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Do Lax Environmental Regulations Attract Foreign Investment?

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Abstract. There has been considerable controversy over the empirical significance of the theoretically predicted pollution haven hypothesis. Generally, empirical papers have failed to find an effect on industrial location of weaker or stricter environmental regulations. In this paper we find confirmation of theoretical predictions. We present a statistical test of the impact of environmental regulations on the capital movement of polluting industries. The empirical study is conducted by examining foreign direct investment (FDI) of several US industries, representing industries with high pollution control costs (chemicals and primary metals) as well as industries with more modest pollution control costs (electrical and non-electrical machinery, transportation equipment, and food products). At issue is the effect of the laxity of environmental regulation on FDI. As laxity is not directly observed, we posit two equations, one for FDI determination and one for pollutant emissions, a variable positively correlated with the unobserved variable. We use aggregate national sulfur emissions as the pollutant. Using instruments for the unobserved variable, the statistical results show that the laxity of environmental regulations in a host country is a significant determinant of FDI from the US for heavily polluting industries and is insignificant for less polluting industries.

Key words: control costs, pollution, predictions, sulfur

JEL classification: Q22, Q28

1. Introduction

Environmental regulation has proceeded at different paces in different countries of the world. These differences are particularly pronounced between industrialized countries and developing countries, and have given rise to much controversy and debate on the influence of environmental regulation on economic growth in an open economy. One important aspect of the debate is the impact of environmental regulation on international competitiveness and the location of polluting industries. Overly strong regulations are hypothesized to lead to industrial flight whereas lax regulations are feared to turn the country into a "pollution haven." The underlying hypothesis is that environmental regulations have a strong effect on industrial location and that differential regulations between two countries will at minimum induce specialization and probably significant capital movements to the country with the weaker regulations.

There are three primary justifications for this view. Strong environmental regulations are viewed to: (a) directly drive up production costs by requiring certain equipment; (b) decrease waste disposal capacity (e.g., by restricting areas that can be used for landfills); and (c) prohibit certain factor inputs or outputs. In all of these cases, the bottom line is that production costs are increased. It is obviously in a firm's interest to locate its production facilities in a country with lower production costs if the firm has the choice of location (all other things being equal). Unambiguously, this argument focuses solely on the cost effect of environmental regulations on polluting industries, and presumes that production cost differentials are a sufficient inducement for a firm to relocate its production facility or site a greenfields facility.

There is some theoretical justification for this hypothesis. Several authors use a general equilibrium framework[1] to conclude that a country with lenient environmental regulations will tend to specialize in pollution intensive industries or at least enjoy a comparative advantage in such industries. This implies that it is optimal for polluting industries to transfer their production facilities to the "pollution haven." Multinational enterprises (MNE), which already have distributed overseas production, would appear to be particularly likely to reorganize their overseas operation, locating production facilities in countries with lax environmental regulations. The strong opposition to NAFTA in the US from labor unions and environmental groups reflects how widely such a view is held.

An alternative view, without as much theoretical justification, is that environmental regulations have no effect on plant location. The basic argument is either that cost effects are so small as to be negligible or that increased environmental quality is reflected in reduced employee compensation. Without regulation, employees would have to be paid more to live and work in polluted conditions. Thus in equilibrium, the total costs will be the same. Using the later argument, one would still expect to see particularly polluting industries moving to locations endowed with a clean environment (perhaps temporarily) and with weaker environmental regulations. The empirical literature to date supports the view that environmental regulations do not matter.[2]

While empirical studies of the industrial flight/pollution haven hypotheses have been illuminating, their shortcomings suggest that the question has not yet been fully answered. One problem with previous empirical studies is that the endogenous variable, intended to track the effects of environmental regulations, is unsatisfactory. For instance, Low and Yeates (1992) use a country's share of production in total world trade of pollution-intensive products as a proxy for specialization in polluting goods. This is a coarse measure of specialization. Such a variable is determined by a wide variety of factors in addition to the strictness of environmental regulations. Furthermore, it is capital flow, not goods flow, which should be most affected by differential environmental regulations. Only in the long run will a country's production mix reflect capital movements induced by differential environmental regulations.

Another shortcoming of previous empirical studies lies in measuring the strictness of environmental regulations. Considering the complexity of any country's environmental regulations, this is no easy task. In most empirical studies there is no measure of the strictness of regulations and the policy discussion is primarily descriptive. Bartik (1988) uses a variety of quantitative measures for the magnitude of stringency of environmental regulation. Fundamentally all the measure are based on pollution abatement and control cost. It is well known that there is no precise definition of control costs, and further that average control costs per unit output is an inappropriate measure of stringency. To examine the effect of environmental policy on trade, Tobey (1992) employs a subjective scale ranging from 1 to 7 to indicate the degree of stringency of environmental policy.[3] He then uses this variable in a Heckschler-Ohlin-Vanek model of trade.[4] Although this is a useful paper, we find such a qualitative measure disquietingly ambiguous and potentially imprecise. Van Beers and van der Bergh (1997) address this question in more detail but ultimately use an analyst-specified and thus somewhat arbitrary measure of stringency.

The purpose of this paper is to complement the previous studies, and provide a new methodology examining the effect of environmental policy on the location of polluting industries. We introduce what we think is a better quantitative measure of the strictness of environmental policy. To test the "industrial flight" hypothesis, we use foreign direct investment of a typical polluting industry as a proxy. The rationale is that for an industry, locating its production capacity overseas is basically foreign direct investment (FDI). In addition, if environmental regulations generate distortions in the operation of polluting industries, the multinational enterprise may initially respond with the intra-firm transfer of its production facility, or increase the investment in its subsidiaries located in the country with lenient regulation. Such adjustment may not involve relocation of the entire plant, but it would change its FDI flow. Hence, FDI may be more sensitive to environmental regulations than the other proxies. Of course a country's specialization in polluting industries need not be via FDI but if FDI is attracted to areas with weak environmental regulations, then the pollution haven hypothesis will be supported.

We focus on several industries, including two of the most polluting industries, chemicals and primary metals, using FDI to reflect location decisions on productive capacity. We compare our results for this industry to results for industries that are less pollution intensive. Thus we extend the existing literature by using a more direct measure of capital movements as well as a better (in our view) measure of the strictness of environmental regulations. The results are interesting and run counter to other analyses. For pollution-intensive industries, we find a significant effect of the strictness of environmental regulation on FDI. We find that weaker environmental regulations do tend to attract capital. Furthermore, we do not find this result for the less polluting industries.

In the next section we briefly review theories on FDI. We then present an empirical model of FDI with the environmental variable as one of the explanatory variables, and test the role of environmental policy in determining FDI flows in the chemical industry. Finally, we summarize our findings.

2. The Determinants of Foreign Direct Investment

Foreign direct investment (FDI) is a special form of capital flow that not only includes capital but also intangible assets such as management skills. A variety of theoretical studies on FDI have identified many determinants of FDI, including differences in the marginal return to capital, market size of host countries, exchange rate risk, trade impediments and market power. Agarwal (1980) and Cave (1983) provide comprehensive reviews of theories of FDI determination.

The classic explanation of FDI is based on capital return differentials across countries. The argument is that FDI is driven by international differences in the marginal return to capital. FDI flows out of countries with low return to those expected to yield higher marginal returns. In other words, FDI is a simple capital arbitrage phenomenon. The "industrial flight" hypothesis mentioned earlier emphasizes production cost differentials caused by environmental regulation, implying that such cost discrepancies would result in the relocation of polluting industry. The conventional economic analysis of the effect of environmental policy on capital movements of polluting industries is basically an application of the capital arbitrage argument. For instance, in McGuire (1982), the expected capital outflow for a polluting industry from a country with stringent environmental policy to one which has no or lax environmental policy, is triggered by different factor rewards which are caused by differential environmental policies between the two countries. In a recent study on the location of plant in reaction to environmental policy under imperfect competition, Markusen and Morey (1993) conclude that plant location can be a function of environmental policy. This conclusion is based on the cost effect caused by an emission tax representing environmental protection.

Tax policy in different countries appears to be one significant determinant of cost differences among countries although, as discussed by Hines (1996), part of this differential is eroded for US corporations by US tax policy which taxes worldwide earnings and gives a tax-credit for foreign taxes paid. Grubert and Mutti (1991) examine the effect of foreign tax policy on the location of US capital and find it a significant explanatory variable.

In the studies confined to US direct investment in the EEC from 1958–1968. Scaperlanda and Mauer (1969) emphasize the role of the host country market in the FDI decision, particularly market size and market growth. The market size hypothesis states that, due to scale economies, FDI will not flow into a country until its market approaches a certain size, a size necessary to efficiently implement the production technology. Once a foreign investor constructs a production facility in a country, the capital inflow increases as demand rises. In empirical analysis, the market size is approximated by the host country's GDP or per capita GDP. The role of demand growth is based on the relationship between aggregate demand and the capital stock needed to satisfy that demand. Specifically, the growth hypothesis postulates a positive relationship between capital inflow and the rate of growth of host country GDP. In some applications, market growth is measured by the relative growth rate between the host country and the country of origin of FDI. A simple regression by Scaperlanda and Mauer indicates that US direct investment in the EEC, measured by the annual change in the book value of the US investment position in the EEC, is consistent with the market size hypothesis. Goldberg (1972) redefines the regression equation and concludes that US direct investment is mainly explained by market growth rather than market size. In recent studies on the determinants of German manufacturing FDI, Moore (1993) finds that both market size and growth rate of host countries are significantly related to German manufacturing FDI from 1980 to 1990. Wheeler and Mody (1992) investigate the manufacturing investments by US multinationals in the 1980s and conclude that the market size of host countries is significant and has a large positive impact on FDI.

The "liquidity hypothesis" is another explanatory basis of FDI theory. This hypothesis conjectures a positive relationship between internal cash flow and investment outlays of a firm. The hypothesis is based on the premise that internal funds are viewed by investors as cheaper than external financial resources. In theoretical studies on FDI, Froot and Stein (1991) argue that the incompleteness of financial markets results in incomplete information to investors which results in internal financial resources being cheaper than external funds for multinationals (MNE). Many economists have examined this "liquidity hypothesis" and found some evidence in favor of the argument. In the studies of US MNE overseas operations, Barlow and Wender (1955) observe that the initial investment of US companies in foreign markets is modest. The expansion of their foreign affiliates is largely conducted though reinvestment of their local profits. Similar evidence is found in other empirical studies. Safarian (1969) analyzes US FDI in Canada from 1957–1965, and reports that more than 60 percent of funds used by US subsidiaries in Canada came from internal financial resources, especially from income and depreciation. Brash (1966) investigates US FDI in Australia and concludes that the most important source of funds for the expansion of U.S. subsidiaries is undistributed profits and depreciation allowances. These studies suggest that FDI should depend positively on the availability of internal funds in host country subsidiaries.[5]

3. A Model of FDI with Environmental Policy

Our goal in this section is to develop a model of how foreign direct investment in a specific industry is influenced by the laxity/stringency of the environmental regulation in that country. We defer to the next section of the paper the issue of the econometrics of estimating the model and testing hypotheses.

A. FOREIGN DIRECT INVESTMENT

In developing an empirical model of FDI determination, we consider two issues. The first is simply what determines FDI, including, we hypothesize, the stringency of environmental regulation. And that brings us to the second issue: how to deal with the fact that the stringency of environmental regulation is not directly observed. We solve this latent variables problem by using observations on pollutant emissions to infer stringency. Dealing with unobserved variables has some history in economics; there are a number of approaches, all relying on the relationship between the unobserved variable and related observed variables (Zellner 1970; Goldberger 1972; Jöreskog and Goldberger 1975; Engle and Watson 1981).

Specifically, our model is

$$I = f(Z, E^*) \tag{1}$$

$$S = e(X, E^*) \tag{2}$$

In eqn. (1), I is FDI, Z is a vector of exogenous variables influencing FDI (e.g., economy size or tax concessions) and E* is the (unobserved) measure of economy-wide environmental regulatory laxity (smaller E*'s are associated with stricter environmental regulations). We are interested in estimating eqn. (1) except that E* is unobserved. This is a standard latent variable problem. Eqn. (2) is used to provide information about E*.

In eqn. (2), S is a measure of economy-wide pollution emissions (such as sulfur), X a vector of exogenous determinants of pollution emissions (e.g., energy prices) and E* the unobserved measure of the laxity of environmental regulations found in eqn (1). The only assumption we will make is that e is invertible in E*, so that eqn (2) can be solved for E* as a function of the other variables. In such a case, we obtain

$$E^* = h(X, S) \tag{3}$$

which can be substituted into eqn (1) to obtain

$$I = g(X, Z, S) \tag{4}$$

The estimation of eqn. (4) is the basic approach of this paper. While obtaining eqn. (4) is straightforward here, clearly there are econometric problems in applying this framework. These include problems of identifying any parameters of the underlying functions f and e, eliminating bias in coefficient estimates, as well as testing hypotheses about the effects of the unobserved E* on I.

B. POLLUTANT EMISSIONS

We turn now to putting a little more structure on eqns (1) and (2). For eqn (2), the pollutant we consider is economy-wide sulfur dioxide emissions, one of the most significant air pollutants worldwide and one of the variables most commonly used

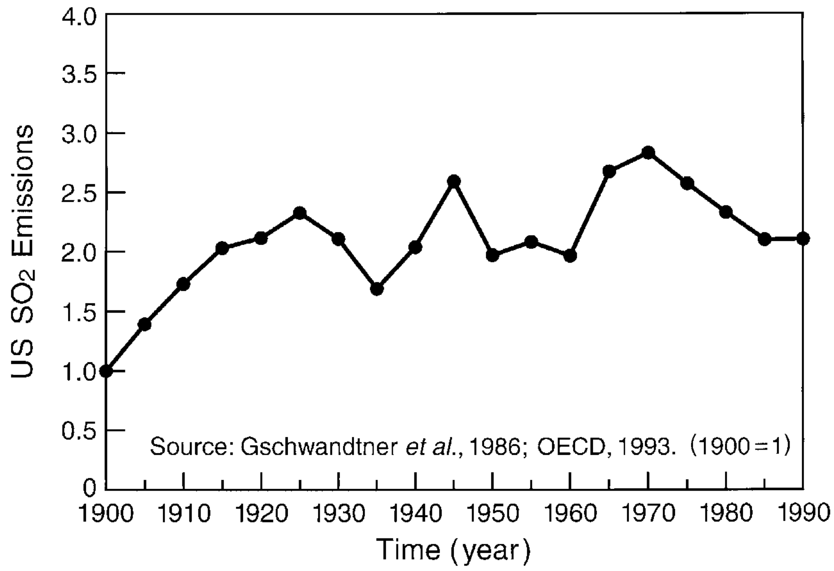

Figure 1.

variables to proxy for environmental quality (e.g., Shafik and Bandypadhyay 1992; OECD 1993; UNEP 1993).

To give intuition on the appropriateness of this measure, Figure 1 shows US SO_2 emissions rise over time (with some significant dips in the 1930s and 1950s. The dip in the 1930s is clearly due to the Great Depression in the US which depressed economic activity generally. The dip in the 1950s is due to a shift to cleaner gas and oil as the price of these fuels dropped relative to dirty coal. This upward trend continues until 1970, the year the Clean Air Act was amended in the US to impose strict air pollution regulations (Figure 2). Emissions have declined since then. Thus the level of economic activity, relative prices of energy and environmental regulations would appear to explain a good deal of Figure 1. In Europe, the control of sulfur dioxide is also significant, although he push to control it occurred later than in the US (Figure 3).

Some critics argue that SO_2 emissions may only reflect environmental policy in a narrow category rather than the overall stringency of environmental regulation. To examine whether SO_2 emissions are determined by the overall level of environmental regulations, we take the U.S. as an example and calculate the correlation coefficients between SO_2 emissions and five other major air pollutants from 1970 to 1991.[6] The pollutants selected are: nitrogen oxides (NO_x), reactive volatile organic compounds (VOCs), carbon monoxide (CO), total suspended particulates (TSP) and lead. We find that except for NO_x, which failed to decline during the period, the SO_2 emissions have highly positive association with the other four pollutants, with the correlation coefficients ranging from 0.846 to 0.950. This finding strongly

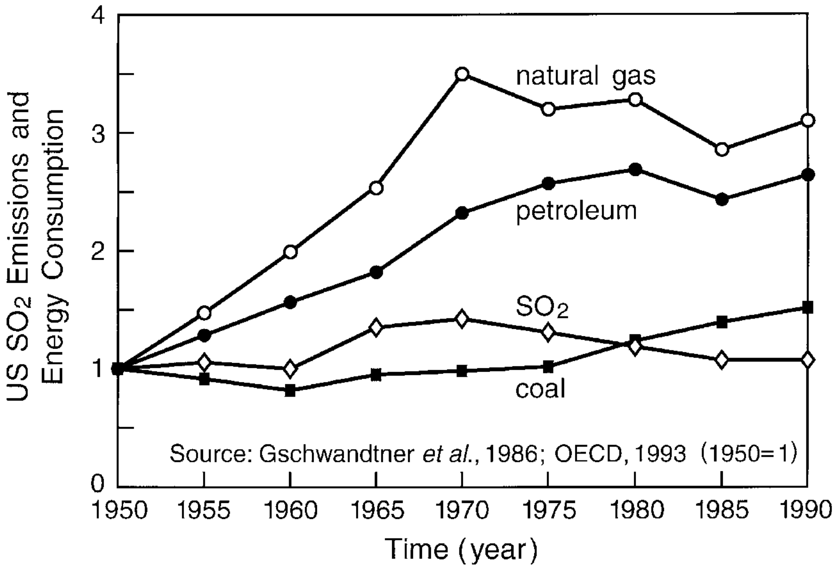

Figure 2.

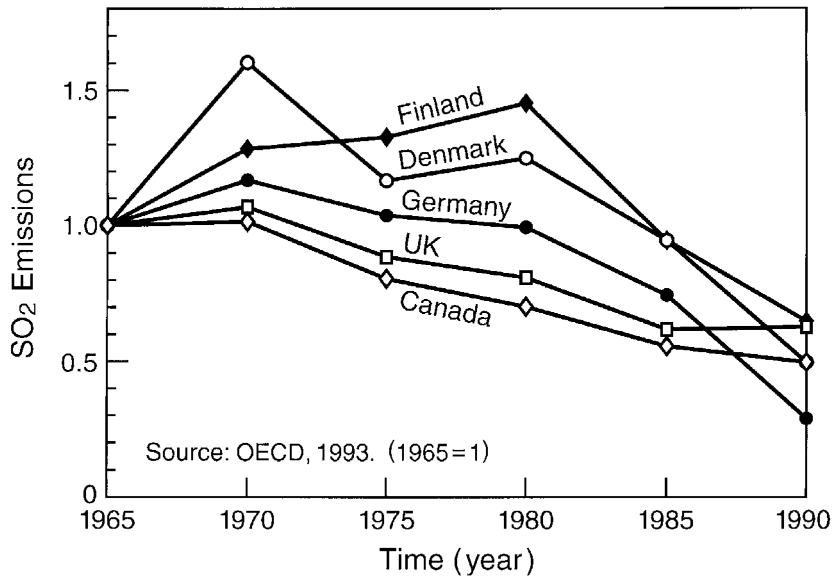

Figure 3.

suggests that SO_2 emissions are highly correlated with emissions of many other pollutants.

Another criticism of the use of SO_2 emissions is that the data series are constructed from fuel consumption data, rather than directly observed. While this is generally the case, the fact that these data are constructed (if the construction is done well) does not bias the series, though additional errors may be introduced.

To give structure to eqn. (2), we must specify the determinants of sulfur dioxide emissions. The first thing to realize is that sulfur dioxide is in large part a by-product of energy consumption, particularly of coal. In fact, this is the basic assumption used by several authors to construct historical series on sulfur emissions (Gschwandtner et al. 1986; Kato and Akimoto 1992; Dignon and Hameed 1989).

Generally, the influence of environmental policy on sulfur emissions can be decomposed into two basic effects. First, stricter environmental regulations can be expected to reduce the emissions of SO_2 per unit of energy consumed. Secondly, tighter regulation of sulfur emissions raises the cost of using energy, thus reducing its consumption. We specify each of these effects separately before combining them.

Stricter environmental regulations typically involve increased use of abatement equipment as well as lower sulfur fuels. We would expect sulfur emissions (S) of a country to be positively related to energy consumption (C) and the laxity of environmental policy (E*), among other determinants (e.g., the endowment of clean vs. dirty fuels): increases in C or E* will lead to increases in S.

The second way in which environmental regulations influence sulfur emissions is by increasing the cost of using energy and thus reducing its consumption. This assumptions is based on basic demand theory where energy consumption in a country is posited to be positively related to national income/net output (G) and the laxity of environmental regulations (E*) (see Slade et al. 1993; Pindyck 1979): increases in G or E* will lead to increases in C. Furthermore, C will be negatively related to the price of energy (π).

Combining these two effects allows us to eliminate energy consumption from direct consideration, focusing on the relationship between sulfur emissions and G, E*, π and other country-specific variables (W):

$$\mathrm{S} = \mathrm{e}(\mathrm{G}, \mathrm{E}^*, \pi, \mathrm{W}) \tag{5}$$

where by assumption, $\partial e/\partial G > 0$, $\partial e/\partial \pi < 0$, and $\partial e/\partial E^* > 0$. Eqn. (5) indicates that SO_2 emissions are a function of national income, the stringency of environmental policy, energy prices and other country-specific factors.[7]

As indicated earlier, we assume that e is invertible in E* so that we may solve for the unobserved E*:

$$\mathrm{E}^* = \mathrm{h}(\mathrm{S}, \mathrm{G}, \pi, \mathrm{W}) \tag{6}$$

which corresponds to eqn. (3). Note from our assumptions on eqn. (5), that $\partial h/\partial S > 0$ and $\partial h/\partial G < 0$.

4. Estimation

We start by making assumptions about the functional form of eqns. (1) and (6), and substitute eqn. (6) into eqn. (1) to obtain eqn. (4). Eqn. (4) is estimated and our goal is to use that estimate to make inferences with regard to the parameters of eqn. (1), specifically, the effect of E* on I.

A. THE MODEL

We assume eqn. (3) is of the form of eqn. (6). We assume a semi-log specification, with country-specific variables included in the error term:

$$E^*_i = \ln S_i - \alpha \ln G_i - \alpha_E ESI_i - \alpha_R R_i + \varepsilon_i \tag{7}$$

where E^*_i is the (unobserved) laxity of environmental regulations in country i, S_i is annual SO_2 emissions of country i, G_i is the real GDP of country i, ESI_i is an electricity structure index relecting the extent of hydroelectric vs fossil-fuel capacity in the country's electricity generating system, R_i is the share of industry output in GDP, and ε_i is an error term with mean zero. Since we do not consider a time series, energy prices will be roughly constant over the cross section and are thus omitted. We would expect ESI_i, R_i, G_i and ε_i to be uncorrelated but because S_i was in fact the endogenous variable in the underlying equation from which eqn. (7) was derived (before eqn. 5 was inverted), S_i and ε_i may very well be correlated. Note that without loss of generality, the coefficient of ln S_i has been set to unity. Note also that because of the positivity of partial derivatives of eqn. (6), $\alpha \geq 0$.

In the FDI determination equation (1), FDI is most precisely defined as the annual capital outflows in an industry (as opposed to the change in capital assets computed from historical FDI). This reduces the influence caused by the fluctuation of exchange rates and avoids the problem of computing capital accumulation. The capital outflows are defined as the sum of equity outflows, reinvested earnings and intercompany debt outflows.

Based on our earlier discussion, there would appear to be four major factors determining FDI: tax rates, market size, industry profitability and environmental regulations.[8] Market size reflects the demand hypothesis while industry profitability reflects the liquidity hypothesis. We use per capita GDP to proxy the market size, viewing the maturity of the economy rather than sheer size as the determining factor. This would rank Switzerland, for example, ahead of India, whereas on the basis of total GDP, the reverse would apply.[9] Further, we use the annual after-tax income of local affiliates (from prior FDI) as the measure of profitability. Thus eqn. (1) can be written in the following linear form:

$$I_i = \beta_O + \beta_T T_i + \beta_P P_i + \beta_Y Y_i + \beta_E E_i^* + \eta_i \tag{8}$$

where I_i is FDI for a particular industry in country i, T_i is the corporate income tax rate in country I, P_i is per capita annual GDP in country i, Y_i is the after-tax annual income of local affiliates in country i,[10] and E^*_i is the laxity of environmental regulations in country i. The error term η_i is assumed to have a mean of zero and be distributed independently from ε_i (thus $E(\varepsilon_i\eta_i) = 0$.

It would seem clear that all of the exogenous variables in eqn. (10) are truly exogenous since they are economy-wide and I_i is FDI in a narrow sector of the economy.

Eqn. (7) and (8) can be combined into

$$\begin{aligned} I_i &= \beta_O + \beta_T T_i + \beta_P P_i + \beta_Y Y_i + \\ &\quad \beta_E[\ln S_i - \alpha \ln G_i - \alpha_E \ln ESI_i - \alpha_R R_i + \varepsilon_i] + \eta_i \\ &= \beta_O + \beta_T T_i + \beta_P P_i + \beta_Y Y_i + \beta_E \ln S_i \\ &\quad -\alpha\beta_E \ln G_i - \alpha_E\beta_E \ln ESI_i - \alpha_R\beta_E R_i + \xi_i \end{aligned} \tag{9}$$

where the composite error term, ξ_i, has zero mean and is uncorrelated with any of the right-hand-side variables in (9), with the possible exception of S_i, consistent with the properties of ε_i and η_i. The endogeneity of S_i implies that S_i is correlated with error term ξ_i. Also, because eqn (9) involves cross-country effects, the variances of error terms ξ_i may not be homogenous. Therefore, OLS estimators are generally neither consistent nor efficient for our model. Furthermore, the OLS estimates will be biased due to the unobserved variable, not unlike an errors-in-variables problem (Kmenta 1986). To pursue consistent, unbiased and efficient estimates, we estimate eqn (9) using instrumental variables. Consistent with the literature, we seek instruments which are uncorrelated with the errors but are correlated with the unobserved variable – regulatory laxity. We have chosen to include as instruments all exogenous variables in our model (except sulfur), and two external exogenous variables (infant mortality rate and population density). These two external exogenous variables are unlikely to be correlated with the error. The infant mortality rate is indicative of a general level of social consciousness in the country, which is likely to accompany strict environmental regulations. The population density is an indicator of congestion and the ability of pollutants to naturally disperse away from population centers. We also correct for heteroskedasticity.[11]

B. THE DATA

Data on FDI originating in the US are readily available for six manufacturing sectors in the *Survey of Current Business*. The exact definition of FDI as well as retained earnings (another variable we use) can be found in that source. Based on US experience, Jaffe et al. (1995) label two of these as "high abatement cost" industries (Chemicals and Primary Metals), one as having "moderate abatement cost" (electrical machinery), and one as having "low abatement cost" (non-electrical machinery). The Census Bureau reports capital and operating expenditures for pollution abatement. Table I shows these data for the six sectors for which we have FDI data. Clearly two sectors stand out as pollution intensive: Chemicals and Primary Metals. The other sectors are much less pollution-intensive.

Table I. Pollution abatement expenditure intensity in US industries, 1991.

Manufacturing sector	(A) Capital	(B) Operating
Chemicals and allied products	12.9%	1.4%
Primary metal industries	11.5%	1.5%
Food and kindred products	5.1%	0.3%
Industrial machinery and equipment	1.8%	0.2%
Electronic and other electric equipment	2.9%	0.4%
Transportation equipment	2.8%	0.3%

Legend: Column *A* reports capital expenditures for pollution abatement as a percentage of all capital expenditures. Column *B* reports pollution abatement operating costs as a percentage of the value of all shipments from the sector.
Source: Pollution Abatement Costs and Expenditures, 1993 (US Dept. of Commerce, 1994).

Our cross-section data set covers 22 countries including 7 developing countries and 15 developed countries and one time point, 1985–1990.[12] All of these countries are major hosts of subsidiaries of US chemical companies. Due to an incomplete set of sulfur emissions data, no Latin American countries are included.

The variable P is per capita GDP and G is total GDP (from the Penn World Tables); S is annual SO_2 emissions (from UNEP); I_i is annual capital outflows from the US industrial sector to country i (from the *Survey of Current Business*); T is corporate tax rates (from Hines and Rice 1994); Y_i is the annual income of US industry country i foreign affiliates (from the *Survey of Current Business*); R is the share of industry output in GDP (taken from the World Bank's *World Development Report*; and ESI is the electricity structure index, defined as the ratio of the annual generation from hydro-electric sources to the annual generation using thermal power (from the UN's *Energy Statistics Yearbook*). The mortality rate instrument and population density come from the Penn World Tables. The detailed data sources are listed in an annex at the end of this paper.

C. RESULTS

We summarize our estimation of eqn. (9) in Tables II and III. Table II shows the OLS estimate of eqn. (9) for the two sectors with the most observations, chemical and electrical machinery, along with the instrumental variables estimate. The OLS estimate involves the observed sulfur emissions whereas the instrumental variables estimate uses the fitted values of sulfur emissions in estimating eqn. (9). The two estimates are very different, particularly for the coefficient of environmental laxity. This illustrates the importance of using instrumental variables. It also suggests the importance of choosing the right instruments. Table III shows the full instrumental variables estimates for eqn. (9) for all sectors. Note the small number of observations for many sectors.

Table II. OLS and IV estimation of Eqn (9), chemicals and electrical machinery.

	Chemicals		Electrical machinery	
	OLS	IV	OLS	IV
β_O	102.9 (1.29)	44.7 (0.75)	−90.5 (−0.77)	−129.8 (−1.01)
β_T	−81.1 (−1.15)	−80.5* (−1.59)	122.5* (1.66)	116.3** (2.22)
β_P	−0.21 (−0.09)	1.93 (0.86)	2.28 (0.94)	2.81* (1.58)
β_Y	0.38** (4.76)	0.33** (4.06)	0.27* (1.45)	0.23* (1.63)
β_E	7.37 (0.63)	26.7** (1.93)	−0.33 (−0.02)	6.20 (0.36)
$\alpha\beta_E$	12.3 (0.96)	29.5** (2.05)	3.15 (0.19)	9.14 (0.46)
$\alpha_E\beta_E$	−4.75 (−0.62)	−4.2 (−0.78)	8.62 (1.15)	7.95** (1.99)
$\alpha_R\beta_E$	1.5 (0.79)	1.14 (1.0)	−1.69 (−0.65)	−2.47 (−0.83)
n	22	22	19	19
Adj. R^2	0.74	0.77	0.27	0.28

NB: t-statistics are in parentheses; significance at 90% (91%) level indicated by *(**); n refers to sample size.
OLS: estimate of Eqn (9) uses observed S_i.
IV: estimate of Eqn (9) uses fitted value of ln S_i, after regressing it on al exogenous variables in Eqn (9), except S_i, plus the mortality rate and population density. Standard errors corrected for heteroskedasticity.

Table III. Instrumental Variable Estimation of Eqn (9).

Coefficient	Chemicals	Primary metals	Electrical machinery	Non-electrical machinery	Food products	Transportation equipment
β_O	44.7 (0.75)	−59.6 (−1.14)	−129.8 (−1.01)	2396 (0.70)	128.0 (0.74)	−262.1 (−0.31)
β_T	−80.5* (−1.59)	88.2* (1.55)	116.3** (2.22)	1046 (1.44)	−107.8 (−0.96)	−385.1 (−1.06)
β_P	1.93 (0.86)	1.47 (1.17)	2.81* (1.58)	−23.1 (−1.09)	−0.53 (−0.10)	−16.8 (−1.03)
β_Y	0.33** (4.06)	1.17** (6.46)	0.23* (1.63)	1.44 (1.23)	0.81** (1.99)	0.78** (2.71)
β_E	26.7** (1.93)	19.6* (1.81)	6.20 (0.36)	−340.6 (−0.70)	−13.1 (−0.41)	5.0 (0.04)
$\alpha\beta_E$	29.5** (2.05)	27.8** (2.66)	9.14 (0.46)	−37.3 (−0.18)	−9.12 (−0.31)	3.9 (0.04)
$\alpha_E\beta_E$	−4.2 (−0.78)	−46.9** (−2.6)	7.95** (1.99)	−262.1** (−2.26)	−40.1 (−0.96)	−179.1 (−0.77)
$\alpha_R\beta_E$	1.14 (1.0)	0.02 (0.02)	−2.47 (−0.83)	26.1 (0.53)	2.28 (0.78)	−10.6 (−0.74)
n	22	17	19	13	17	13
Adj. R^2	0.77	0.78	0.28	0.49	0.45	0.01

Note: t-statistic in parentheses; significance at 90% (95%) level indicated by *(**);
n refers to sample size.

Referring to Table III, of the non-environmental determinants, retained earnings (Y_i), have the most consistent effect on FDI. In nearly all sectors, the coefficient is significantly positive, indicating that higher retained earning generate higher FDI. This is consistent with our earlier argument that after an initial injection of capital, subsequent FDI may be financed in large part by retained earnings. The coefficients on tax rates (T) and per capita GDP are often insignificant. In the case of tax rates, the sign of the coefficient is in two cases significantly positive, which is counter-intuitive.

The impact of environmental regulation on FDI relies on the significance of the laxity measure, E^*_i, and the sign of its coefficient, β_E. The results indicate that for the two heavily polluting industries, chemicals and primary metals, β_E is positive at the 90% significance level. The positive coefficient β_E suggests that the FDI flows are an increasing function of the laxity measure, E^*_i. In accordance with our definition of E^*_i, larger numerical values of E^*_i, correspond to more lenient environmental regulation. Furthermore, the coefficient on E^*_i is insignificant for the other four, less polluting sectors.

These results suggest that for polluting industries, more lax environmental regulations do tend to attract foreign investment. We wouldn't bet the farm on this however. The number of observations is quite low. It happens that we have the most observations for chemicals and relatively fewer observations for most of the less polluting sectors. Nevertheless, the data are suggestive that environmental regulations do affect FDI.

The interpretation of this is that if the other FDI determinants – tax rates T_i, market size P_i, and profitability Y_i – are constant across the host countries, the countries with relatively lax environmental regulations will attract more investment from more polluting industries. Alternatively, the industry will invest less or withdraw their capital from countries with stricter environmental regulations. Since there exists no precise definition about E^*_i, the laxity measure, it may be very difficult to perceive the quantitative implication of our finding should we interpret the coefficient β_E in the traditional way. To illustrate an intuitive interpretation of the estimated coefficient of β_E, we again use SO_2 emissions as a yardstick to characterize the change of environmental regulation stringency. In terms of SO_2 emissions, the quantitative implication of β_E is explained as the following: if a host country relaxes its environmental regulation such that its SO_2 emissions increases by 1%, on average it will be able to attract a quarter of a million dollars of new investment from the MNEs of the U.S. chemical industry (0.27 million dollars). This is small compared to the total annual capital outflows of the US chemical industry (nearly $4 billion in 1991[13]) though less trivial compared to the average each host country received in 1991 of $66 million.

5. Summary and Conclusion

The primary objective of this study has been to evaluate the effect of the stringency of environmental policy on the location of polluting industries. Our methodology differs from previous studies. Considering the location of production facilities in terms of FDI, our analysis focuses on how US FDI is influenced by environmental regulations of foreign host countries. To be specific, we test the relationship between the capital outflow of several US industries and the environmental policy of the destination country. A semi-log linear model of FDI determination is estimated using instrumental variables for six US industries. In the model, we incorporate the stringency of environmental regulation as one of determinants.

The statistical evidence suggests that there exists a significant negative linear relationship between FDI of the US chemical and metal industries and the stringency of environmental regulation in a foreign host country. In general, lax environmental policy tends to attract more capital inflow from the US for pollution intensive industries. Viewed differently, tough environmental regulations would tend to impede or discourage FDI from these industries. Since chemicals and primary metals are probably the most polluting of all industries, this result may have implications for the relationship between environmental regulations and capital movements for other polluting industries. Also, this finding provides indirect support to the "pollution haven" hypothesis, which postulates that developing countries may utilize lenient environmental regulations as a strategy to compete for the investment of polluting industry from developed countries.

This result is strengthened by our inability to find a similar effect for other sectors for which pollution is less of a problem – electrical and non-electrical machinery, transportation equipment and food products.

To correctly interpret our findings, one should keep in mind that the environmental variable is only one of the determinants of the FDI. Our empirical study only identifies the impact of environmental regulations on capital outflows and reveals the role of environmental regulations in the decision-making of the FDI of polluting industries. It would not be appropriate to conclude that environmental regulation alone can decide the direction of FDI flow for a polluting industry. We have no convincing evidence that the environmental variable dominates other determinants in the process of determining FDI of a polluting industry. However, to the extent that the environmental policy gap between developing and developed countries widens, more capital investment associated with polluting industries can be expected to flow to countries with lax environmental regulation. This could result in a significant migration of polluting industry to "pollution havens". The flight of polluting industries may cause economic problems such as unemployment in the short run for the country exporting capital, and may also expedite environment degradation of host countries. In addition, the migration of polluting industries only changes the geographic location of pollution generation. If the pollution is undepleted and can spill over borders (via rivers, aquifers, precipitation or air movement), the reduction of the pollution at the country with strict environmental regulations may be at least partially offset by an increase in pollution in other countries. Thus the free mobility of capital associated with polluting industries may undermine noncooperative efforts at pollution control.

The small size of our data set and the imperfect coverage of the sulfur emissions data suggests that future work should concentrate on expanding the data set and the sectors covered. It would also be appropriate to investigate other methods of accounting for the unobserved variable, the laxity of environmental regulations. Until this is done, we would be reluctant to base policy decisions solely on the basis of our results.

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Notes

1. See Siebert 1974; Pethig 1976; McGuire 1982; Baumol and Oates 1988; Carraro and Siniscalco 1992.
2. See Walter 1982; Leonard and Duerksen 1980; Pearson 1987; Bartik 1988; van Beers and van der Bergh 1997; Leonard 1988; McConnell and Schwab 1990; Lucas, Wheeler and Hememela 1992; Low and Yeates 1992; Tobey 1992. Jaffe et al. (1995) provides a review of much of this literature. None of these studies reports significant evidence in support of the "industrial flight" or "pollution haven" hypotheses.
3. In fact, Tobey's subjective index applies to only 23 countries, mostly OECD countries.
4. One could argue that in a HOV model, the assimilative capacity of the environment, viewed as an endowment, is a more appropriate variable to use than the revealed demand for environmental quality, defined by the environmental regulation.
5. This is a different issue from agglomeration economies (e.g., see Wheeler and Mody 1992), though related. A larger stock of foreign capital in a country should be positively related to the availability of internal funds.
6. The calculation is based on the indexes of the six "criteria air pollutants" from 1970 to 1991, taken from Jaffe et al. (1995).
7. This specification is consistent with Grossman and Krueger (1995) who argue that pollution levels depend on per capita GDP. They take a reduced-form approach so their model is not directly comparable to ours.
8. One of the most recent and comprehensive empirical studies of the determinants of FDI is by Wheeler and Mody (1992). They find that the most significant determinants of FDI are market size and indices of agglomeration benefits, such as the overall level of foreign investment, a variable closely related to industry profitability, a variable they do not consider.
9. It is of course possible that firms locate in a pollution haven in order to serve export markets; in this case, the size of the haven's economy makes less of a difference.
10. It might be more appropriate to measure profitability per unit of capital stock. Capital stock data are not available to us.
11. Since heteroskedasticity does not generate unbiased estimates of coefficients, only excessively large standard errors, we correct the standard errors using White's (1980) heteroskedasticity-consistent covariance matrix. Estimation is using SHAZAM 7.0.
12. Our original data contained Indonesia; however, tax data were not available for this country so it was omitted from our sample. Our data are for the years 1985 and 1990. We have data for some countries for both time points; for other countries for only one of the years. Thus we use an average of the two observations for countries with data at both times and one of the observations for countries for which data is only available for one time point.
13. *Survey of Current Business*, July 1993, p. 103.

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Annex: I. Data Resources

The data used in our estimation are listed in the attached tables, A-I, A-II, A-III and A-IV. The definitions of the variables and documentation of the source of the data are given below.

P (GDP per capita, in thousands of 1985 US dollars per person). Extracted from "The Penn World Data (Table 5)"; a detailed description of the data is available in "The Penn World Table (Mark 5): An Expanded Set of International Comparison: 1950–1988", *The Quarterly Journal of Economics*, May: 327–368.

S (annual SO_2 emissions, in thousands of tonnes). Taken from *Environmental Data Report 1993/94* of United Nations Environmental Program (UNEP), published in 1994 by Basil Blackwell (Oxford).

I_i (annual capital outflows of the U.S. industry i, in millions of 1985 US dollars). Taken from the *Survey of Current Business* July, 1993 (p. 102) and August, 1990 (p. 68). Industry i = chemicals, primary metals, electrical machinery, nonelectrical machinery, food products and transportation equipment.

T (corporate tax rates). Except for China, taken from Hines and Rice (1994), p. 180. Assumed the same for 1985 and 1990. Tax rate for China taken from "Article 5, Income Tax Law of the People's Republic of China for Enterprises with Foreign Investment and Foreign Enterprises," July 1, 1991.

Y_i (annual income of U.S. industry i foreign affiliates, in millions of 1985 US dollars). Taken from *Survey of Current Business* July, 1993 (p.118) and August, 1990 (p.90). Both capital outflows and income of 1990 are all deflated by the GDP price deflator to 1985 dollars. Industry i = chemicals, primary metals, electrical machinery, nonelectrical machinery, food products and transportation equipment.

POP (population, in thousands). From Penn World Data (Table 5).

SHA (share of industry outputs in GDP, percent). Taken from *World Development Report*, 1987 and 1992 issues. World Bank. For the country whose SHA is not available, we use the mean SHA for countries of the same income level.

ESI (electricity structure index). Defined as the ratio of the annual utilization of hydropower capacity (Hydro) to the annual utilization of thermal power capacity (Therm). The data is taken from United Nations' *Energy Statistics Yearbook* of 1987 and 1992.

D (population density). Defined as population per square kilometer times 10. Area taken from World Bank's *World Development Report*.

Table A1. The observations for 1985.

Country	GDP per capita	SO_2 emissions	Population	Population density	Industry share	Electricity structure index	Mortality rate	Tax rate
Canada	15.589	3704	25165	26	30	1.75	7	0.52
China	1.536	19990	1051013	1108	42	0.72	32	0.33
India	1.050	2930	765147	2315	27	0.92	99	0.52
Japan	11.771	1180	120754	3225	41	0.67	5	0.52
Korea	4.217	324	40806	4150	41	0.49	24	0.24
Malaysia	4.146	263	15682	472	43	0.52	24	0.37
Philippines	1.542	610	54700	1824	32	0.77	45	0.33
Singapore	8.616	155	2483	44345	37	0	9	0.21
Thailand	2.463	507	51683	1003	30	0.53	39	0.44
Austria	11.131	99	7555	893	37	0.98	11	0.41
Belgium	11.285	452	9858	2985	31	0.10	10	0.45
France	12.206	1470	55170	998	34	1.47	8	0.5
Germany	12.535	2396	61058	2458	40	0.62	9	0.48
Greece	6.224	500	9934	753	29	0.28	17	0.43
Ireland	7.275	140	3540	349	34.56	0.40	9	0.04
Italy	10.808	2400	57141	1888	33	0.39	11	0.39
Netherlands	11.539	276	14492	3888	34	0.91	8	0.4
Portugal	5.070	198	10157	1094	40	1.27	15	0.4
Spain	7.536	2190	38574	773	34.56	0.49	10	0.33
Sweden	13.451	270	8350	184	31	5.19	6	0.6
Switzerland	14.864	96	6470	1523	34.56	2.38	7	0.17
UK	11.237	3724	56618	2273	36	0.24	9	0.52

Table A2. The observations for 1990.

Country	GDP per capita	SO_2 emissions	Population	Population density	Share	Index	Mortality rate
Canada	20.752	3800	26522	29	30	1.39	7
China	1.536	19990	1133683	1221	42	0.72	27
India	1.505	3070	849515	2869	29	0.91	88
Japan	17.625	1140	123537	3279	42	0.57	5
Korea	8.271	324	42869	4334	41	0.49	21
Malaysia	5.991	263	17763	545	43	0.52	14
Philippines	2.112	370	61480	2093	35	0.76	40
Singapore	14.384	155	2705	44639	37	0	7
Thailand	4.270	612	56303	1090	39	0.40	26
Austria	15.560	99	7712	917	37	0.98	8
Belgium	16.533	420	9967	3255	33	0.17	8
France	16.956	1206	56735	1021	29	1.11	7
Germany	18.235	1002	63230	2510	39	0.66	7
Greece	8.203	500	10123	768	29	0.28	8
Ireland	11.273	168	3503	540	32.4	0.47	7
Italy	15.309	2400	57661	1940	33	0.39	8
Netherlands	16.096	238	14952	4408	31	0.81	7
Portugal	9.005	198	9868	1119	40	1.27	12
Spain	11.765	2190	38959	785	32.4	0.46	6
Sweden	18.024	204	8559	205	35	6.66	6
Switzerland	20.729	62	6712	1662	32.4	2.13	7
UK	15.741	3774	57411	2369	32.4	0.40	7

Table A3. Capital outflows by sector (FDI) units: millions of 1985 US dollars.

	1985						1990					
	Chemical industry	Electric equip.	Non-elec machinery	Primary metals	Food products	Transport. equipment	Chemical industry	Electric equip.	Non-elec machinery	Primary metals	Food products	Transport. equipment
Canada	56	131	165	97	148	756	131	16.53	119.1	452.1	482.6	N.A.
China	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	−1.7	0.8	N.A.
India	8	N.A.	12	4	N.A.	N.A.	N.A.	N.A.	13.2	0.8	N.A.	N.A.
Japan	−16	−83	N.A.	−51	35	184	−83	223.97	9.9	−24.0	15.7	N.A.
Korea	5	−13	0	N.A.	5	N.A.	−13	−63.64	N.A.	N.A.	52.9	N.A.
Malaysia	N.A.	58	N.A.	N.A.	N.A.	0	58	119.01	N.A.	N.A.	−2.5	0
Philippines	−8	−13	N.A.	N.A.	−39	N.A.	−13	19.83	−1.7	−2.5	11.6	0
Singapore	N.A.	26	50	−2	−1	N.A.	26	55.37	115.7	3.3	−0.8	N.A.
Thailand	−2	−20	N.A.	N.A.	N.A.	0	−20	30.58	N.A.	4.1	N.A.	0
Austria	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	24.79	N.A.	N.A.	7.4	N.A.
Belgium	48	17	−49	9	12	N.A.	17	14.05	−58.7	N.A.	55.4	N.A.
France	116	−6	399	19	1	13	−6	40.50	N.A.	100	5.0	−85.1
Germany	55	47	436	7	31	N.A.	47	50.41	194.2	220.7	74.4	N.A.
Greece	1	N.A.	0	0	N.A.	0	N.A.	N.A.	0	0	N.A.	0
Ireland	179	31	86	7	77	N.A.	31	−44.63	−131.4	N.A.	22.3	38.8
Italy	N.A.	75	N.A.	N.A.	49	N.A.	75	39.67	N.A.	−3.3	172.7	−20.7
Netherlands	−7	−1	142	N.A.	82	−5	−1	108.26	46.3	54.5	90.9	4.1
Portugal	−11	12	N.A.	N.A.	4	N.A.	12	N.A.	N.A.	N.A.	10.7	N.A.
Spain	93	−28	N.A.	N.A.	N.A.	−213	−28	−22.31	N.A.	−18.2	52.9	−213
Sweden	1	−1	N.A.	N.A.	N.A.	N.A.	−1	−6.61	N.A.	N.A.	N.A.	N.A.
Switzerland	44	N.A.	N.A.	N.A.	N.A.	0	N.A.	N.A.	N.A.	N.A.	N.A.	0.8
UK	71	−13	475	6	201	−227	−13	109.92	−160.3	207.4	−63.6	−1088.4

N.A. ≡ not available

Table A4. Income of US Foreign affiliates, by sector units: millions of 1985 US dollars.

	1985						1990					
	Chemical industry	Electric equip.	Non-elec machinery	Primary metals	Food products	Transport. equipment	Chemical industry	Electric equip.	Non-elec machinery	Primary metals	Food products	Transport. equipment
Canada	379	175	326	129	235	975	484.2	86.78	242.1	140.5	280.2	N.A.
China	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	4.96	N.A.	N.A.	−1.7	0.8	N.A.
India	17	N.A.	11	4	N.A.	N.A.	17.36	N.A.	14.0	0.8	N.A.	N.A.
Japan	35	−40	N.A.	−44	58	73	90.91	88.43	448.8	12.4	135.5	N.A.
Korea	9	14	0	N.A.	13	N.A.	16.53	−4.96	N.A.	N.A.	25.6	N.A.
Malaysia	N.A.	24	N.A.	N.A.	N.A.	0	5.79	61.16	N.A.	N.A.	0.8	0
Philippines	25	7	N.A.	N.A.	−44	N.A.	45.45	27.27	0	2.5	33.9	0
Singapore	N.A.	138	50	−2	−2	N.A.	5.79	238.84	237.1	2.5	−1.6	N.A.
Thailand	3	17	N.A.	N.A.	N.A.	0	17.36	14.88	N.A.	7.4	N.A.	0
Austria	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	4.13	27.27	N.A.	N.A.	6.6	N.A.
Belgium	138	−1	−8	8	4	N.A.	469.42	−0.83	−2.5	N.A.	57.9	N.A.
France	147	8	331	15	39	24	405.79	31.40	N.A.	33.9	149.6	49.6
Germany	157	102	537	76	68	N.A.	288.43	137.19	705.8	162.8	182.6	N.A.
Greece	3	N.A.	0	0	N.A.	0	N.A.	N.A.	0	0	N.A.	0
Ireland	105	36	111	10	111	N.A.	365.29	33.88	62.8	N.A.	37.2	6.6
Italy	N.A.	79	N.A.	N.A.	51	N.A.	252.89	−8.26	N.A.	22.3	90.9	−7.4
Netherlands	188	26	120	N.A.	75	−3	426.45	62.81	145.5	79.3	151.2	9.9
Portugal	−4	14	N.A.	N.A.	6	N.A.	N.A.	N.A.	N.A.	N.A.	9.1	N.A.
Spain	56	−32	N.A.	N.A.	N.A.	−76	71.90	−27.27	N.A.	30.6	111.6	−76
Sweden	4	−1	N.A.	N.A.	N.A.	N.A.	2.48	−4.13	N.A.	N.A.	N.A.	N.A.
Switzerland	25	N.A.	N.A.	N.A.	N.A.	0	22.31	N.A.	N.A.	N.A.	N.A.	0.8
UK	387	45	500	49	198	9	479.34	21.49	700.8	127.3	230.6	327.3

N.A. ≡ not available