Environmental Regulation and the Pattern of Outward FDI: An Empirical Assessment of the Pollution Haven Hypothesis*

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Abstract

This paper studies how environmental regulation plays a role in shaping the pattern of outward foreign direct investment, and thereby assesses the pollution haven hypothesis. Empirical evidence for the pollution haven hypothesis has been inconsistent in the literature, possibly due to data aggregation across industries, clean technology innovation in advanced countries, factor endowment effects, unobserved heterogeneity, or endogeneity of environmental policies. To circumvent these problems, we exploit highly disaggregated industry-level panel data from South Korea along with an identification and estimation strategy that has been rarely used in prior studies. After dealing with such issues, we find strong evidence that polluting industries tend to invest more in countries with laxer environmental regulations. As a complementary evidence, we also find that environmentally lax countries tend to specialize in polluting industries when the same strategy is applied to South Korean import data covering the same sample countries, industries, and time periods.

JEL classification codes: F18, F23, Q56

Keywords: pollution haven hypothesis, environmental regulation, comparative advantage, foreign direct investment, South Korea

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1 Introduction

The fall of economic barriers around the globe, along with technological advance, has been accelerating the international fragmentation of production processes for the last few decades. Firms are strategically relocating their part of production systems into foreign countries where they can benefit from country-specific advantages. This incentive is referred as the comparative advantage (or vertical) motive for foreign direct investment (FDI). An emerging question is, then, which country-specific characteristic can actually generate a comparative advantage that shapes the pattern of FDI. The literature has typically focused on factor endowments, such as (skilled and unskilled) labor and (physical) capital, and found evidence that countries with an abundant factor endowment attract more foreign investors in industries that use the factor intensively.[1]

Interestingly, in a separate strand of literature, the laxity of environmental regulations has also been assessed as another potential source of comparative advantage in FDI. The theoretical rationale is simple: polluting firms have an incentive to shift their production system to countries with lax environmental regulations to lower production costs. Classical Heckscher-Ohlin trade theory is then applied to predict that environmentally lax countries specialize in polluting goods, whereas stringent countries specialize in non-polluting goods.[2] However, tests of this so-called pollution haven hypothesis (PHH or pollution haven effect, PHE) have yielded inconsistent empirical evidence. While some studies find supportive evidence for the PHH (e.g., Keller and Levinson 2002; Cole and Elliott 2005; Kellenberg 2009), some find little (e.g., Eskeland and Harrison 2003; Javorcik and Wei 2004; Raspiller and Riedinger 2008), and others find limited evidence that is only observed in particular regions or industries (e.g., Dean et al. 2009; Wagner and Timmins 2009; Millimet and Roy 2011).[3]

The goal of this paper is first to figure out what are the underlying problems with prior investigations, and second to test if we can find a systematic pollution haven effect once such problems are accounted for. The underlying problem with the identification of the PHH can be summarized in two-fold: data and econometric issues. One data issue often pointed out in the literature is aggregation bias. When data is aggregated across industries, the incentive of polluting industries may be masked by non-polluting industries.[4] Another concern is that most studies have been relying on data from the US or advanced European countries. It is true that those countries impose tough environmental standards, but they also have advanced cost-saving

[1] See Yeaple (2003), Hanson et al. (2005), and Alfaro and Charlton (2009) for skill endowment, and Antrás (2003) and Bernard et al. (2010) for capital endowment as a source of comparative advantage for FDI.

[2] See Pethig (1976), McGuire (1982), Copeland and Taylor (1994, 2003) for theoretical background.

[3] See Jaffe et al. (1995), Brunnermeier and Levinson (2004), and Shadbegian and Wolverton (2010) for reviews of the literature on the PHH.

[4] In fact, Yeaple (2003) points out that this aggregation is one of the reasons any comparative advantage motive had not found empirical support in the literature.

clean technologies. Adoption of clean technologies may alleviate a firm's incentive to offshore production by reducing expenses on pollution control and abatement or related tax. Unless this technology effect is accounted for, using advanced country data may mask the pollution haven effect.

We exploit highly disaggregate industry-level data to avoid the aggregation bias. There are 120 4-digit industries according to the International Standard Industrial Classification Revision 4 (ISIC4) in our sample. To circumvent the second data issue, we choose to investigate the pattern of South Korean outward FDI. If clean technology does extenuate industry shift, the pollution haven effect would be more apparent in countries where regulation standards are strong enough to pressure firms, and yet clean technologies are not widely used. We expect that such case would be well observed in recently developed countries, like South Korea, Taiwan, Portugal, and Czech Republic.

In terms of econometric issues, first, the prior literature has often omitted other sources of comparative advantage in the model that might counteract the pollution haven effect. For example, polluting industries tend to capital-intensive. This correlation may make pollution havens less attractable because countries with lax environmental regulations usually have a scarce capital stock and rich labor force. Second, the literature has not been successful controlling for unobserved heterogeneity, especially in models for FDI flow. Since FDI decisions are far more complex than trade decisions, the determinants of FDI involve a wide range of country and industry characteristics. However, empirical models choose only a few of them to control for and many important determinants remain in error term. Third, even if the first two issues are absent, the endogeneity of environmental policies may stem from reverse causality or measurement error. Yet, the literature has not treated environmental policies as endogenous or failed to rely on credible exclusion restrictions.[5]

To deal with econometric issues, this paper adopts an identification strategy that has been rarely used in the pollution haven literature, despite being popular in the trade literature: determinants of comparative advantage are identified by interaction terms between country and industry characteristics. As an example, Romalis (2004) interacts country factor endowments (i.e., skilled labor, capital, and raw material) with industry factor intensity to test whether those factor endowments are determinants of comparative advantage.[6] If environmental laxity is a determinant of comparative advantage, it also can be evaluated in the same way as factor endowments are evaluated, that is, the pollution haven effect is identified through the interaction

[5]Kellenberg (2009) exceptionally provides good instruments for environmental policies. Millimet and Roy (2011) use alternative estimation methods that do not rely on exclusion restrictions.

[6]This identification strategy originates from Rajan and Zingales (1998) who examine whether countries with more developed financial system provoke a disproportionate growth in industries that relies more intensively on external finance. Using the same identification strategy, Levchenko (2007) and Nunn (2007) test for contract enforcement as a source of comparative advantage, Cuñat and Melitz (2012) for labor market flexibility.

term between host country's environmental laxity (relative to home country) and industry pollution intensity.

Our identification strategy helps resolve the econometric issues enumerated above. First, it can disentangle opposing forces between environmental laxity and other determinants of comparative advantage by pooling them in a single model. Also, since the pollution haven effect is identified by the environmental laxity interaction, we can control for all country- and industry-specific unobserved heterogeneity through country-year and industry-year fixed effects. More importantly, given that environmental laxity is absent in the country-year group demeaned model, we successfully provide a consistent instrumental variable (IV) estimate for the interaction of environmental laxity and pollution intensity. Advanced statistical tests for the validity of our instruments are provided. Another benefit of our model with these two fixed effects is that it simplifies to a popular empirical model for trade flow. Hence, we can directly apply the same model to trade data and test whether a similar pattern is observed in trade flow.[7]

After data and econometric issues are carefully treated, we find a strong evidence for the PHH: both fixed effect (FE) and IV estimation results clearly show that countries with lenient environmental regulations tend to attract more South Korean FDI in polluting industries than in non-pollution industries, which is theoretically in line with a chain proposition of comparative advantage (or the Quasi-Heckscher-Ohlin prediction).[8] To highlight the importance of each issue, the evidence disappears if either (i) data is aggregated to 2-digit industry level, (ii) capital endowment interaction is omitted from the model, or (iii) country- and industry-specific unobserved heterogeneities are not controlled for. Endogenization of environmental policies hardly alters the significance and magnitude of FE estimates given the validity of our instruments. Thus, while the prior literature has focused much attention on the potential endogeneity of environmental regulation, our results suggest that model specification and aggregation issues are significantly more important.[9]

Our finding is robust to the inclusion of additional controls, alternative samples, and alternative measure of environmental laxity or pollution intensity. When our model is applied to South Korean import data covering the same sample countries, industries and time periods, we find that countries with lax environmental regulations tend to specialize in polluting goods and export them to South Korea. Consequently, it provides a complementary evidence for the PHH.

[7] There are many studies that assess the pollution haven hypothesis using trade data. See Ederington et al. (2004, 2005), Levinson and Taylor (2008), and Broner et al. (2011) for example.

[8] The term, the chain proposition of comparative advantage, originates from Jones (1956), who states that, in two-country, many-goods, and two-factor model, when goods are ranked in order of a factor intensity, say capital, all exporting goods in relatively capital abundant country should lie higher on the list than all of its importing goods. For example, if the country exports 5th goods and imports 6th goods out of ten goods, then it should also export the first four goods and import the last four goods. Deardorff (1979) formally derives certain conditions under which the chain proposition of comparative advantage holds. Romalis (2004) extends the proposition to many-country, continuum of goods, and many-factor case, while he calls it the Quasi-Heckscher-Ohlin prediction.

[9] Testing directly the effect of clean technology innovation is beyond the scope of this paper.

We are aware of a few paper that apply the same identification strategy for evaluating the PHH. Javorcik and Wei (2004) exploit firm-level inbound FDI data in 25 transition economies to identify both overall and differential effect of environmental regulations, but they find little support for both effects. However, their results are doubtful, since they neither control for unobserved heterogeneity, nor treat environmental regulations as endogenous. More recently, Mulatu et al. (2010) and Broner et al. (2011) test whether or not environmental regulations can determine the pattern of industry location and trade flow, respectively. Both employ cross-sectional data, and face a simultaneity problem. Although they find a significant pollution haven effect, their treatments of the simultaneity problem are not satisfactory. Also, cross-sectional models cannot account for dynamic phenomena such as industrial agglomeration and spillover effects which have been shown to be important determinants of FDI. Hence, we extend the strategy to three-dimensional panel setting to apply to a model for FDI flows (as well as trade flows), and treat the endogeneity problem using an IV approach.

The remainder of this paper is organized as follows. Section 2 starts with an empirical model and related econometric issues. Section 3 describes the dataset and measurement of variables, whilst more detail information on the data is provided in the appendix. Section 4 presents estimation results and checks their robustness. Section 5 concludes.

2 Empirical Model

2.1 A Conceptual Framework

We first introduce a conceptual framework from which our model is developed. It comprises two distinct fundamental motivations in FDI: horizontal and vertical.[10] In a horizontal FDI model, due to Markusen (1984), multinational enterprises (MNEs) directly invest in host countries to serve local markets. Hence, MNEs prefer larger market size, regardless of industry types. This market-oriented motive causes the proximity-concentration trade-off: multinational sales come at the cost of losing plant-level scale economics (Brainard 1997). Consequently, long distance from home country, high transport cost of goods, and high trade barriers encourage local affiliate productions rather than exports. Also, if scale economies at the firm-level are relatively larger than the plant-level scale economies, firms want to own the same multiple production facilities in multiple host countries.

The vertical motivation is pioneered by Helpman (1984), where he argued that MNEs have incentives to fragment their production process and move to countries with lower production costs. Host country's comparative advantage in a production factor attracts FDI in industries using

[10] Recent studies emphasize the emergence of more complex versions of FDI, such as export platform or complex vertical FDI (e.g. Yeaple 2003; Grossman et al. 2006; Ekholm et al. 2007). However, we only focus on pure horizontal and vertical FDI for analytical simplicity.

that factor intensively. Contrary to the horizontal case, MNEs face the proximity-comparative advantage trade-off with the vertical FDI (Arkolakis et al. 2011). While MNEs can benefit from cheap production costs in host countries, they have to ship their products back to home country to serve domestic market or to proceed with further production processing. Hence, abundant resources in host countries spur vertical FDI, but this incentive is dampened by high transport costs and home country's trade barriers.

Both horizontal and vertical motivations have turned out important in empirical studies. Carr et al. (2001) tests so-called knowledge-capital model in which both horizontal and vertical activity can coexist endogenously. Using US foreign affiliate sales data, they find that both market size and differences in skill endowment are important determinants for foreign affiliate production. Yeaple (2003) examines the pattern of the US outward FDI to 39 host countries in 50 manufacturing industries in 1994, and confirms that FDI is driven by both market- and factor-seeking motivations. In particular, he finds a chain proposition of comparative advantage in skilled labor: skilled-labor intensive industries have a tendency to invest more in skilled-labor abundant countries, whereas skilled-labor non-intensive industries invest more in skilled-labor scarce countries. Bergstrand and Egger (2007) add physical capital as a third factor endowment to the knowledge-capital model predicting that relative capital abundance (as well as skill abundance) matters in the pattern of FDI. Capital-seeking motivation is observed in their panel data of bilateral FDI flows among 17 OECD countries from 1990 to 2000.

2.2 Model Specification

The baseline model includes horizontal and vertical motivation in the following way:

$$FDI_{ict} = \alpha Horizontal_{ict} + \beta Vertical_{ict} + \Delta + \epsilon_{ict} \,. \tag{1}$$

This model is similar to Yeaple (2003), but is extended to include time dimension and four different sources of comparative advantages in vertical motivation. In the model, home country's (South Korea's) FDI outflows in industry i to host country c at year t is a function of two motivations and a set of fixed effects (Δ).[11] All covariates in two motivations are lagged one year to avoid the simultaneity problem. In fact, lagged covariates are more appropriate than present ones if we assume that a firm's foreign investment decision is based on information at that time. Formally, we assume that a multinational's foreign investment decision for a year is made based on information through the end of last year.

In horizontal motive, we include the sum of home and host country's market size (mkt_{ct}), similarity between home and host country (sim_{ct}), average firm-level scale economies relative

[11] We borrow the expression for set of fixed effects from Levchenko et al. (2009).

to plant-level scale economies in an industry (SE_{it}), and host country tariff rate ($Htariff_{ict}$).[12] Thus,

$$\alpha Horizontal_{ict} = \alpha_1 mkt_{ct-1} + \alpha_2 sim_{ct-1} + \alpha_3 SE_{it-1} + \alpha_4 Htariff_{ict-1}\,. \tag{2}$$

The sum of market size is defined as the sum of host country c's GDP and home country k's GDP, i.e., $mkt_{ct} = GDP_{ct} + GDP_{kt}$. Similarity, sim_{ct}, is defined as $1 - s_{ct}^2 - s_{kt}^2$ with $s_{ct} = GDP_{ct}/(GDP_{ct} + GDP_{kt})$ and $s_{kt} = GDP_{kt}/(GDP_{ct} + GDP_{kt})$.[13] This measure hits the maximum at one half when two countries are identical in terms of GDP, and declines toward zero as they get further apart from each other. We expect that signs of four coefficients in horizontal motivation are all positive.

In vertical motive, we have four sources of comparative advantage: environmental laxity and three factor endowments. Specifically, we include relative environmental laxity in host country c to home country ($rlax_{ct}$), relative capital abundance (rkl_{ct}), relative skill abundance (rhl_{ct}), and relative raw material abundance (rml_{ct}) in vertical motivation. The last three factor endowments are all scaled by unskilled labor, following Romalis (2004). Then, these country characteristics are interacted with pollution intensity (PI_{it}), capital intensity (KI_{it}), skill intensity (HI_{it}), and raw material intensity (MI_{it}), respectively, to capture disproportionate effects of each source of comparative advantage, i.e., these four interaction terms tell us which source can determine a comparative advantage in FDI. Import tariff rate from host country c to home country ($Ktariff_{ict}$) is also included in vertical motivation. In sum, vertical motivation consists of the following covariates:

$$\begin{aligned}\beta Vertical_{ict} = {} & \beta_1 rlax_{ct-1} + \beta_2 rlax_{ct-1} PI_{it-1} + \beta_3 PI_{it-1} + \beta_4 rkl_{ct-1} + \beta_5 rkl_{ct-1} KI_{it-1} \\ & + \beta_6 KI_{it-1} + \beta_7 rhl_{ct-1} + \beta_8 rhl_{ct-1} HI_{it-1} + \beta_9 HI_{it-1} + \beta_{10} rml_{ct-1} \\ & + \beta_{11} rml_{ct-1} MI_{it-1} + \beta_{12} MI_{it-1} + \beta_{13} Ktariff_{ict-1}\,. \end{aligned} \tag{3}$$

Our variable of interest is $rlax_{ct-1}PI_{it-1}$. If $\beta_2 > 0$, as relative environmental laxity between a host country c and home country goes up, country c receives disproportionately more FDI in polluting industries compared to non-polluting industries. More precisely, positive β_2 implies that the elasticity of FDI to relative environmental laxity is linearly increasing in pollution intensity, and we interpret this as an evidence for the PHH. By same logic, all coefficients on interaction terms are expected to be positive, while we are not sure about the signs of coefficients on main terms. We expect β_{13} to be negative.

One might be also interested in the main term, $rlax_{ct-1}$. If β_1 is positive, we can interpret

[12] We do not include distance measure in the model, although it is an essential determinant of FDI. Distance is time-invariant and is simply subsumed in any configuration of fixed effects we consider.

[13] Measures of market size and similarity follow Baltagi et al. (2007).

this as evidence of a pollution haven effect. However, even if it is not, that does not necessarily mean that the PHH should be rejected. β_1 shows the effect of environmental laxity on the aggregate (or overall) amount of outward FDI, which sums up investments from all industries. Hence, β_1 can be negative if, for a marginal increase of relative environmental laxity, decrease in FDI of non-polluting industries outweighs increase in FDI of polluting industries for some reason. But even in such case, we still should be able to see a pollution haven effect in polluting industries through β_2.

Finally, our baseline model is flexible for various configurations of fixed effects. We will estimate the baseline model with three different configurations: (i) country, industry, and year fixed effects, (ii) country-industry and year fixed effects, and (iii) country-year and industry-year fixed effects. The first configuration is the most basic. The second configuration captures more unobserved heterogeneity than the first, but given that both country and industry characteristics vary little over time, country-industry fixed effects will absorb most country-by-industry variations and the within-transformed model may perform poor.

The third configuration is the most preferred since it not only captures more unobserved heterogeneity than the first, but also has other advantages. First of all, it complies with our purpose of the paper. Since this paper investigates how differently polluting industries respond to a given environmental laxity compared to non-polluting industries, we want to exploit cross-industry variations within a country-year pair to explain the variations in FDI outflow. Second, the baseline model is nicely simplified to a popular empirical model for trade flow. When we apply the third configuration, the model reduces to

$$\begin{aligned} FDI_{ict} = {} & \beta_2 rlax_{ct-1} PI_{it-1} + \beta_5 rkl_{ct-1} KI_{it-1} + \beta_8 rhl_{ct-1} HI_{it-1} + \beta_{11} rml_{ct-1} MI_{it-1} \\ & + \beta_{13} Ktariff_{ict-1} + \alpha_4 Htariff_{ict-1} + \mu_{it} + \lambda_{ct} + \epsilon_{ict} \end{aligned} \tag{4}$$

where μ_{it} is industry-year fixed effect and λ_{ct} is country-year fixed effect. Note that all main terms of country- and industry-specific characteristics are subsumed in these two high-dimensional fixed effects, and we only have four interactions and two tariff variables remaining. This model specification resembles the one used in many empirical trade papers.[14] Hence, we can directly apply equation (4) to trade data for another test of the PHH, which provides us a complimentary result. The baseline model with our preferred configuration also helps resolving econometric issues as explained below.

[14] For comparison, see Romalis (2004), Levchenko (2007), Nunn (2007), Broner et al. (2011).

2.3 Econometric Issues

2.3.1 Environmental Laxity vs. Factor Endowments

The baseline model has four factor endowments as sources of comparative advantage, as well as environmental laxity. Including factor endowments in the model is important for evaluating the PHH because industry characteristics are correlated with each other. For example, polluting industries tend to be capital intensive. The pollution haven incentive can be mitigated in such case by the incentive to look for an abundant capital stock as most capital-abundant countries impose stringent environmental standards. Non-polluting industries, on the other hand, happen to be relatively labor intensive, and they can move into the pollution havens to exploit cheap labor. As Copeland and Taylor (2003, p. 213) conclude, "since comparative advantage is determined jointly by differences in pollution policy and differences in factor endowments, most of the predictions of the pollution haven model can be reversed in a world where factor endowments matter... Dirty good production can remain in high-income countries despite much tighter regulation if these cost disadvantages are offset by other factors." Cole and Elliott (2005) pay attention to this problem, predicting that countries with (relatively) lenient environmental regulations while having rich capital are the most likely to be pollution havens. Brazil and Mexico are such countries in their sample, and they find that the US outward FDI into these two countries increases as an industry is more pollution- and capital-intensive.

We generalize their case study to cross-country level analysis by including four interaction terms in the model. Specifically, we let the marginal effect of pollution- and other factor-intensities be a conditional function of environmental laxity and factor abundances of a country, respectively. If the country has lax environmental regulations and a rich capital stock, it pins down to exactly the same analysis as Cole and Elliott (2005).[15] In this way, the baseline model unravels the opposing forces between environmental laxity and factor endowments in each country.

2.3.2 Unobserved Heterogeneity

Even after controlling for all potential sources of comparative advantage, the model still may suffer from omitted variable bias due to unobserved heterogeneity. Prior studies often employ panel data to remove time-invariant fixed effects.[16] However, when it comes to studies on determinants of FDI, time-invariant fixed effects are not enough to control for important unobservables. According to two recent surveys by Blonigen and Piger (2011) and Eicher et al. (2011), there are more than 50 country-level determinants of FDI that have been found

[15] Brazil and Mexico are indeed in our sample host countries.

[16] For example, Keller and Levinson (2002) find a significant deterrent effect of environmental stringency on inbound FDI to the US in their panel fixed-effect estimation.

significant, and many of them are time-varying such as business cycle, regional trade agreement, infrastructure, corruption, political stability, consumer prices, and market capitalization. Instead of controlling for all determinants, studies have selected a limited set of covariates in their model specifications, based on their interest. This is problematic because, as Blonigen and Piger (2011, p. 4) argue, "inference regarding the effects of included covariates can depend critically on what other covariates are included versus excluded".

Since the pollution haven effect is identified by the interaction term of environmental laxity and pollution intensity in our model, we can control for all country-level unobserved heterogeneity through country-year fixed effects at the cost of losing the main term for environmental laxity. Likewise, industry-year fixed effects capture all industry-specific characteristics, including industry regulations in home country, R&D intensity, and geographic mobility. Geographic mobility (or footlooseness) has received a particular attention in the pollution haven literature (Ederington et al. 2005; Cole et al. 2010). Thus, the baseline model with two high-dimensional fixed effects captures important unobserved heterogeneities without losing much variation.

2.3.3 Endogeneity of Environmental Policies

We use one-year lagged covariates to get around the simultaneity problem. However, reverse causality from FDI can still run into environmental policies because policies can respond to future (expected) FDI flows. One possible scenario is that policymakers in host (home) country may strengthen or weaken environmental standards in advance, if they know how much foreign investment in polluting industries flows in (out) next year. Another possibility is that firms may lobby and bribe policymakers in host countries in which they will eventually invest (Cole et al. 2006; Cole and Fredriksson 2009). Thus, environmental laxity in our model is potentially endogenous.

Even if there is no such a reverse causality, endogenous environmental policies may come from other sources. One source is omitted variable bias problem. There are some important determinants of FDI that vary over country-industry-time level and are correlated with environmental regulations. Typical examples are business regulations and promotions, tax policies, industrial agglomeration, etc. Another source of the endogeneity is measurement error in environmental regulations. Environmental regulation is difficult to measure accurately due to its complexity, and none of the measures in the literature are perfect (Levinson 2008).

In this paper, the endogeneity of environmental laxity is treated via an IV method, using the concentration level of particulate matter (PM10) and the notification rate of tuberculosis (TB) as two instruments. These instruments must satisfy the following conditions for their validity: they should be (i) uncorrelated with FDI flows or any unobservable affecting it conditional on environmental laxity, (ii) exogenous in the model for FDI flows, and (iii) correlated with environmental regulations. For the first condition, we can hardly imagine that PM10 concentration level or TB notification rate directly affects FDI decision. However, they may indirectly affect FDI through unobserved country characteristics. Hence, our baseline model will be extended later to include additional covariates to block possible channels through which our instruments can affect FDI flows. For the second condition, we again use one-year lagged variables to make sure that two IVs are exogenous. That is, rpm_{ct-2}, rtb_{ct-2}, $rpm_{ct-2}PI_{it-1}$ and $rtb_{ct-2}PI_{it-1}$ are used as instruments for $rlax_{ct-1}$ and $rlax_{ct-1}PI_{it-1}$. The rationale for the third condition is that past air pollution level and environmental health outcomes, such as respiratory diseases, are reflected in the current environmental policies. While TB is often considered to be a disease coming from poverty or unsanitary living conditions rather than pollution, there are rich evidences of the direct link between TB and air pollution.[17] Hence, TB should be correlated with environmental policies via the pollution level.

Owing to the configuration of country-year and industry-year fixed effects, all country-specific characteristics, including the environmental laxity main term, are removed in the country-year group demeaned model. Therefore, we only need to instrument for the interaction between environmental laxity and pollution intensity (using our two IVs interacted with pollution intensity). We will thoroughly check the validity of our instruments in later section with the first-stage regression results and recently developed over-, under-, and weak-identification tests.

Host and home country tariff policies may also suffer from the endogeneity problem by the same way environmental regulations being endogenous. We do not try to treat them as endogenous in this paper. As a consequence, the estimated coefficients on tariff rates may be biased, and need careful interpretation. The bottom line is that IV estimates of coefficient on environmental laxity should still be consistent unless our instruments are correlated with host and home country tariff rates. We will also test this argument by excluding tariffs from the model. The idea behind the test is that if tariffs were correlated with IVs and omitted from the model, then the error term which now includes tariffs should be correlated with IVs. Therefore, IVs are no longer exogenous and over-identification test would reject the null of valid IVs.

3 Data

In this section, we discuss about some important features of our sample dataset. More detailed information on data sources and variable definitions are described in the appendix.

[17]For example, Tremblay (2007) examines historical relationship between air pollution from coal combustion and TB incidence during industrialization. He finds that TB epidemic had surged during industrialization in the West, and the same pattern is now replicated by China and India, which have recently been industrializing. Kumar et al. (2008) provide a biochemical evidence: nitric oxide (NO) and carbon monoxide (CO) cause Mycobacterium tuberculosis (MTB), the etiologic agent of most cases of TB. Both pollutants are by-products of combustion of various fuels. See also Cohen and Mehta (2007) and references therein for more evidences.

3.1 South Korean Outward FDI

For our analysis, we employ South Korean outward FDI data in manufacturing industry over 1996 to 2007, which came from the Export-Import Bank of Korea. Our sample period spans from 2000 to 2007, for which the data on environmental laxity is only available, and the previous 4 years data are used for industrial agglomeration measures and their instrumental variables. The original FDI data is classified by the Korean Standard Industrial Classification (KSIC) 9th edition, which later is converted into the International Standard Industrial Classification (ISIC) Revision 4. After all, we have 120 four-digit industries in our sample. Such disaggregation of data allows us to experiment how estimation results change simply because the data is more aggregated.

Another motivation to choose South Korea as the country of our interest is to minimize clean technology effect. While studies have mainly focused on firm behavior in the most developed countries, such as the US and EU countries, investigations on other countries are scarce. Such extension must be helpful for better understanding about the nature of pollution haven effect. In particular, we argue a possibility that the pollution haven effect may be more evident in recently developed countries, like South Korea, than in the countries that have been developed for a long time. In the most developed countries where pollution has long been a public concern, clean technologies have been widely innovated and adopted across industries. Since technological improvement reduces production costs through saving expenditures on pollution taxes or abatements (at least in the long-run), polluting firms may have less incentives to flee their country. Di Maria and Smulders (2004) theoretically show that rich countries can be pollution havens in the presence of a clean technology effect. In fact, Levinson (2009) finds that the advance in production and abatement technologies account for most of the pollution reduction in the US manufacturing industry from year 1987 to 2001, and only one-tenth can be explained by shifting polluting industries overseas.[18]

On the other hand, South Korea and other recently developed countries, such as Israel, Portugal, Taiwan, or Czech Republic, can be said to be rather in a stage where clean technologies have not been adopted as fully as in more developed countries, but at the same time environmental standards are tougher than in developing countries.[19] Given that pollution abatement per unit of emission is more costly in South Korea than in, say, the US, tightening environmental

[18] Similar result is found in Norway over the period from 1980 to 1996, according to Bruvoll and Medin (2003).

[19] Smulders et al. (2011) show theoretically that the pollution level in a country has an inverse U-shaped relationship with its income level, also known as environmental Kuznets curve, through the development of clean technologies. In their model, pollution rises as an economy grows until its environmental quality is seriously degraded (confidence phase). Once environmental problem becomes a public concern, then the government starts regulating pollution emissions, which in turn incentivizes firms to develop clean technologies. During this time (alarm phase), pollution level stays same due to environmental regulations. After clean technologies are arrived and being diffused across industries, pollution gradually decreases while the economy continues to grow (clean-up phase). Roughly speaking, developing countries are in confidence phase, the most developed countries are in clean-up phase, and recently developed countries are in alarm phase.

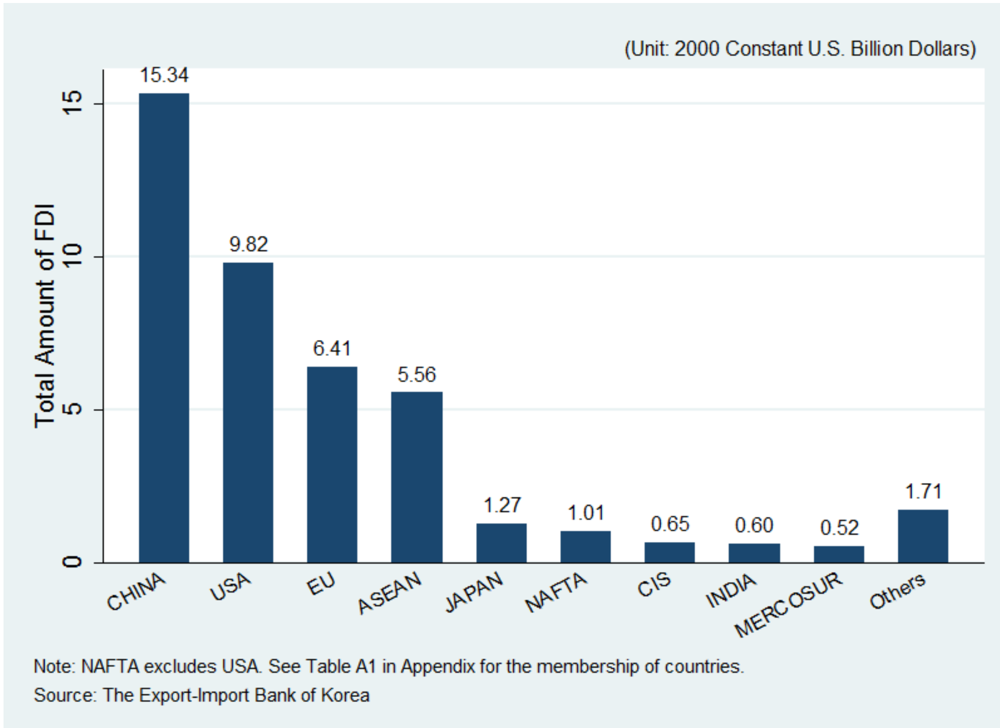


Figure 1: Distribution of South Korean Outward FDI by Region, 2000-2007

standards at a marginal level induces a larger cost increase in South Korea. This incentivizes South Korean multinationals, more than the US multinationals, to migrate into a country where environmental regulations stay lax.

We only consider greenfield mode of FDI in this paper since mergers and acquisitions (M&A) would require a different model specification to estimate. South Korean greenfield FDI accounts for 83 percent of total outflow of FDI in manufacturing industry over 2000-2007, contrary to worldwide trend of investment where M&A are dominant. After dropping missing observations due to country characteristics, we are left with 50 host countries that received South Korean FDI at least once during the sample period. This data sample indicates that our study should be interpreted as the impact of environmental laxity on the intensive margin of FDI, i.e., the intensity of activity at a given location decision.[20] Figure 1 provides total amount of South Korean outward FDI during 2000-2007 distributed by region. China receives the largest share of manufacturing FDI from South Korea, followed by the US and EU countries. Concentration of FDI in China may create a spurious causality: evidence of a pollution haven effect might be simply driven by China. As a robustness check, we drop China from our sample and estimate the same model.

[20] Analyzing the impact of environmental laxity on the extensive margin of FDI requires different estimation strategy. Javorcik and Wei (2004) consider the extensive margin of FDI using a probit model.

Table 1: Average Ranking of environmental Laxity and Factor Abundances

Ranking	Environmental laxity		Capital / Labor		Skill / Labor		Raw Material / Labor	
(Top to Bottom)								
1	Kyrgyz Republic	1.705	Luxembourg	2.752	United States	1.128	Australia	181.78
2	Cambodia	1.600	Japan	2.627	Czech Republic	1.128	Canada	127.47
3	Nicaragua	1.558	Switzerland	1.873	New Zealand	1.097	Kazakhstan	83.81
4	Bangladesh	1.541	United States	1.537	Australia	1.068	Russia	53.90
5	Guatemala	1.540	Belgium	1.462	Ireland	1.042	Argentina	37.26
6	Vietnam	1.509	Germany	1.345	Sweden	1.037	New Zealand	31.51
7	Ecuador	1.503	Italy	1.241	Germany	1.037	Finland	27.38
8	Kazakhstan	1.479	France	1.235	Slovak Republic	1.030	Chile	27.33
9	Honduras	1.453	Australia	1.232	Hungary	1.028	Peru	25.23
10	Pakistan	1.452	Netherlands	1.227	Canada	1.021	Brazil	22.51
(Bottom to Top)								
1	Germany	0.395	Cambodia	0.013	Guatemala	0.518	Bangladesh	0.460
2	Sweden	0.463	Kyrgyz Republic	0.015	India	0.535	Netherlands	0.965
3	Finland	0.483	Kenya	0.017	Bangladesh	0.546	Japan	1.312
4	Switzerland	0.483	Bangladesh	0.019	Pakistan	0.568	Belgium	1.635
5	Netherlands	0.487	Vietnam	0.027	Vietnam	0.592	India	1.748
6	Luxembourg	0.561	Pakistan	0.034	Nicaragua	0.603	Vietnam	1.831
7	Belgium	0.581	India	0.036	Indonesia	0.609	United Kingdom	1.941
8	New Zealand	0.587	Indonesia	0.056	Egypt	0.610	Germany	2.050
9	Australia	0.624	Nicaragua	0.057	Cambodia	0.641	Philippines	2.106
10	Canada	0.641	Philippines	0.058	Honduras	0.647	El Salvador	2.143

Notes: All measures are averaged over year 1999-2006 and expressed in relative terms.

3.2 A Measure of Environmental Laxity and Pollution Intensity

Measuring the laxity of environmental regulations has been an issue in the pollution haven literature, especially when it comes to country-level data. A commonly used measure is pollution abatement costs (e.g., Keller and Levinson 2002; Eskeland and Harrison 2003). However, pollution abatement costs are only available in a few countries, and even if data are available, there remains a standardization issue for comparison across countries. Another concern for using pollution abatement costs is that it can be a measure of pollution intensity rather than regulatory stringency (e.g., Cole and Elliot 2005; Manderson and Kneller 2012).

Our measure of environmental laxity came from the Global Competitiveness Report (GCR) from 2000 to 2007-2008 edition.[21] There are a couple of benefits in this survey measure. First, it covers wide range of countries around the world with a standardized method of measurement, so that it allows a direct comparison across countries. Second, since the survey is conducted by executives in representative firms from each country, the measure may reflect *de facto* environmental regulations, which is more related with firm's investment decision. However, we do not argue that this measure is flawless. One concern about the measure is that, as pointed out in Manderson and Kneller (2012), survey respondents are too optimistic or pessimistic depending on a given firm-specific or economy-wide situation. This perception bias can be reduced once

[21] This measure has been popularized by recent studies. See, e.g., Kellenberg (2009), Wagner and Timmins (2009), and Manderson and Kneller (2012).

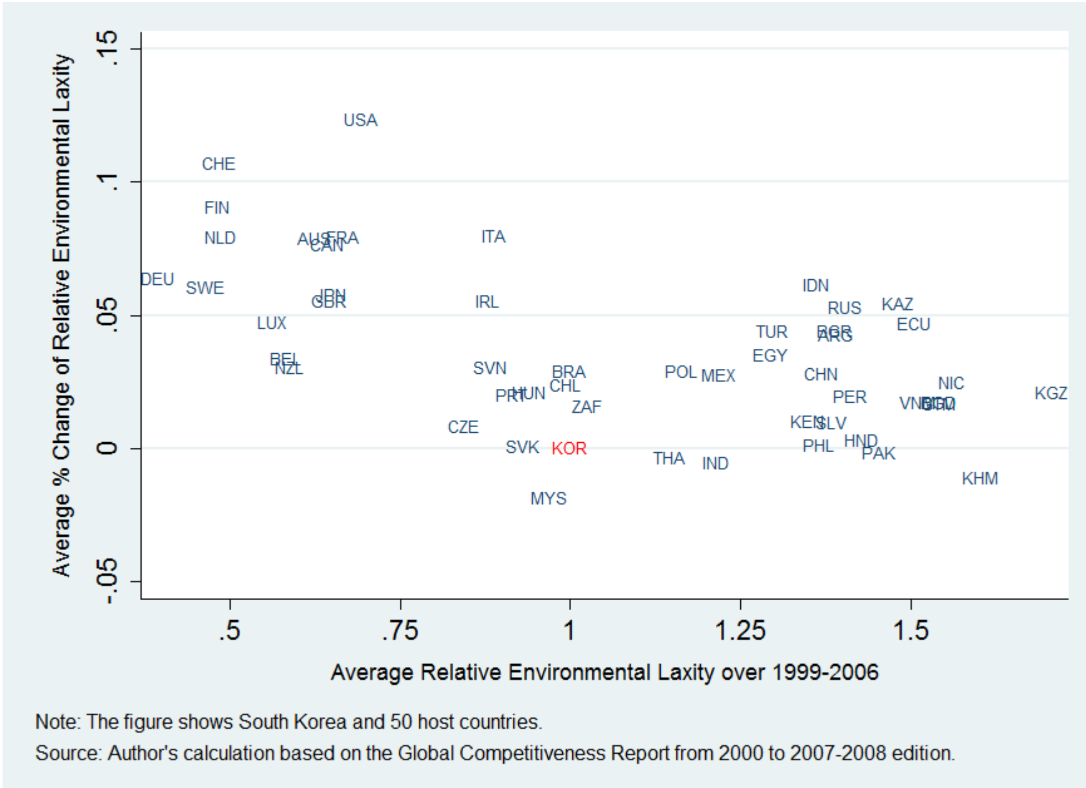
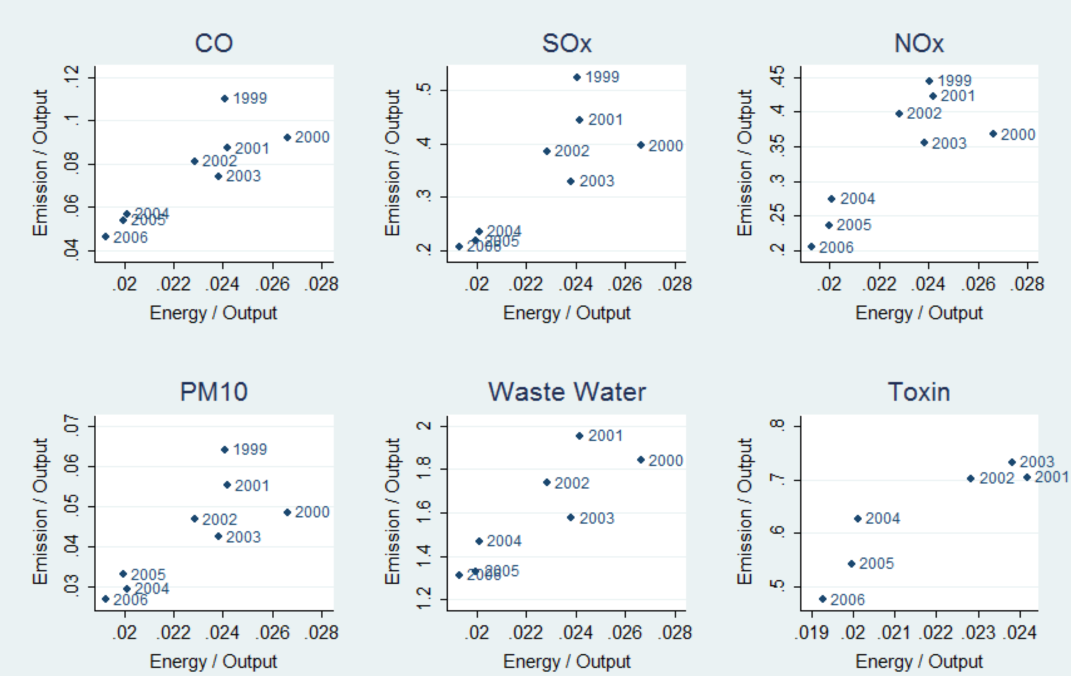


Figure 2: Average of Relative Environmental Laxity and its Change Rate during 1999-2006

we use the relative ratio of a host to home country as a measure of environmental laxity. Nevertheless, measurement error problem can occur regardless, and we treat this problem via an IV method.

Top and bottom 10 ranking among the 50 host countries for environmental laxity and factor abundances are listed in Table 1. All measures are averaged over years 1999-2006 since all country characteristics are lagged one-year. Note that all measures are in relative terms. If environmental laxity is greater than 1, then that country has laxer environmental regulations than South Korea. Similarly, if a factor endowment is greater than 1, the country is richer in that factor than South Korea. As we expect, top 10 countries in environmental laxity are all developing countries. Germany is the most stringent country in environmental regulations among our sample countries. South Korea is in between 26th and 27th, which is close to the middle. Not only for environmental laxity, but for other factor endowments, South Korea ranks in the middle range.

Figure 2 plots average relative environmental laxity versus average percent change rate of relative environmental laxity during year 1999-2006. X-axis measures how lax a country is in environmental regulations relative to South Korea on average. Countries with laxity greater than 1 is environmentally laxer than South Korea, and more stringent if laxity is less than 1.



Note: Waste water emission for 1999 and toxic emission for 1999 and 2000 are not available.
Source: NIER, KOSIS, PRTR for air, waste water, and toxic pollutants, respectively. See Appendix for more information.

Figure 3: Relationship between Energy Usage and Pollution Emissions in South Korea, 1999-2006

We can see that most developing countries are laxer than South Korea, while most developed countries are more stringent. Y-axis shows how environmental laxity has changed over the sample period compared to South Korea. Countries with change rate above zero have become laxer in their environmental policies relative to South Korea, while countries below zero have become tougher. Only a few among 50 host countries have got tougher than South Korea.[22] The figure informs that South Korea is in middle range in overall environmental laxity, but its policies are getting tougher at a faster rate compared to other countries. Besides, we can see that Czech Republic, Slovak Republic, and Portugal are in similar paces to South Korea, and these countries are all recently developed countries.[23] This pattern supports our argument that there may be more apparent pollution haven incentive in recently developed countries than in the most developed countries.

For a measure of industrial pollution intensity, the total emissions of pollutants by industry-level would be appropriate. For example, the Industrial Pollution Projection System (IPPS) in World Bank estimates the emission levels of various pollutants for 360 four-digit SIC industries in the US over the year 1987 (see Hettige et al. 1995). Unfortunately, there is no such pollution

[22]Figure 2 shows 50 host countries in our sample. However, the result remains same when we include all 92 countries that have three or more years' data on environmental laxity from the Global Competitiveness Report.
[23]Malaysia is exceptionally high at both average laxity and average change rate.

Table 2: Ranking of Pollution Intensity

Ranking	ISIC4	Pollution Intensity (Our Measure)		ISIC4	Pollution Intensity (IPPS)	
Top 10 Most Polluting Industries						
1	2394	Cement, lime and plaster	0.196	2394	Cement, lime and plaster	107.121
2	2392	Clay building materials	0.177	2396	Cutting, shaping and finishing of stone	37.670
3	1701	Pulp, paper and paperboard	0.103	2392	Clay building materials	27.742
4	1062	Starches and starch products	0.099	1701	Pulp, paper and paperboard	27.658
5	1313	Finishing of textiles	0.092	1910	Coke oven products	25.681
6	2431	Casting of iron and steel	0.084	1629	articles of cork and plaiting materials	20.994
7	2030	Man-made fibres	0.081	1702	Corrugated paper and paperboard	20.155
8	2011	Basic chemicals	0.077	1920	Refined petroleum products	19.639
9	2393	Other porcelain and ceramic products	0.074	2410	Basic iron and steel	19.163
10	2310	Glass and glass products	0.067	1709	Articles of paper and paperboard	18.439
Top 10 Least polluting Industries						
1	2630	Communication equipment	0.002	1104	Soft drinks	0.010
2	1512	Luggage, handbags and the like	0.003	2680	Magnetic and optical media	0.010
3	2620	Computers and peripheral equipment	0.003	2620	Computers and peripheral equipment	0.013
4	2660	Irradiation, electromedical equipment	0.003	2660	Irradiation, electromedical equipment	0.031
5	2640	Consumer electronics	0.004	2733	Wiring devices	0.057
6	1410	Wearing apparel, except fur apparel	0.004	1393	Carpets and rugs	0.078
7	1200	Tobacco products	0.004	2651	Measuring and control equipment	0.110
8	2815	Ovens, furnaces and furnace burners	0.004	1394	Cordage, rope, twine and netting	0.111
9	3212	Imitation jewelery and related articles	0.004	1391	Knitted and crocheted fabrics	0.112
10	3020	Railway locomotives and rolling stock	0.005	2812	Fluid power equipment	0.129

Notes: All measures are averaged over year 1999-2006 and expressed in relative terms.

intensity measure at 4-digit industry-level in South Korea. We employ, instead, the amount of energy consumption per output by industry as a measure for pollution intensity.[24] Since energy consumption produces various kinds of pollutants, we assume that pollution emissions are monotonically increasing in energy usage. Cole et al. (2005) support the validity of our assumption by examining the relationship between energy usage and four major air pollutants, sulfur dioxide (SO2), nitrogen oxides (NOx), carbon monoxide (CO), and particulate matter (PM10).

Although not at the 4-digit industry-level, we can actually check how pollution emissions are correlated with energy usage in total manufacturing industry. Figure 3 provides the relationship between energy usage per output and emission per output of six pollutants (SOx, NOx, CO, PM10, water waste, and chemical toxins) generated from aggregate manufacturing industry in South Korea from 1999 to 2006. Each plot shows the overall linear relationship. It also indicates that energy-saving and pollution control technologies had continued to be adopted across industries over the sample period with a big jump between 2003 and 2004.

We also calculate the linear correlation coefficient between energy usage and pollution intensity from the US data to see how energy usage is associated with pollution intensity. When

[24] See, e.g., Eskeland and Harrison (2003) and Kahn (2003) for other studies that use energy usage as a measure of pollution intensity.

Table 3: Correlation between Industry and Country Characteristics

Industry Characteristics	PI	KI	HI	MI	CI	VA
Pollution Intensity (PI)	1					
Capital Intensity (KI)	0.459	1				
Skill Intensity (HI)	-0.222	0.068	1			
Raw Material Intensity (MI)	-0.297	0.094	0.189	1		
Machinery Intensity (CI)	0.374	0.451	-0.273	0.080	1	
Value Added (VA)	0.137	-0.113	-0.130	-0.868	-0.063	1

Country Characteristics	rlax	rkl	rhl	rml	riq	rgdppc	rpm	rtb
Environmental Laxity (rlax)	1							
Capital Abundance (rkl)	-0.775	1						
Skill Abundance (rhl)	-0.694	0.589	1					
Raw Material Abundance (rml)	-0.152	0.058	0.322	1				
Institutional Quality (riq)	-0.909	0.770	0.738	0.153	1			
GDP per capita (rgdppc)	-0.810	0.964	0.654	0.101	0.826	1		
PM10 Concentration (rpm)	0.573	-0.448	-0.662	-0.211	-0.573	-0.468	1	
TB Notification Rate (rtb)	0.370	-0.408	-0.261	-0.040	-0.430	-0.359	0.063	1

Notes: Industry characteristics are based on the ISIC Revision 4. Country characteristics are in relative terms: ratio of a host country to home country.

pollution emissions in 1987 from the IPPS dataset are matched with energy usage per shipment in 1987 from US manufacturing industry, the correlation coefficient is 0.90.[25] This strongly suggests that energy usage is a good proxy for the actual pollution emissions. When we directly compare the pollution emissions in IPPS with our measure of average pollution intensity over 1999-2006, the correlation coefficient is 0.69. Considering technology differences between Korea and the US and time difference between our sample and 1987, this is fairly high. The IPPS data will be used as an alternative measure of pollution intensity in our sensitivity analysis. In Table 2, we compare the top 10 most and least polluting industries from our measure of pollution intensity and the IPPS.

Finally, the correlation coefficients among sample industry and country characteristics used in this paper are shown in Table 3. As expected, pollution intensive industries tend to be capital intensive, with a correlation coefficient of 0.46. This indicates that environmental regulation and capital abundance should jointly determine the location choice in FDI. Country characteristics are also highly correlated with each other. Environmentally lax countries tend to have less capital stock and skilled labor force. Institutional quality and GDP per capita, shown in the table, will be added to our model specification as additional sources of comparative advantage,

[25] The data is from NBER-CES Manufacturing Industry Database (Bartelsman and Gray 1996). The correlation coefficient is based on 4-digit industry-level in ISIC4.

interacted with machinery intensity and value added, respectively. We will explain the details about these characteristics in the next section.

4 Estimation and Results

4.1 Baseline Model

Table 4 reports estimation results of the baseline equation (4). We have 3,137 observations in the final sample. Robust standard errors are clustered at each country-year group. When only environmental laxity is included as a determinant of comparative advantage, we find no evidence of a pollution haven effect in column (1). However, the estimate reflects the composite effect of environmental regulation and factor endowments. In column (2) through (4), we include three different factor endowment (relative to unskilled labor). We find a statistically significant pollution haven effect when capital is included. This highlights that capital-seeking incentive matters in identifying the pollution haven effect. Also, physical capital by itself is a significant determinant of comparative advantage in FDI. The result for capital is in line with Antràs (2003) and Bernard et al. (2010), although capital intensity is interpreted as headquarter intensity in their studies. In column (3), skill endowment is shown as another source of comparative advantage, following the results of Yeaple (2003) and Alfaro and Charlton (2009).

Environmental laxity, capital abundance, and skill abundance are jointly important in shaping the pattern of FDI flows in column (5). The magnitude of the estimate reflecting the PHH indicates that a one standard deviation above the mean relative environmental laxity of a host country would attract 14% more foreign investment from an industry with a one standard deviation above the mean pollution intensity. For capital endowment, a one standard deviation above the mean relative capital abundance in a host country would attract 18% more FDI from an industry with a one standard deviation above the mean capital intensity. Similarly, a one standard deviation above the mean relative skill abundance in a host country is associated with 10% increase of FDI from an industry with a one standard deviation above the mean skill intensity. All figures indicate the economic significances of three determinants of comparative advantage in FDI.[26]

In column (6) through (8), environmental laxity interaction is treated as endogenous and instrumented by lagged PM10 concentration and lagged TB notification rate interacted with pollution intensity, respectively. The two-step efficient generalized method of moments (IV-GMM) is employed for the estimation. The evidence for the PHH is relatively unchanged from column (5) to (6). Greater magnitude in the IV estimate in column (6) signifies that there might be unobserved heterogeneity negatively correlated with environmental laxity. For example, if

[26] We do not interpret the marginal effect of tariff rates due to their potential endogeneity, but at least their signs are consistent with our theoretical prediction.

Table 4: Estimation Results of the Baseline Model

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Dependent Variable: FDI_{ict}	FE	FE	FE	FE	FE	IV-GMM	IV-GMM	IV-GMM	FE	IV-GMM
Environmental Laxity × Pollution Intensity	0.162	0.538***	0.077	0.160	0.429***	0.588***	0.546***	0.239*	0.267	0.419
	(0.100)	(0.138)	(0.096)	(0.100)	(0.133)	(0.183)	(0.181)	(0.131)	(0.188)	(0.255)
Capital Abundance × Capital Intensity	–	0.164***	–	–	0.143***	0.165***	0.160***	–	0.117***	0.130***
	–	(0.032)	–	–	(0.032)	(0.033)	(0.033)	–	(0.037)	(0.040)
Skill Abundance × Skill Intensity	–	–	2.163***	–	1.549***	1.350**	1.372***	–	0.801	0.861
	–	–	(0.541)	–	(0.526)	(0.529)	(0.528)	–	(0.912)	(0.901)
Material Abundance × Material Intensity	–	–	–	0.205	0.046	0.024	0.028	–	0.133	0.125
	–	–	–	(0.150)	(0.144)	(0.143)	(0.143)	–	(0.150)	(0.150)
Home Country Tariff Rate	-0.126	-0.171	-0.140	-0.124	-0.175	-0.185	–	-0.130	-0.153	-0.115
	(0.128)	(0.125)	(0.128)	(0.127)	(0.126)	(0.126)	–	(0.128)	(0.214)	(0.208)
Host Country Tariff Rate	0.171**	0.189**	0.164**	0.171**	0.182**	0.195**	–	0.179**	0.060	0.078
	(0.080)	(0.078)	(0.080)	(0.080)	(0.078)	(0.078)	–	(0.080)	(0.137)	(0.137)
Level of Industry Aggregation	4-digit	4-digit	4-digit	4-digit	4-digit	4-digit	4-digit	4-digit	2-digit	2-digit
Country-Year & Industry-Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Environmental Laxity Treated as Endogenous?	No	No	No	No	No	Yes	Yes	Yes	No	Yes
Observations	3,137	3,137	3,137	3,137	3,137	3,137	3,137	3,137	1,611	1,611
Within R-squared	0.44	0.45	0.44	0.44	0.45	0.45	0.45	0.44	0.36	0.36
Hansen J statistic (P-value)	–	–	–	–	–	0.00 (.99)	0.00 (.96)	0.03 (.86)	–	0.91 (.34)
Endogeneity test statistic (P-value)	–	–	–	–	–	1.77 (.18)	2.00 (.16)	1.02 (.31)	–	0.76 (.38)

Notes: All variables are log transformed. Country characteristics are in relative terms, which are defined as the ratio of a host to home country variables. Robust standard errors clustered at country-year level in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

policymakers in a host country want to attract foreign investors while preserving their environment, they may relax other business regulations or offer tax break to foreign investors while strengthening environmental standards. Attenuation bias stemming from measurement error on environmental laxity might also explain the greater magnitude in IV estimate. However, it is noteworthy that the test for endogeneity fails to reject the null of exogeneity.

The endogeneity of tariff policies are not directly considered as mentioned. Rather, we test whether tariffs are correlated with our instruments by omitting them from the model in column (7). If tariffs are correlated with instruments, the Hansen J statistic will reject the null that two instruments are exogenous. The statistic clearly suggests that there is no such correlation. Column (8) tests whether IV estimation alone can capture the pollution haven effect without conditioning on factor endowment interactions. Estimate for the environmental laxity interaction is statistically significant, but only at the 10% level, and its magnitude is not very different from the one in the first column. Hence, correctly incorporating factor endowments into the model specification is needed to identify a pollution haven effect.

In column (9) and (10), we estimate the same model, but data are now aggregated to 2-digit industry-level in ISIC4 to see whether the pollution haven effect can still be identified in the aggregate level data. All industry characteristics and tariffs are averaged over 2-digit industries, while FDI outflows are summed. This test can explain about another potential reason of inconsistent evidence for the PHH: if the estimate on environmental laxity interaction is no longer positively significant, it means that data disaggregation is important in identifying the pollution haven effect. The results in column (9) and (10) suggest that it does matter.

In Table 5, we compare estimation results with three configurations of fixed effects and highlight the importance of controlling for country- and industry-specific unobserved heterogeneities. Column (1) includes country, industry, and year fixed effects. Since these fixed effects do not subsume time-varying country and industry characteristics, all covariates affecting the horizontal and vertical motivations are included for estimation. Here we only report estimates for the pollution haven effect.[27] Although FE estimates are statistically significant at the 5% level, we suspect that environmental laxity is highly correlated with unobserved country-specific characteristics, such as institutional quality or GDP per capita. IV method avoids this problem but faces another: country-level covariates, in combination with the need to instrument for two endogenous variables, weaken the partial correlation (i.e., Angrist-Pischke partial R^2) between environmental laxity and instruments in the first-stage equation. Weak-identification test statistics (i.e., Kleibergen-Paap rk Wald F statistic and Angrist-Pischke F statistic) do not strongly reject the presence of weak instruments either.

Those problems do not go away when the configuration of country-industry and year fixed effects is used in column (2). On top of that, the country-industry fixed effects absorb most of the

[27]See Table A4 in the Appendix for complete estimation results.

Table 5: Comparison among Alternative Configurations of Fixed Effects

Second-Stage	(1)		(2)		(3)	
dependent variable: FDI_{ict}	FE	IV-GMM	FE	IV-GMM	FE	IV-GMM
Environmental Laxity ($rlax$)	1.607**	0.206	-0.033	-1.718	–	–
	(0.747)	(1.740)	(1.191)	(2.549)	–	–
Env. Laxity × Pollution Int. ($rlax \times PI$)	0.411**	0.489	0.054	0.066	0.429***	0.588***
	(0.185)	(0.300)	(0.239)	(0.458)	(0.133)	(0.183)
Unit of panel observations	Country		Country-Industry		Country-Year	
Included dummy variables	Industry & Year		Year		Industry-Year	
Observations	3,137	3,137	3,137	3,137	3,137	3,137
Within R-squared	0.29	0.28	0.11	0.10	0.45	0.45
Hansen J statistic (P-value)	–	0.09 (.95)	–	0.76 (.68)	–	0.00 (.99)
Kleibergen-Paap rk LM statistic (P-value)	–	8.27 (.04)	–	103.4 (.00)	–	59.77 (.00)
Kleibergen-Paap rk Wald F statistic	–	9.65^{+}	–	88.91^{+++}	–	149.7^{+++}
Anderson-Rubin Wald χ^2 statistic (P-value)	–	5.20 (.27)	–	3.16 (.53)	–	11.01 (.00)
CLR test statistic (P-value)	–	–	–	–	–	11.00 (.00)

First-Stage	(1)		(2)		(3)	
dependent variables	$rlax$	$rlax \times PI$	$rlax$	$rlax \times PI$	$rlax$	$rlax \times PI$
PM10 Concentration (rpm)	0.129*	0.543	0.080	1.523***	–	–
	(0.076)	(0.360)	(0.075)	(0.399)	–	–
PM10 Con. × Poll. Int. ($rpm \times PI$)	0.004	0.226***	-0.014	0.492***	–	0.242***
	(0.003)	(0.040)	(0.016)	(0.085)	–	(0.020)
TB Notification Rate (rtb)	0.154***	-0.046	0.167***	-0.429***	–	–
	(0.026)	(0.175)	(0.025)	(0.133)	–	–
TB Not. Rate × Poll. Int. ($rtb \times PI$)	-0.001	0.147***	0.003	0.052*	–	0.138***
	(0.001)	(0.022)	(0.006)	(0.030)	–	(0.015)
Angrist-Pischke Partial R^2	0.12	0.24	0.04	0.04	–	0.59
Angrist-Pischke Wald χ^2 statistic (P-value)	43.33 (.00)	155.56 (.00)	58.70 (.00)	57.73 (.00)	–	301.1 (.00)
Angrist-Pischke F statistic	14.07^{++}	37.53^{+++}	19.43^{+++}	19.11^{+++}	–	149.7^{+++}

Notes: All variables are log transformed. Country characteristics are in relative terms, which are defined as the ratio of a host to home country variables. Robust standard errors clustered within the unit of panel observations in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively. $^{+++}$, $^{++}$, and $^{+}$ denote the rejection of null hypothesis of weak instruments according to the critical values at 10%, 15%, 20% maximal IV size when significance level is 5%, respectively (Stock and Yogo 2005).

variation in the data and make the (within-transformed) model perform poor. Most regressors are indeed statistically insignificant with low within R^2 (0.10). Thus, overall results in column (1) and (2) suggest the need for controlling for country-specific (and possibly industry-specific) fixed effects to get consistent estimates for the PHH.

Column (3) reposts the estimation results in column (5) and (6) in Table 4 with additional test statistics. Over-, under-, and weak-identification test statistics as well as the first-stage regression result clearly support the validity of our instruments. Even with these strong results, we also provide the Anderson-Rubin Wald and Conditional Likelihood Ratio (CLR) test statistics in case of a concern over weak instruments.[28] These two weak IV-robust test statistics

[28] CLR test, introduced by Moreira (2003), can only be used for single endogenous regressor. It is known as

reject the null of a zero coefficient on the environmental laxity interaction.

4.2 Robustness Checks

The baseline results in Table 4 are further tested for robustness. We first include additional determinants of FDI that may cause inconsistent estimates if they are omitted from the model. Then, we test whether the results are sensitive to alternative samples or measures.

4.2.1 Other Sources of Comparative Advantage

The literature on the pattern of trade flow has found many sources of comparative advantage other than factor endowments. In particular, the role of contractual frictions on trade flows has been emphasized in recent studies, such as Levchenko (2007) and Nunn (2007).[29] One of their common findings are that if final good producers have to make non-contractible, relationship-specific investments, they tend to invest in a country where the quality of contract enforcement is high in order to avoid the hold-up problem. To show this pattern, they develop their own measures of intensity of contract dependence at industry-level and interact them with country-level institutional quality in their empirical models. They utilize an index of institutional quality from the Worldwide Governance Indicators (WGI) developed by Kaufmann et al. (2005).

We test for institutional quality as an additional source of comparative advantage in FDI by including the interaction of institutional quality and machinery intensity. Our measure of institutional quality is from Kaufman et al. (2009), which is an updated version of Kaufman et al. (2005). Relation specificity of an industry is measured by the stock of machinery in the total capital stock, following Nunn and Trefler (2011). While other kinds of capital, such as buildings and automobiles, have outside values, machinery is only useful in the production process. Hence, machinery stock relative to total capital stock (i.e., machinery intensity) gauges how much that industry makes relationship-specific investments.

Inclusion of this interaction term will clarify one potential concern: since environmental laxity can be viewed as one aspect of institutional quality or its outcome, one may be concerned that our estimates merely pick up the effect of institutional quality interacted with an industry characteristic that is correlated with pollution intensity. This suspicion gains more ground when we look at correlations in Table 3. The correlation between environmental laxity and institutional quality is -0.91 in our sample. Also, the correlation between pollution intensity and machinery intensity is 0.37. Thus, including the institutional quality interaction is a good robustness check for our result. By the same reason, we also consider a possibility that high

the most powerful test among existing weak IV-robust tests, when the model is over-identified (See Andrew et al. 2006).

[29] Contractual frictions affect not only the location of production and trade flows, but also organizational decisions of MNE, i.e., whether to internalize or outsource. Helpman (2006) and Antrás and Rossi-hansberg (2009) provide nice surveys on how contractual frictions can affect MNE's behaviors.

Table 6: Agglomeration and other sources of comparative advantage

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent Variable: FDI_{ict}	FE	IV-GMM	IV-GMM	IV-GMM	IV-GMM	IV-GMM
Environmental Laxity × Pollution Intensity	0.440***	0.610***	0.380***	0.559***	0.386***	0.576***
	(0.151)	(0.215)	(0.128)	(0.177)	(0.147)	(0.209)
Capital Abundance × Capital Intensity	0.168***	0.184***	0.132***	0.156***	0.161***	0.178***
	(0.041)	(0.041)	(0.032)	(0.033)	(0.041)	(0.040)
Skill Abundance × Skill Intensity	1.359**	1.185**	1.488***	1.265**	1.285**	1.088**
	(0.542)	(0.541)	(0.495)	(0.498)	(0.510)	(0.511)
Material Abundance × Material Intensity	0.158	0.144	0.045	0.017	0.156	0.138
	(0.170)	(0.168)	(0.141)	(0.139)	(0.166)	(0.164)
Institutional Quality × Machinery Intensity	-0.235	-0.094	–	–	-0.303	-0.151
	(0.490)	(0.512)	–	–	(0.480)	(0.502)
GDP per capita × Value Added	0.194*	0.216**	–	–	0.186*	0.214**
	(0.106)	(0.110)	–	–	(0.104)	(0.108)
Home Country Tariff Rate	-0.166	-0.173	-0.182	-0.194	-0.174	-0.183
	(0.126)	(0.126)	(0.124)	(0.125)	(0.124)	(0.124)
Host Country Tariff Rate	0.184**	0.197**	0.166**	0.181**	0.166**	0.182**
	(0.079)	(0.079)	(0.078)	(0.078)	(0.078)	(0.079)
Agglomeration in the same Industry	–	–	0.014	0.014	0.014	0.014
	–	–	(0.011)	(0.011)	(0.011)	(0.011)
Agglomeration across Relevant Industries	–	–	-0.008	-0.008	-0.008	-0.008
	–	–	(0.013)	(0.013)	(0.013)	(0.013)
Country-Year & Industry-Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Environmental Laxity Treated as Endogenous?	No	Yes	No	Yes	No	Yes
Observations	3,137	3,137	3,137	3,137	3,137	3,137
Within R-squared	0.45	0.45	0.46	0.46	0.46	0.46
Hansen J statistic (P-value)	–	0.00 (.97)	1.71 (.79)	1.59 (.90)	1.71 (.79)	1.57 (.90)
Kleibergen-Paap rk LM statistic (P-value)	–	57.16 (.00)	81.04 (.00)	81.05 (.00)	80.85 (.00)	80.95 (.00)
Kleibergen-Paap rk Wald F statistic	–	137.6	201.1	151.2	199.3	148.2

Notes: All variables are log transformed. Country characteristics are in relative terms, which are defined as the ratio of a host to home country variables. Robust standard errors clustered at country-year level in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

income countries may receive a disproportionate amount of FDI in high-tech and high value-added industries. To account for the possibility, relative GDP per capita of the host to the home country is interacted with industry-level value-added per output. Since GDP per capita is highly correlated with institutional quality and considered as a determinant of environmental policies, a similar concern may apply. We expect that the coefficients for two interaction terms are both positive.

Column (1) and (2) in Table 6 report the result with inclusion of two additional sources of comparative advantage. In general, institutional quality and GDP per capita are not strong determinants of comparative advantage in FDI, while the pollution haven effect remains strong.

4.2.2 Industrial Agglomeration

As a second sensitivity analysis, we include industrial agglomeration as an additional determinant of FDI. Agglomeration economies, also referred as external economies of scale, have received a particular attention in recent FDI literature. Head et al. (1995) and Head and Mayer (2004) find that MNEs tend to invest in countries where firms in the same industry have already clustered to take advantage of positive spillovers, such as well-established infrastructure or information sharing through networks. Amiti and Javorcik (2008) and Debaere et al. (2010) further look at how agglomerations of related industries through forward and backward linkages can affect an MNE's location choice. Their argument is that, since an industrial agglomeration can spill over into other close industries, clusters of relevant industries are also expected to attract more FDI in that region. This argument is supported by their empirical results.

Industrial agglomeration can be a key factor in assessing the pollution haven hypothesis (e.g., Wagner and Timmins 2009). A cluster in the same industry or relevant industries may either strengthen or weaken a MNE's the pollution haven incentive, depending on which country those industries flock together in. If relevant industries are located in a country with high environmental standards, it will undermine the pollution haven incentive. In this case, industrial agglomeration is an opposing force to environmental laxity (Zeng and Zhao 2009). On the other hand, it is also possible that polluting industries happen to invest in countries with lax environmental regulations simply because there are large clusters of relevant industries.

When we include agglomeration effects, our baseline model with country-year and industry-year fixed effects becomes

$$FDI_{ict} = \alpha Horizontal_{ict} + \beta Vertical_{ict} + \gamma Agglomeration_{ict} + \mu_{it} + \lambda_{ct} + \epsilon_{ict}\,.$$

Industrial agglomeration consists of two factors. One is agglomeration within an industry i, and the other is agglomeration within the same 2-digit, but across different 4-digit industries. As measures of the former, we include the lagged amount of FDI in the same industry in the same host country, or its three- and five-year moving average (FDI_{ict-1}).[30] Many studies exploit the stock of FDI until the previous year as a proxy for an agglomeration within an industry. Compared to the stock measure, our flow measures of agglomeration are more appropriate to show recent trends in FDI. Agglomeration across relevant industries is measured by the weighted average of lagged FDI in all j industries (other than i) under the same 2-digit, where the weight for industry j is the output of industry j over the total output of the 2-digit industry net of industry i ($OFDI_{ict-1}$). Again, we alternatively use its three- and five- moving averages. In terms of equation, we write

[30] Three- and five-year moving average have two weights. One is simple weight (i.e., equal weight), and decreasing weight (i.e., weight decreases by one for each lag). Hence, we end up with having four moving averages to use.

$$\gamma Agglomeration_{ict} = \gamma_1 FDI_{ict-1} + \gamma_2 OFDI_{ict-1}\,.$$

Since the two agglomerations are likely to be endogenous, we again employ two-step efficient GMM estimation method with Blundell-Bond type instruments (Blundell and Bond 1998). Specifically, ΔFDI_{ict-1}, ΔFDI_{ict-2}, ΔFDI_{ict-3} and $\Delta OFDI_{ict-1}$, $\Delta OFDI_{ict-2}$, $\Delta OFDI_{ict-3}$ are used as instruments, where $\Delta(O)FDI_{ict-s} = (O)FDI_{ict-s} - (O)FDI_{ict-(s+1)}$, $s = 1, 2, 3$.

Column (3) through (6) in Table 6 report results with two agglomeration effects. These estimations are based on lagged FDI and weighted average of lagged FDI in relevant industries. Results do not change when we use moving averages as measures of agglomeration.[31] Over-, under-, and weak-identification test statistics support the validity of instruments for the two agglomeration measures. Column (3) and (5) assume that environmental laxity is exogenous, while the agglomeration variables are endogenous. In column (4) and (6), environmental laxity is treated as endogenous as well as the two agglomeration variables. Overall, the results indicate that the pollution haven effect remains robust after agglomeration effects are included. It turns out, however, that industry activity over the past few years does not have a persistent impact on current level of FDI, at least in our sample.

4.2.3 Alternative Samples and Measures

As shown in the data section, South Korean outward FDI is heavily concentrated in China, one of the countries with less stringent environmental standards. One concern may be that our result is simply capturing a China "effect". Hence, we drop China from our sample. Column (1) in Table 7 presents the regression results of our baseline model excluding China. The sample size is now 2,467. Contrary to our concern, the estimate suggests that the pollution haven effect is even stronger without China.

Now, we test for the PHH using an alternative measure of environmental laxity. As Kellenberg (2009) and Broner et al. (2011) argue, a closer measure to *de facto* environmental stringency may need to account for how consistently environmental regulations are enforced. Without a proper enforcement, *de jure* environmental regulations could be meaningless no matter how stringent they are. The Global Competitiveness Report 2000 through 2006-2007 edition have information about the consistency of environmental regulations as well as stringency. The consistency measure is also scaled from 1 to 7. Kellenberg (2009) and Broner et al. (2011) multiply the regulatory stringency and consistency to generate an environmental policy index to reflect the enforcement aspect. Similar to them, we construct an alternative measure of environmental laxity by multiplying the regulatory laxity with inconsistency, where inconsistency is equal to 8 minus consistency. Our baseline model with the alternative measure is presented

[31] The estimation results are available up on request.

Table 7: Alternative Samples and Measures

Dependent Variable: FDI_{ict}	(1) FE	(1) IV-GMM	(2) FE	(2) IV-GMM	(3) FE	(3) IV-GMM
Environmental Laxity × Pollution Intensity	0.616***	0.923***	0.263***	0.326***	0.136*	0.276***
	(0.152)	(0.198)	(0.080)	(0.106)	(0.080)	(0.101)
Country-Year & Industry-Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Environmental laxity treated as endogenous?	No	Yes	No	Yes	No	Yes
Observations	2,467	2,467	2,536	2,536	3,137	3,137
Within R-squared	0.42	0.42	0.46	0.46	0.45	0.45
Hansen J statistic (P-value)	–	1.65 (.20)	–	0.06 (.81)	–	0.05 (.83)
Kleibergen-Paap rk LM statistic (P-value)	–	57.94 (.00)	–	50.28 (.00)	–	48.11 (.00)
Kleibergen-Paap rk Wald F statistic	–	130.7	–	209.0	–	108.7

Notes: Column (1) drops China from sample. Column (2) shows the results with an alternative measure of environmental laxity, and an alternative measure of pollution intensity is used in column (3). All variables are log transformed. Country characteristics are in relative terms, which are defined as the ratio of a host to home country variables. Robust standard errors clustered at country-year level in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

in column (2). Since the Global Competitiveness Report 2007-2008 edition does not report the regulation consistency, observations in 2007 are all dropped out, which leaves us 2,536 observations. The result still supports the PHH. Magnitudes of estimates are reduced roughly by half compared to ones in column (5) and (8) in Table 4, but the standard deviation of environmental laxity is doubled around 0.65. Hence, the impact on FDI flow is about the same.

An alternative measure of pollution intensity is also considered. Although we demonstrate that energy usage is a good measure for pollution intensity, the baseline model is estimated using pollution emissions data from the IPPS. The IPPS data is neither a panel data, nor data for South Korean industry during the sample years. In order for the IPPS data to be regarded as a proper measure of pollution intensity, therefore, we require a strong assumption that industry characteristics are the same across countries and production technology does not change over time. Given the assumption, column (3) shows the regression result when environmental laxity is interacted with pollution emissions from the IPPS. IV estimate suggests a significant pollution haven effect at the 1% significance level.

4.3 Comparison with Trade Data

In this subsection, we provide a complementary evidence for the PHH using trade data. If environmental laxity is indeed a source of comparative advantage, countries with laxer environmental regulations than South Korea are likely to export polluting goods to South Korea. Hence, we can implement this test by analyzing South Korean import data. In fact, most cross-country level studies on the PHH investigate either FDI or trade flow.[32] However, no study has ever analyzed these two related industry activities at the same time. Investigation on trade flows exploiting our baseline model, thus, can reinforce our findings for the PHH, if we can find a similar pattern from trade data.

This analysis yields other benefits, too. First, it verifies our model specifications and measures of country and industry characteristics by checking whether the estimation results are consistent with our prediction. If the estimation results are inconsistent, then we may first need to worry about if models and measures are correctly defined. Second, the analysis can reaffirm the validity of our instruments. Since we expect that lagged PM10 concentration and lagged TB notification rate still satisfy the exclusion restriction for the equation of import flows, we should be able to see over- , under-, and weak identification test statistics indicating that our instruments are valid.

To implement the analysis, we restrict the sample to the same countries, industries, and periods as in the FDI analysis. Thus, South Korean import data comprise 50 trading partners in 120 industries from 2000 to 2007. Also, we apply the same model specifications and estimation methods used in Tables 4 and 6 so that results from FDI and import data can be directly compared. We expect that the coefficient on environmental laxity interaction is positively significant, because the more environmentally lax country c is relative to South Korea, it will specialize in polluting industries and export more polluting goods to South Korea. Likewise, coefficients for all other sources of comparative advantage (i.e., all other interaction terms) should be positively significant. For example, the better institutional quality country c has, industries that require intensive relationship-specific investment will tend to locate in country c. Therefore, country c exports more to South Korea in machinery intensive goods.

Estimation results are presented in Table 8. The import data are obtained from the United Nations Conference on Trade and Development (UNCTAD), which is classified by Harmonized System (HS) 6-digit product-level. After converted and aggregated into 4-digit industries according to ISIC4, we have 24,555 observations. In all specifications, we find a strong pollution haven effect in the pattern of trade. Not only that, but the magnitudes of coefficient estimates on the environmental laxity interaction in both FE and IV estimations are similar to the ones in Tables 4 and 6. Thus, environmental laxity as a determinant of comparative advantage has a similar impact on the pattern of FDI and trade flows.

All other five sources of comparative advantage are important determinants of the pattern of trade flows following the literature. Home country tariffs are obviously a major deterrent of imports. All these results are consistent with country and industry characteristics being appropriately measured. Moreover, our instruments appear valid for the model for trade flows with strong test statistics in all columns. Lagged imports in the same industry and relevant

[32] Mulatu et al. (2010) exceptionally use total industry production data.

Table 8: Effect of Environmental Laxity on Import Flows

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent Variable: $Import_{ict}$	FE	IV-GMM	FE	IV-GMM	IV-GMM	IV-GMM
Environmental Laxity × Pollution Intensity	0.394***	0.429***	0.536***	0.621***	0.524***	0.601***
	(0.050)	(0.072)	(0.057)	(0.090)	(0.056)	(0.089)
Capital Abundance × Capital Intensity	0.054**	0.060**	0.065***	0.074***	0.063***	0.071***
	(0.023)	(0.024)	(0.024)	(0.025)	(0.024)	(0.024)
Skill abundance × Skill Intensity	3.811***	3.731***	4.011***	3.867***	3.966***	3.838***
	(0.318)	(0.318)	(0.323)	(0.316)	(0.322)	(0.314)
Material abundance × Material Intensity	0.384***	0.387***	0.447***	0.451***	0.438***	0.441***
	(0.056)	(0.055)	(0.056)	(0.055)	(0.055)	(0.054)
Institutional Quality × Machinery Intensity	–	–	0.755***	0.850***	0.733***	0.819***
	–	–	(0.176)	(0.203)	(0.171)	(0.198)
GDP per capita × Value added	–	–	0.441***	0.460***	0.433***	0.450***
	–	–	(0.049)	(0.053)	(0.048)	(0.052)
Home Country Tariff Rate	-0.763***	-0.758***	-0.734***	-0.726***	-0.724***	-0.718***
	(0.101)	(0.099)	(0.100)	(0.098)	(0.099)	(0.097)
Host Country Tariff Rate	-0.065	-0.064	-0.059	-0.057	-0.062	-0.060
	(0.063)	(0.063)	(0.063)	(0.062)	(0.062)	(0.062)
Lagged Import in the Same Industry	–	–	–	–	0.013**	0.013**
	–	–	–	–	(0.007)	(0.007)
Lagged Import across Relevant Industries	–	–	–	–	-0.010	-0.010
	–	–	–	–	(0.009)	(0.009)
Country-Year & Industry-Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Environmental laxity treated as endogenous?	No	Yes	No	Yes	No	Yes
Observations	24,555	24,555	24,555	24,555	24,555	24,555
Within R-squared	0.28	0.28	0.29	0.29	0.31	0.31
Hansen J statistic	–	0.07 (.80)	–	0.13 (.72)	2.22 (.33)	2.27 (.52)
Kleibergen-Paap rk LM statistic	–	173.0 (.00)	–	165.7 (.00)	278.5 (.00)	278.6 (.00)
Kleibergen-Paap rk Wald F statistic	–	389.2	–	329.1	1005.2	682.6

Notes: All variables are log transformed. Country characteristics are defined as the ratio of a host to home country characteristics. Robust standard errors clustered at country-year level in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

industries are included in column (5) and (6) in the same way as that our two agglomeration measures enter the model in Table 6. Same Blundell-Bond type instruments are also applied with IV-GMM method. Their overall economic impacts on current imports is minimal.

5 Concluding Remarks

Whether and how much – if any – openness in developing countries destroys their environment has been an important concern to both researchers and practitioners. Environmental policies play a central role in the core of the concern, and a great deal of empirical work has been carried out to understand the causal relationship between environmental policies and economic activities. However, their results are still short of providing a clear answer about the relationship. Part of the reasons is lack of available data that has (repeated) disaggregate observations, but another reason relates to poor identification and estimation strategies.

This paper contributes to the literature by unwrapping potential problems that might invalidate existing tests of the pollution haven hypothesis, and providing credible evidence regarding the empirical validity of the PHH after we get around those problems. To do that, we examine the pattern of South Korean outward FDI flows, as well as import flows, with a carefully designed empirical model. Our finding suggests that the difference in environmental laxity between a host and home country is a significant determinant of comparative advantage in both FDI and trade, alongside capital and skill abundances. Especially, this finding follows the theoretical Quasi-Heckscher-Ohlin prediction (or a chain proposition of comparative advantage). It is also found that ignoring either data aggregation, other determinants of comparative advantage, unobserved heterogeneity, or endogenous environmental policies can cause significantly different estimation results on the pollution haven effect. Thus, we conclude that environmental policies disproportionately affect the behavior of firms depending on their pollution intensity, but finding such effect requires deliberate attention on what data and identification strategy are used.

Although our finding shows the causal effect of environmental regulations on firm behavior in the South Korean context, further research must be done to assess external validity. Whether the pollution haven effect is a global feature or is a Korean-specific phenomenon remains unanswered. In particular, we interpret the PHH as a phenomenon of development process in the sense that the pollution haven incentive is more evident in recently developed countries than in the most developed countries. Since this interpretation relates to the unobserved effect of clean technology innovation in polluting industries, the isolation of a clean technology effect will clarify our prediction. Also, if our prediction is indeed true, a similar pattern should be observable in other recently developed countries.

Finally, evidence for the PHH may be only a stepping stone in answering questions that are more directly related to policy and welfare implications. For example, the pollution haven effect does not directly tell us whether there is an environmental "race to the bottom", how much pollution emissions and related health outcomes in a country is due to the industrial migration, or how environmental policies in each country affect global pollution levels. In that sense, the scope of the present paper should be limited to the effect of environmental policies on the spatial distribution of economic activity. However, the PHH does tell us, at least, that environmental policymakers need to take this evidence into account.

A. Data Appendix

50 sample host countries are listed in Table A1. The sample includes 120 4-digit manufacturing industries classified by the International Standard Industrial Classification (ISIC) Revision 4. All monetary values are converted in 2000 constant US$, using official exchange rate and Consumer Price Index from the Bureau of Labor Statistics. Assuming that firm's investment decision is made at the beginning of each year based on the information at the time, outward FDI is matched with previous year's country and industry characteristics to avoid the potential simultaneity problem.[33] All variables are log-transformed for our analysis. Summary statistics of data used in analyzing our baseline equation (4) is presented in Table A2.

A.1. South Korean outward FDI, import, and tariff data

We only considered strictly positive investment and import cases as our sample observations: observations of zero investment or trade by country, industry and year level are dropped out. However, the sample includes zero tariff rate, since all tariff rates are added by one and log-transformed.

Outward FDI: From the Oversea Investment Statistics database in the Export-Import Bank of Korea. Since each firm is required to report information about its investment to the bank, the database keeps all South Korean foreign direct investment by year, country, and industry level throughout the sample periods. Original data is classified by Korean Standard Industry Classification (KSIC) Revision 9, which is converted into the ISIC Revision 4.

Import: South Korean import data are taken from the United Nations Conference on Trade and Development (UNCTAD). Original data is classified by Harmonized System (HS) combined.

Host and home country tariff: Tariff data comes from The World Integrated Trade Solution (WITS). Original tariff data is classified by the Harmonized System (HS).

A.2. Country Characteristics

Basic country characteristics are obtained from the World Development Indicators (WDI) 2011, available from the World Bank database. TB notification rate is from World Health Organization (WHO). Each host country's characteristic is divided by home country's (i.e., South Korea) one so that it is measured in relative term.[34]

Environmental laxity: Laxity of environmental regulation measure is taken from the Global Competitiveness Report, edition 2000 to 2007-2008. The World Economic Forum, the

[33] For example, we assume that a firm's FDI to chemical industry in China during 2007 is due to the decision made at the beginning of 2007, and that decision is based on information at the end of 2006, which corresponds to country and industry data in 2006.

[34] For example, relative physical capital abundance is country c's physical capital stock per worker relative to home country k's one: $rkl_{ct} = \frac{K_{ct}/L_{ct}}{K_{kt}/L_{kt}}$.

Table A1: List of 50 host countries by RTAs

ASEAN (6)	MERCOSUR (2)	EU (17)	N/A (19)
Cambodia	Argentina	Belgium	Australia
Indonesia	Brazil	Bulgaria	Bangladesh
Malaysia		Czech Republic	Chile
Philippines		Finland	China
Thailand		France	Ecuador
Vietnam		Germany	Egypt
		Hungary	El Salvador
		Ireland	Guatemala
		Italy	Honduras
CIS (3)	**NAFTA (3)**	Luxembourg	India
Kazakhstan	Canada	Netherlands	Japan
Kyrgyz Republic	Mexico	Poland	Kenya
Russia	United States	Portugal	New Zealand
		Slovak Republic	Nicaragua
		Slovenia	Pakistan
		Sweden	Peru
		United Kingdom	South Africa
			Switzerland
			Turkey

publisher of the report, surveys annually around 10,000 top management business leaders from sample countries. They are asked the question "how stringent is your country's environmental regulation? (1 = lax compared with that of most countries, 7 = among the world's most stringent)". The final country score is averaged over this executive opinion surveys. To construct a measure of environmental laxity, we simply subtract the environmental stringency score from 8, so that the order is reversed preserving the 1 to 7 scale. Since the survey is conducted in the early months of each year, the score reflects mostly previous year's experience. Hence, we regard environmental stringency at year t in the report as the one at year $t-1$, following Kellenberg (2009).

Capital abundance: Physical capital abundance in a country is measured by a country's physical capital stock divided by total labor force. To estimate the level of physical capital stock, we follow the perpetual inventory method (See, for example, Egger 2000). Specifically, we set a country c's initial capital stock in year 1995 as $K_{c,1995} = 5 \times (GFCF_{c,1994} + GFCF_{c,1995})$, where $GFCF$ is the gross fixed capital formation in constant 2000 US$. Assuming the capital stock is depreciated by 7% in each year, we construct the capital stock of the following year as $K_{ct} = 0.93 \times K_{c,t-1} + GFCF_{ct}$. $GFCF$ and total labor force are drawn from the WDI 2011.

Skill abundance: Skill abundance (or human capital endowment) is defined as human capital per worker.[35] We followed Hall and Jones (1999) to construct the measure using Barro

[35]We also used alternative measure of skill endowment: a country's skilled worker share of total labor force. For a measure of skilled worker, we used the total number of people aged between 15-64 with tertiary education,

Table A2: Summary Statistics in FDI Sample

Variable	Mean	Std. Dev.	Min	Max
Outflow of Foreign Investment (FDI)	13.40	2.219	3.357	21.139
Market Size (mkt)	7.361	0.933	6.224	9.401
Similarity (sim)	-1.459	0.752	-5.331	-0.693
Environmental Laxity ($rlax$)	0.0803	0.377	-1.153	0.588
Capital Abundance (rkl)	-1.796	1.557	-4.463	1.023
Skill Abundance (rhl)	-0.249	0.235	-0.670	0.165
Raw Material Abundance (rml)	1.541	1.146	-0.819	5.229
Institutional Quality (riq)	-0.231	0.316	-0.829	0.381
GDP per capita ($rgdppc$)	-1.461	1.601	-3.788	1.357
PM10 Concentration (rpm)	0.128	0.621	-1.260	1.407
TB Notification rate (rtb)	-0.671	1.135	-2.877	2.080
Pollution Intensity (PI)	-4.438	0.883	-6.779	-1.550
Capital Intensity (KI)	3.790	0.851	1.820	6.709
Skill Intensity (HI)	-1.241	0.256	-2.051	-0.438
Raw Material Intensity (MI)	-0.688	0.215	-1.635	-0.198
Machinery Intensity (CI)	-0.911	0.378	-3.245	-0.245
Value Added per Output (VA)	-0.945	0.217	-2.013	-0.305
Ratio of Firm/Plant-level Scale Economies (SE)	4.337	1.042	1.032	8.867
Host Country Tariff Rate ($Htariff$)	2.157	0.843	0	4.931
Home Country Tariff Rate ($Ktariff$)	2.029	0.613	0	5.827
N	3,137			

Notes: All variables are log transformed. Relative terms are defined as the ratio of a host to home country variables.

and Lee's educational attainment dataset (2010). For the detail, see Hall and Jones (1999).

Raw material abundance: It is proxied by a country's land area per worker in the labor force. Land area is drawn from the WDI 2011.

Institutional Quality: Data for institutional quality is taken from the Worldwide Governance Indicators (WGI), which has six indicators for governance in a country. See Kaufmann et al. (2009) for more detail information. Rather than choosing one indicator out of six, we take average of all six indicators and add 2.5 to avoid negative values.

GDP per capita: in constant 2000 US$. data is drawn from the WDI 2011.

PM10 concentration level: measured as urban-population weighted PM10 levels in residential areas of cities with more than 100,000 residents. Data and detail description are available in the WDI 2011.

TB Notification rate: Total notified new and relapse tuberculosis cases per 100,000 population. Data and detail description are available in WHO webpage.[36]

which came from the International Institute for Applied Systems Analysis & Vienna Institute of Demography (IIASA/VID) educational attainment dataset. This dataset is available in the World Bank database. The analysis using this measure did not change the results qualitatively.

[36] http://www.who.int/tb/country/data/download/en/index.html

Table A3: Correlations between Measures of Pollution Intensity

	PI	PI_NBER	PI_IPPS
Pollution Intensity (PI)[a]	1		
Energy per Shipment in NBER (PI_NBER)[b]	0.813*	1	
Pollution Emissions per Output in IPPS (PI_IPPS)[b]	0.694*	0.897*	1

Notes: [a]Pollution intensity is averaged over year 1999-2006. [b]All measures are converted into ISIC Revision 4 for comparison. * indicates significance at 1% level.

A.3. Industry Characteristics

South Korean industry characteristics are sourced from the Korean Statistical Information Service (KOSIS). Original datas are classified by either KSIC Revision 8 or 9. Alternative measures of pollution intensity are obtained from the IPPS and NBER, respectively. Table A3 provides the correlation between three measures of pollution intensity.

Pollution intensity: pollution intensity is proxied by energy intensity, which is the sum of fuel and electricity usage scaled by total output.

Physical capital intensity: physical capital intensity is measured by the real capital stock per worker in an industry. The real capital stock includes the total amount of tangible buildings and structures, machines, equipments, vehicles and other tangible assets. Land asset is not included.

Skill intensity: measured by non-production worker's share out of total employment.

Raw material intensity: measured by the value of raw material inputs per output.

Machinery intensity: measured by the value of machinery per output.

Value added: measured by the value added per output.

Ratio of firm- to plant-level scale economies: Firm-level scale economies are average number of non-production workers per establishment. Plant-level scale economies are total value of buildings, structures, and land per output. The ratio is firm-level scale economies divided by plant-level scale economies.

A4. Pollution Emissions in South Korea

Emissions of six pollutants in manufacturing industry during 1999-2006 are used in figure 3.

Four air pollutants (SOx, NOx, CO, PM10): sourced from National Institute of Environmental Research (NIER, 2008).

Waste Water: the Korean Statistical Information Service (KOSIS).

Toxin: Pollutant Release and Transfer Registers (PRTR).[37]

[37]http://ncis.nier.go.kr/total/triopen/eng/sub2.jsp

Table A4: Second Stage Regression Results in Table 5

Dependent Variable: FDI_{ict}	(1) FE	(1) IV-GMM	(2) FE	(2) IV-GMM	(3) FE	(3) IV-GMM
Environmental Laxity	1.607**	0.206	-0.033	-1.718	–	–
	(0.747)	(1.740)	(1.191)	(2.549)	–	–
Environmental Laxity × Pollution Intensity	0.411**	0.489	0.054	0.066	0.429***	0.588***
	(0.185)	(0.300)	(0.239)	(0.458)	(0.133)	(0.183)
Pollution Intensity	-0.288	-0.285	0.101	0.111	–	–
	(0.233)	(0.227)	(0.176)	(0.193)	–	–
Capital Abundance	0.005	0.723	0.807	1.552	–	–
	(0.949)	(1.045)	(1.147)	(1.257)	–	–
Capital Abundance × Capital Intensity	0.146***	0.155***	0.122	0.110	0.143***	0.165***
	(0.037)	(0.045)	(0.142)	(0.141)	(0.032)	(0.033)
Capital Intensity	0.415*	0.411**	0.608	0.565	–	–
	(0.212)	(0.185)	(0.399)	(0.397)	–	–
Skill Abundance	6.845**	1.809	4.063	-0.881	–	–
	(2.626)	(4.053)	(4.354)	(5.722)	–	–
Skill Abundance × Skill Intensity	1.657***	1.540***	-0.607	-0.369	1.549***	1.350**
	(0.601)	(0.559)	(1.681)	(1.644)	(0.527)	(0.529)
Skill Intensity	-0.625	-0.656	-1.054*	-1.061*	–	–
	(0.512)	(0.506)	(0.634)	(0.612)	–	–
Raw Material Abundance	-0.806	-0.216	2.076	2.483	–	–
	(2.137)	(2.477)	(2.735)	(2.717)	–	–
Material Abundance × Material Intensity	-0.131	-0.134	-0.017	-0.004	0.046	0.024
	(0.195)	(0.187)	(0.423)	(0.419)	(0.144)	(0.143)
Raw Material Intensity	0.565	0.553	0.333	0.354	–	–
	(0.786)	(0.763)	(0.917)	(0.895)	–	–
Home Country Tariff Rate	-0.211*	-0.247**	-0.059	-0.155	-0.175	-0.185
	(0.113)	(0.105)	(0.368)	(0.373)	(0.126)	(0.126)
Host Country Tariff Rate	0.159	0.173	-0.184	-0.135	0.182**	0.195**
	(0.113)	(0.109)	(0.321)	(0.320)	(0.078)	(0.078)
Market Size	4.990*	3.336	6.544**	5.069*	–	–
	(2.542)	(2.635)	(2.789)	(3.006)	–	–
Similarity	5.246**	3.972*	6.534***	5.378**	–	–
	(2.344)	(2.285)	(2.523)	(2.685)	–	–
Ratio of Firm/Plant-level Scale Economies	0.441*	0.421*	0.583***	0.558***	–	–
	(0.225)	(0.220)	(0.196)	(0.193)	–	–
Unit of panel observations	Country		Country-Industry		Country-Year	
Included dummy variables	Industry & Year		Year		Industry-Year	
Observations	3,137	3,137	3,137	3,137	3,137	3,137
R-squared	0.29	0.28	0.11	0.10	0.45	0.45
Hansen J statistic (P-value)	–	0.09 (.95)	–	0.76 (.68)	–	0.00 (.99)
Kleibergen-Paap rk LM statistic (P-value)	–	8.27 (.04)	–	103.4 (.00)	–	59.77 (.00)
Kleibergen-Paap rk Wald F statistic	–	9.65	–	88.91	–	149.7

Notes: All variables are log transformed. Country characteristics are in relative terms, which are defined as the ratio of a host to home country variables. Robust standard errors clustered within the unit of panel observations in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

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