FDI Spillovers, Environmental Pollution and Energy Consumption Intensities, and Industries' Productivity*

Zhongyuan Zhang*　Guoqing Zhao**

Abstract

Using the correlated data of 28 Chinese manufacturing industries during 1999-2008, this paper examines the effects of the foreign direct investment, which is distinguished as horizontal, forward linkage and backward linkage spillovers, and environmental pollution and energy consumption intensities on industries' productivity. The empirical results show that FDI spillovers are more likely existing in the vertical linkages across industries rather than horizontal linkages and environment pollutions and energy consumption do have disadvantages on industry' productivity even we use different industries' productivity measures and give emphasis to the endogeneity problem of these variables. We link this result with abatement efficiency of industries' physical capital intensive and demonstrate that the most environmental pollution emission and energy intensive industries are likely to be less efficient and therefore relatively lower industries' productivity. Further study suggests that horizontal FDI spillover decreases the emission of environment pollution emission and energy consumption intensities though vertical FDI spillovers have limited effect on them.

Key Word: *FDI, Environmental Pollution, Energy Consumption, Industries' Productivity*

JEL Classification: *F21 O19 Q53*

1. Introduction

It is often argued that FDI is a mechanism through which knowledge and technology flows across borders. The most pronounced reason for policy incentives to attract FDI is that FDI is an effective conduit for technology transfer through technology spillovers to domestically owned firms in the host country. However, whether these huge FDI inflows indeed bring about productivity spillovers for recipient countries, the evidence is fairly

* National Institute of International Strategy, Chinese Academy of Social Sciences.
**Corresponding author : Guoqing Zhao, School of Economics, Renmin University of China, Beijing, 100872,China.
Email: zhaogq@ruc.edu.cn; **Acknowledgements** This research is supported by the Fundamental Research Funds for the Central Universities, and the Research Funds of Renmin University of China (No. 12XNK015).

mixed so far. Some empirical studies confirm positive productivity spillovers from FDI (e.g., Blomstrom and Sjoholm,1999; Sadik and Bolbol, 2001). But others find negative or no spillovers (e.g., Xu, 2000; Aitken and Harrison, 1999; Veugelers and Cassiman, 2004). The mixed evidence intuitively implies that there is no universal relationship between FDI and domestic firms' productivity. It is well recognized now that the extent of technology spillovers depends on the nature of the technology transferred and the joint venture and the local economics' properties. There are several studies have been put forward to motivate different effects for heterogeneous firms, industries and countries, such as the domestic firms' characteristics or host countries' ability to absorb productivity spillovers (e.g., Waldkirch and Ofosu, 2010; Bekes et al., 2009; Lai et. al., 2009).

Recent researches broaden the scope of FDI spillover by distinguishing between intra- and inter-industry FDI externalities (e.g., Javorcik, 2004; Smarzynska, 2004; Blalock and Gertler, 2008). This is seen as providing an answer as to why much of the literature on horizontal spillovers failed to find a beneficial role of multinationals in the host economy. Many studies find significant inter-industry knowledge spillovers occurring through vertical linkages though little evidence in support of intra-industry productivity spillovers from FDI (e.g., Swinnen, 2004; Bwalya, 2006; Jordaan, 2008). Additionally, a number of anecdotes and case studies of China's FDI spillovers also suggest that many multinationals play an important role in actively assisting their suppliers and customers to improve their quality and efficiency (Lin et. al., 2009), and backward linkages seem to be statistically the most important channel through which spillovers occur (Liu, 2008). However, the measures of vertical linkages in studies on spillover from FDI are potentially problematic as they depend on a number of restrictive assumptions (Barrios et al., 2011). This research explores avenues to improve the statistical identification of FDI spillovers and finds that the choice of backward linkage measure, using plant level data for Ireland, matters greatly in order to draw possible conclusions regarding the existence of FDI related spillovers.

Although empirical studies on the FDI spillovers are extensive, there is little research into the relationship among FDI spillovers, environmental pollution and energy consumption intensities on industries' productivity for China. The ongoing debate of the environmental behavior of FDI is framed by two schools of thought. One is the pollution haven hypothesis (PHH), which states that FDI will be attracted to those countries with less stringent environmental regulations thus inducing a regulatory "race to the bottom" in order to attract higher FDI inflows from dirty sectors to the detriment of the host country's environment (Esty and Geradin, 1997; Mani and Wheeler, 1998; List and Co, 2000). In contrast, the pollution halo hypothesis argues that, foreign plants are significantly more energy efficient and use cleaner types of energy than their local peers, are not likely significantly attracted by weak standards (Eskeland and Harrison, 2003; List et al., 2004; Dean et al., 2009). As a result of the transfer of environmental knowledge via environmental technology spillovers, the presence of foreign-owned firms may yield substantial environmental benefits to developing countries since FDI has been known to directly encourage the dissemination of environmental related knowledge and technologies (Albornoz et al., 2009). The opposing forces of these two effects may lead up to mixed results. For further discussion, see Antweiler et al. (2001), Cole and Elliott (2003; 2005) and Elliott and Shimamoto (2008).

Given China's rapid industrial expansion, Cole et al. (2008) utilize a dataset of Chinese industry specific emissions for a variety of pollutants between 1997 and 2003 and find an industry's emissions to be a negative function of its productivity. Dean et al. (2009) find EJVs in highly-polluting industries funded through Hong Kong, Macao and Taiwan are attracted by weak environmental standards in China. The Chinese economy is also in a stage of energy transition: from low efficiency solid fuels to oil, gas, and electric power, from heavy industry to lighter and high tech industry. With its rapid economic growth, China's primary energy consumption has exceeded domestic energy production since 1994, leading to a substantial expansion in energy imports (Adams and Shachmurove, 2008). Zhang (2003) investigates the change in energy consumption in China's industrial sector in the 1990s and finds that there is a decline trend in industrial energy use in the 1990s which can be overwhelmingly contributed to the decline in real energy intensity. However, Ma and Stern (2008) find that, though China experienced a dramatic decline in energy intensity from the onset of economic reform in the late 1970s until 2000, the rate of decline slowed and energy intensity actually increased in 2003.

The aim of this paper is to identify the effects of the FDI, which is distinguished as horizontal, forward linkage and backward linkage spillovers, and environmental pollution and energy consumption intensities on industries' productivity, thereby providing a greater understanding of the linkages among FDI spillovers, environmental regulations and pollution intensity and industries' productivity. The paper makes the following contributions. First, using the correlated data of 28 Chinese manufacturing industries during 1999-2008, the empirical results show that FDI spillovers are more likely existing in the vertical linkages across industries rather than horizontal linkages and environment pollutions and energy consumption do have disadvantages on industry' productivity even we use different industries' productivity measures and give emphasis to the endogeneity problem of these variables.

Second, we investigate the role of the FDI spillovers on environment pollution and energy consumption intensities. The results suggest that horizontal FDI spillover decreases the emission of environment pollution emission and energy consumption intensities though vertical FDI spillovers have limited effect on them, which indicate that foreign firms may adopt "green" technologies within the same industry to enforce their competitive ability but they have little incentive to transfer environmental knowledge to their forward and backward linkages customers.

Third, the environmental pollution emission and energy consumption intensities have significant negative impact on industries' productivity. We link our results with abatement efficiency for physical capital intensive industries are also the most environmental pollution emission and energy intensive ones and implies that those industries that use relatively low level technologies, older second-hand machineries and less "green" technologies typically generate greater volumes of pollution and require substantive capital stocks to maintain them, which are likely to be less efficient and therefore relatively lower industries' productivity. Our result is consistent with the explanation that more productive industries are more resource efficient and better managed and hence less environment pollution emission and energy intensive.

The remainder of the paper is organized as follows. Section 2 presents the simple model framework, describes the empirical specification, and discusses the data. Section 3 presents the main empirical results, that is, the effects of FDI spillover, environmental pollution and energy consumption intensities on industries productivity. Section 4 presents the results of FDI spillover effect on environment pollution and energy consumption intensities; Section 5 concludes.

2. Empirical Analysis Framework and Data

2.1 Basic Specification

This section derives the empirical methodology used. To examine factors determining industry productivity, we start with the Cobb-Douglas production function specified as:

$$Y = AK^{\alpha}L^{\beta} \qquad (1)$$

where Y represents output (value added), A, K and L denote the total factor productivity (TFP), capital stock, and number of workers. Note that α and β are constants and no constant returns to scale are imposed.

Dividing both sides by L gives the production function in its intensive form, and taking logs, adding the industry (i) and period (t) dimension, and rearranging slightly, we obtain:

$$LPL_{it} = TFP_{it} + \lambda LKL_{it} + \gamma LK_{it} \qquad (2)$$

where $\lambda = 1 - \beta$, $\gamma = \alpha + \beta - 1$. LPL_{it} is the value added per worker or labor productivity of industry i in period t in nature log form, that is, LPL_{it} represents

$Ln(Y/L)_{it}$. TFP_{it}, LKL_{it} and LK_{it} stand for $Ln(A_{it})$, $Ln(K/L)_{it}$ and $Ln(K_{it})$ respectively. The capital stock LK_{it} is included as an additional variable in order to relax the constant-return-to-scale assumption.

As externalities are not directly observable, their presence needs to be identified in an indirect way. In our empirical analysis, we specify that the TFP contains the spillover effect from FDI (horizontal and vertical) to examine the correlation between industry TFP and FDI in the same sector (intra-industry) and inter-industry. We also include the effect of human capital (H) and expenditures on science and technology activities (RD), this gives the following empirical model:

$$TFP_{it} = \phi + \beta_1 FDI\_H_{it} + \beta_2 FDI\_FW_{it} + \beta_3 FDI\_BW_{it} + Z'_{it}\delta + \mu_i + \varepsilon_{it} \quad (3)$$

where FDI_H_{it} 、 FDI_FW_{it} and FDI_BW_{it} measures the horizontal, forward and backward spillovers from FDI respectively. Z'_{it} is a $K \times 1$ vector of control variables (human capital (H_{it}) and expenditures on science and technology activities (RD_{it})), δ is the corresponding coefficient vector. μ_i is the individual effect for industry i and ε_{it} is the error term.

Insert the environmental pollution and energy consumption indices in equation (3) in order to investigate their effects on industries' productivity. It is conceivable that a substantial period may pass between the spillover from FDI on productivity and it is possible reverse causality that industries with higher productivity attract more foreign investments. To allow for such a possibility, we use horizontal, forward and backward spillovers from FDI lagged by 1 period which help avoid such possible reverse causality. In this specification, we have:

$$\begin{aligned} TFP_{it} = \phi &+ \beta_1 FDI\_H_{it-1} + \beta_2 FDI\_FW_{it-1} + \beta_3 FDI\_BW_{it-1} \\ &+ \beta_4 EP_{it} + Z'_{it}\delta + \mu_i + \varepsilon_{it} \end{aligned} \quad (4)$$

where EP_{it} are environmental pollution and energy consumption indices.

By substituting Eqn. (4) in (2), we obtain:

$$\begin{aligned} LPL_{it} = \phi &+ \lambda LKL_{it} + \gamma LK_{it} + \beta_1 FDI\_H_{it-1} + \beta_2 FDI\_FW_{it-1} \\ &+ \beta_3 FDI\_BW_{it-1} + \beta_4 EP_{it} + Z'_{it}\delta + \mu_i + \varepsilon_{it} \end{aligned} \quad (5)$$

Eqn. (5) depicts labor productivity of industries as a function of the capital labor ratio and capital stock of these industries, incorporating the effect of FDI (horizontal and vertical), the environmental pollution and energy consumption intensities and other variables that can be hypothesized to affect labor productivity.

2.2 Another Productivity Measuring: A Stochastic Frontier Approach (SFA)

When measuring efficiency and productivity, researchers face the choice of alternative approaches, such as conventional production (cost) functions as specified above, data envelopment analysis (DEA), and stochastic frontier production (cost) function. Following Kumbhakar and Lovell (2000) the stochastic frontier approach (SFA) is used in this paper to estimate a production function and an inefficiency function simultaneously. Suppose that a producer has a production function as follows:

$$Y_{it} = f(Z_{it}, \beta)\xi_{it} \exp(v_{it})$$

where ξ_{it} is the level of efficiency. A fundamental element of stochastic frontier analysis is that each producer potentially produces less than it might because of a degree of inefficiency. The producer is achieving the optimal output with the technology embodied in the production function $f(Z_{it}, \beta)$ if $\xi_{it} = 1$, while the producer is not making the most of the inputs zit given the technology embodied in the production function $f(Z_{it}, \beta)$ when $\xi_{it} < 1$.

Taking the natural log of both sides and defining $u_{it} = -\ln(\xi_{it})$, which represents technical inefficiency, we have:

$$Ln(Y_{it}) = Ln(f(Z_{it}, \beta)) + v_{it} - u_{it}$$

Restricting $0 < \xi_{it} \leq 1$ implies that $u_{it} \geq 0$. The technical inefficiency effects, u_{it}, are assumed as a function of factors specified in Eqn.(4), which can be specified as follows:

$$\begin{aligned} u_{it} = \phi + \beta_1 FDI\_H_{it-1} + \beta_2 FDI\_FW_{it-1} + \beta_3 FDI\_BW_{it-1} \\ + \beta_4 EP_{it} + Z'_{it}\delta + \mu_i + \varepsilon_{it} \end{aligned} \quad (6)$$

However, the coefficients on FDI (horizontal and vertical) variables, the environmental pollution and energy consumption intensities variables in Eqn.(4) and (6), $\beta_i, i = 1,2,3,4.$, are expected to have opposite sign each other.

2.3 Measuring FDI Vertical Spillovers

One of the main aims of this paper is to explain systematic variation in industries' TFP, which reflects its technology, by spillovers from multinational firms which are not observable. Apart from its own technology, the industries' productivity might also be affected by sectoral linkages and local competition. We expect spillovers to stem from linkages with foreign multinational firms and examine the effect of horizontal linkages, of backward and of forward linkages on industry-specific productivity.

(1) Measuring forward spillovers

Vertical spillovers can arise from multinational firms' presence in backward or forward industries. Linkages with suppliers and customers might increase the industries' efficiency. As in Javorcik (2004), the variable Horizontal FDI is measured by the foreign presence in the same industry. While forward FDI shows the foreign presence in the upstream industry u from which industry j purchases its intermediate inputs. We calculate forward FDI spillover effect in the following way:

$$FDI\_FW_{jt} = \sum_u \delta_{jut} \times FDI\_H_{ut}$$

Where FDI_H_{ut} is the percentage of gross industry output value of upstream industrial enterprises with Hong Kong, Macao, Taiwan and foreign funds in the same industry. δ_{jut} is the proportion of industry $j's$ total intermediate input that is supplied by industry u. Then

$$\delta_{jut} = {m1_{jut}} \Big/ {\sum_u m1_{jut}}$$

where $m1_{jut}$ is the value of intermediate inputs at current prices that industry j purchases from its' upstream industry .

(2) Measuring backward spillovers

Similarly, backward FDI captures the foreign presence in the downstream industry b that is supplied by industry j. We calculate backward FDI spillover effect in the following way:

$$FDI\_BW_{jt} = \sum_b \lambda_{jbt} \times FDI\_H_{bt}$$

Where FH_{bt} is the percentage of gross industry output value of downstream industrial interprises with Hong Kong, Macao, Taiwan and foreign funds in the same industry. λ_{jbt} is the proportion of industry $b's$ total intermediate input that is supplied by industry j. Then

$$\lambda_{jbt} = {m2_{jbt}} \Big/ {\sum_b m2_{jbt}}$$

where $m2_{jbt}$ is the value of intermediate inputs at current prices that downstream industry b purchases from industry j.

As above, This paper calculates δ_{jut} and λ_{jbt} using the 2002 Input-Output Table for 1999-2002, the 2005 Input-Output Table for 2003 and 2005 and the 2007 Input-Output Table for 2006-2008.

However, it can be easily argued that the measures of vertical linkages in studies on spillover from FDI are potentially problematic, as they depend on a number of restrictive assumptions (Barrios et al., 2011). The results of Barrios et al., using plant level data for Ireland, show that the choice of backward linkage measure matters greatly in order to draw possible conclusions regarding the existence of FDI spillovers. Unfortunately China's I-O tables, which we use here, don't allow the distinction between imported and domestically sourced inputs then baffle us to perform a similar exercise. Hence, it is difficult to infer what extents of our vertical FDI spillovers measure suffer from the same problem, namely that (i) multinationals use domestically produced inputs in the same proportion as imported inputs, (ii) multinationals have the same input sourcing behavior as domestic firms, and (iii) the demand for locally produced inputs by multinationals is proportional to their share of locally produced output. These are how one may work around existing data limitations for further studies.

2.4 Data and definitions of key variables

The empirical analyses in this paper are based on a sample of manufacturing industries in China. The datum were obtained from the *China Statistical Yearbook* (NBSC, 2000–2009) which cover 28 industries from 1999 to 2008(2004 was the year for which the data was unavailable). The scopes of industrial statistics are all State-owned industrial enterprises and non-State-owned industrial enterprises with revenue from principal business over 5 million yuan from 1998 to 2006. For 2007 and 2008, the scopes of industrial statistics are the industrial enterprises above designated size with revenue from principal business over 5 million yuan. The data contain information on value-added of industry, annual average balance of net value of fixed assets, annual average employed persons, gross industry output value, revenue from principal business, asset-liability ratio, number of times of turnover of working capital(times/year), and so on.

This paper uses the 122 manufacturing industries defined in the 2002 Input-Output Table, the 62 manufacturing industries defined in the 2005 Input-Output Table and the 135 manufacturing industries defined in the 2007 Input-Output Table for both forward and backward spillover variables. This paper also uses total volume of industry wasted water discharge, total volume of industrial sulphur dioxide emission and total volume of industrial soot emission for environment pollution indices. These datum are all from *China Statistical Yearbook* (2000–2009). Consumption of total energy and its main varieties by sector, which are from *Chinese energy statistical yearbook (2009), are used as energy consumption index*.

Many studies find that spillovers from FDI do not occur in isolation from economic factors that may facilitate spillover absorption. Such factors usually include host country and sector characteristics (e.g. education attainment of the labor force, domestic research and development (R&D) expenditures). This paper uses human capital quality, which is measured by science and technology personnel as a percentage of total employed persons, and expenditures on science and technology activities, which is measured by expenditures on science and technology activities as a percentage of total revenue from the sale of products, as control variables which facilitate spillover absorption. These data are from *China Statistical Yearbook on Science and Technology* (2000–2009).

Table 1 presents definitions of the key variables used in the empirical estimations. The value-added of the industry is deflated by the price deflator and the net value of fixed assets is deflated by the fixed assets deflator at constant price of 1999. Both the price deflator and the fixed assets deflator are from *China Statistical Yearbook* (2000–2009). Descriptive statistics are shown in Table 2. Panel A presents summary statistics and Panel B presents the correlation matrix of the variables. There is considerable variation in the FDI spillovers variables (FDI_H, FDI_FW and FDI_BW), ranging from 0.84 to 0.0, 0.69 to 0.09, 0.79 to 0.0 respectively. Environmental pollution and energy consumption intensities variables (WA, SO2, SMO SCE and EPOW) also shows variation, ranging from 5.42 to -1.12 for industry wasted water discharge (WA), from 6.45 to -1.35 for industrial sulphur dioxide emission (SO2), from 6.79 to -2.12 for industrial soot emission (SMO), from 10.71 to 6.22 for industrial energy consumption (SCE), from 8.16 to 4.45 for industrial electric power consumption (EPOW).

Table 1 Definitions of the key variables

Variable	Defination
LY	Output (in 100 million RMB yuan): log of value-added of industry which is deflated using GDP price deflator at constant price of 1999
LK	Capital stock(in 100 million RMB yuan): log of the real annual average balance of net value of fixed asset which is deflated by the fixed assets deflator at constant price of 1999
LL	Labor(10000 persons): log of annual average employed persons
LPL	Labor productivity (in 10000 RMB yuan /person): log of real value-added of industry in 10000RMB yuan per person
LKL	Capital stock per worker(in 10000 RMB yuan /person): log of the real annual average balance of net value of fixed asset in 10000RMB yuan per person
LKY	Capital stock per value-added of industry (%): log of the real annual average balance of net value of fixed asset per value-added of industry
TFP	Total factor productivity: calculated using Eqn.(2) in section 2.1
U	The technical inefficiency effects: calculated following the stochastic frontier approach specified in section 2.2
FDI_H	Horizontal FDI spillovers (%): the percentage of gross industry output value of industrial enterprises with Hong Kong, Macao, Taiwan and foreign funds in the same industry
FDI_FW	Forward FDI spillovers (%): specified in section 2.3
FDI_BW	Backward FDI spillovers (%): specified in section 2.3
WA	Environment pollution intensity (tons/10000 RMB yuan): log of industry wasted water discharge per gross industrial output value
SO2	Environment pollution intensity (tons/100 million RMB yuan): log of total volume of industrial sulphur dioxide emission per gross industrial output value
SMO	Environment pollution intensity (tons/100 million RMB yuan): log of total volume of industrial soot emission per gross industrial output value
SCE	Energy consumption intensity (in tons of standard coal equivalent per 100 million RMB yuan): total volume of industrial energy consumption per gross industrial output value. Industrial energy consumption includes the consumption of coal, oil, natural gas, electricity, heat and others.

EPOW	Energy consumption intensity (in kwh per 10000 RMB yuan): total volume of industrial electric power consumption per gross industrial output value.
H	Human capital quality (%): science and technology personnel as a percentage of total employed persons of large and medium-sized 1ndustrial enterprises by industry
RD	Expenditures on science and technology activities (%): expenditures on science and technology activities as a percentage of total revenue from the sale of products of large and medium-sized 1ndustrial enterprises by industry

Table 2 Descriptive statistics
Panel A Summary statistics

	Mean	Maximum	Minimum	Std. Dev.	Observations
LY	6.86	9.00	4.36	0.96	252
LK	6.99	9.06	4.66	0.92	252
LL	4.80	6.52	2.71	0.88	252
LPL	2.07	4.85	0.98	0.63	252
LKL	2.19	3.61	0.59	0.64	252
LKY	0.12	1.28	-1.64	0.50	252
TFP	0.01	2.17	-1.02	0.46	252
U	1.83	3.95	-0.66	0.98	252
FDI_H	0.33	0.84	0.00	0.17	252
FDI_FW	0.28	0.69	0.09	0.10	252
FDI_BW	0.34	0.79	0.00	0.11	252
WA	1.54	5.42	-1.12	1.44	224
SO2	2.63	6.45	-1.35	1.73	224
SMO	2.30	6.79	-2.12	1.88	224
SCE	8.15	10.71	6.22	1.08	252
EPOW	6.10	8.16	4.45	0.85	252
H	4.51	11.82	0.60	2.62	224
RD	1.54	3.60	0.20	0.82	224

Panel B in Table 2 shows the correlations among the selected variables. There is a strong negative correlation between environmental pollution and energy consumption intensities variables (WA, SO2, SMO SCE and EPOW) and industries' productivity measures (TFP), which are -0.54, -0.54, -0.54, -0.68, and -0.71 respectively, but no strong negative for output (LY) and labor (LL). What is gonging on here is that the environmental pollution and energy consumption intensities have great negative impact on industries' productivity but limited influence on output and labor. We also find that environmental pollution and energy consumption intensities variables (WA, SO2, SMO SCE and EPOW) have strong positive correlation with the capital stock intensity variable (capital stock per value-added of industry, LKY), which has strong negative correlation (-0.92) with industries' productivity measures (TFP), and mild negative correlation (-0.33) with output (LY).

The link between industries' productivity and industrial emissions is less straight-forward. Several studies have suggested that those sectors that face the largest abatement costs per unit of value added also have the greatest physical capital requirements (Antweiler et al. 2001; Cole and Elliott 2003; Cole et al. 2005). China's evidence suggests that those industries that are the most reliant on machinery and equipment generate more pollution emissions and plants with higher levels of abatement costs, which would tend to be those pollution intensive industries, tend to have lower levels of productivity (Cole et al., 2008). One interpretation of our result is that industries productivity is correlated with abatement efficiency since physical capital intensive industries are also the most environmental pollution emission and energy intensive ones, which implies that those industries that use relatively low technologies, older second-hand machineries and less "green" technologies typically generate greater volumes of pollution and require higher levels quantity capital stocks to maintain them, which are likely to be less efficient and therefore relatively lower industries' productivity. On the other hand, industries that employ newer and cleaner technologies, are likely to be more efficient and therefore result in higher level industries' productivity.

Panel B Correlation matrix

	LY	LK	LL	LPL	LKL	LKY	TFP	U	FDI_H	FDI_FW	FDI_BW	WA	SO2	SMO	SCE	EPOW	H	RD
LY	1.00	0.85	0.76	0.42	0.15	-0.33	0.30	0.49	-0.19	-0.03	0.02	-0.12	-0.10	-0.16	-0.07	-0.14	0.41	0.27
LK	0.85	1.00	0.71	0.27	0.41	0.21	-0.20	0.87	-0.34	-0.17	-0.10	0.23	0.29	0.20	0.38	0.29	0.46	0.36
LL	0.76	0.71	1.00	-0.26	-0.35	-0.14	-0.13	0.51	0.11	0.13	0.28	-0.09	-0.15	-0.15	-0.06	-0.02	0.21	0.29
LPL	0.42	0.27	-0.26	1.00	0.71	-0.30	0.63	0.03	-0.43	-0.22	-0.36	-0.05	0.07	-0.03	-0.02	-0.17	0.32	-0.01
LKL	0.15	0.41	-0.35	0.71	1.00	0.46	-0.09	0.51	-0.59	-0.40	-0.50	0.43	0.58	0.47	0.58	0.42	0.35	0.10
LKY	-0.33	0.21	-0.14	-0.30	0.46	1.00	-0.92	0.65	-0.26	-0.26	-0.22	0.64	0.70	0.67	0.81	0.79	0.06	0.15
TFP	0.30	-0.20	-0.13	0.63	-0.09	-0.92	1.00	-0.62	0.06	0.12	0.02	-0.54	-0.54	-0.54	-0.68	-0.71	0.03	-0.17
U	0.49	0.87	0.51	0.03	0.51	0.65	-0.62	1.00	-0.37	-0.25	-0.17	0.49	0.56	0.48	0.69	0.61	0.38	0.35
FDI_H	-0.19	-0.34	0.11	-0.43	-0.59	-0.26	0.06	-0.37	1.00	0.87	0.88	-0.36	-0.61	-0.56	-0.60	-0.46	-0.05	0.02
FDI_FW	-0.03	-0.17	0.13	-0.22	-0.40	-0.26	0.12	-0.25	0.87	1.00	0.85	-0.27	-0.54	-0.50	-0.58	-0.50	0.09	0.09
FDI_BW	0.02	-0.10	0.28	-0.36	-0.50	-0.22	0.02	-0.17	0.88	0.85	1.00	-0.34	-0.50	-0.47	-0.48	-0.33	-0.03	0.05
WA	-0.12	0.23	-0.09	-0.05	0.43	0.64	-0.54	0.49	-0.36	-0.27	-0.34	1.00	0.82	0.77	0.70	0.60	-0.06	-0.02
SO2	-0.10	0.29	-0.15	0.07	0.58	0.70	-0.54	0.56	-0.61	-0.54	-0.50	0.82	1.00	0.91	0.91	0.79	-0.08	-0.07
SMO	-0.16	0.20	-0.15	-0.03	0.47	0.67	-0.54	0.48	-0.56	-0.50	-0.47	0.77	0.91	1.00	0.83	0.70	-0.11	-0.10
SCE	-0.07	0.38	-0.06	-0.02	0.58	0.81	-0.68	0.69	-0.60	-0.58	-0.48	0.70	0.91	0.83	1.00	0.92	-0.01	0.00
EPOW	-0.14	0.29	-0.02	-0.17	0.42	0.79	-0.71	0.61	-0.46	-0.50	-0.33	0.60	0.79	0.70	0.92	1.00	-0.01	0.09
H	0.41	0.46	0.21	0.32	0.35	0.06	0.03	0.38	-0.05	0.09	-0.03	-0.06	-0.08	-0.11	-0.01	-0.01	1.00	0.82
RD	0.27	0.36	0.29	-0.01	0.10	0.15	-0.17	0.35	0.02	0.09	0.05	-0.02	-0.07	-0.10	0.00	0.09	0.82	1.00

3. Estimation results

Table 3 presents results using labor productivity, defined as value added per worker, as the dependent variable that specified in equation (5). We first entry FDI_H, FDI_FW and FDI_BW (excluding environment pollution and energy consumption intensity variables) into the equation. We use the Hausman test for our regression model to select the proper specification between fixed-effect and random-effect approach. We list the results of the fixed-effect specification and the random-effect specification in column

(1) and (2) respectively since the statistics of Hausman test are not available here. The coefficients on capital stock per worker are significant positive and of the expected sign. The coefficients on capital stock are positive and statistically significant at a 0.1% level, which indicates a increasing return to scale. As for the effect of FDI, the coefficients on variable FDI_H are insignificant negative in both the fixed and random effect models which suggest that the presence of FDI creates neglectable negative intra-industry externalities on labor productivity. However, the coefficients on variable FDI_FW and FDI_BW are all significant positive except variable FDI_FW in column (1) which is marginal, suggesting the possibilities of FDI externalities through backward linkages.

Next, environment pollution and energy consumption intensity variables are added into equation (5) one by one. The Hausman tests support the random-effect specification in column (3) but the fixed-effect specification from column (4) to (7). Focusing our attention to the spillover effects of FDI firstly, we do not find any significant positive effects of horizontal FDI spillover on labor productivity since the coefficients on FDI_H, though insignificant in some specifications (in column (4), (5) and (6)), are all negative. In contrast, we find strong positive effects of backward FDI spillover on industry's labor productivity for the coefficients on FDI_BW are significant positive (except in column (3)), suggesting effectively backward linkages across industries. We also find weaker positive spillovers from forward FDI spillover for the coefficients on FDI_FW are positive though insignificant in some specifications (in column (4), (5) and (6)). The results support that FDI spillovers are more likely existing in the vertical linkages across industries when we explicitly distinguish backward linkages and forward linkages.

Table 3 The Effects of FDI Spillover, Environmental Pollution and Energy Consumption intensities on Labour Productivity (LPL)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
LKL	**0.784*****	**0.663*****	**0.809*****	**0.865*****	**0.779*****	**0.844*****	**0.791*****
	(12.23)	(10.84)	(17.25)	(13.95)	(12.14)	(18.08)	(15.37)
LK	**0.683*****	**0.432*****	**0.182*****	**0.473*****	**0.595*****	**-0.00949**	**0.231*****
	(11.52)	(8.97)	(4.05)	(5.84)	(7.91)	(-0.14)	(3.57)
FDI Spillover							
FDI_H(-1)	**-0.360**	**-0.109**	**-0.788***	**-0.350**	**-0.283**	**-0.281**	**-0.863***
	(-0.70)	(-0.23)	(-2.15)	(-0.70)	(-0.55)	(-0.75)	(-2.07)
FDI_FW(-1)	**0.734**	**1.660***	**1.259***	**0.212**	**0.433**	**0.699**	**1.105†**
	(0.98)	(2.05)	(2.10)	(0.29)	(0.58)	(1.29)	(1.83)
FDI_BW(-1)	**2.194*****	**1.408***	**0.575**	**1.824*****	**1.883*****	**0.675†**	**1.192****
	(4.03)	(2.30)	(1.28)	(3.56)	(3.57)	(1.64)	(2.66)
Environment Pollution and Energy consumption intensity			WA	SO2	SMO	SCE	EPOW
EP			**-0.294*****	**-0.131*****	**-0.0374***	**-0.598*****	**-0.549*****
			(-12.35)	(-4.02)	(-2.36)	(-13.12)	(-10.26)

Control Variables							
H	**0.103*****	**0.0823*****	**0.0226**	**0.0688*****	**0.0809*****	**0.0398****	**0.0575*****
	(5.79)	(4.06)	(1.43)	(3.85)	(4.49)	(2.88)	(3.82)
RD	**-0.127***	**-0.178****	**-0.0584**	**-0.122***	**-0.135****	**-0.0594†**	**-0.0768†**
	(-2.53)	(-3.03)	(-1.33)	(-2.52)	(-2.69)	(-1.61)	(-1.89)
Constant	**-5.500*****	**-3.375*****	**-0.808***	**-3.464*****	**-4.522*****	**4.750*****	**1.510***
	(-13.18)	(-8.74)	(-2.10)	(-5.28)	(-7.51)	(5.67)	(1.98)
Obs.	224	224	210	210	210	224	224
Dependent variable	LPL	LPL	LPL	LPL	LPL	LPL	LPL
R Squared	0.7311	0.7082	0.8146	0.7602	0.7461	0.8596	0.8195
Hausman Test	NA	NA	4.8300	37.8500	326.0200	33.8000	24.7700
P Value			0.7754	0.0000	0.0000	0.0000	0.0017
Model Selection	FE	RE	RE	FE	FE	FE	FE

Notes: t statistics in parentheses. †Significant at the 10% level; * significant at the 5% level; ** significant at the 1% level, *** significant at the 0.1% level

There are five environment pollution and energy consumption intensity indices as proxies for EP: industry wasted water discharge per gross industrial output (WA), total volume of industrial sulphur dioxide emission per gross industrial output (SO2), total volume of industrial soot emission per gross industrial output (SMO), total volume of industrial energy consumption per gross industrial output value(SCE) and total volume of industrial electric power consumption per gross industrial output value (EPOW). The most striking result from Table 3 is that, in all specifications (from column (3) to (7)), the coefficients on WA, SO2, SMO, SCE and EPOW are all significantly negative at conventional significant level, suggesting low level environment pollutions and energy consumption intensities do have advantages on industry's labor productivity.

With regard to the control variables, the coefficients on human capital (H) are positive and significant in all equations, suggesting the increasing human capital quality is in favor of industry's labor productivity. However, the coefficients on expenditures on science and technology activities (RD) are significant negative in all equations, suggesting expenditures on science and technology activities have passive effects on industry' labor productivity.

How robust is this result to changes in the measurement of the productivity variable while TFP in principle contains more information than simple labor productivity? In order to investigate this, we now examine the effect of FDI and environmental pollution and energy consumption intensities on TFP measures.

Our empirical specification is aimed at explaining the effects of FDI and environment pollutions and energy consumption intensities on industry' productivity, that is, FDI spillovers and environment pollutions and energy consumption intensities have potential force on industries productivity. As is likely, industries productivity also can affect FDI and environment pollutions and energy consumption intensities by attracting more FDI inflow to these industries and enabling them to invest in cleaner technologies etc. when they get more productive. In dealing with the possible endogeneity bias arising from FDI and environment pollutions and energy consumption intensities variables, we have used lagged measures of FDI spillovers instead of FDI spillovers at time t. Lags may be appropriate because spillovers may take time to materialize. Unbiasedness and consistency of panel data estimates (RE and FE methods) rest on the assumption that the explanatory variables are uncorrelated with the stochastic disturbance terms. This assumption becomes invalid now that makes the use of panel data estimates approach inappropriate. Next, this study pursues two strategies to copy with the possible endogeneity bias.

The first strategy is to adopt a simultaneous equation approach where 2SLS has emerged as a good compromise choice which involves estimation in two stages and avoids the simple one-stage bias and inconsistency. The second strategy is to employs the Arellano-Bond GMM estimator, which adds lagged dependent variables and specifies that a set of endogenous variables be included in the right side of the model and lagged two or more periods independent variables as instrumental variables.

The simultaneous equation approach of dealing with the endogeneity problem of environmental pollution and energy consumption intensities variables is to run a 2SLS estimator that requires instrumental variable (IV) methods to obtain consistent parameter estimates. In this part we employ two techniques, fixed effects 2SLS (FE2SLS) and random effects 2SLS (EC2SLS), to get the estimations of simultaneous equations using panel data. Baltagi (2005) suggests a Hausman test based on the difference between fixed effects 2SLS and random effects 2SLS, which distributes as χ^2, to examine whether or not to reject the null hypothesis that random effects 2SLS yields a consistent estimator.

Table 4 The Results of 2SLS Method of FDI Spillovers, Environmental Pollution and Energy Consumption Intensities on Industries' Productivity (TFP)

	(1)	(2)	(3)	(4)	(5)
FDI Spillover					
FDI_H(-1)	**0.148**	**0.669**	**-0.206**	**0.372**	**-0.239**
	(0.31)	(1.28)	(-0.23)	(0.90)	(-0.53)
FDI_FW(-1)	**1.139**	**0.949**	**-1.765**	**1.287†**	**1.534***
	(1.55)	(1.05)	(-0.84)	(1.89)	(2.34)
FDI_BW(-1)	**1.273***	**1.908*****	**1.557†**	**1.495****	**1.375****
	(2.52)	(3.37)	(1.87)	(3.04)	(2.78)
Environment Pollution and Energy consumption intensity	WA	SO2	SMO	SCE	EPOW
EP	**-0.244*****	**-0.151*****	**-0.276***	**-0.310*****	**-0.489*****
	(-4.34)	(-3.63)	(-2.53)	(-5.08)	(-5.14)
Control Variables					
H	**0.0535****	**0.0823*****	**0.0524†**	**0.0782*****	**0.0689*****

	(3.21)	(4.62)	(1.82)	(5.48)	(4.72)
RD	**-0.0413**	**-0.111***	**-0.194***	**-0.0847***	**-0.0763†**
	(-0.85)	(-2.08)	(-2.38)	(-1.97)	(-1.78)
Constant	**-0.557**	**-0.882****	**0.778**	**1.349†**	**2.005***
	(-1.60)	(-2.63)	(0.71)	(1.96)	(2.48)
Obs.	210	210	210	224	224
Dependent variable	TFP	TFP	TFP	TFP	TFP
R Squared	0.7333	0.6184	0.2173	0.7569	0.7625
Hausman Test	43.6700	75.0100	12.9200	41.9400	43.5800
P Value	0.0000	0.0000	0.0444	0.0000	0.0000
Model Selection	FE	FE	FE	FE	FE

Notes: t statistics in parentheses. †Significant at the 10% level; * significant at the 5% level; ** significant at the 1% level, *** significant at the 0.1% level

Table 4 gives fixed effects 2SLS (FE2SLS) and the random effects (EC2SLS) estimators where environmental pollution and energy consumption intensities variables (WA, SO2, SMO SCE and EPOW) are treated as endogenous variables. Some studies find that capital-intensive sectors are typically pollution intensive and the capital-abundant industries will specialize in pollution-intensive production, whilst the labor-abundant industries will do the opposite. So the capital-labor ratio is a good indicator for pollution and energy consumption intensities. The correlations between environmental pollution and energy consumption intensities variables (WA, SO2, SMO SCE and EPOW) and capital-labor ratio (LKL) are from 0.42 to 0.58, showed in Table 2 of our study, which imply LKL is a reasonable instrumental variable (IV) for environmental pollution and energy consumption intensities variables.

The Hausman statistics support the fixed effects 2SLS (FE2SLS) over the random effects (EC2SLS) specifications. For the impact of FDI spillovers, there are no positive effects of horizontal FDI spillovers on industries' productivity since the coefficients on FDI_H, though positive in most specifications, are all insignificant. In contrast, there are strong positive effects of backward FDI spillovers on industry's productivity for the coefficients on FDI_BW are all significant positive, suggesting effectively backward linkages across industries. We also find weaker positive spillovers from forward FDI spillover for the coefficients on FDI_FW are positive though significant in some specifications (in column (4) and (5)). The results also support that FDI spillovers are more likely existing in the vertical linkages across industries rather than horizontal linkages. The coefficients on EP variables are significantly negative in all specifications, reinforcing the conclusion that environment pollutions and energy consumption do have disadvantages on industry' productivity.

It is the possibility that the annual observations on FDI spillovers, environment pollutions and energy consumption intensities may not represent long-run equilibrium values in any given year because of slow adjustment to changes in other variables. To allow for the possibility of partial adjustment, this study specifies a dynamic panel data method which includes a lagged dependent variable, TFP_{it-1}. The empirical model is therefore as follows:

$$\begin{aligned} TFP_{it} &= \phi + \rho \cdot TFP_{it-1} + \beta_1 FDI\_H_{it} + \beta_2 FDI\_FW_{it} \\ &\quad + \beta_3 FDI\_BW_{it} + \beta_4 EP_{it} + Z'_{it}\delta + \mu_i + \varepsilon_{it} \end{aligned} \tag{7}$$

It is well known that OLS estimates are biased and inconsistent when there are dynamic effects and simultaneities in the specification. To account for these effects the generalized method of moments (GMM) techniques developed by Arellano and Bond (1991) is specifically designed to address the econometric problems induced by unobserved group-specific effects and endogeneity of the explanatory variables in lagged dependent variable models. Arellano-Bond estimation starts by transforming all regressors by differencing and so is called difference GMM. The Arellano and Bover (1995)/Blundell and Bond (1998) estimator augments Arellano-Bond by making an additional assumption, that first differences of instrumenting variables are uncorrelated with the fixed effects, which allows the introduction of more instruments, and can dramatically improve efficiency. It builds a system of two equations, the original equation as well as the transformed one, and is known as system GMM. This paper employs the system GMM method.

More specifically, we use the two-step GMM instead of one-step because two-step is asymptotically more efficient. There are two tests for the validity of the instruments. The first is either a Sargan or Hansen test of over-identifying restrictions, which tests the overall validity of the instruments. The second test is the autoregressive (AR) test, which examines the hypothesis that the error term is not serially correlated in both the difference regression and the system difference-level regression. Two diagnostics are computed using the Arellano and Bond GMM procedure to test for first order and second order serial correlation in the disturbances. The differenced error term is allowed to be first-order serially correlated, but the second order serially correlation of error term will violate the assumption of GMM procedure.

Table 5 The Dynamic Panel Data Method of FDI Spillovers, Environmental Pollution and Energy Consumption Intensities on Industries' Productivity (TFP)

	(1)	(2)	(3)	(4)	(5)
TFP(-1)	**0.792*****	**0.923*****	**0.822*****	**0.740*****	**0.783*****
	(15.16)	(16.52)	(41.23)	(32.56)	(24.47)
FDI Spillover					
FDI_H	**0.337**	**-0.465**	**-0.632****	**-0.799*****	**-0.0892**
	(0.59)	(-1.51)	(-2.62)	(-5.26)	(-0.29)
FDI_FW	**-0.487**	**0.00597**	**-0.0989**	**0.164**	**-0.0705**
	(-0.75)	(0.02)	(-0.39)	(0.34)	(-0.18)
FDI_BW	**0.799†**	**0.622†**	**0.492**	**0.251**	**0.388†**

	(1.80)	(1.65)	(1.59)	(0.85)	(1.84)
Environment Pollution and Energy consumption intensity	WA	SO2	SMO	SCE	EPOW
EP	**-0.0576***	**-0.000930**	**-0.0452*****	**-0.132*****	**-0.139*****
	(-2.44)	(-0.04)	(-8.97)	(-9.78)	(-6.50)
Control Variables					
H	**-0.0000549**	**0.000575**	**0.00916**	**0.0258*****	**0.0152***
	(-0.01)	(0.04)	(0.91)	(3.86)	(1.98)
RD	**0.0826†**	**0.0354**	**-0.0402**	**-0.0380**	**0.0358**
	(1.73)	(0.82)	(-1.05)	(-1.34)	(1.51)
Constant	**-0.200**	**-0.0278**	**0.274****	**1.226*****	**0.726*****
	(-1.12)	(-0.35)	(2.85)	(7.60)	(5.58)
Obs.	224	224	210	210	210
Dependent variable	TFP	TFP	TFP	TFP	TFP
AR(1) statistics	-4.0745	-3.8684	-4.0949	-3.9951	-3.7581
P Value	0.0000	0.0001	0.0000	0.0001	0.0002
AR(2) statistics	0.5354	0.9210	-0.4632	0.4566	0.4486
P Value	0.5924	0.3571	0.6432	0.6479	0.6537
Sargan statistics	19.9313	25.5528	25.9191	27.4557	23.6679
P Value	1.0000	1.0000	1.0000	1.0000	1.0000

Notes: t statistics in parentheses. †Significant at the 10% level; * significant at the 5% level; ** significant at the 1% level, *** significant at the 0.1% level

Table 5 presents the two-step system GMM estimations of equation (7) which employ the Blundell and Bond dynamic panel-data estimation technique. Here we treat FDI spillovers variables (FDI_H, FDI_FW and FDI_BW), environmental pollution and energy consumption intensities variables (WA, SO2, SMO SCE and EPOW) as endogenous variables since they may have bidirectional feedback mechanism on TFP. The P-values of Sargan statistics are all larger than conventional level (10% significant level) which implies failure to reject the null hypotheses that the over-identifying moment conditions are valid. The P-values of AR(1) statistics are all below 0.1% level but the P-values of AR(2) statistics are all larger than conventional critical level 10%, which rejects the null hypothesis of no serial correlation at order one in the first-differenced errors but can't to reject the null hypothesis at two orders which again implies that the moment conditions are valid.

The coefficients on lagged dependent variable, TFP(-1), are positive significant in all specifications, suggesting productivity has a strong consolidation among itself. The coefficients on variable FDI_H are negative in most specifications (except in column (1)), suggesting that the presence of FDI creates negative intra-industry externalities on industries' productivity which implies the competition effects preponderate over horizontal FDI spillover effects. The coefficients on variable FDI_BW are all positive, while at mild significant level (10% level), suggesting that the possibility of spillovers exist among the backward linkages across industries is flimsy when we take the feedback among productivity into account. The coefficients on variable FDI_FW are all insignificant with mixed sign, suggesting the absence of spillovers among the forward linkage compared with the possibilities of FDI externalities through backward linkages. As for environment pollution and energy consumption intensity variables, the coefficients on EP variables are significantly negative in most specifications (except in column (2)), suggesting environment pollutions and energy consumption do have disadvantages on industry' productivity, which are exiguous different from the results in Table 4.

The overall picture supports the conclusions that FDI spillovers are more likely existing in the vertical linkages across industries rather than horizontal linkages and environment pollutions and energy consumption do have disadvantages on industry' productivity even we use different industries' productivity measures and give emphasis to the endogeneity problem of environmental pollution and energy consumption intensities variables.

Table 6 shows results using the technical inefficiency effects as the dependent variable that specified in equation (6). Despite the mild statistical significance in some specifications (i.e., the 10% level), the positive coefficients on FDI_H suggest that FDI horizontal spillovers decrease China's industries to utilize their resources in a more efficient way, which then lead to negative productivity gains. The coefficients on FDI_FW are almost insignificant negative (except in column (5)) but the coefficients on FDI_FW are significant negative, confirming the expected FDI spillovers are more likely existing in the vertical linkages across industries, especially among backward linkages, which increase China's industries to utilize their resources in a more efficient way and lead to productivity gains. The coefficients on WA, SO2, SMO, SCE and EPOW are all positive though insignificant in column (2) and (3), suggesting low level environment pollutions and energy consumption intensities can reduce the inefficiency of China's industries to utilize their resources then promote their industry's productivity.

Table 6 The Effects of FDI Spillover, Environmental Pollution and Energy Consumption intensities on technical inefficiency effects (U)

	(1)	(2)	(3)	(4)	(5)	(6)
FDI Spillover						
FDI_H(-1)	**0.953†**	**1.155***	**0.937†**	**0.901†**	**1.181***	**1.397****
	(1.97)	(2.38)	(1.90)	(1.81)	(2.52)	(2.96)
FDI_FW(-1)	**-0.534**	**-0.00914**	**-0.224**	**-0.454**	**0.158**	**-0.0115**
	(-0.73)	(-0.01)	(-0.30)	(-0.61)	(0.22)	(-0.02)
FDI_BW(-1)	**-2.120*****	**-1.626****	**-1.850*****	**-1.865*****	**-1.741****	**-1.733****
	(-3.83)	(-3.07)	(-3.43)	(-3.44)	(-3.21)	(-3.23)
Environment Pollution and Energy consumption intensity		WA	SO2	SMO	SCE	EPOW

EP		**0.0781*** **	**0.0257**	**0.00496**	**0.136*** **	**0.192*** **
		(3.39)	(1.26)	(0.40)	(3.99)	(4.39)
Control Variables						
H	**-0.0905*** **	**-0.0612*** **	**-0.0710*** **	**-0.0711*** **	**-0.0837*** **	**-0.0808*** **
	(-5.40)	(-3.64)	(-4.18)	(-4.16)	(-5.16)	(-5.00)
RD	**0.134** **	**0.108* **	**0.132* **	**0.135** **	**0.121* **	**0.119* **
	(2.61)	(2.15)	(2.58)	(2.63)	(2.44)	(2.42)
Constant	**2.575*** **	**2.009*** **	**2.272*** **	**2.404*** **	**1.066** **	**0.967* **
	(16.49)	(9.98)	(10.69)	(12.08)	(2.62)	(2.45)
Obs.	224	210	210	210	224	224
Dependent variable	U	U	U	U	U	U
R Squared	0.2471	0.2598	0.2184	0.2120	0.3112	0.3222
Model Selection	FE	FE	FE	FE	FE	FE

Notes: t statistics in parentheses. †Significant at the 10% level; * significant at the 5% level; ** significant at the 1% level, *** significant at the 0.1% level

The findings now show that two types of spillovers effect arise from the presence of FDI, negative intra-industry spillovers and positive spillovers through inter-industry. At the level of the industry, the superior knowledge brought into the economy through FDI, it will also affect the competitive landscape in the domestic economy, leading to an increase in competition for domestic industries. Hence, the effect of horizontal FDI spillover may depend on the trade-off between technological externalities from FDI spillover and competition: if horizontal FDI spillover preponderates over negative competition then we would expect a positive horizontal FDI spillover effect. If, however, they are just the reverse we would expect increasing levels of FDI to discourage the improvement of productivity in domestic industries. The finding of negative intra-industry spillovers in the paper is consistent with the findings of the presence of a negative competition effect which arises when FDI takes part of the market from China's domestic firms which are then forced to produce at a lower production volume, leading to decreased efficiency levels. The finding of positive spillovers among inter-industry is that input–output relations between multinational companies and local firms often include various forms of assistance and technological support offered by multinational companies, such as multinational companies often offers advice and assistance to local firms to introduce new technologies into their production process, which results in productivity increases and thus positive externalities.

Our findings also imply that China's industries' technology differences are conditioned by pollution emission and energy consumption intensities behaviors. Industries that have induced innovation and production of environment-friendly technology, which then have lower pollution emission and energy consumption intensities and also attract FDI that often employs newer and cleaner technology, would result in higher level industries' productivity. While industries that typically use older and less "green" technologies and even purchase second-hand machineries, which results in higher level pollution emission and energy consumption intensities, have lower level industries' productivity. It seems particularly promising to explore the possibility that industries productivity is correlated with abatement efficiency. Though we do not have any direct evidence on the levels of technology used by China's industries in our sample, however many China's industries have relatively limited access to green technologies, our results would be consistent with technology-based explanations which are focused on expanding access to abatement technology and lowering the cost of its adoption.

4. The FDI Spillovers on Environment Pollution and Energy Consumption Intensities

Multinational corporations may still employ relatively cleaner production technologies to the subsequent benefit of the host country though they choose to locate in a developing country to avoid a high regulatory burden. Thus firms can absorb environmental and energy consumption knowledge either directly or indirectly through forward links with suppliers and backward links with customers or horizontal links with competitors. To test the FDI spillovers on environment pollution and energy consumption intensities, in this section we introduce the following model:

$$\begin{aligned} EP_{it} = \gamma_0 + \gamma_1 FDI\_H_{it-1} + \gamma_2 FDI\_FW_{it-1} \\ + \gamma_3 FDI\_BW_{it-1} + \lambda \cdot TFP_{it} + W_{it}'\theta + \mu_i + \varepsilon_{it} \end{aligned} \tag{8}$$

where EP denotes environment pollution and energy consumption intensities which include WA, SO2, SMO, SCE and EPOW. W is a vector of control variables (human capital (H) and expenditures on science and technology activities (RD)), μ_i is the individual effect for industry i, and ε_{it} is the residual.

Table 7 The FDI Spillovers on Environment Pollution and Energy Consumption Intensities

	(1)	(2)	(3)	(4)	(5)	(6)
FDI Spillover						
FDI_H(-1)	**-2.038***	**-0.460**	**-4.075***	**-0.502**	**-1.446****	**-1.672*****
	(-2.24)	(-0.32)	(-2.49)	(-0.85)	(-2.95)	(-3.84)
FDI_FW(-1)	**-0.711**	**-7.192*****	**-3.400**	**-1.319**	**0.0651**	**-0.445**
	(-0.49)	(-3.40)	(-1.18)	(-1.45)	(0.09)	(-0.62)
FDI_BW(-1)	**-0.0237**	**2.712†**	**0.246**	**0.318**	**0.281**	**0.607**
	(-0.02)	(1.70)	(0.11)	(0.46)	(0.49)	(1.10)
TFP	**-1.824*****	**-1.777*****	**-2.444*****	**-1.318*****	**-0.974*****	**-0.965*****
	(-16.24)	(-10.64)	(-10.59)	(-18.84)	(-16.68)	(-17.85)
Control Variables						
H	**0.0158**	**0.126***	**0.0717**	**0.0735*****	**0.0405***	**0.0334†**
	(0.44)	(2.48)	(0.95)	(3.45)	(2.28)	(1.96)
RD	**0.0747**	**-0.144**	**-0.599****	**-0.0542**	**-0.0330**	**-0.0322**
	(0.71)	(-0.97)	(-2.59)	(-0.87)	(-0.63)	(-0.63)
Constant	**2.251*****	**3.566*****	**5.178*****	**8.347*****	**6.346*****	**6.484*****

	(5.70)	(6.39)	(9.51)	(34.94)	(31.82)	(34.37)
Obs.	210	210	210	224	224	224
Dependent variable	WA	SO2	SMO	SCE	EPOW	EPOW
R Squared	0.7223	0.5972	0.4875	0.7833	0.7446	0.7432
Hausman Test	7.5800	15.9900	7.6600	30.5100	NA	NA
P Value	0.2707	0.0138	0.2641	0.0000		
Model Selection	RE	FE	RE	FE	FE	RE

Notes: t statistics in parentheses. †Significant at the 10% level; * significant at the 5% level; ** significant at the 1% level, *** significant at the 0.1% level

Initially equation (8) is estimated using the panel data method. Table 7 reports the regression results. The coefficients on TFP are all significant negative, suggesting improvement of industries' productivity reduces environment pollution and energy consumption intensities, which is very familiar with the result of Cole et al. (2008) who also find an industry's emissions to be a negative function of its productivity in China. It is now widely recognized that technological change will play a substantial role in reducing greenhouse gases emissions. Fisher-Vanden and Wing (2008) show that efficiency-improving has opposing influences on energy and emission intensities. Ma et al. (2008) argues that China's energy intensity is increasing during the period of 1995-2004 and the major driver appears to be due to the increased use of energy intensive technology. Ma and Stern (2008) find that technological change is the dominant contributor to the decline in energy intensity and the increase in energy intensity since 2000 is explained by negative technological progress. Our result is consistent with the explanation that unproductive industries generate more pollution. We might expect an industry that is more productive to be more resource efficient and better managed and hence to be less environment pollution emission and energy intensive per unit of output. Furthermore, highly productive industries should also be better placed to respond relatively quickly to any change in pollution control incentives.

The coefficients on variable FDI_H are negative and significant in most specifications (except in column (2) and (4)), suggesting horizontal FDI spillovers decreases the emission of environment pollution and energy consumption. However, the coefficients on backward FDI spillovers variable (FDI_BW) and forward FDI spillover effect variable (FDI_FW) are insignificantly in many specifications (except in column (2)), suggesting backward FDI spillovers and forward FDI spillovers have limited effects on the emission of environment pollution and energy consumption. Hence, any better understanding of the FDI spillovers is likely to increase our knowledge of mitigation possibilities. Valentina Bosetti et al. (2008) explore how international knowledge flows affect the dynamics of the domestic environmental emissions and find that international knowledge spillovers tend to increase free-riding incentives and decrease the investments in energy R&D.

As for the control variables, the coefficients on human capital (H) are positive and significant in most specification, suggesting the increasing human capital quality is not in favor of the abatement of the emission of environment pollution and energy consumption. However, the coefficients on expenditures on science and technology activities (RD) are negative though insignificant in most specification, suggesting expenditures on science and technology activities have no significant effects on the abatement of the emission of environment pollution and energy consumption.

To allow for the possibility of partial adjustment and the endogeneity of independent variables, we specify a dynamic equation which includes a lagged dependent variable, EP_{it-1}. The empirical model is therefore as follows:

$$\begin{aligned} EP_{it} = \gamma_0 + \rho \cdot EP_{it} + \gamma_1 FDI\_H_{it} + \gamma_2 FDI\_FW_{it} \\ + \gamma_3 FDI\_BW_{it} + \lambda \cdot TFP_{it} + W_{it}'\theta + \mu_i + \varepsilon_{it} \end{aligned} \tag{9}$$

Table 8 The Dynamic Panel Data Method of FDI Spillovers on Environment Pollution and Energy Consumption Intensities

	(1)	(2)	(3)	(4)	(5)
EP(-1)	**0.768*****	**0.812*****	**0.107*****	**0.790*****	**0.766*****
	(9.40)	(10.75)	(4.90)	(30.19)	(22.36)
FDI Spillover					
FDI_H	**-0.520**	**0.552**	**-9.466*****	**-0.891*****	**-0.535****
	(-0.91)	(0.58)	(-3.46)	(-3.76)	(-3.02)
FDI_FW	**0.789**	**-0.377**	**2.091**	**0.649**	**0.272**
	(1.52)	(-0.26)	(0.52)	(0.94)	(0.84)
FDI_BW	**-1.317*****	**-0.705**	**-0.156**	**-0.317**	**-0.114**
	(-3.30)	(-0.79)	(-0.08)	(-0.80)	(-0.56)
TFP	**-0.547****	**-0.571****	**-2.757*****	**-0.406*****	**-0.375*****
	(-3.06)	(-3.28)	(-12.68)	(-9.76)	(-12.96)
Control Variables					
H	**-0.0264†**	**0.0316****	**0.226****	**0.0226****	**-0.00613**
	(-1.73)	(2.95)	(3.00)	(3.09)	(-0.74)
RD	**-0.00622**	**-0.131****	**-1.732*****	**-0.0223**	**0.0446***
	(-0.11)	(-2.82)	(-7.20)	(-1.33)	(2.56)
Constant	**0.722*****	**0.551†**	**6.295*****	**1.757*****	**1.458*****
	(3.40)	(1.85)	(7.11)	(5.89)	(4.75)
Obs.	196	196	196	210	210
Dependent variable	WA	SO2	SMO	SCE	EPOW
AR(1) statistics	-1.9828	-2.0531	-3.6365	-1.9710	-1.5729
P Value	0.0474	0.0401	0.0003	0.0487	0.1157
AR(2) statistics	0.5559	1.6240	1.3672	-0.7870	-1.1439
P Value	0.5783	0.1044	0.1716	0.4313	0.2527
Sargan statistics	26.5667	16.9937	23.6952	26.2974	24.6330
P Value	1.0000	1.0000	1.0000	1.0000	1.0000

Notes: t statistics in parentheses. †Significant at the 10% level; * significant at the 5% level; ** significant at the 1% level, *** significant at the 0.1% level

Table 8 reports the results of equation (9) which include the lagged environment pollution and energy consumption intensities in the right hand side. We treat FDI spillover variables (FDI_H, FDI_FW and FDI_BW) and TFP as endogenous variables since they may have bidirectional feedback mechanism to environmental pollution and energy consumption intensities variables (WA, SO2, SMO SCE and EPOW). The coefficients on lagged dependent variable, EP(-1), are positive significant in all specifications, suggesting environmental pollution and energy consumption intensities have a strong feedback among itself. Again, the coefficients on lagged TFP are all significant negative suggesting productivity progress reduce environment pollution and energy consumption intensities. The coefficients on horizontal FDI spillovers variable (FDI_H) are significant negative except in column (1) and (2) specifications, suggesting horizontal FDI spillovers decreases the emission of environment pollution and energy consumption intensities. However, the coefficients on backward FDI spillovers variable (FDI_BW) and forward FDI spillovers variable (FDI_FW) are almost insignificantly in all specifications (except in column (1)), suggesting backward FDI spillovers and forward FDI spillovers have limited effect on the emission of environment pollution and energy consumption intensities which echoes the results in Table 7.

The consistently significant coefficient on horizontal FDI spillovers variable indicates that foreign firms may adopt low-environment-pollution-intensity and low-power consuming technologies which low the emission of environment pollution and energy consumption. However, it is not mean that they be willing to transfer environmental knowledge within the same industry because their generosity does not appear to extend to direct competitors. Albornoz et al. (2009) identify the relationship between FDI and the environmental performance of firms by investigating the influence of a foreign presence and the role of spillovers, on the extent to which firms have implemented environmental management systems (EMS). They find that foreign-owned firms are more likely to adopt EMS than domestic firms and are also more likely to adopt a wider range of EMS, but they have evidence of spillovers moving from one foreign firm to another, rather than from foreign to domestic firms as may have been expected. As an adminicle we find no evidences that the vertical FDI spillovers decrease the emission of environment pollution and energy consumption intensities, though the vertical FDI spillovers promote industry' productivity.

5. Conclusions

Using the correlated data of 28 Chinese manufacturing industries during 1999-2008, this paper examines the effects of the FDI, which is distinguished as horizontal, forward linkage and backward linkage spillovers, and environmental pollution and energy consumption intensities on industries' productivity. The empirical results show that FDI spillovers are more likely existing in the vertical linkages across industries rather than horizontal linkages and environment pollutions and energy consumption do have disadvantages on industry' productivity even we use different industries' productivity measures and give emphasis to the endogeneity problem of these variables. Further studies of the FDI spillovers on environment pollution and energy consumption intensities suggest that horizontal FDI spillover decreases the emission of environment pollution emission and energy consumption intensities though vertical FDI spillovers have limited effect on them, which indicate that foreign firms may adopt "green" technologies within the same industry to enforce their competitive ability but they have little incentive to transfer environmental knowledge to their forward and backward linkages customers.

The environmental pollution emission and energy consumption intensities have significant negative impact on industries' productivity. One interpretation of our result is that industries productivity is correlated with abatement efficiency since physical capital intensive industries are also the most environmental pollution emission and energy intensive ones, which implies that those industries that use relatively low level technologies, older second-hand machineries and less "green" technologies typically generate greater volumes of pollution and require substantive capital stocks to maintain them, which are likely to be less efficient and therefore relatively lower industries' productivity. On the other hand, improvement of industries' productivity can reduce environment pollution emission and energy consumption intensities. Our result is consistent with the explanation that more productive industries are more resource efficient and better managed and hence less environment pollution emission and energy intensive.

Overall, our findings may provide a justification for policy intervention to encourage foreign investment. Blalock and Gertler (2008) test the hypothesis that multinational firms operating in emerging markets transfer technology to local suppliers is Pareto improving output and profits increase for firms in both the supplier and buyer sectors. A policy designed to promote technology transfer to China, especially to promote FDI vertical spillovers effect will help put FDI to spur innovation, promote industrial restructuring and ease regional imbalance. Imposing local content requirements may be a practical proposal.

Unfortunately, vertical FDI spillovers have limited effect on the reduction of environment pollution emission and energy consumption intensities though they have positive spillovers on industries' productivity. It is reasonable to consider the environmental friendly policies that can spur economic growth at a least cost to the environment by encouraging substitution toward the technologies and practices for pollution prevention and control. It is a possible policy prescription that governments encourage local firms (both foreign and domestic) to take part in the innovation of low energy consumption and low environment pollution emission technologies.

References

Adams, F. G. and Y. Shachmurove, "Modeling and forecasting energy consumption in China: Implications for Chinese energy demand and imports in 2020", *Energy Economics*, 30 (2008): 1263-1278.

Aitken, Brian J. and A. E. Harrison, "Do Domestic Firms Benefit from Direct Foreign Investment? Evidence from Venezuela", *American Economic Review*, 89(1999): 605-618.

Albornoz, F., M. A. Cole, R. J. R. Elliott and M. G. Ercolani, "In Search of Environmental Spillovers", World Economy, 1(2009):136-163.

Antweiler, W., B. R. Copeland and M. S. Taylor, "Is free trade good for environment?", *American Economic Review*, 91(2001): 877−908.

Arellano, M. and O. Bover, "Another Look at The Instrumental-Variable Estimation of Error-Components Models." *Journal of Econometrics*, 68(1995):29–52.

Arellano, M., and S. Bond, "Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations", *Review of Economic Studies*, 58(1991): 277–97.

Baltagi, B. H., *Econometric analysis of panel data* (3rd ed.), John Wiley & Sons Ltd (2005), England.

Barrios, S., H. Gorg, E. Strobl, "Spillovers through backward linkages from multinationals: Measurement matters!", *European Economic Review*, 55(2011): 862–875.

Bekes, G., J. Kleinert and F. Toubal, "Spillovers from Multinationals to Heterogeneous Domestic Firms: Evidence from Hungary", *World Economy*, 10(2009): 1408-1433.

Blalock, G. and P. J. Gertler, "Welfare gains from foreign direct investment through technology transfer through local suppliers", *Journal of International Economics*, 74(2008): 402–421.

Blomstrom, M. and F. Sjoholm, "Technology transfer and spillovers: Does local participation with multinationals matter?", *European Economic Review*, 43(1999): 915-923.

Blundell, R. and S. Bond, "Initial Conditions and Moment Restrictions in Dynamic Panel Data Models." *Journal of Econometrics*, 87(1998): 115-143.

Bwalya, S. M., "Foreign direct investment and technology spillovers: Evidence from panel data analysis of manufacturing firms in Zambia", *Journal of Development Economics*, 81(2006): 514-526.

Cole, M. A. and R. J. R. Elliott, "Determining the Trade-Environment Composition Effect: The Role of Capital, Labour and Environmental Regulations", *Journal of*

Environmental Economics and Management, 46(2003): 363-83.

Cole, M. A. and R. J. R. Elliott, "FDI and the Capital Intensity of "Dirty" Sectors: A Missing Piece of the Pollution Haven Puzzle", *Review of Development Economics*, 9(2005): 530-48.

Cole, M. A., R. J. R. Elliott and K. Shimamoto, "Industrial characteristics, environmental regulation and air pollution: An analysis of the UK manufacturing sector", *Journal of Environmental Economics and Management*, 50(2005): 121−143.

Cole, M. A., R. J.R. Elliott and S. Wu, "Industrial activity and the environment in China: An industry-level analysis", *China Economic Review*, 19(2008): 393-408.

Dean, J. M., M. E. Lovely and H. Wang, "Are foreign investors attracted to weak environmental regulations? Evaluating the evidence from China", *Journal of Development Economics*, 90(2009): 1-13.

Dries, L. and J. F. M. Swinnen, "Foreign Direct Investment, Vertical Integration, and Local Suppliers: Evidence from the Polish Dairy Sector", *World Development*, 32(2004): 1525-1544.

Elliott, R. J. R. and K. Shimamoto, "Are ASEAN Countries Havens for Japanese Pollution-Intensive Industry?", *World Economy*, 2(2008): 236-254.

Eskeland, G. S. and A. E. Harrison, "Moving to greener pastures? Multinationals and the pollution haven hypothesis", *Journal of Development Economics*, 70(2003): 1-23.

Esty, D. C., and D. Geradin, "Market Access, Competitiveness, and Harmonization: Environmental Protection in Regional Trade Agreements", *The Harvard Environmental Law Review*, 21(1997): 265- 336.

Fisher-Vanden, K. and I. S. Wing, "Accounting for quality: Issues with modeling the impact of R&D on economic growth and carbon emissions in developing economies", *Energy Economics*, 30 (2008): 2771-2784.

Javorcik, B., "Does Foreign Direct Investment Increase the Productivity of Domestic Firms? In Search of Spillovers Through Backward Linkages", *American Economic Review*, 94(2004): 605-627.

Jordaan, J. A., "Intra- and Inter-industry Externalities from Foreign Direct Investment in the Mexican Manufacturing Sector: New Evidence from Mexican Regions", *World Development*, 36(2008): 2838-2854.

Kumbhakar, S. C. and C. A. K. Lovell, *Stochastic Frontier Analysis*, Cambridge: Cambridge University Press (2000).

Lai, M., H. Wang and S. Zhu, "Double-edged effects of the technology gap and technology spillovers: Evidence from the Chinese industrial sector", *China Economic Review*, 20(2009): 414-424.

Lin, P., Z. Liu and Y. Zhang, "Do Chinese domestic firms benefit from FDI inflow?

Evidence of horizontal and vertical spillovers", *China Economic Review*, 20(2009): 677-691.

List, J. A. and C. Y. Co, "The effects of environmental regulations on foreign direct investment", *Journal of Environmental Economics and Management*, 40(2000): 1-20.

List, J. A., W. W. McHone and D. L. Millimet, "Effects of environmental regulation on foreign and domestic plant births: is there a home field advantage? ", *Journal of Urban Economics*, 56(2004): 303-326.

Liu, Z., "Foreign direct investment and technology spillovers: Theory and evidence", *Journal of Development Economics*, 85(2008): 176–193.

Ma, C. and D. I. Stern, "China's changing energy intensity trend: A decomposition analysis", *Energy Economics*, 30(2008): 1037-1053.

Ma, H., L. Oxley, J. Gibson and B. Kim, "China's energy economy: Technical change, factor demand and interfactor/interfuel substitution", *Energy Economics*, 30(2008): 2167-2183.

Mani, M. and D. Wheeler, "In Search of Pollution Havens: Dirty Industry in the World Economy 1960–95", *Journal of Environment and Development*, 7(1998): 215-47.

Sadik, A. T. and A. A. Bolbol, "Capital Flows, FDI, and Technology Spillovers: Evidence from Arab Countries", *World Development*, 29(2001): 2111-2125.

Smarzynska, B. S., "Does foreign direct investment increase the productivity of domestic firms: In search of spillovers through backward linkages", *American Economic Review*, 94(2004): 605-627.

Valentina B., C. Carraro, E. Massetti and M. Tavoni, "International energy R&D spillovers and the economics of greenhouse gas atmospheric stabilization", *Energy Economics*, 30 (2008): 2912-2929.

Veugelers, R. and B. Cassiman, "Foreign subsidiaries as a channel of international technology diffusion: Some direct firm level evidence from Belgium", *European Economic Review*, 48(2004): 455-476.

Waldkirch, A. and A. Ofosu, "Foreign Presence, Spillovers, and Productivity: Evidence from Ghana", *World Development*, 38(2010): 1114-1126.

Xu, B., "Multinational enterprises, technology diffusion, and host country productivity growth", *Journal of Development Economics*, 62(2000): 477-493.

Zhang, Z., "Why did the energy intensity fall in China's industrial sector in the 1990s? The relative importance of structural change and intensity change", *Energy Economics*, 25 (2003): 625-638.