industrial composition indicator will permit us to investigate the domination situation between the traditional comparative advantage theory and the "pollution haven" hypothesis in composition effect determination.

[5] Like many analyses in environmental economics fields, the production function that we employ in this paper includes the environment as a production factor. By doing so, we consider pollution as the unavoidable utilization of the environmental factor in production activities, which should be the same as the other conventional production factors including capital and labor.

environmental regulation may attract the inflow of “pollution haven”-seeking FDI, while on the other hand, China’s cheap labor forces will also be attractive to labor-intensive FDI, which is generally supposed to be less polluting. As the influence of FDI on industrial composition (Ω_{FDI}) can be determined by these two forces running in opposite directions, we can not predict which force will dominate. We equally include the environmental regulation strictness in this equation, our consideration being that industrial composition is likely to adjust according to the reinforcement of environmental regulations, that means $z_\tau<0$.

Equation (4) describes the environmental regulation strictness determination. We consider two determinants in this equation. The first is FDI inflows, as FDI inflows can facilitate the reinforcement of environmental regulation by improving cleaner technology supply and intensifying competition in the host economy. Therefore, we suppose $t_{KF}>0$. The second determinant is economic growth (Y_{it}). This factor seizes regulation intensification forces coming from the demand side. As the demand for a better environment generally increases with the income level, faster economy growth surely facilitates the reinforcement of environmental regulation. So we expect $t_y>0$.

Since the direct and indirect impact of FDI on air pollution can be found in all four functions, to calculate the total environmental impact of FDI, we need to add up the different aspects. To facilitate our analysis, we make total differentiation to all the four estimation functions, so that the variables in the system will be expressed in growth rate terms and their estimated coefficients become the elasticity of the dependant variable with respect to independent variables. In this case, the indirect impact of FDI on pollution through its influence on one economic determinant of pollution can be easily calculated by multiplying the direct elasticity of pollution to this economic determinant with the elasticity of this determinant with respect to FDI variation.

The function forms used in estimation are the following; the expected sign for coefficients is marked below each term.

We have four endogenous variables in this system:

$\frac{\dot{E}_{it}}{E_{it}}$, $\frac{\dot{Y}_{it}}{Y_{it}}$, $\frac{\dot{\Omega}_{it}}{\Omega_{it}}$ and $\frac{\dot{\tau}_{it}}{\tau_{it}}$.

The four exogenous variables are:

$\frac{\dot{K}_{it}}{K_{it}}$, $\frac{\dot{K}_{Fit}}{K_{Fit}}$, $\frac{\dot{L}_{it}}{L_{it}}$ and $\frac{\dot{F}_{it}}{Y_{it}}$.

$$\frac{\dot{E}_{it}}{E_{it}} = e_\tau \times \frac{\dot{\tau}_{it}}{\tau_{it}} + e_y \times \frac{\dot{Y}_{it}}{Y_{it}} + e_\Omega \times \frac{\dot{\Omega}_{it}}{\Omega_{it}} + e_{FDI} \times \frac{\dot{K}_{F\,it}}{K_{F\,it}} \qquad (1^*)$$

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$$\frac{\dot{Y}_{it}}{Y_{it}} = g_{Ai} + \underset{(+)}{y_k \times \frac{\dot{K}_{it}}{K_{it}}} + \underset{(+)}{y_l \times \frac{\dot{L}_{it}}{L_{it}}} + \underset{(+)}{y_e \times \frac{\dot{E}_{it}}{E_{it}}} + \underset{(+)}{y_{FDI} \times \frac{\dot{K}_{F\,it}}{K_{F\,it}}} + \underset{(+)}{\frac{\delta}{1+\delta} \times \frac{\dot{F}_{it}}{Y_{it}}} \qquad (2^*)$$ [6]

$$\frac{\dot{\Omega}_{it}}{\Omega_{it}} = \underset{(?)}{z_{FDI} \times \frac{\dot{K}_{F\,it}}{K_{F\,it}}} + \underset{(+)}{z_{\tau} \times \frac{\dot{\tau}_{it}}{\tau_{it}}} \qquad (3^*)$$

$$\frac{\dot{\tau}_{it}}{\tau_{it}} = \underset{(+)}{t_{FDI} \times \frac{\dot{K}_{Fit}}{K_{Fit}}} + \underset{(+)}{t_y \times \frac{\dot{Y}_{it}}{Y_{it}}} \qquad (4^*)$$

To avoid the data requirement on detailed domestic and foreign sectors' production factor use in the original equation (2), with the help of a simple assumption that factor productivity in foreign direct investment sectors is generally higher than that in domestic sectors by δ percent, that means $f_{K_F}=(1+\delta)h_{K_H}, f_{L_F}=(1+\delta)h_{L_H}, f_{E_F}=(1+\delta)h_{E_H}$, we are able to sum up the three production factors, capital, labor and pollution, used in both domestic and foreign sectors. The data requirement is then reduced to only the total capital (K_{it}), labor (L_{it}) and pollution (E_{it}), the FDI stock term to capture the spillover effect and a term $(\frac{\dot{F}}{Y})$ to measure the supplementary production due to the higher factor productivity of the foreign sector.

This arrangement is in fact inspired from Feder (1983). Detailed mathematical derivation is given in the appendix. Besides the three production factors having positive coefficients, we equally anticipate a positive sign for $(\frac{\dot{K_F}}{K_F})$ to signify a positive spillover effect of FDI on growth. The coefficient $(\frac{\delta}{1+\delta})$ should also be positive to support the assumption that foreign sectors have higher factor productivity.[7] This production function also allows the total factor productivity A_{it} to be time-variable. In the total differentiation step, we assume the total factor productivity of each city to grow at a constant rate, therefore we can use its average growth rate g_{Ai} to express it in (2*). Given the model will be regressed with panel data by a fixed effect estimator, g_{Ai} should be captured in the fixed effect of each city, and therefore disappears from our estimation results. [8]

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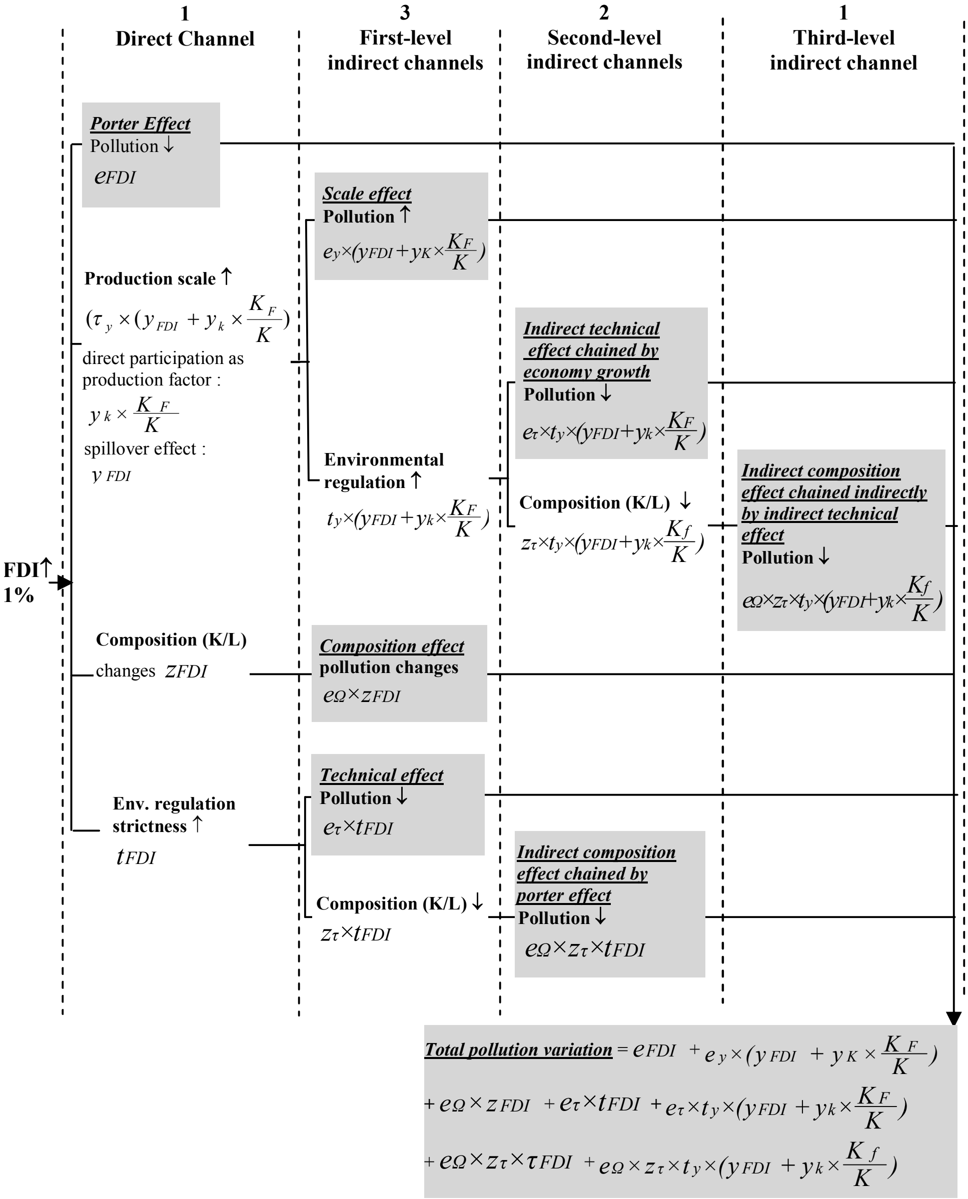
[6] Except for the variable $(Y_{FDI}/Y)_{it}$, which is expressed in an $(\dot{Y}_{FDI})/Y$ form in the estimation. A more detailed mathematical derivation for this simultaneous model is given in the Appendix.

[7] The value of the δ can then be derived from the estimated coefficient before the term $(\frac{\dot{F}}{Y})$, say the coefficient is $\theta=\frac{\delta}{1+\delta}$, so δ=θ/(1-θ).

[8] I would like to thank an anonymous referee for his relevant comments on this point.

Figure 2. Illustration of the different channels of the impacts of FDI on pollution (based on the simultaneous system)



To assess the total impact of FDI on the air pollution situation in China, by this model, we can distinguish seven channels, direct or indirect, through which FDI impacts on air pollution. As shown in Figure 2, the first channel is the direct one through which FDI serves as a catalyst in technology progress in pollution abatement activities, e_{FDI} *(direct impact*). Then we distinguish the three first-level indirect channels through which FDI's environmental impacts go in the increased production scale, $e_y \times (y_{FDI} + y_K \times \frac{K_F}{K})$ (*scale effect*), in the industrial composition transformation, $e_\Omega \times z_{FDI}$ (*composition effect*) and in the reinforcement in environmental regulation strictness, $e_\tau \times t_{FDI}$ (*technical effect*).

Table 1. Data statistical description

Variable	**Data**	**Obs**	**Mean**	**Stand Dev.**	**Min.**	**Max.**
E: Air pollution indicators						
SO_2	Growth rate of the annual average concentration of SO2	625	-0.020	0.339	-0.833	2.333
TSP	Growth rate of the annual average concentration of total suspended particles	603	-0.016	0.190	-0.662	1.242
Economic determinants of pollution						
GDP(2)	GDP density's growth rate	628	0.157	0.152	-0.868	1.166
Capital(1) (2)	Capital accumulation growth rate (in density terms)	628	0.215	0.129	-0.755	0.844
Labor (2)	Labor force growth rate (in density terms)	628	-0.047	0.189	-0.864	1.164
FDI(1) (2)	FDI stock accumulation growth rate (in density terms)	628	1.402	19.225	-0.593	474.981
$\dot{F}$ /**Y**(3)	Portion of gross output of foreign funded enterprises in all state-owned and non-state-owned industrial enterprises of above designated size.(2)	628	0.030	0.042	-0.034	0.275
Ω	Capitalistic ratio growth rate (K/L)	628	0.360	0.632	-0.449	9.294
τ (4)	Growth rate of the environmental regulation strictness for air pollution	628	0.064	0.641	-0.841	6.393

(1) The capital stock is calculated with the performance method by using the data on the value of fixed investment per year (Wu, 1998). FDI stock is calculated by a simple accumulation of the FDI inflows per year in one city.

(2) To correspond to the air pollution indicators in concentration terms appearing in the production function as a production factors, we divided all the other variables in the production function GDP, labor, capital and FDI stock also by the cities' surface.

(3) The portion of foreign industrial sector production is actually the data on the provincial level that corresponds to each city.

(4) Environment regulation data are calculated by provincial waste gas emission levy revenue divided by the total waste gases emission of the province to which the city belongs, and then multiplied by the density of the population in each city.

We equally have two second-level indirect channels that explain further indirect FDI impact on pollution. They are, the derived environmental regulation reinforcement due to the economic growth fueled by FDI inflows,

$e_{\tau} \times t_{y} \times (y_{FDI} + y_{k} \times \frac{K_F}{K})$ (*indirect technical effect chained by economy growth*) and the derived composition transformation chained by the reinforcement of environmental regulation, $e_{\Omega} \times z_{\tau} \times t_{FDI}$ (*indirect composition effect chained by porter effect*). Lastly, we have the derived composition transformation due to the indirect technical effect chained by FDI-led economic growth, $(e_{\Omega} \times z_{\tau} \times t_{y} \times (y_{FDI} + y_{k} \times \frac{K_f}{K})$, which can be called the *indirect composition effect chained by the indirect technical effect*.

4. ECONOMETRIC ANALYSIS BASED ON THE SIMULTANEOUS MODEL

4.1. The data

Table 1 provides the statistical description of the data used in the estimation. Two air pollution concentrations will be examined in this paper, one is the annual average concentration of SO2 and another is annual average concentration of total suspended particles (TSP). Both data come from the China Environmental Statistic Yearbook (1994-2002).

Since the environmental indicators used in the paper are actually in concentration terms, we use the density of GDP, capital and labor and FDI stock instead of their absolute value to maintain coherence in the production function (2*). For the $\dot{F}/Y$ term, we use provincial level data since the corresponding data on the city level are not available. Environmental regulation strictness in each city is also an approximation given limited data availability. Here we divide the total waste gas levy revenue of the province to which the city belongs by the total industrial waste gases emission of the same province to get a basic idea of the unit levy rate on the provincial level, and then we multiply this provincial-level average levy rate by the population density of the city. The economic consideration supporting this approximation is that, the higher the population density of a city, for the same pollution concentration, the larger the marginal damage to the utility, therefore a stricter environmental regulation should be carried out to compensate for this marginal utility loss.

4.2. The empirical method

Our econometric analysis is based on the simultaneous model and a database of an annual panel data of over 80 cities, which have a time dimension of 9 years. The estimation combines three econometrical strategies: the fixed effect estimator takes care of the city specific effect. Secondly, as the time length is 9 years for each city, we also need to take into account the potential serial auto-correlation problem, this is carried out by the Anderson-Hsiao (1982), which suggests including a lagged dependant variable into the right-hand side of the estimation function, and this lagged dependant variable should be firstly instrumented by its lagged values of the previous years. Finally, the GMM system estimator for simultaneous equations (Greene, 2003, chapter 15, p409-411) is further combined with the previous two strategies, which is to correct the biased estimation problems caused by the existence of the system endogenous variables (the variables on the left-hand side of each equation) as these four system endogenous variables are simultaneously determined by the exogenous variables and between themselves. Another advantage of the GMM system estimator is that it can also help us to get rid of the heterosckedasticity problems in the four estimation functions.

4.3. The results

The estimation results are listed in Table 2. Each column represents the estimation result of one equation with the title line marked by the corresponding dependant variable. Most of the coefficients are compliant with what we anticipated. In the result for the pollution determination equation, we find the expected positive and significant scale effect (0.378 for SO_2 and 0.451 for TSP).

But contrary to our expectation, the coefficient for the composition effect is found to be negative in both pollution cases. A possible explanation is the potential ambiguity in using capital abundance as a measurement for environmental performance of the industrial composition, since the "capital intensive sector could also be more likely to be clean technology owner" (Dinda et al., 2000). He (2005, 2006) found similar results in her analyses on EKC hypothesis using Chinese provincial level data. The coefficients for the technical effect are both significantly negative. This corresponds to what we anticipated. Compared with the coefficients of the technical effect for the SO_2 and TSP, we see that the reduction of SO_2 concentration responds more flexibly to the reinforcement of pollution control policies than TSP, which also reflects the current situation in China. We detected a significant but very weak direct impact of FDI inflows on pollution reduction in both pollution cases.

Concerning the impact of FDI on scale, composition and technical effects, we see that the contribution of FDI in enlarging the production scale rests mainly in its direct participation in production activities. The divergence and very small value found for the coefficients of the spillover effect of FDI on economic growth make it difficult to draw a clear-cut conclusion. The results confirm the productivity gap between domestic and FDI sectors with the positive coefficients for Y_F/Y terms, which signify the productivity of foreign sectors, is about 1.5-1.7% higher.

In the composition equation, we only find a very small composition adjustment related to FDI inflows (-0.0003% for SO_2 case and –0.0004% for TSP cases). Since this coefficient can be considered as a final result of the force contrast between China's natural endowment comparative advantage in labor-intensive sectors and its pollution haven comparative advantage in capital-intensive polluting sectors, these negative coefficients can be regarded as evidence for the domination of labor endowment comparative advantage in this country. This equation also reveals the negative and very significant correlation between China's composition character and environmental regulation restrictiveness.

The direct impact of FDI on environmental regulation strictness found in the last equation of the system turns out to be positive but very small and not very significant. This result reminds us to a certain extent of the complexity in the FDI-environmental regulation nexus which has been largely debated and analyzed without having achieved a consensus yet. A more important environmental regulation improvement due to FDI inflows actually lies in the indirect channel that goes through FDI's positive scale enlarging effect, which is represented by the coefficient for the scale effect term.

Table 2. The results of the simultaneous system: the case of the annual concentration indices of SO_2 and TSP in air

	SO_2				**TSP**			
Variables	**Pollution (E_{it})**	**Production (Y_{it})**	**Composition (Ω_{it})**	**Technical (τ_{it})**	**Pollution (E_{it})**	**Production (Y_{it})**	**Composition (Ω_{it})**	**Technical (τ_{it})**
Lagged endogenous variables								
$E_{i,t-1}$	**0.567* (1.944)**				**-0.096* (1.750)**			
Y_{it-1}		0.209** (2.917)				0.265*** (2.973)		
Ω_{it-1}			-0.118* (1.936)				-0.120** (1.990)	
τ_{it-1}				-0.108 (1.294)				-0.151° (1.604)
Endogenous variables								
E_{it}		0.152*** (3.441)				0.569*** (18.041)		
$Y_{it}^{(3)}$	**0.268 (1.166)**			0.225 (1.264)	**0.390*** (3.412)**			0.138 (0.725)
Ω_{it}	**-0.123*** (4.645)**				**-0.020 (1.258)**			
$\tau_{it}^{(2)}$	**-0.452*** (6.544)**		-2.343*** (13.846)		**-0.185*** (4.287)**		-2.392*** (14.607)	
Exogenous variables								
L_{it}		0.103*** (4.390)				0.108*** (3.546)		
K_{it}		0.342*** (6.575)				0.258*** (4.392)		
K_{Fit}	**-0.0003** (2.874)**	**-0.0001** (2.230)**	**-0.0004 (1.191)**	**0.0001 (1.151)**	**-0.0004*** (3.108)**	**7.14E-05 (0.600)**	**-0.0005° (1.451)**	**9.21E-0.5 (0.791)**
$\dot{Y}_F/Y$ **(2)**		0.017*** (6.727)				0.015*** (5.469)		
Sargan test	142.77 (0.000)				154.61 (0.000)			
Determinant residual covariance	1.80E-04				4.43E-05			

Panel data on the city level : about 80 cities, 1993-2001, Fixed Effect, GMM for simultaneous system, heteoroskedasticity and auto-correlation problems controlled.

1. The data for Y_{FDI}/Y are panel data on the provincial level.

*2. The P values in the parenthesis are already purged of the problems of heterosckedasticity and auto-correlation. *** indicates a significance of 99%, ** indicates a significance of 95% and * indicates a significance of 90%, while ° indicates a significance of 85%. The lagged endogenous variables of the system are instrumented by all the system exogenous variables lagged one and two period, inspired by Anderson and Hsiao (1982).*

What is the total effect of FDI on the situation concerning the concentration of pollution? As there are various channels through which FDI can exert its impacts on the environmental situation, a better way to show the total result is to use the illustration as in Figure 2 with the estimated results for the SO_2 and TSP cases. The numbers followed by % signify the percentage changes of economic factors preceding the impact in question and the simple numbers used to multiply the percentage changes are the corresponding coefficients obtained in the estimation, which measure the size of the impacts.

Figure 3. The various channels of the impacts of FDI on SO_2 concentration (based on the Results of Table 2)

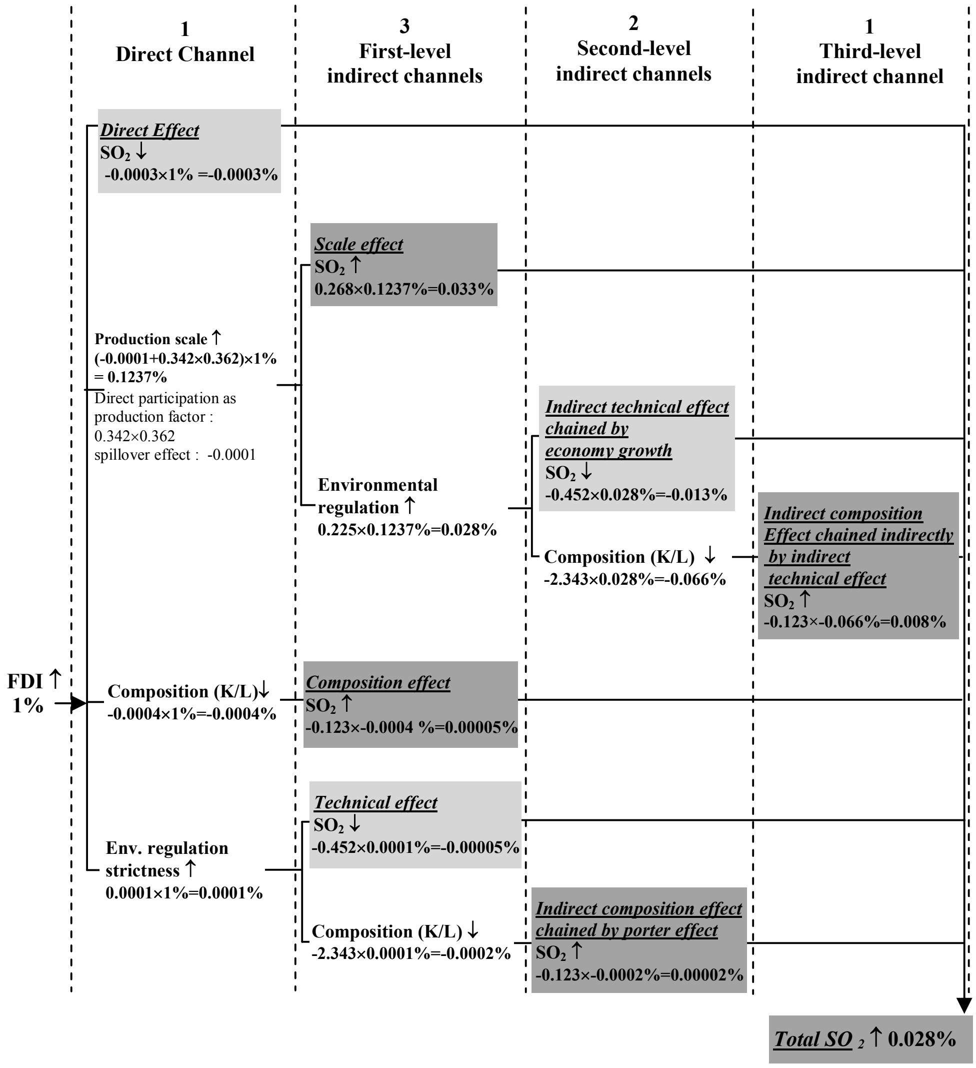


Figure 4. The various channels of the impacts of FDI on TSP_2 concentration (based on the Results of Table 2)

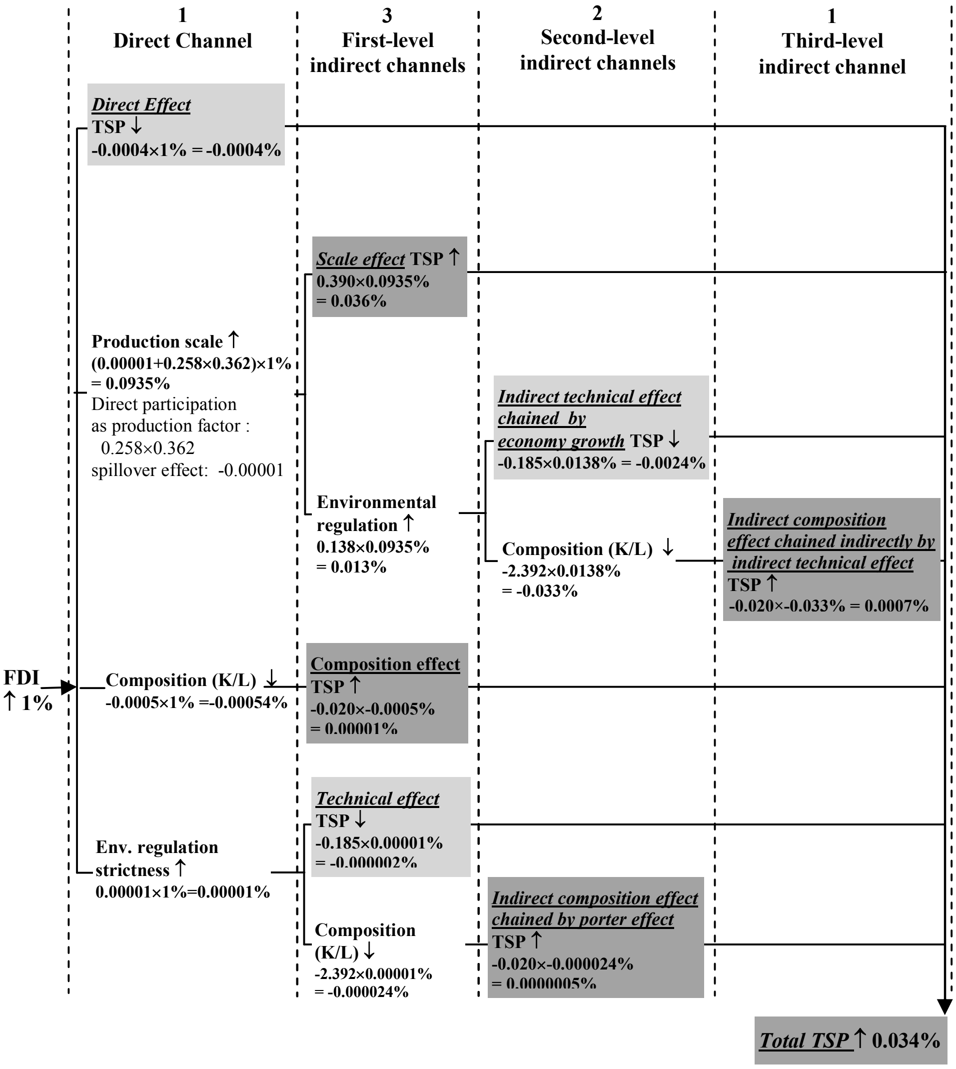


Figure 3 shows the SO_2 situation and Figure 4 highlights the TSP concentration situation. We used a light grey box to show the reduction of pollution and a dark grey box for an increase in pollution. We can see the two figures describe quite similar structures for the relationship of FDI with TSP and SO_2. With a 1% FDI stock increase, the direct FDI impact first causes pollution concentration to decrease slightly (SO_2 by 0.0003% and TSP by 0.0004%). The first-level indirect channels show that among the three pollution determinants, it is through the scale effect that FDI exerts the greatest impact on pollution. In the SO_2 situation, a 1% FDI increase enlarges the production scale by 0.1237% and results in a total 0.033% increase in SO_2 concentration. Both composition and technical effects contribute only marginally to pollution variations. The situation for the second–level indirect channels is quite similar to that of the first-level, significant pollution reduction results only from the reinforcement of indirect environmental regulation chained by FDI-led economic growth, while the pollution variation related to indirect composition effect is almost negligible. According to the estimation result of the composition determination in our system, the significant regulation reinforcement chained by FDI-led economy growth will also activate some auto-adjustment in industrial composition. However, due to the anti-intuition negative coefficient that we find for the composition effect in the pollution determination function (1*), the auto-adjustment in industrial composition to the reinforced environmental regulation turns out to be a pollution-increasing factor! However, as this counter-intuition result only predicts a very small pollution increase, (0.008% for SO_2 case and 0.0007% for TSP case with a 1% increase in FDI stock), therefore the total impact of regulation reinforcement chained by FDI-led economy will still push the pollution concentration downwards. In this sense, our results are still compliant with those of Dean (1998). This point is further confirmed by the fact that in both figures 3 and 4, the impact of FDI on pollution directly going through the composition and technical effect (illustrated in the channels starting from the composition and technical effect changes at the bottom part of the figures) is very small and in most cases negligible both in terms of magnitude and significance. How will our estimation results change if we remove the composition effect determination function and the direct impact of FDI on technical effect from the initial system?

Therefore we estimate the following simplified function system and the new estimation results are given in Table 3.

$$\frac{\dot{E}_{it}}{E_{it}} = \underset{(-)}{e_\tau} \times \frac{\dot{\tau}_{it}}{\tau_{it}} + \underset{(+)}{e_y} \times \frac{\dot{Y}_{it}}{Y_{it}} + \underset{(+)}{e_\Omega} \times \frac{\dot{\Omega}_{it}}{\Omega_{it}} + \underset{(-)}{e_{FDI}} \times \frac{\dot{K}_{F\,it}}{K_{F\,it}} \qquad (5^*)$$

$$\frac{\dot{Y}_{it}}{Y_{it}} = \underset{(+)}{y_k} \times \frac{\dot{K}_{it}}{K_{it}} + \underset{(+)}{y_l} \times \frac{\dot{L}_{it}}{L_{it}} + \underset{(+)}{y_e} \times \frac{\dot{E}_{it}}{E_{it}} + \underset{(+)}{y_{FDI}} \times \frac{\dot{K}_{F\,it}}{K_{F\,it}} + \underset{(+)}{\frac{\delta}{1+\delta}} \times \frac{\dot{F}_{it}}{Y_{it}} \qquad (6^*)^{9}$$

$$\frac{\dot{\tau}_{it}}{\tau_{it}} = \underset{(+)}{t_y} \times \frac{\dot{Y}_{it}}{Y_{it}} \qquad (7^*)$$

---

[9] Excepts the variable $(Y_{FDI}/Y)_{it}$, which is actually expressed in $(\dot{Y}_{FDI})/Y$ form in the estimation. A more detailed mathematical derivation for this simultaneous model is given in the Appendix.

Compared to table 2, the restructured system seems to give relatively stable estimation results. However, once the total impact of FDI on pollution is calculated in Figure 5 (SO_2) and 6 (TSP), the simplified model reveals a more clear-cut image for FDI's environmental impact: in the case of SO_2 pollution, FDI becomes a pollution reducing factor and in TSP case, 1% increase in FDI leads only to a 0.023% pollution increase. These differences in the final results are principally caused by the significant divergence in coefficient values of the technical effect terms. The estimation based on the simplified system seems to give more significant importance to the technical effect's pollution reduction impact.

Table 3. The results of the simplified simultaneous system: the case of the annual concentration indices of SO_2 and TSP in air

	SO_2			**TSP**		
Variables	**Pollution (E_{it})**	**Production (Y_{it})**	**Technical (τ_{it})**	**Pollution (E_{it})**	**Production (Y_{it})**	**Technical (τ_{it})**
Lagged endogenous variables						
$E_{i,t-1}$	**-0.102° (1.601)**			**0.421 (1.394)**		
Y_{it-1}		0.250*** (2.639)			0.195** (2.475)	
Ω_{it-1}						
τ_{it-1}			-0.344*** (3.276)			-0.333** (3.173)
Endogenous variables						
E_{it}		0.152*** (3.441)			0.119* (1.773)	
$Y_{it}^{(3)}$	**0.532 (4.484)**		1.245*** (4.307)	**0.386* (1.660)**		1.606*** (4.742)
Ω_{it}	**-0.014 (4.459)**			**-0.056** (2.231)**		
$\tau_{it}^{(2)}$	**-0.234*** (5.131)**			**-0.468*** (4.395)**		
Exogenous variables						
L_{it}		0.098*** (3.970)			0.085*** (3.918)	
K_{it}		0.267*** (4.729)			0.371*** (6.857)	
K_{Fit}	**-0.0003** (4.016)**	**-0.0001° (1.564)**		**-0.0002** (2.210)**	**0.0001** (2.423)**	
$\dot{Y_F}/Y$ (2)		0.015*** (5.485)			0.015*** (5.947)	
Sargan test		93.30 (0.000)			93.03 (0.000)	
Determiant residual covariance		1.12E-04			4.41E-04	

Panel data on the city level : about 80 cities, 1993-2001, Fixed Effect, GMM for simultaneous system, heteoroskedasticity and auto-correlation problems controlled.

1. The data for YFDI/Y are panel data on a provincial level.

*2. The P values in the parenthesis are already purged of the problems of heterosckedasticity and auto-correlation. *** indicates a significance of 99%, ** indicates a significance of 95% and * indicates a significance of 90%, while ° indicates a significance of 85%. The lagged endogenous variables of the system are instrumented by all the system exogenous variables lagged one and two period, inspired by Anderson and Hsiao (1982).*

Figure 5. The various channels of the impacts of FDI on SO_2 concentration (based on the Results of Table 3)

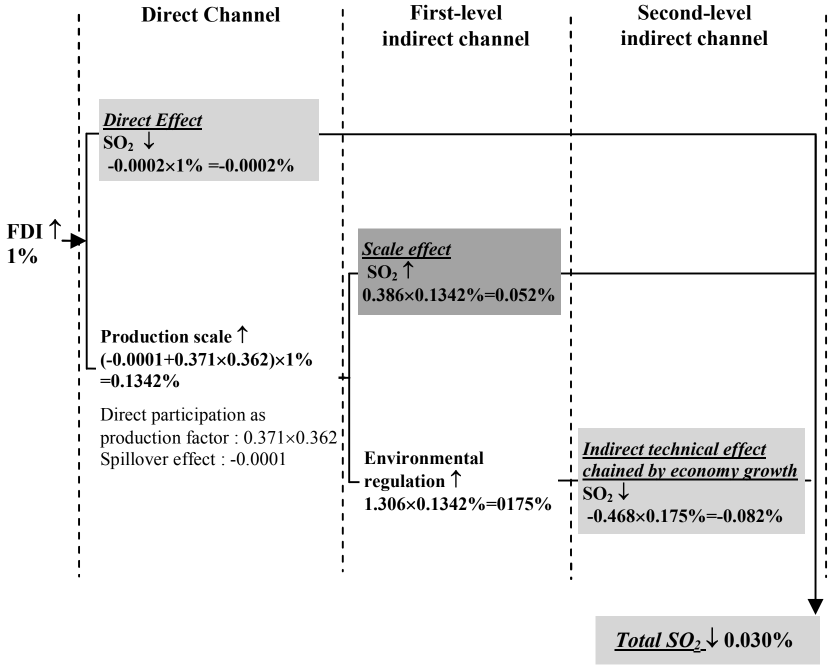
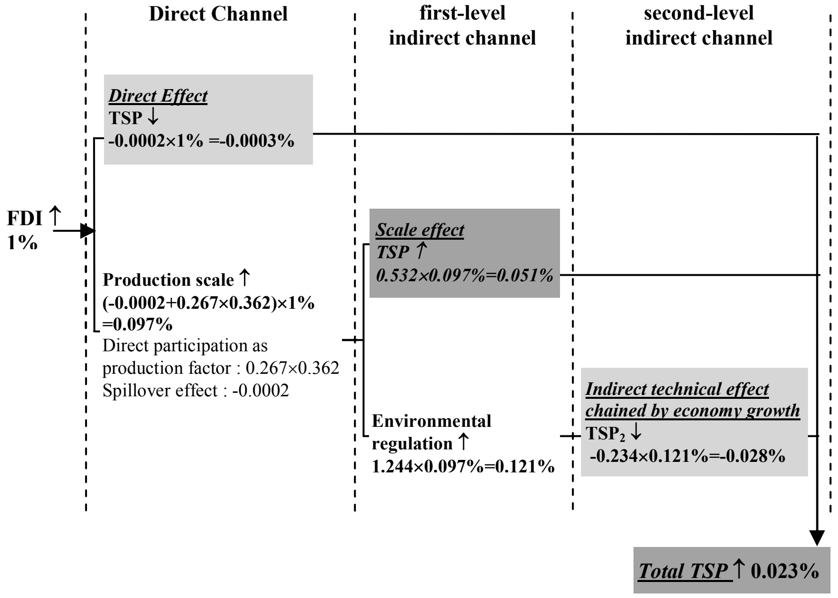


Figure 6. The various channels of the impacts of FDI on TSP concentration (based on the Results of Table 3)



3. CONCLUSION

In this paper, inspired by Dean (1998), we have constructed a simultaneous system, in which the situation of air pollution is determined by the economic scale, the industrial composition and the strictness of the environmental regulation of the economy. The role of FDI in air pollution is in fact captured from the direct inclusion of FDI into the pollution determination function and from the potential indirect channels going through the three structural determinants of environmental quality. The system is tested by annual average SO_2 and TSP concentration data in 80 Chinese cities from 1993 to 2001.

Besides a slight environmental improvement role through the direct channel, the estimation results reveal that the impacts of FDI on pollution mainly operate through the scale and technical effect. The environmental quality variations caused by FDI-led composition changes are generally negligible and insignificant. In the wake of Dean's model (1998), in which he discussed the relationship between trade and waste water emission in China, our model also emphasizes the force-contrast between the pollution deterioration tendency caused by FDI-led production scale enlargement and the possibility to reduce pollution ensured by the technical effect reinforcement benefiting from the same FDI-led economic growth. The separated estimation results for SO_2 and TSP concentration indicators gave one reasonable explanation for the divergence of the evolution tendency between these two pollution cases in China ; the technical effect is actually more successful in preventing the SO_2 concentration from increasing in proportion with economic growth. This may be due to the fact that SO_2 concentration is principally caused by coal combustion in industrial production whose sources are easier to identify and whose abatement technologies are more abundant and cheaper.

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

According to Feder (1983), the host economy can be considered as consisting of two sectors, the domestic sector H and the foreign sector F, so that:

$$
\begin{aligned}
&Y = F + H \\
&F = f(K_F, L_F, E_F) \\
&H = h(K_H, L_H, E_H, K_F) \\
&K = K_H + K_F \\
&L = L_H + L_F \\
&E = E_H + E_F \\
&\textit{and}\ : \\
&\frac{F_K}{H_K} = \frac{F_L}{H_L} = \frac{F_E}{H_E} = 1 + \delta
\end{aligned}
$$

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

With 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 effects of FDI in the host economy, a positive $H_F \times \frac{K_F}{Y}$ means FDI plays a positive spillover effects on the host economy.

The corresponding econometric production function is as follows :

$$\frac{\dot{Y}}{Y} = y_K \times \frac{\dot{K}}{K} + y_L \times \frac{\dot{L}}{L} + y_E \times \frac{\dot{E}}{E} + y_{K_F} \times \frac{\dot{K}_F}{K_F} + \frac{\delta}{1+\delta} \times \frac{\dot{F}}{Y} \qquad (2^*)$$

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INVESTISSEMENTS DIRECTS ÉTRANGERS ET POLLUTION DANS LES VILLES CHINOISES

Résumé *- Un système d’équations simultanées est construit pour évaluer l’impact des IDE sur la pollution de l’air des villes chinoises. L’indicateur de pollution est déterminé par la taille économique de la ville, la structure industrielle et le niveau de contrôle de la pollution urbaine. L’IDE, à son tour, peut affecter l’échelle de production, la structure industrielle et les progrès techniques. Le modèle est estimé pour deux types de pollution : la concentration de* SO_2 *et les particules en suspension. Basé sur les données en panel de 80 villes chinoises entre 1993 et 2001, le modèle à équations simultanées est estimé par la méthode des moments généralisés (GMM). L’estimateur de l’effet fixe pour les données de panel et la méthode proposée par Anderson et Hsiao (1982) sont inclus pour prendre en compte l’effet spécifique de chaque ville et pour contrôler le problème d’autocorrélation de premier ordre. Les résultats montrent, bien qu’il existe différents canaux de transmission à travers lesquels l’IDE affecte le niveau de pollution, que l’impact de l’IDE sur l’environnement dépend principalement de l’échelle et des techniques de production. Comparé aux études similaires, l’impact de l’IDE sur les deux types de pollution considérés est relativement faible.*