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Foreign Direct Investment, Human Capital and Environmental Pollution in China

Jing Lan · Makoto Kakinaka · Xianguo Huang

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Abstract By using provincial socioeconomic and environmental data, this paper examines the relationship between human capital, FDI and pollution emissions in China. The result shows the impact of FDI on pollution emission is highly dependent on the level of human capital. FDI is negatively associated with pollution emissions in provinces with the higher levels of human capital, whereas FDI is positively related to pollution emissions in provinces with the lower levels of human capital. This suggests that pollution haven hypothesis (PHH) holds only in those provinces with low human capital. This study also finds that the sign of FDI's effect on each pollutant' emission requires the different threshold level of human capital, which may help to reconcile the current conflicting PHH empirical evidences partially.

Keywords FDI · Human capital · Pollution haven hypothesis · Environmental pollution · China

1 Introduction

China has witnessed a continuously increasing level of foreign direct investment (FDI) over the past three decades. It is now the world's largest recipient of FDI with an inward flow of US$ 95 billion at the end of 2009, giving China an accumulated total of FDI equivalent to US$473 (UNCTAD 2010). However, increasing levels of FDI have been accompanied by

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J. Lan (✉) · X. Huang
National Graduate Institute for Policy Studies, 7-22-1 Roppongi, Minato-ku, Tokyo 106-8677, Japan
e-mail: phd09011@grips.ac.jp

X. Huang
e-mail: phd09008@grips.ac.jp

M. Kakinaka
Graduate School of International Relations, International University of Japan, 777 Kokusai-cho,
Minami Uonuma-shi, Niigata 949-7277, Japan
e-mail: kakinaka@iuj.ac.jp

increasingly noticeable deterioration in the environmental deterioration. Many researchers have sought to understand the precise relationship between them. Given the fact that FDI plays an important role in the recipient country's production through transfers of technology, questions arise as to whether FDI has turned China into "pollution haven". The answers have come with a fair bit of ambiguity as the empirical findings. Sha and Shi (2006), for example, suggest that FDI has a negative impact on environment in China, claiming that a 1 percent increase in the assets of foreign industrial enterprises was associated with an increment of 0.358% in emissions of industrial wasted gas. On the other hand, Dean et al. (2009) indicate that the pollution haven effect in China is evident mainly with FDI flows from Taiwan, Hong Kong and Macau, and their conclusions stack up against the pollution haven hypothesis (PHH) which claims that pollution havens are sought primarily by investors from the more heavily industrialized countries.

Many works have been conducted on empirical studies of the effects of environmental stringency or standard on trade and investment flows. However, they have not focused on the mechanisms through which FDI affects pollution and how that effect might vary from one country to another. Fu (2008) suggests that the host country's absorptive capacity (which is determined by the level of human capital) plays an important role in explaining the technology that accompanies FDI is diffused. Thus, the regions with higher technological capabilities due to levels of high human capital are able to adopt more advanced technologies and consequently reduce the pollution. This paper considers the mechanisms related to the transfer of technologies through FDI. If we assume, as is generally accepted, that an industry's technological level corresponds its level of human capital in the host country and is also reflected in the technological level introduced with FDI inflows, we may hypothesize (i) that the impact of FDI on environmental pollution will be influenced by the human capital level in the host country or in specific regions of that country and (ii) that higher levels of human capital will be associated with less environmental pollution as FDI flows into the country or its regions.

According to PHH, pollution in developing countries is positively correlated with FDI flow from developed countries, and FDI is also linked to the environmental regulations of host countries. Accordingly, the stringency of environmental regulations must also be introduced into our analysis. Due to the lack of a direct method to measure the stringency of such regulations within regions, this paper uses formal and informal measures.

The results of this study show that there is a clear relationship between FDI and pollution emissions. Most significantly the findings reveal that the impact of FDI on pollution emissions in China depends heavily on the level of human capital. FDI is negatively related to pollution emissions in provinces with a high level of human capital, while FDI is positively associated with pollution emissions in provinces with a low level of human capital. This leads us to conclude that the pollution haven effect arises only in the provinces with a relatively low level of human capital, where a high level of FDI is associated with high pollution emissions. Our study also discusses how FDI affects pollution emissions at the provincial level by estimating the threshold level of human capital differentiating the sign of FDI's effect on pollution emissions. This may help reconcile conflicting empirical evidence concerning the validity of the PHH.

The remainder of this paper is organized as follows. Section 2 reviews some theoretical and empirical issues about FDI's effects on environmental pollution. Section 3 provides an explanation of the econometric specification and the data. Section 4 presents the results with discussion. The final section concludes.

2 Literature Review

Many papers have attempted to explain the issues of pollution emissions from different perspectives. In his study of what determines the level of pollution, Lamla (2009) uses three indicators of the level of pollution with a data set of 34 variables in 47 countries over the period 1980–2000 and confirms the environmental Kuznets curve hypothesis of a non-linear relationship between output and pollution. Concerning the relationship between FDI and pollution in developing countries, one of the major debates concerns the PHH (Bommer 1999; Cole 2000; Letchumanan and Kodama 2000; Ederington 2007). The hypothesis is that developed countries transfer their pollution-intensive industries to developing countries through FDI by taking advantages of lower labor costs and lower environmental standards. It is further posited that developing countries are likely to "race-to-bottom" by undervaluing environment damage in order to attract more FDI. The consequence of such processes is that excessive pollution and environmental degradation occurs in the developing countries. There are numerous empirical studies on this hypothesis with mixed findings.

As for evidence supporting PHH, List and Co (2000) employ a conditional logit model to estimate the effect of state environmental regulations on foreign multinational corporations' new plant locations between 1986 and 1993. Their findings suggest that the stringency of environmental control and the attractiveness of a location are negatively related. The implication is that foreign investment is sensitive to environmental standards. Xing and Kolstad (2002) conduct an inter-country analysis to examine how US FDI is influenced by environmental regulations in developing countries, and find that lax environmental regulation in a host country is a significant determinant of FDI from the US. He (2006) establishes a simultaneous system using panel data on industrial SO_2 emission in China's 29 provinces, and the results show that with a 1 percent increase in the FDI capital stock, industrial SO_2 emission will increase by 0.099%, providing convincing evidences supporting the PHH in China.

Another study by Zhang and Fu (2008) also supports the PHH with regard to China by employing an inter-regional analysis to measure how sensitive FDI is to governmentally enacted environmental controls. The estimates of Baek and Koo (2009) are also consistent with the PHH. They apply cointegration analysis and a vector error-correction model to look at the short-run and long-run relationship between FDI and the environment in China and India. Kellenberg (2009) also yields a further confirmation of the pollution haven effect from his cross-country study which seeks to account for strategically determined environment, trade and intellectual property right policies. Dean et al. (2009) examine pollution haven behavior by estimating the determinants of location choice for equity joint ventures (EJVs) in China. Their results show that weak environmental standards attract EJVs in highly-polluting industries funded through ethnically Chinese sources such as Hong Kong, Macao, and Taiwan, while they do not significantly attract EJVs funded from non-ethnically Chinese sources regardless of the pollution intensity of the industry. More recently, Cole et al. (2011) investigate the relationship between economic growth and industrial pollution emissions in China using data for 112 major cities between 2001 and 2004. Their research also indicates that FDI is directed to regions with relatively weak environmental regulations, which also provides some evidence for the existence of the pollution haven effect in China.

Other findings, however, do not lend support to the PHH. Birdsall and Wheeler (1993), for example, argue that the more open an economy, the more likely it is to attract cleaner industries. They conclude that FDI inflows may impact the environment in a positive manner in some developing countries, suggesting that the reality is more complex than what the pollution-haven hypothesis tells. Eskeland and Harrison (2003) challenge the hypothesis claiming that foreign firms tend to use cleaner and more efficient energy and show that increased FDI in Latin America is not linked with the emission of pollution intensive industries. Jaffe et al. (1995) review the literature and conclude that there is hardly any empirical support for the existence of a pollution heaven effect. Several studies focusing on Asia find that "rapidly spreading multinational facilities are relatively clean" because they employ more environment-friendly technologies (Huq and Wheeler 1993; Pargal and Wheeler 1996; Hartman et al. 1997). This result is also significant in Indonesia, Thailand, China, and South Asia (Afsah et al. 1996).

According to Porter's hypothesis (Porter and Van Der Linde 1995), strict environmental regulations induce firms to innovate in ways that create cleaner products and production processes rather than inducing migration of dirty industries to locations with less stringent environmental standards. Wang and Jin (2007) examine firm-level pollution discharge in China to explore the differences in the pollution control performance of industrial enterprises with various types of ownerships. They find that investments driven by community owned enterprises perform better environmentally than projects undertaken by state owned enterprises and private owned enterprises. Using a nested logit model, Di (2007) shows that FDI firms in polluting industries tend to locate in Chinese provinces with higher potential abatement costs savings adjusted for local environmental regulation. The study of Zheng et al. (2010) with cross-city panel data in Chinese cities argues that FDI does not appear to facilitate the growth of pollution havens in China, since the marginal valuation for green amenities rises over time, and Chinese cities with higher levels of per-capita FDI flows have lower pollution levels.

Many studies of the controversy surrounding the PHH have been done to explain what may cause different empirical results. Researchers, such as Dean et al. (2009) and Eskeland and Harrison (2003), argue that the environment-friendly FDI inflow of joint ventures which are specialized in pollution abatement technology may be an important factor that undermines PHH. The invalidity of PHH can be explained by the "technology effect" and it acts through the channel of advanced technological treatment into countries which would otherwise have serious emissions. Caselli and Coleman (2001) show that most developing countries acquire embodied technologies through capital imports from technological leaders, but the technology effect from the adoption and implementation of advanced technologies may be affected by human capital level in recipient countries. Thus, human capital can at least partially explain an economy's capacity to absorb new technologies including pollution abatement technologies (Romer 1991). Costantini and Monni (2008) point to the importance of investment for human capital accumulation in order to have sustainable development. In this regard, the evidences from cross-country studies show that there is a minimum threshold level of human capital necessary for sustainable growth (Eaton and Kortum 1997; Xu 2000).

Considering the concerns above, this study seeks to clarify the relationship between FDI, environmental pollution, and human capital. It proposes a mechanism by which the environmental impact of FDI is tempered through the technology effect. The model reveals that the location choice of environment-friendly FDI with pollution treatment technology depends on the level of human capital. It suggests that a place with higher levels of human capital is more likely to absorb advanced green technology and experience less environmental pollution. On the other hand, a place with lower levels of human capital is associated with less green technology and more environmental pollution.

3 Methodology

3.1 The Empirical Model

This study examines the link between human capital and its influence on FDI's environmental effect. In this paper, a crucial variable-an interaction term between FDI and human capital is introduced to capture regional disparity in FDI's environmental effect which depends on levels of human capital. The basic empirical specification is:

$$P_{it} = \alpha + \beta_1 FDI_{it} + \beta_2 H_{it} + \beta_3 H_{it} \times FDI_{it} + \beta_X X_{it} + \eta_i + \gamma_t + \varepsilon_{it}. \tag{1}$$

The subscripts i and t denote region and year respectively, P_{it} denotes pollution emissions intensity measured as pollution emission per unit of industrial value-added. The variable H_{it} is the level of human capital stock measured as the average years of schooling. X_{it} is a set of regional controls, including energy consumption ($energy_{it}$), capital intensity (CI_{it}), the degree of industrialization (Ind_{it}), investment in pollution treatment ($RegIPT_{it}$), unemployment rate ($RegUER_{it}$), population density ($RegPD_{it}$), and the degree of public ownership ($RegPO_{it}$). The variable η_i stands for time-invariant regional specific effects whilst γ_t denotes to location-invariant time specific effects. Equation (1) is estimated for 29 provinces in mainland of China, and the period covers 11 years from 1996 to 2006. The data information is shown in Appendix Tables A1 and A2.

Considering all variables above, our estimating equation originating from equation (1) can be described by:

$$\begin{aligned} P_{it} = {} & \alpha + \beta_1 FDI_{it} + \beta_2 H_{it} + \beta_3 H_{it} \times FDI_{it} + \beta_4 energy_{it} + \beta_5 CI_{it} + \beta_6 Ind_{it} \\ & + \beta_7 RegIPT_{it} + \beta_8 RegUER_{it} + \beta_9 RegPD_{it} + \beta_{10} RegPO_{it} + \eta_i + \gamma_t + \varepsilon_{it}, \end{aligned} \tag{2}$$

The expected sign of β_1 is positive, that is, FDI is positively related to environmental pollution, indicating the existence of pollution haven effect; the expected sign of β_2 is negative which means human capital plays a positive and important role of environment improvement, and a place with a higher level of human capital is associated with a lower degree of pollution; the expected sign of β_3 is negative, implying that when FDI is combined with well-educated human capital, it can reduce environmental pollution. Applying the derivative of the empirical Eq. 2 shows that:

$$\frac{\partial P}{\partial FDI} = \beta_1 + \beta_3 H. \tag{3}$$

When $\beta_1 > 0$ and $\beta_3 < 0$ as expected, the relationship between human capital and the impact of FDI on pollution can be represented as Fig. 1.

Figure 1 illustrates the positive and negative FDI's environmental effects under different levels of human capital. The sign of $\partial P/\partial FDI$ can shift from positive to negative when the level of human capital surpasses a certain threshold. When the level of human capital is less than the threshold H_0, $\partial P/\partial FDI > 0$ holds. In this case, FDI is positively related to pollution emission and tends to increase environmental pollution when human capital is at the relatively low level. In contrast, when the level of human capital reaches above H_0, $\partial P/\partial FDI < 0$ holds. In this case, FDI is negatively correlated with environmental pollution at the relatively high level of human capital, i.e., the higher level of human capital is associated with the lower degree of environmental pollution.

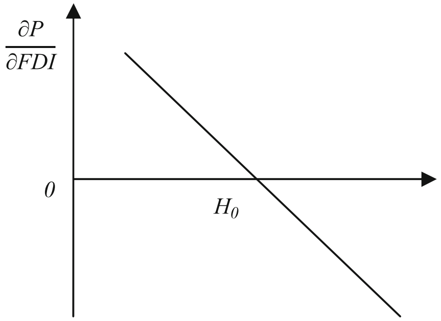

Fig. 1 The relationship between human capital and $\partial P/\partial FDI$

3.2 Main Variable Descriptions

3.2.1 Pollution Variables

The dependent variable, P_{it}, is pollution emission intensity measured as pollution emission per unit of industrial value-added. Considering the fact that FDI in China mainly flows into industrial sectors, especially manufacturing sectors, Eq. 1 is estimated separately for three distinct industrial pollutants, namely water, soot and SO_2. Waldkirch and Gopinath (2008) outline a number of conditions that make the pollutant relevant in their study. In this paper, similarly, we claim that the pollutants that is useful for our analysis should (a) be a by-product of the production process, (b) exist with available pollution abatement technologies for implementation, and (c) be sensitive to environmental stringency due to its noxious effect on the population. In addition, the selection of pollutants is also limited due to the data availability.

3.2.2 FDI Stock

The measurement for FDI faces the problem of variables to employ either stock or incremental variable, and in the meantime, depreciation should also be taken into account. Data on FDI is available for only annual increment of FDI from National Bureau of Statistics of China database. Similar to the relationship between capital and investment, FDI should be transformed to a stock variable since FDI inflow does not have immediate influence on the pollution emission in production. Using the formula of capital stock for reference, FDI stock can be calculated as follows:

$$FDI_{i,t+1} = (1-\delta)\, FDI_{it} + \frac{I^{\mathrm{F}}_{i,t+1}}{p_{it}}, \tag{4}$$

where δ, I^F, FDI and p are the average depreciation rate, annual FDI inflow, FDI stock, and the price index of FDI, respectively.[1] This paper calculates the FDI stock for each province from the initial year that has the data of FDI inflow to year 2004.[2] Considering the availability of the data, a balanced panel of 29 regions over a 11-year period from 1996 to 2006 is applied in this paper. Following Yao (2006), the average depreciation rate is 7.5%,

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[1] The price index of FDI is in accordance with annual consumer price index of the U.S.

[2] As for the initial year of FDI stock, though the data of FDI stocks in most provinces is available from the beginning of 1982, some did not have the data of FDI stock as late as 1985. Thus, the initial year for each province is different.

indicating that the average using age of capital goods is 13.3 years which is consistent with the using age of capital recommended by the government.

3.2.3 Human Capital Stock

Although human capital is hard to define and measure precisely, it seems sensible to quantify it by the accumulated educational investment embodied in the current labor force. As a stock variable, educational attainment takes into account the total amount of formal education received by the labor force. The average years of schooling has been commonly used as the specification of the quantity of human capital stock empirically. Several studies, such as Barro and Lee (1993),Barro and Lee (2001),Krueger and Lindahl (2001),Wang and Yao (2003), and Cohen and Soto (2007), have tried to construct data on school or educational attainment as a proxy of human capital stock.

This paper adopts the average year of schooling to measure the educational attainment of the population aged 15 and above as an indicator of human capital stock at the provincial level. To handle the problem of low frequency of Chinese population census, we follow the perpetual inventory method of Barro and Lee (2001) and use school enrollment ratios to construct current flows that are added to the benchmark stock (census observations only in 1990 and 2000). We categorize five levels of schooling for people aged 15 and above as follows: no school, primary, junior secondary, senior secondary and higher. We also distinguish incompletion and completion of schooling to derive the completion ratio at each level of schooling (for further details, see Barro and Lee 1993, 2001).[3] By using the distribution of educational attainment analyzed from data and the actual duration of schooling at each level adjusted by the completion ratio, we generate the number of the average year of schooling for each province (see the summary statistics in appendix Table A3).

3.3 Regional Controls

Following Pargal and Wheeler (1996) and Cole et al. (2008), we investigate other regional determinants of pollution emissions by using a "pollution demand-supply" framework where pollution is considered as the use of an environmental service. The demand for pollution is defined as the demand for environmental service, which can be considered as an additional input in production, while the supply of pollution is defined as the amount of pollution emission that is allowed to emit within a community. The greater the pollution generated in a region, the higher the costs or pressure imposed by a local community.

3.3.1 "Demand" Variable Considerations

(1) Energy consumption
The Chinese economy relies highly on the production in heavy industries which require high levels of raw materials and energy inputs. Since the use of raw materials and energy inputs is likely to be a crucial determinant of industrial pollution, we expect that provinces with more energy intensive production tend to have greater demand for pollution. In the paper, $energy_{it}$ denotes total energy consumption per unit industrial value-added,

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[3] Following the same processing method of Barro and Lee (2001), we use half of the total duration to people who enter primary school but do not complete it. The duration of primary school is 6 years, and the duration of each of two phases of secondary schools is 3 years. Moreover, the duration of higher education is 4 years.

including consumption of coal, coke, crude oil, gasoline, kerosene, diesel oil, fuel oil, natural gas, and electricity.

(2) Physical capital intensity
In this paper, CI_{it} denotes physical capital intensity which is measured as the total capital used in production divided by total labor employed. The pollution level of an industry may be influenced by its physical capital intensity. As generally (or traditionally) polluting heavy industries employ more capital in their production, the common sense suggests that physical capital intensity can be regarded as an approximation for environmental performance of the industrial structure of an economy, i.e., higher capital intensity (measured by capital/labor abundance ratio) means that more intensive polluting industries are concentrated in an economy.
The anecdotal studies show that those sectors that confront the largest cost of abatement per unit of industrial value added also have the greater requirements of physical capital (Antweiler et al. 2001; Cole et al. 2003, 2006). In China, the recent evidence suggests that those industries that are the most reliant on machinery and equipment generate more pollution emission than those that is more dependent upon labor. According to Cole et al. (2006), one possible interpretation is that physical capital intensive industries are the most energy intensive, and even after controlling for energy consumption, there may be a positive relationship between physical capital use and pollution.

(3) Investment in pollution treatment
The investment in pollution treatment, $RegIPT_{it}$, is the total investments of enterprises in construction and installation projects, and the purchase of equipment and instruments required in pollution harnessing projects for the treatments of waste water, waste gas, solid wastes, noise pollution, and other pollution. Due to the fact that most of investment in pollution treatment is from enterprise self-fundraising in China, we categorize *RegIPT* into the demand side factor of emission determination. The higher level of investment is associated with the lower demand for emissions.

3.3.2 "Supply" Variable Considerations

Following Cole et al. (2008), "the environmental supply schedule" is determined by environmental regulations, which would guarantee that the larger use of environmental service, the higher costs it imposes. Environmental regulations can be defined as formal and informal regulations. With regards to formal regulations, regional authorities carry out pollution controls, such as command, taxes, and tradable permit, on behalf of community. Differently from formal regulation, informal regulation is the leverage provided by social pressure which can lead to the compliance with community-determined standards of acceptable performance. In this paper, we use regional determinants of formal and informal regulations to measure the supply of pollution emissions.

(1) Unemployment rate
Since the stress imposed on pollution regulations by local authorities may rely on the social problems within a province, a provincial unemployment rate ($RegUER_{it}$) could be included to reflect the social status of that province. Although it is generally admitted that a more tightening environmental regulation will reduce pollution, the fear that the enforcement of these regulations would exacerbate the problem of unemployment is widespread. The unemployment rate might affect local pollution regulations via two channels (Cole et al. 2008). First, a high unemployment rate in a region might divert the attention of local authorities to devote more resources to deal with unemployment,

which allocates fewer resources to controlling pollution. Second, communities in a region may put up with polluting plants nearby if they provide more job opportunities. Such a phenomenon is more likely to emerge in regions with a high unemployment rate. The high level of unemployment limits the scope for active environmental policies. Thus, regions with a high unemployment rate are more likely to have lax environmental regulations and attract more pollution intensive industries (Gray and Deily 1996).

(2) Population density

Regional environmental regulations may be a function of a region's population density ($RegPD_{it}$). On the one hand, given the same income and pollution levels, higher population density intensifies the marginal damage of pollution and hence opposition to a pollution intensive plant may be greater (He 2006). On the other hand, within a densely populated area a pollution intensive plant may be less 'visible' and hence is less likely to attract local people's attention (Cole et al. 2008). Thus, population density can be included as a determinant for environmental regulation stringency in order to examine which of these competing effects is dominant.

(3) Degree of public ownership

The degree of public ownership ($RegPO_{it}$) might also play a role in determining regional regulations. State-owned enterprises (SOEs) are likely to be less efficient, creating more waste residuals and pollution than other counterparts (Dasgupta et al. 1997). It is common that SOEs in China have stronger bargaining powers with local environmental authorities. In developing countries the informal regulation is in effect no matter how the formal regulation is absent or effective (Wang and Jin 2007), and its soft budget constraints might reduce the managers' responsiveness to pollution charges. Besides, it is acknowledged that it is difficult for government regulators to punish violations by state-owned enterprises. Political and bureaucratic factors such as corruption seem to hinder the effective inspection of government agencies by another (Hettige et al. 1996). If the situation is similar in China, we would expect that public ownership tends to increase pollution emissions.

3.4 Model Selection and Potential Problems

As η_i is part of the unobserved error term and it is correlated with the error term, OLS estimates are biased. Thus, we need to check whether the unobserved regional specific effects and time effects (η_i and γ_t) should be treated as random variables or as parameters to be estimated for each cross-region observation i and time t. This study estimates both fixed effects and random effects error component models. For the fixed effects models, we use the within regression estimator which is a pooled OLS estimator based on time de-mean variables. For the random effect models, we use the generalized least square (GLS) estimator which generates a matrix average of the between and within estimator results. In order to check whether ε_{it} are uncorrelated with the independent variables and choose a valid model, this paper employs the Hausman specification test under the null hypothesis $\mathrm{H}_0:\ \mathrm{E}\ (\varepsilon_i|X_{it}) = 0$.

As there are some regional control variables in the model, endogeneity is one of the potential problems. The regional unemployment rate (*RegUER*) could have reverse causality with pollution intensity, since pollution causes worse environments for investment, which may provide less employment opportunity. It is also likely to have an endogenous problem for the investment in pollution treatment (*RegIPT*). As more social attention is paid to the pollution issue, it may bring more investment to alleviate it. Other possible endogenous problems may include population density (*RegPD*) and public ownership (*RegPO*). For instance, population density in a region may also be determined by that region's pollution severity. Individuals may choose not to reside near a pollution-intensive area and accordingly the population density of that area could be lower (Cole et al. 2008). To address this problem, we carry out Davidson-MacKinnon tests by using lagged variables, *RegUER*, *RegIPT*, *RegPD*, and *RegPO*, as the instrument variables.

The other potential problem is multicollinearity between human capital stock and FDI as FDI entry decision are dependent on human capital stock of the recipient area, which can also lead to the biasedness of estimates. We will check the sign stability of FDI coefficient by adding and dropping of the interaction terms which help to evaluate the result of the model.

4 Estimation Result and Discussion

4.1 Main Results

As we use provincial level panel data, our empirical analysis shall pay attention to the dynamic panel data characteristics of our database. Since the regional specific characteristics are part of the unobserved error term and it may be correlated with the error term, OLS estimates may be biased. Meanwhile, Hausman tests suggest random effect estimates are inconsistent (see Table 1). Thus, this paper places great emphasis on fixed effect results.

Moreover, Davidson–MacKinnon tests under fixed effect model reject the null of consistency for *RegUER, RegIPT, RegPD* and *RegPO*, suggesting no simultaneity bias among them (see Table 1). Therefore, our estimates are not biased by the endogeneity problem. Furthermore, Table A4 in the appendix reports OLS results of specification Eq. 2 without and with the interaction term. Our tests for multicollinearity in the table show the signs of FDI and human capital stock coefficients are stable before and after the inclusion of the interaction term for the three pollution proxies. Thus, multicollinearity problem is not serious concern in the paper.

The main results are shown in Table 1 for both fixed effect and random effect specifications. The dependent variable is pollution emission intensity of industrial waste water emission, industrial soot emissions, and industrial sulfur dioxide, denoted as WATER, SOOT and SO_2. The Hausman specification test rejects the null of consistency when using these three industrial emissions as the dependent pollution variables. Thus, the Hausman test suggests that fixed effects results may be considered appropriate for WATER, SOOT, and SO_2. Estimations of Eq. 1 under different scenarios are presented as below: columns (1), (3) and (5) are fixed effects estimations for WATER, SOOT and SO_2, respectively, without formal and informal regulation controls. Columns (2), (4) and (6) are fixed effects estimations for these three pollutants with regulation controls. Columns (7), (9) and (11) are random effects estimations without regulation controls, and columns (8), (10) and (12) with regulation controls.

4.1.1 Human Capital and FDI's Environmental Effect

Focusing on statistically significant coefficients in the fixed effects models of SOOT, WATER, and SO_2, Table 1 shows that pollutants have a positive relationship with FDI and a negative relationship with human capital stock (H) and its interaction with FDI (H*FDI). Recall from Eq. 1 that the coefficient on FDI is expected to be positive under the PHH, and the coefficients on human capital stock (H) and the interaction (H*FDI) are expected to be negative. Thus, our regression analysis is consistent with the expected results in the previous sections. The results suggest that FDI's environmental effect can be influenced by the level of human capital stock. The positive coefficient on FDI and the negative coefficient on the interaction

Table 1 Results of fixed and random effect

	Fixed effect						Random effect					
	(1) WATER	(2) WATER	(3) SOOT	(4) SOOT	(5) SO$_2$	(6) SO$_2$	(7) WATER	(8) WATER	(9) SOOT	(10) SOOT	(11) SO$_2$	(12) SO$_2$
H*FDI	−0.369	−0.427	−0.513	−0.515	−0.015	−0.008	−0.199	−0.245	−0.423	−0.327	−0.025	−0.005
	(−2.11)**	(−2.26)**	(−2.31)**	(−2.15)**	(−1.94)*	(−1.79)*	(−2.23)**	(−1.49)	(−2.06)**	(−1.50)	(−1.86)*	(−0.23)
H	−0.028	−0.026	−0.026	−0. 029	−0.025	−0.019	−0.019	−0.164	−0.018	−0. 023	−0.024	−0.017
	(−5.98)**	(−5.07)**	(−4.40)***	(−4.53)***	(−7.05)***	(−4.95)***	(−5.25)***	(−4.21)***	(−3.70)***	(−4.15)***	(−6.84)***	(−4.52)***
FDI	2.941	3.392	3.831	3.829	0.058	0.102	1.748	2.044	3.207	2.504	−0.182	−0.044
	(2.40)**	(2.53)**	(2.17)**	(2.25)**	(1.25)	(1.92)**	(1.55)	(1.72)*	(2.17)**	(1.60)	(−0.72)	(−1.88)**
Energy	5.873	5.724	12.024	12.538	0.591	1.268	3.631	3.237	9.161	9.797	−0.609	−1.371
	(4.57)***	(4.31)***	(7.35)***	(7.43)***	(1.14)	(2.37)**	(4.37)***	(3.97)***	(7.91)***	(8.07)***	(−1.19)	(2.55)**
CI	0.012	0.014	0.017	0.015	0.001	0.001	0.126	0.013	0.015	0.015	0.0007	0.0003
	(2.78)***	(3.00)***	(3.13)***	(2.62)***	(1.75)*	(1.95)**	(3.69)***	(3.76)***	(3.26)***	(3.15)***	(1.30)	(1.14)
Ind	−0.157	−0.178	−0.158	−0.130	−0.186	−0.169	−0.065	−0.069	−0.064	−0.076	−0.182	−0.159
	(−2.56)**	(−2.76)***	(−2.03)	(−1.61)	(−4.26)***	(−3.94)***	(−1.49)	(−1.58)	(−1.04)	(−1.19)	(−4.38)***	(−3.87)***
RegIPT		0.468		−0.172		−3.098		0.221		−0.081		−2.393
		(0.68)		(−1.96)**		(−2.89)***		(0.32)		(−0.54)		(−2.20)**
RegUER		0.001		0.003		0.005		−0.0007		−0.0006		0.005
		(0.35)		(0.82)		(3.14)***		(−0.31)		(−0.21)		(3.50)***
RegPD		0.0005		0.0005		0.0003		0.0005		0.005		0.0003
		(0.49)		(0.41)		(0.45)		(0.53)		(0.41)		(0.36)
RegPO		0.032		0.035		0.046		0.023		−0.051		0.059
		(1.79)*		(2.03)**		(2.55)**		(1.00)		(−1.66)*		(3.41)***
F-statistic	37.30	22.32	44.73	26.86	60.66	50.52						
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)						

Table 1 continued

	Fixed effect						Random effect					
	(1) WATER	(2) WATER	(3) SOOT	(4) SOOT	(5) SO_2	(6) SO_2	(7) WATER	(8) WATER	(9) SOOT	(10) SOOT	(11) SO_2	(12) SO_2
Wald chi2							198.47	195.35	276.21	279.22	109.18	139.62
							(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
R^2	0.592	0.599	0.535	0.521	0.322	0.388	0.590	0.547	0.611	0.631	0.319	0.382
Hausman							30.94	25.50	29.16	24.99	28.99	29.69
FE.V RE							(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
D-M Exog.												
RegUER		1.37		2.73		1.87						
		(0.29)		(0.42)		(0.53)						
RegIPT		0.68		1.07		3.58						
		(0.13)		(0.11)		(0.10)						
RegPD		1.34		1.72		0.71						
		(0.33)		(0.18)		(0.39)						
RegPO		5.76		3.23		0.19						
		(0.23)		(0.56)		(0.66)						
N	319	319	319	319	319	319	319	319	319	319	319	319

T-statistics in parentheses for fixed effects and Z-statistics in parentheses for random effects. *Significant at 10% level; **significant at 5% level; ***significant at 1% level. The dependent variables are expressed in terms of pollution intensities, measured as emissions per unit of industrial value added. All regressions include a constant (not reported). D-M Exog is the value of Davidson and Mackinnen test for exogeneity and the test cannot be performed for random effects estimations term reveal that there exists the pollution haven effect in China, but the PHH is appropriate only to provinces with low human capital.

From our results in columns (2), (4), and (6), we can get the threshold value for years of schooling are 7.94 for WATER, 7.43 for SOOT, and 12.75 for SO_2. Concerning WATER and SOOT, FDI inflow is associated with low pollution emissions in provinces with a high level of human capital, such as Beijing, Tianjin, and Shanghai. In contrast, a high level of FDI is associated with high pollution emission in provinces with a low level of human capital, such as Yunnan, Guizhou, and Gansu. As for SO_2, the threshold value of years of schooling is as high as 12.75 years, which is even higher than the highest regional human capital level (Beijing) during the given period. This implies that the level of human capital is lower than the required level for reducing industrial SO_2 emissions for all provinces.

4.1.2 Pollution Supply

(1) Energy consumption

The estimation result shows the significantly positive coefficient for energy consumption (*energy*), as expected. This suggests that the increasingly deteriorated environment might be accountable on excessive consumption of energy. In recent decade, China's industrial production depends heavily on energy consumption that has been increasing rapidly. To adopt energy-saving and environment friendly technology, workmanship, and equipment is of great importance in China.

(2) Capital intensity

With regard to capital intensity (*CI*), the result shows that provinces with high capital intensive industries generate more pollution than those with high labor intensive industries for all pollution proxies, WATER, SOOT, and SO_2, which is consistent with our intuition suggesting that industrial sectors using capital intensively in the production process generate serious pollution problems. This confirms the argument in Copeland and Taylor (2004) that pollution intensities of production are correlated with capital intensities.

(3) The degree of industrialization

The degree of industry agglomeration in each province is captured by *Ind*. The negative coefficients are found in the regression results for the three pollution proxies, although the model of SOOT shows less significant coefficients. The negative sign indicates that provinces with the higher degree of industrialization are associated with the less pollution intensity. This result is also consistent with the theory. According to Zeng and Zhao (2009), the location of industries is conventionally determined by comparative advantage of factor endowments and differences in technology, instead of pollution policies. Industrial agglomeration engenders positive externalities by facilitating knowledge spillovers, upgrading the skill set of the labor force, and multiplying forward and backward linkages between industries. Thus, the omission of externalities from industrial agglomeration can account for the lack of evidence for the PHH in the previous work. Considering that manufacturing production usually involves technologies of increasing returns to scale, the agglomeration force of industries might be a potential reason for firms not to locate in pollution haven places.

(4) Investment in pollution treatment

Turning to the variable of investment in pollution treatment (*RegIPT*), the coefficients associated with pollution proxies of SOOT and SO_2 are significant with expected negative signs. This result indicates that both SOOT and SO_2 are a decreasing function of investment in pollution treatment. The significantly negative signs show that the more investment in pollution treatment is linked with less pollution, implying that Chinese government's investment in pollution treatment is effective. For another pollution proxy, WATER, we fail to find a significant relationship between industrial waste water emission and investment in pollution treatment.

4.1.3 Pollution Demand

(1) Unemployment rate
The coefficients on unemployment rate (*RegUER*) show an insignificant impact of unemployment rate on pollution intensity for WATER and SOOT but a significantly positive impact for SO_2. One possible explanation of the insignificant coefficients resides in the distempered function of the labor market. The existence of structural unemployment and frictional unemployment weakens the substitution effect of pollution and unemployment. Hence, the seemingly positive or statistically insignificant correlation between provincial unemployment rate and pollution emission emerges in the result.

(2) Population density
In terms of population density (*RegPD*), the results show insignificant coefficients for all pollution indicators. One possible reason could be imputed to a statistic aspect. The population data censored in China consists of errors and omission. He (2006) mentions that the rigid "Hukou" registration system and "family-plan" policy weakens the reliability of the population data, particularly in the richer coastal provinces, and also they ignore the inter-province migration. An underestimation for the population density in richer province and an overestimation for those in the poorer ones may exist. This unavoidable weak point confounds the correlation between population density and environmental regulation stringency. The second reason might be linked to the phenomenon of agglomeration and urbanization. Verhoef and Nijkamp (2002) suggest that the potential cost of pollution control is accentuated in the agglomeration economy. If people place more importance on economic growth rather than environmental protection, it may deter the progress of the reinforcement of environmental regulation in the agglomeration economy.

(3) Degree of public ownership
The results consistently show that pollution intensity is significantly and positively associated with public ownership (*RegPO*) for all of three pollution proxies. Region with a high degree of public ownership tend to generate more pollution. In addition to the reason mentioned in the previous section, the state-owned ownership is relatively less efficient in terms of resource allocation, including organizing in pollution treatment. The results provide a piece of suggestion for the policy makers. To protect the environment efficiently, it might be better for state-owned capital to withdraw timely from the market.

4.2 Estimated Elasticity Analysis

The focus of this paper is to examine the impact of FDI on environmental pollution in relation to human capital. The elasticity of environmental pollution to a change in FDI for each region helps assess and compare FDI's environmental performance under different levels of human capital.

Recall that the threshold value (H^*) of years of schooling for WATER is 7.94. We divide all provinces into two groups, provinces with a low level of human capital ($H < 7.94$) and

Table 2 The estimated elasticities of WATER

	$\overline{\mathrm{H}}$	$\overline{P}$	$\overline{FDI}$	$\varepsilon = \frac{\overline{FDI}}{\overline{P}} \times (\beta_1 + \beta_3\overline{\mathrm{H}})$
Low H (H<H*)	7.22	0.029	0.043	0.46
High H (H>H*)	8.65	0.012	0.056	−1.41

Table 3 The estimated elasticities of SOOT

$\overline{\mathrm{H}}$	$\overline{\mathrm{H}}$	$\overline{P}$	$\overline{FDI}$	$\varepsilon = \frac{\overline{FDI}}{\overline{P}} \times (\beta_1 + \beta_3\overline{\mathrm{H}})$
Low H (H<H*)	6.88	0.068	0.058	0.24
High H (H>H*)	8.31	0.033	0.047	−0.64

provinces with a high level of human capital ($H > 7.94$). Table 2 shows the elasticities, which are calculated based on the average levels of human capital, pollution emission, and FDI, for each of the two groups and indicates that FDI's performance on environmental pollution varies by the level of human capital. The elasticities for provinces with a low level of human capital and for provinces with a high level of human capital are 0.46 and −1.41, respectively. This suggests that a 10% increase in FDI per unit of value added will lead to 4.6% increase in pollution intensity of industrial waste water emission for provinces with a low level of human capital. In contrast, a 10% increase in FDI per unit of value added will reduce industrial waste water emission intensity by 14.1% for provinces with a high level of human capital.

Similarly, we use the threshold value of years of schooling (7.43) for SOOT to classify provinces with a low level of human capital and provinces with a high level of human capital. The calculated elasticities of SOOT to a change in FDI per unit of value added for each group are shown in Table 3. The results are consistent with the results for WATER. The elasticity is negative for provinces with a high level of human capital, while it is positive for provinces with a low level of human capital. Specifically, a 10% increase in FDI per unit of value added will lead to a 2.4% increase in soot intensity for provinces with a low level of human capital. Conversely, a 10% in FDI per unit of industrial valued added will reduce soot intensity by 6.4% for provinces with a high level of human capital.

Elasticity analysis for SO_2 cannot be conducted since the threshold value of years of schooling is as high as 12.75 years, which is even higher than the highest regional human capital level (Beijing) for the given period. This indicates that for all provinces, the levels of human capital are lower than the threshold level to reduce industrial SO_2 emission by FDI, and FDI fails to contribute to reduce SO_2 emission for all provinces.

5 Concluding Remarks

To our best knowledge, this paper is the first study of FDI's impact on environmental pollution from the perspective of human capital. It has used provincial socioeconomic and environmental data and has investigated how human capital influences the relationship between FDI and pollution emissions in China. Our results have shown that the impact of FDI on pollution emissions is highly dependent on the level of human capital. For provinces with a high level of human capital, FDI is negatively related to pollution emissions. In contrast, for provinces with a low level of human capital, FDI is positively related to pollution emissions. The findings suggest PHH holds only in provinces with a low level of human capital.

We conclude that FDI in China has different environment effects for industrial waste water emission and industrial soot emission across provinces, relying on the regional level of human capital. However, there is no province which passes the threshold value of human capital for SO_2 and hence FDI has caused more SO_2 emission for all 29 provinces. Our study has also found that FDI has opposite performances—either deteriorating or alleviating pollution emission—depending on different pollutants and different regions, which helps explain why conflicting evidences exist about PHH.

Moreover, this paper has carefully examined the possible factors that may influence industrial pollution emissions in China. Despite the lack of direct measures of pollution regulations, we have attempted to capture the effect of formal and informal regulations, using regional characteristics that are likely to influence the stringency of regulations. The proxies for informal regulations do not perform particularly well in this paper. The majority of the regional characteristic variables have an insignificant effect on pollution, except for the provincial investment in pollution treatment (*RegIPT*) that has a significant negative relationship with pollution intensity of SOOT and SO_2, and the degree of public ownership (*RegPO*) that has a significant relationship with pollution intensity for each of the three pollutants.

The findings in this study have important policy implications. The fast economic growth has turn off China into one of the largest pollution producers in the world, and FDI is regarded as an engine or catalyst for this growth process. Evidence from this study suggests that PHH does not always hold in all provinces within China. PHH is appropriate only to provinces with a low level of human capital. The invalidity of PHH can be explained by different levels of human capital over the regions. Therefore, if China needs to maintain fast growth and reduce pollution emissions, the government shall be encouraged to develop high education to raise the national level of human capital rather than raise the stringency of environmental regulation or standard.

Appendix

Table A1 Data information

Variables	Definition	Source
WATER	Industrial waste water emission divided by industrial value added	China Statistical Yearbook 1997–2007
SOOT	Industrial soot emission divided by industrial value added	China Statistical Yearbook 1997–2007
SO_2	Industrial SO_2 emission divided by industrial value added	China Statistical Yearbook 1997–2007
FDI	FDI stock divided by industrial value added (calculated by the formula, initial year is 1985, before 1985 was assumed zero)	International Economics and Trade chapter, China population statistics yearbook 1984–2007
H	The average years of schooling by regions, use enrollment ratios, the number of four broad levels of schooling: no school, some primary, some secondary and above, completion ratios, regional population to calculate it follow the formulas provided by Barro and Lee (2001)	Chinese Statistical Yearbook (1991–2007); China education Yearbook (1991–2007); China's Population Statistics Yearbook (1991–2006); China Population and Employment Statistical Yearbook (2007)
FDI*H	Interaction term of FDI and H	FDI multiplied by H

Table A1 continued

Variables	Definition	Source
Energy	Total energy consumption per unit of industrial value added	directly from China Statistical Yearbook 1997–2007
CI	Physical capital intensity: industrial capital stock per worker	Industrial capital data from China industrial economic statistical yearbook 1997–2007; number of workers data from China Labor Statistical Yearbook, Comprehensiveness chapter 1997–2007
Ind	The degree of industrialization: industrial value added scaled by GDP	China Statistical Yearbook 1997–2007
RegIPT WATER	Annual investment in industrial waste water emission treatment divided by regional industrial value-added	China Environmental Statistics Yearbook 1997–2007
RegIPT SOOT	Annual investment in industrial soot emission treatment divided by regional industrial value-added	China Environmental Statistics Yearbook 1997–2007
RegIPT SO_2	Annual investment in SO2 treatment divided by regional industrial value-added	China Environmental Statistics Yearbook 1997–2007
RegUER	Regional unemployment rate	Employment and Unemployment chapter, China Labor Statistical Yearbook 1999–2007
RegPD	Population density is calculated by dividing provincial population with provincial surface	Population chapter, China statistical Yearbook 1997–2007; area data from http://www.usacn.com
RegPO	Degree of public ownership defined as annual fixed asset investment of state-owned enterprises divided total social fixed asset investment	Investment of Fixed Assets chapter, China Statistical Yearbook 1999–2007

Table A2 Summary statistics

Variables	Mean	Median	Std.dev	Min	Max	Unit
WATER	0.025	0.014	0.030	0.00032	0.168	Tonnes/Yuan
SOOT	0.056	0.041	0.052	0.0005	0.247	Tonnes/Yuan
SO2	0.057	0.039	0.053	0.008	0.312	Tonnes/Yuan
FDI	0.054	0.008	0.082	0.001	0.502	Dollars/Yuan
H	7.831	7.320	0.88	5.372	10.776	Year
FDI*H	0.444	0.058	0.669	0.005	5.409	Dollar/(Year*Yuan)
Energy	0.0016	0.0068	0.0038	0.000014	0.0322	Tonnes of standard coal/Yuan
CI	0.842	0.528	1.031	0.138	5.416	10,000 Yuan per capita
Ind	0.263	0.256	0.084	0.126	0.567	Index
RegIPT for WATER	0.00323	0.00249	0.00276	0.00028	0.0222	Ratio (yuan/yuan)
RegIPT for SOOT	0.00327	0.00341	0.00273	0.00023	0.0216	Ratio (yuan/yuan)
RegIPT for SO_2	0.00168	0.00134	0.0013	0.00019	0.0094	Ratio (yuan/yuan)
RegUER	3.437	3.500	1.042	0.060	7.400	%
RegPD	0.629	0.229	1.329	0.011	10.368	Thousand people per KM^2
RegPO	0.323	0.490	0.138	0.251	0.744	Index

Table A3 The average years of schooling

ID	Province	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Mean
1	Beijing	9.65	9.58	9.81	10.05	10.03	10.31	10.31	10.38	10.59	10.66	10.78	10.20
2	Tianjin	8.12	8.47	8.22	8.78	9.03	8.90	9.19	9.28	9.68	10.04	10.23	9.09
3	Hebei	7.03	7.29	7.55	7.54	7.77	7.77	8.04	8.38	8.37	8.6	8.77	7.92
4	Shanxi	7.62	7.73	7.64	7.88	8.03	8.16	8.24	8.38	8.36	8.58	8.67	8.12
5	Inner Mongolia	7.30	7.35	7.59	7.53	7.85	7.84	8.00	7.89	8.24	8.52	8.64	7.89
6	Liaoning	7.88	8.12	8.05	8.18	8.39	8.24	8.40	8.87	8.78	9.17	9.28	8.49
7	Jilin	7.85	8.08	8.09	8.26	8.26	8.50	8.60	8.68	8.77	8.93	9.05	8.46
8	Heilongjiang	7.86	7.95	7.94	7.92	7.92	8.32	8.35	8.45	8.51	8.75	8.83	8.25
9	Shanghai	9.09	8.98	9.07	9.33	9.35	9.51	9.66	10.15	10.15	10.34	10.47	9.65
10	Jiangsu	7.21	7.13	7.26	7.47	7.91	7.82	7.72	7.83	7.92	8.18	8.27	7.70
11	Zhejiang	6.89	7.01	7.19	7.3	7.54	7.45	7.79	7.87	8.07	8.34	8.49	7.63
12	Anhui	6.53	6.78	6.76	6.77	7.14	7.31	7.16	7.78	7.63	7.8	7.94	7.24
13	Fujian	6.51	6.89	6.87	6.95	7.54	7.65	7.55	7.68	7.62	7.83	7.97	7.37
14	Jiangxi	6.67	7.11	7.09	7.19	7.56	7.73	7.51	8.28	7.99	8.48	8.65	7.66
15	Shandong	6.68	6.74	6.85	7.02	7.65	7.91	8.13	7.95	8.02	8.29	8.46	7.61
16	Henan	7.04	7.26	7.39	7.28	7.79	8.04	8.14	8.03	8.27	8.28	8.43	7.81
17	Hubei	7.11	7.35	7.43	7.42	7.82	7.99	7.47	8.00	8.17	8.37	8.50	7.78
18	Hunan	7.09	7.33	7.38	7.55	7.84	7.94	7.97	8.12	8.21	8.48	8.62	7.87
19	Guangdong	6.94	7.59	7.64	7.70	8.10	7.81	8.13	8.05	8.16	8.38	8.53	7.91
20	Guangxi	6.84	6.78	6.94	6.98	7.60	7.67	7.71	7.84	8.07	8.14	8.30	7.53
21	Hainan	6.87	7.36	7.36	7.42	7.77	7.68	8.02	8.26	8.45	8.54	8.74	7.86
22	Sichuan	6.64	6.76	6.93	6.88	7.20	7.35	7.43	7.55	7.48	7.72	7.83	7.25
23	Guizhou	6.09	6.18	6.11	6.38	6.41	6.77	6.95	7.12	7.16	7.33	7.46	6.72
24	Yunnan	6.01	6.11	6.11	6.12	6.56	6.43	6.43	6.29	6.99	7.19	7.31	6.50
26	Shaanxi	7.06	7.26	7.22	7.35	7.81	7.72	7.59	8.23	8.35	8.21	8.37	7.74
27	Gansu	6.21	6.48	6.44	6.69	6.82	7.01	7.03	7.28	7.46	7.71	7.87	7.00
28	Qinghai	5.54	5.37	5.55	6.39	6.51	6.35	6.64	6.99	7.05	7.12	7.31	6.44
29	Ningxia	6.82	6.78	6.87	6.94	7.25	7.46	7.56	7.52	7.84	7.81	7.94	7.34
30	Xinjiang	7.35	7.58	7.54	7.98	7.77	8.03	8.38	8.48	8.48	8.69	8.84	8.10

Table A4 POOLED OLS result

	(1) WATER	(2) WATER	(3) SOOT	(4) SOOT	(5) SO_2	(6) SO_2
H*FDI		−0.174		−0.400		−0.068
		(1.68)*		(−1.94)**		(−1.74)*
H	−0.011	−0.009	−0.013	−0.009	−0.011	−0.138
	(−4.72)***	(−3.16)***	(−3.77)***	(−2.00)**	(−2.34)**	(−2.66)***
FDI	0.332	1.564	0.296	3.125	−0.098	−0.643
	(2.01)**	(1.99)**	(1.98)**	(2.01)**	(−1.99)**	(−1.97)**
Energy	2.065	2.271	8.059	8.203	1.522	1.429
	(3.72)***	(3.82)***	(9.65)***	(9.84)***	(1.75)*	(2.37)**

Table A4 continued

	(1) WATER	(2) WATER	(3) SOOT	(4) SOOT	(5) SO_2	(6) SO_2
CI	0.009	0.011	0.007	0.010	0.001	0.000
	(3.25)**	(3.46)***	(1.72)*	(2.24)**	(1.57)	(0.63)
Ind	−0.163	−0.164	−0.242	−0.244	−0.131	−0.133
	(−5.34)***	(−5.38)***	(−5.36)***	(−5.44)***	(−3.21)***	(−3.25)***
RegIPT	1.328	1.256	0.0005	0.0000	0.0011	0.0013
	(1.77)*	(1.67)*	(0.15)	(0.09)	(5.62)***	(5.52)***
RegUER	0.0013	0.0010	−0.003	−0.004	0.013	0.013
	(0.63)	(0.52)	(−1.02)	(−1.29)	(4.84)***	(4.74)***
RegPD	0.0007	0.0008	0.001	0.001	0.0008	0.0007
	(0.63)	(0.70)	(0.60)	(0.70)	(0.43)	(0.40)
RegPO	0.031	0.035	0.067	0.058	0.127	0.123
	(1.62)	(1.80)*	(2.40)**	(2.04)**	(4.84)***	(4.67)**
F-statistic	22.65	20.56	39.35	40.42	21.67	19.71
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
R^2 (adjusted)	0.513	0.542	0.651	0.677	0.438	0.442
N	319	319	319	319	319	319

The dependent variables are expressed in terms of pollution intensities, measured as emissions per unit of industrial value added. * Significant at 10% level; ** Significant at 5% level; *** Significant at 1% level. All regressions include a constant (not reported)

References

Afsah S, Laplante B, Wheeler D (1996) Controlling industrial pollution: a new paradigm. Working paper no. 1672. Policy Research Department, World Bank, Washington, DC

Antweiler W, Copeland BR, Taylor MS (2001) Is free trade good for environment? Am Econ Rev 91(4): 877–908

Baek J, Koo WW (2009) A dynamic approach to the FDI-environment nexus: the case of China and India. J Int Econ Stud 13(2):87–108

Barro RJ, Lee J-W (1993) International comparisons of educational attainment. J Monet Econ 32(3):363–394

Barro RJ, Lee J-W (2001) International data on educational attainment: updates and implications. Oxf Econ Pap 53(3):541–563

Birdsall N, Wheeler D (1993) Trade policy and industrial pollution in Latin America: where are the pollution havens. J Environ Dev 2(1):137–149

Bommer R (1999) Environmental policy and industrial competitiveness: the pollution-haven hypothesis reconsidered. Rev Int Econ 7(2):342–355

Caselli F, Coleman WJ (2001) Cross-country technology diffusion: the case of computers. Am Econ Rev 91(2):328–335

Cohen D, Soto M (2007) Growth and human capital: good data, good results. J Econ Growth 12(1):51–76

Cole MA (2000) Air pollution and ‘dirty’ industries: how and why does the composition of manufacturing output change with economic development? Environ Resour Econ 17(1):109–123

Cole MA, Elliott RJR, Shimamoto K (2003) US specialization in pollution-intensive industries: factor intensities versus environmental regulations. The School of Economics discussion paper series, no. 0321. The University of Manchester

Cole MA, Elliott RJR, Shimamoto K (2006) Globalization, firm-level characteristics and environmental management: a study of Japan. Ecol Econ 59(3):312–323

Cole MA, Elliott RJR, Wu S (2008) Industrial activity and the environment in China: an industry-level analysis. China Econ Rev 19(3):393–408

Cole MA, Elliott RJR, Zhang J (2011) Growth, foreign direct investment and the environment: evidence from Chinese cities. J Reg Sci 51(1):121–138

Copeland BR, Taylor MS (2004) Trade, growth, and the environment. J Econ Lit 42(1):7–71

Costantini V, Monni S (2008) Environment, human development and economic growth. Ecol Econ 64(4):867–880

Dasgupta S, Huq M, Wheeler D (1997) Bending the rules: discretionary pollution control in China. Policy research working paper, no.1761. Development Research Group, World Bank, Washington, DC

Dean JM, Lovely ME, Wang H (2009) Are foreign investors attracted to weak environmental regulations? Evaluating the evidence from China. J Dev Econ 90(1):1–13

Di W (2007) Pollution abatement cost savings and FDI inflows to polluting sectors in China. Environ Dev Econ 12(6):775–798

Eaton J, Kortum S (1997) Engines of growth: domestic and foreign sources of innovation. Jpn World Econ 9(2):235–259

Ederington J (2007) NAFTA and the pollution haven hypothesis. Policy Stud J 35(2):239–244

Eskeland GS, Harrison AE (2003) Moving to greener pastures? Multinationals and the pollution haven hypothesis. J Dev Econ 70(1):1–23

Fu X (2008) Foreign direct investment, absorptive capacity and regional innovation capabilities: evidence from China. Oxford Dev Stud 36(1):89–110

Gray WB, Deily ME (1996) Compliance and enforcement: air pollution regulation in the U.S. steel industry. J Environ Econ Manag 31(1):96–111

Hartman RS, Huq M, Wheeler D (1997) Why paper mills clean up: determinants of pollution abatement in four Asian countries. Policy Research Department working paper, no.1710, World Bank, Washington, DC

He J (2006) Pollution haven hypothesis and environmental impacts of foreign direct investment: The case of industrial emission of sulfur dioxide (SO2) in Chinese provinces. Ecol Econ 60(1):228–245

Hettige H, Huq M, Pargal S, Wheeler D (1996) Determinants of pollution abatement in developing countries: evidence from South and Southeast Asia. World Dev 24(12):1891–1904

Huq M, Wheeler D (1993) Pollution reduction without formal regulation: evidence from Bangladesh. Environment Department working paper 1993-39. World Bank, Washington, DC

Jaffe AB, Peterson SR, Portney PR, Stavins RN (1995) Environmental regulation and the competitiveness of US manufacturing: what does the evidence tell us. J Econ Lit 33(1):132–163

Kellenberg DK (2009) An empirical investigation of the pollution haven effect with strategic environment and trade policy. J Int Econ 78(2):242–255

Krueger AB, Lindahl M (2001) Education for growth: why and for whom. J Econ Lit 39(4):1101–1136

Lamla MJ (2009) Long-run determinants of pollution: a robustness analysis. Ecol Econ 69(1):135–144

Letchumanan R, Kodama F (2000) Reconciling the conflict between the ‘pollution-haven’ hypothesis and an emerging trajectory of international technology transfer. Res Policy 29(1):59–79

List JA, Co CY (2000) The effects of environmental regulations on foreign direct investment. J Environ Econ Manag 40(1):1–20

Pargal S, Wheeler D (1996) Informal regulation of industrial pollution in developing countries: evidence from Indonesia. J Polit Econ 104(6):1314–1327

Porter ME, Van Der Linde C (1995) Green and competitive : ending the stalemate green and competitive. Harv Bus Rev 73(5):120–134

Romer PM (1991) Endogenous technological change. J Polit Econ 98(5):71–102

Sha B, Shi T (2006) The environmental effect of FDI: an analysis based on provincial panel dataset in China. World Econ Study 25(6):18–25 (in Chinese)

UNCTAD (2010) FDI Statistics. http://unctadstat.unctad.org/TableViewer/tableView.aspx. Accessed 7th May 2010

Verhoef ET, Nijkamp P (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. Ecol Econ 40(2):157–179

Waldkirch A, Gopinath M (2008) Pollution control and foreign direct investment in Mexico: an industry-level analysis. Environ Resour Econ 41(3):289–313

Wang H, Jin Y (2007) Industrial ownership and environmental performance: evidence from China. Environ Resour Econ 36(3):255–273

Wang Y, Yao Y (2003) Sources of China’s economic growth 1952–1999: incorporating human capital accumulation. China Econ Rev 14(1):32–52

Xing Y, Kolstad CD (2002) Do lax environmental regulations attract foreign investment? Environ Resour Econ 21(1):1–22

Xu B (2000) Multinational enterprises, technology diffusion, and host country productivity growth. J Dev Econ 62(2):477–493

Yao S (2006) On economic growth, FDI and exports in China. Appl Econ 38(3):339–351

Zeng D-Z, Zhao L (2009) Pollution havens and industrial agglomeration. J Environ Econ Manag 58(2): 141–153

Zhang J, Fu X (2008) FDI and environmental regulations in China. J Asia Pac Econ 13(3):332–353

Zheng S, Kahn ME, Liu H (2010) Towards a system of open cities in China: home prices, FDI flows and air quality in 35 major cities. Reg Sci Urban Econ 40(1):1–10