Effect of foreign direct investment on firms' pollution intensity: evidence from a natural experiment in China

Xuefeng Wang[1] and Haiyun Liu[2*]

[1]Institute for Advanced Studies in Finance and Economics, Hubei University of Economics, China and [2]School of Economics, Huazhong University of Science and Technology, Wuhan, PR China

[*]Corresponding author. E-mail: lhaiyun@hust.edu.cn

Online Appendix

Appendix A. Decomposing the effects of FDI

The appendix provides an additional explanation and discussion on section 2. We consider an economy producing two goods, *X* and *Y*, using two factors, labor (*l*) and capital (*k*). The prices of the two factors are ω and γ. We treat *Y* as the numeraire, and the price of *X* is *p*. We assume that the production of *Y* does not pollute, while the production of *X* generates pollution *Z*. The emissions of *Z* are positively correlated with the output of *X*. Firms need to pay for the emissions of *Z* as the pollution has negative externalities, and the price for each unit of pollution is τ. Therefore, unlimited emission is not the most attractive option. Firms choose to use some of the production factors for pollution abatement. We assume the proportion of factors for pollution abatement is θ. If a firm takes no effort on abatement ($\theta = 0$), it produces its potential output. The production function with constant returns to scale of *X* and *Y* is

$$Y = f_y(k, l)$$

$$X = (1 - \theta) f_x(k, l),$$

where the functions are increasing, concave, and linearly homogeneous, and firms' emission of *Z* is:

$$Z = \frac{1}{\alpha\beta}\psi(\theta) f_x(k, l)$$

where $\psi(\theta) = (1 - \theta)^{1-\sigma}$ and it is a decreasing function of firms' pollution abatement input θ. α is firms' productivity. Firms with higher productivity generate fewer emissions with the same output scale and industry structure. β is firms' pollution management technique. Then the output of *X* is

$$X = (\alpha\beta Z)^{\sigma} f_x(k, l)^{1-\sigma}.$$

We can treat $\alpha\beta Z$ and $f_x(k, l)$ as the inputs for *X* for convenience. This function is in the Cobb-Douglas form, implying that:

$$\frac{(1-\sigma)\alpha\beta Z}{\sigma f_x(k,l)} = \frac{c^f}{\tau}$$

where c^f is the minimum cost per unit of output. It is related to the optimal capital-labor ratio derived based on the exogenous capital cost (γ) and labor cost (ω). In a perfectly competitive market, the profit of *X* is zero. Then we get:

$$pX = \tau\alpha\beta Z + c^f f_x(k,l).$$

The pollution intensity (emission per unit of *X*) is:

$$e \equiv \frac{Z}{X} = \frac{\sigma p}{\tau\alpha\beta} \ .$$

We defined the economy scale and the output share of *X* as *S* and *C*,

$$S = pX + Y$$

$$C = \frac{pX}{pX+Y} \ .$$

Then the emission of *Z* is

$$\mathrm{Z} = S \cdot C \cdot \frac{\sigma}{\tau\alpha\beta},$$

where σ and τ are exogenous variables. Hence the emission of *Z* rises as the economic scale and the output share of *X* rise, or the productivity and pollution management techniques fall. After taking the logarithm, we decompose the pollution intensity (*E*=*Z*/*S*) to the productivity, pollution management, and industry structure effects as follows:

$$\ln E = -\ln\alpha - \ln\beta + \ln C.$$

Appendix B. Summary of the related empirical literature

Table B1. Summary of the related empirical literature

Panel A. Related studies supporting the pollution halo hypothesis				
Literature	Method	Data	Findings	Economic significance
Bu *et al.* (2019)	OLS	Firm level (2005–2007)	Foreign firms have lower energy intensity than domestic firms.	Energy intensity of foreign firms is 13.8% lower than that of domestic firms on average.
Kong *et al.* (2020)	OLS and DID	Firm level (2006-2016)	FII positively impacts energy firms' innovation	A 1% rise in foreign shareholding increases the patent applications of energy firms by 0.009% on average.
Huang and Chang (2019)	Tobit model	Firm level (2004)	Using the ratio of sales to sewage charges to denote the firms' sewage density, they find that foreign firms have lower pollution costs than domestic firms.	Sewage density of foreign firms is 13% lower than that of domestic firms on average.
Jiang *et al.* (2014)	OLS	Firm level (2006-2007)	Foreign firms have less intensive pollution emissions than state-owned firms.	Sulfur dioxide emission intensity of foreign firms is 49.5% lower than that of domestic firms on average.
Panel B. Related studies supporting the pollution haven hypothesis				
Literature	Method	Data	Findings	Economic significance
Bu and Wagner (2016)	OLS	Firm level (1992-2009)	The US multinationals with low environmental capabilities target less-regulated Chinese provinces to avoid pollution management costs.	The US multinationals' environmental concern is negatively related to provincial environmental regulation strictness in China (β= -2.35, p = 0.04)
Wu *et al.* (2017)	Logit model	Firm level (2006-2010)	New polluting firms, especially foreign firms, were driven to the western regions with lax environmental mandates by the pollution regulation of China's Eleventh Five Year Plan.	A 1% rise in pollution reduction mandates of a province reduces the birth of new polluting firms by 2.2%.
Xu *et al.* (2021)	DDD	Firm level (2003−2013)	The stringent environmental management shrinks the foreign firms' output and drives the new foreign firms to cities with less pollutant reduction pressure.	One standard deviation rise in the emission reduction target reduces the output value of foreign firms in polluting industries by 1.83%.