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US Environmental Regulation and FDI: Evidence from a Panel of US-Based Multinational Firms[†]

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This paper measures the response of US-based multinationals to the Clean Air Act Amendments (CAAA). Using a panel of firm-level data over the period 1966–1999, I estimate the effect of regulation on a multinational's foreign production decisions. The CAAA induced substantial variation in the degree of regulation faced by firms, allowing for the estimation of econometric models that control for firm-specific characteristics and industrial trends. I find that the CAAA caused regulated multinational firms to increase their foreign assets by 5.3 percent and their foreign output by 9 percent. Heavily regulated firms did not disproportionately increase foreign investment in developing countries. (*JEL* F23, K32, L51, Q52, Q53, Q58)

Do tougher environmental regulations cause firms to flee the country? Although several studies document the impact of environmental regulation on domestic production, the question of whether firms increase foreign manufacturing in response to new domestic regulation has remained unanswered.[1] Consequently, our understanding of the efficacy of environmental policy is limited, as is our understanding of the distributional impacts of "local" environmental policies. To offer evidence on this topic, this paper compiles detailed firm-level regulation data to investigate the link between regulation and a firm's foreign production decisions. Specifically, I test whether the Clean Air Act Amendments (CAAA)—legislation that dramatically strengthened environmental regulation in the United States—resulted in increased foreign direct investment (FDI) by US based multinational firms. In addition, I evaluate claims that the regulations spurred firms to disproportionately increase manufacturing in developing countries, which would have important distributional effects.

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[1] See, for example, Wayne B. Gray and Ronald J. Shadbegian (1995), Adam B. Jaffe et al. (1995), Arik Levinson (1996), Randy Becker and Vernon Henderson (2000), and Michael Greenstone (2002).

This paper contributes to the literature on the relationship between environmental regulation and FDI. Previous studies have mostly focused on the impact of a receiving country's (or state's) environmental stringency on inward FDI (Yuqing Xing and Charles D. Kolstad, 1998; Beata K. Smarzynska and Shang-Jin Wei 2001; Sheoli Pargal, Muthukumara Mani, and Mainul Huq 1997; Wolfgang Keller and Levinson 2002; Per G. Fedriksson, John A. List, and Daniel L. Millimet 2003; Sébastien Raspiller and Nicolas Riedinger 2004; Judith M. Dean, Mary E. Lovely, and Hua Wang 2004). Gunnar S. Eskeland and Ann E. Harrison (1997) is a notable departure from the literature. Their paper tests whether the pattern of outbound US investment during the 1980s and early 1990s can be explained by variations in pollution abatement costs across different sectors of the US economy. Both approaches have yielded mixed conclusions, and, for the most part, have failed to uncover robust evidence of industrial relocation in response to environmental regulation.[2]

This lack of evidence may be attributable to two factors. First, it is difficult to measure environmental stringency across regions. In general, only broad measures of environmental stringency across host countries or states (participation in treaties, abatement costs) are available, and these are often correlated with other factors important in attracting FDI. Second, most environmental regulations apply to all manufacturing firms in a country or all firms in a particular industry, and therefore, it is difficult to find a control group against which to evaluate the effects of new regulations. Previous studies have typically tested whether the effect of environmental stringency differs across industries of varying pollution intensity, under the hypothesis that the regulation effect on FDI is concentrated in polluting industries. However, there have been concerns in the literature (Jaffe et al. 1995; Smarzynska and Wei 2001) that this strategy may potentially confound industry specific trends in FDI (such as oil shocks, recessions) with regulation.

This paper aims to overcome these limitations and determine whether a causal relationship exists between environmental regulation and FDI. Following Eskeland and Harrison (1997), I analyze whether tougher environmental regulation at home increases outbound FDI. Rather than using industry-level measures of environmental stringency, this study exploits the plausibly exogenous variation in firm-level regulation created by the CAAA. Following the passage of the CAAA in 1970, the Environmental Protection Agency (EPA) established separate national ambient air quality standards—a minimum level of quality that all US counties are required to meet—for four criteria pollutants. Each year, counties where air pollution concentrations exceed federal standards for a specific pollutant receive a *nonattainment* designation for that pollutant, while counties that are in *attainment* of federal standards receive an attainment designation. Manufacturing plants that emit a criteria pollutant and are located in a county that is designated as nonattainment are subject to relatively tougher regulatory oversight than emitting plants in attainment counties.

The nature of the CAAA regulatory program allows for a differences-in-differences-style approach to test whether firms were more likely to expand their overseas

[2] In fact, Pargal, Mani, and Huq (1997), and Dean, Lovely, and Wang (2004) find that foreign investors tend to invest in areas with high environmental stringency.

manufacturing operations when the US counties in which they operate fell into nonattainment and were, thereby, subject to tougher environmental oversight. In contrast to the previous literature, this approach allows for the estimation of regulation effects that are purged of bias associated with industry specific trends. This is particularly important because, during this period, there were many factors (e.g., oil shocks, country liberalizations, technology changes) that may have had differential impacts on industry-level FDI. In addition, because the CAAA induced substantial variation in the level of regulation faced by an individual firm across time, I can compute the effect of regulation that is independent of firm specific characteristics (e.g., production process, firm size) that may also potentially affect FDI. As a result, this paper overcomes objections in the literature (for example, Lyuba Zarsky 1999) that earlier studies on the impact of environmental regulation ignored firm-specific effects.

To implement this strategy, I take advantage of a confidential, firm-level dataset collected by the Bureau of Economic Analysis (BEA) of the US Department of Commerce, on the activities of US based multinational firms. The data provide detailed information on the financial and operating characteristics of US firms manufacturing abroad between the years 1966 and 1999. I augment this dataset with annual data on the four pollutant-specific, attainment/nonattainment designations for each US county and with detailed data on the US operations of each multinational firm.

I find evidence that the CAAA legislation increased the outbound FDI of US based multinational firms. In particular, the analysis in this paper suggests that the CAAA regulations caused multinationals to increase their foreign assets in polluting industries by 5.3 percent and their foreign output by 9 percent. Larger multinational firms accounted for much of the increase in FDI. Contrary to popular belief, heavily regulated firms did not disproportionately increase production in developing nations relative to other countries.

The paper proceeds as follows. Section I discusses the CAAA and the conceptual framework. Section II describes the data and empirical strategy, and Section III presents the results. Section IV provides a discussion of the results, while Section V concludes.

I. The Environment and Foreign Direct Investment

A. *The Clean Air Act Amendments*

This study uses the variation in firm level regulation induced by the CAAA to determine whether firms expand their foreign manufacturing operations in response to domestic environmental regulation. Initially passed in 1970, the CAAA stipulated that the EPA classify US counties into pollutant-specific nonattainment and attainment categories, based on the ambient concentrations of four relevant pollutants: carbon monoxide (CO), ozone (O_3), sulfur dioxide (SO_2), and particulate matter (PM).[3] Each July, the classifications are re-evaluated, and every US county is officially reclassified

[3] I classify a county as nonattainment for ozone if it is additionally in nonattainment for nitrogen oxide.

as being either in or out of attainment of the national standards for each of the criteria pollutants.

Relative to attainment counties, strict regulatory oversight is exerted on polluting manufacturers in nonattainment counties. When a county falls into nonattainment, the law requires its state to develop a State Implementation Plan (SIP), which lays out specific regulations for every major source of each pollutant for which the county is in nonattainment. The plans impose substantial regulations on both new and existing manufacturing facilities. In general, the SIPs stipulate that new investments or plant renovations must be paired with the installation of state-of-the-art pollution abatement equipment. Existing plants are subject to "reasonably available control technologies," which usually involves retrofitting existing equipment. States may also dictate changes in an industry's production process, such as forcing existing printers in nonattainment counties to substitute highly polluting inks with more expensive, cleaner versions. Furthermore, the regulations make it more costly for an existing plant to modify its operations, as they require that the entire plant comply with current standards for new sources. In contrast, large-scale investments in attainment counties require relatively cheaper abatement equipment, and existing plants are essentially unregulated.[4] Nonpolluters are free from regulation in both categories of counties.

In nonattainment counties, the regulations are vigorously enforced by both federal and state agencies, and violating manufacturers may face extensive "civil penalty plus recovery of any economic benefit of non-compliance" and orders requiring the "correction of the violation."[5] Although individual states have some leeway to create and implement the SIP, the EPA enjoys substantial oversight of each state's enforcement activities. In particular, the EPA may withhold federal highway funding, impose a federal moratorium on new plant construction, and seize control over the state's environmental policy if it deems that a state is delinquent in its responsibilities.

Enforcement efforts appear to have had "bite." The CAAA substantially affected US industrial activity. Mark A. Cohen (1998) documents the effectiveness of the regulations at the plant level. A series of papers (for example, Matthew E. Kahn 1997 and Greenstone 2002) show that the regulations retarded the growth of polluting manufacturers in nonattainment counties. Moreover, Becker and Henderson (2000) provide evidence that, controlling for socioeconomic conditions across counties, firms were more likely to choose an attainment county for a new plant.[6]

Further evidence of the bite of the regulation can be found in firm reactions. In 1997, the business community attempted (unsuccessfully) to lobby against the EPA's plans to alter ozone standards, which would have effectively doubled the number of counties in nonattainment for ozone.[7] Lastly, perhaps the most compelling piece of

[4] New and modified sources in attainment counties that emit large quantities of the criteria pollutant are subject to the "best available control technologies." However, this is negotiable for individual cases and, unlike the nonattainment counties, this is sensitive to economic burdens.

[5] See EPA Compliance Web site (http://www.epa.gov/compliance).

[6] Several papers found results contrary to Becker and Henderson (2000). For example, Virginia D. McConnell and Robert M. Schwab (1990) concluded that a county's nonattainment designation did not deter new plants in the motor vehicle industry. Their estimation strategy, though, did not account for the fact that counties are often in nonattainment because polluting plants have historically viewed them as productive, cost-effective places to locate.

[7] "Supreme Court Roundup; Justices Broaden Their Look at the Clean Air Act." *New York Times*, May 31,2000.

evidence that the regulations are successfully enforced is the fact that air pollution concentrations declined at a relatively faster rate in nonattainment counties subsequent to the regulations (Henderson 1996; Kenneth Y. Chay and Greenstone 2003).

B. *Sources of Policy Variation*

The particular structure of the CAAA regulatory program enables a compelling identification strategy with which to determine the effect of tougher environmental regulation on a firm's foreign production decisions.[8]

Most importantly, the regulations only apply to manufacturing facilities operating within nonattainment counties, inducing variation in the level of regulation across firms. Second, the policy was designed to ensure that all counties that achieve nonattainment status are similarly regulated. The CAAA emission standards are federally mandated and, thus, consistently applied throughout the country. Although individual states formulate separate enforcement policies, the EPA has sufficient mechanisms to ensure that each state similarly regulates polluting manufacturers. As a result, this eliminates the possibility that differences in tastes or other characteristics across counties are potentially correlated with firm production choices, which would bias the estimated regulation effects.

Another possible concern is that nonattainment and attainment counties may have different underlying socioeconomic conditions (such as population density, unionization rates), which may cause a spurious correlation between the probability that a county earns a nonattainment designation (high pollution) and the FDI of firms operating within these counties. However, because nonemitting plants are not subject to CAAA regulation in either type of county, I can isolate changes in the FDI outcomes of nonemitting firms across US counties to remove the effect of manufacturing in a nonattainment county that is independent of regulation.

Finally, the designation of nonattainment status is reevaluated annually. A firm that is subject to varying levels of regulation at different points in time can be followed, thereby allowing the paper to include estimates that are derived from within a firm. This methodology ensures that firm specific factors (firm size, production technologies) do not drive the results.

C. *Conceptual Framework*

US environmental regulations are often met with the claim that by making domestic production more costly, they induce significant changes in the patterns of domestic production. For example, some firms may react to regulation by simply producing fewer pollution-intensive goods, or by shifting production from high- to low-intensity goods (see, e.g., Khan 2003; Levinson 2009). Depending on both the structure of regulation and production technologies, regulation may cause some firms to relocate part (or even all) of their production to a less regulated region (see, e.g., Eskeland and Harrison 1997). Rather than shifting all production abroad, firms

[8] List et al. (2003), and List, W. Warren McHone, and Millimet (2004), employ a similar difference-in-difference strategy.

can instead choose to obtain pollution-intensive inputs abroad, by either directly manufacturing them abroad or importing them (see, e.g., Josh Ederington, Levinson, and Jenny Minier 2004). In the most extreme scenario, if costs become prohibitively high, regulation may cause pollution-intensive firms to shut down entirely (or may prevent new plants from starting up in the first place).

This paper studies the relocation decision of firms in response to regulation. Domestic regulation affects outbound FDI primarily through the fact that regulation increases the relative costs of producing at home relative to abroad. However, there are many other channels through which regulation may affect FDI. For example, an increase in regulation may signal a change in the future expectations of regulation, and therefore the future expected production costs. In this case, depending on how firms update their expectations, FDI could increase or decrease. Yet another channel is that if firms reduce domestic assets and production in the face of stricter regulation, they may have a lower ability to invest abroad (see, e.g., Michael Ollinger and Jorge Fernandez-Cornejo 1998; Becker and Henderson 2000; Dean, Lovely, and Wang 2004; Millimet 2003). While understanding how these different mechanisms contribute to the regulation effect is important, data constraints limit this analysis to measuring the overall, reduced-form effects of regulation.

The results presented in this paper provide a good measure of the effect of the CAAA regulatory program on US outbound FDI, as the program is currently written. It is important to note, however, that this empirical strategy may underestimate the overall effect of environmental regulation on relocation, and therefore this should be taken into account when generalizing the results to other settings. Based on the way the regulation is currently designed, a *relocating* firm can move to another (less regulated) US county or move abroad. Quite simply, if the expected profits of foreign production exceed the profits of producing within another US county, the firm will move abroad; otherwise the firm will relocate within the United States. Using the identification strategy detailed in this paper, the estimated regulation effect, therefore, measures the actual change in FDI that results from the CAAA regulation. However, some firms residing in high regulation counties may shift production to low-regulation counties rather than moving abroad (and, similarly, some firms in low-regulation counties may shift production abroad in response to regulation). Therefore, this strategy provides a lower bound of the effect of regulation had it been equally implemented across the United States. The extent to which this lower bound underestimates the overall effect depends on the number of firms that switched to another US county.

There are numerous reasons why the expected costs of foreign production may be greater than the costs of producing in another county, and each reason has different implications for the interpretation of the estimated regulation effect. For example, consider a world with adjustment costs, where firms cannot instantaneously react to regulation. A firm may be unwilling to pay the costs of relocating to another US county that, though unregulated today, has a nonzero probability of future regulation. In this case, the bias of the regulation effect would be smaller than the case where it is costless for a firm to shift between US counties. Alternatively, consider the most extreme scenario: it is possible that the expected costs of US regulation are sufficiently high that all US firms would prefer shifting production abroad. However, in the short run, only firms for whom the expected compliance costs exceed the adjustment costs will relocate. Firms would never shift production to another US county. Thus, the empirical strategy would provide an unbiased estimate of the short-run effect of environmental regulation (in the long run, regulation would force all firms abroad).

II. Data and Empirical Strategy

A. *Data*

This paper brings together a variety of data sources to determine the impact of domestic environmental regulations on the foreign manufacturing outcomes of US multinational firms. This section describes the sources and structure of the data.

Foreign Direct Investment Data.—Foreign manufacturing outcomes are obtained from confidential, affiliate-level data collected by the Bureau of Economic Analysis (BEA) of the US Department of Commerce on the activities of US based multinational firms.[9] A multinational firm is defined as the combination of a single US entity that has made the direct investment, called the US parent, and at least one foreign business enterprise, called the foreign affiliate. Since the International Investment and Trade in Services Survey Act ensures that the "use of an individual company's data for tax, investigative, or regulatory purposes is prohibited," the BEA believes survey responses are highly accurate, and that the coverage of data is close to complete. Moreover, since the data contain the percentage of each parent's ownership in each affiliate, it is possible to determine ownership stakes in the presence of indirect ownership, providing the most accurate available picture of US investment positions abroad.[10]

The BEA surveys can be linked across years, creating a comprehensive panel on the financial and operating characteristics of US firms manufacturing abroad. Extensive data are available for 1966,[11] 1977, 1982, 1989, 1994, and 1999, when the BEA conducted benchmark surveys. The selection criterion for the survey varied across years, causing the data to be censored. In 1966, all foreign affiliates with sales, assets, or net income in excess of $50,000 in absolute value were required to report to the BEA. The cutoff jumped to $0.5 million in 1977, $3 million in 1982–1994, and $7 million in 1999.[12] To rectify this, I imposed a uniform censoring point ($5.591 million 1982 USD) across all years.[13]

[9] The data are collected by the BEA to produce aggregated tabular data on multinational company operations for release to the general public.

[10] Data only include majority-owned affiliates.

[11] While other researchers have used the 1977–1999 data, the affiliate-level 1966 data have not previously been used for academic research. Significant changes were made between the 1966 and 1977 survey, complicating the analysis (parent identification codes changed, industry classification codes were more aggregated, etc).

[12] The rise in the cutoff is attributed to the Paperwork Reduction Act of 1980. Another reason for the increasing exemption level is limited staff resources; in particular, this may have been the main reason for the rise in the cutoff from 1966 to 1977.

[13] The level of assets falling below the cutoff comprises a minimal percentage (0.38 percent) of total assets abroad, suggesting that the bottom-coding problem is negligible (estimated from the 1999 FDI data). Nonetheless, missing "middle" years were interpolated to mitigate problems associated with censored data. The percentage of interpolated data is low (less than 0.5 percent of the firm-industry-year observations), and the results are robust to the interpolation.

I substantially reorganized the survey data in two ways. First, to create measures of a US-based multinational's scope of foreign manufacturing within each industrial segment (assets, plant and property expenditures, expenditures to produce goods, etc.), I computed the US parent's ownership stake in each foreign affiliate, and then aggregated the data from the foreign affiliates to the level of the US parent firm, by industry and year.[14] To calculate a firm's foreign capital in each industrial segment, total foreign affiliate assets were multiplied by the percentage of affiliate sales in each industry.[15] While this methodology represented the best approximation of capital use given the data limitations, it is subject to measurement error if the capital to labor ratios vary significantly across industries. In this case, this approach may systematically underestimate the foreign capital dedicated to capital-intensive industries.

Second, the FDI data include a firm-year observation only if the firm had foreign assets, sales, or income in that year. An analysis using only these data would fail to capture, for example, a heavily regulated multinational firm that did not produce abroad in a given year, biasing the estimated regulation effects upward. To remove this potential bias, I completed the panel. For each firm, I obtained the birth and closure dates from a variety of electronic and print sources.[16] If a firm operated in the United States in a given year, but was absent from the survey data, I assigned the firm "zero" FDI for that year. As such, the empirical work presented in this paper captures both channels through which regulation impacts a multinational's foreign production choices. First, the analysis captures whether a firm will move abroad in response to regulation or, in other words, whether a firm will become a multinational. Second, it determines whether a firm that already produces abroad will increase its foreign production activities in response to regulation.

It is important to note, however, that the study does not include firms that never produced abroad between the years of 1966 and 1999.[17] Thus, while the regulation effects derived in this paper provide a good estimate of a multinational's response to regulation, the effects are most likely an *overstatement* for the entire universe of firms. While this is a concern, there are reasons to believe that the selection bias is unlikely to be large. As Greg Mankiw and Phillip L. Swagel (2006) point out, multinationals comprise a large share of the US economy. The firms surveyed in the BEA database account for approximately 60 percent of US sales and employment in manufacturing, 70 percent of exports, and 80 percent of private R&D in manufacturing. Moreover, from a policy standpoint, we mostly care about the multinational

[14] Industrial classifications are based on International Surveys Industry (ISI) classifications, giving 45 industries in manufacturing. The ISI is an internal BEA classification system based on the Standard Industrial Classification (SIC) system.

[15] Although the data on affiliate sales are broken down by industry, the data on affiliate assets are not.

[16] Firm births and closures were mainly taken from various volumes of Moody's Industrials and firm Web sites. These data sources were supplemented by Hoover's Company Database, bankruptcy articles, and several additional sources. The 5 percent of firms that were either missing a birth date, closure date, or both, were assigned to be operating for the duration in which investment data was available.

[17] To obtain data on firms that never invested abroad during this period, I matched Compustat to the BEA data. However, the match was poor for a variety of reasons. First, the BEA data includes private firms, while Compustat does not. Second, the Compustat data for the 1960s and 1970s was not comprehensive. Third, the level of firm level aggregation differs between the two datasets. The effective match rate between Compustat and the BEA data was about 50 percent. Due to these data limitations, the analysis is limited to multinationals.

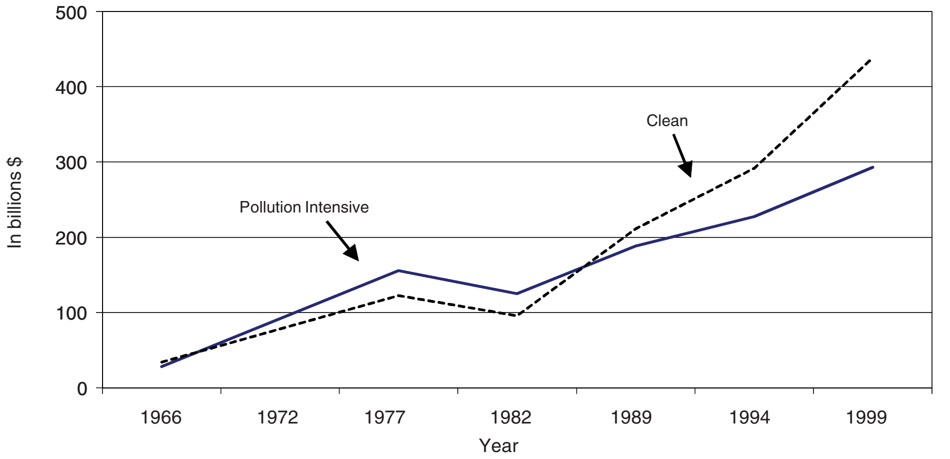

Figure 1A. Foreign Assets in Manufacturing of US-based Multinationals, by Industrial Pollution Status

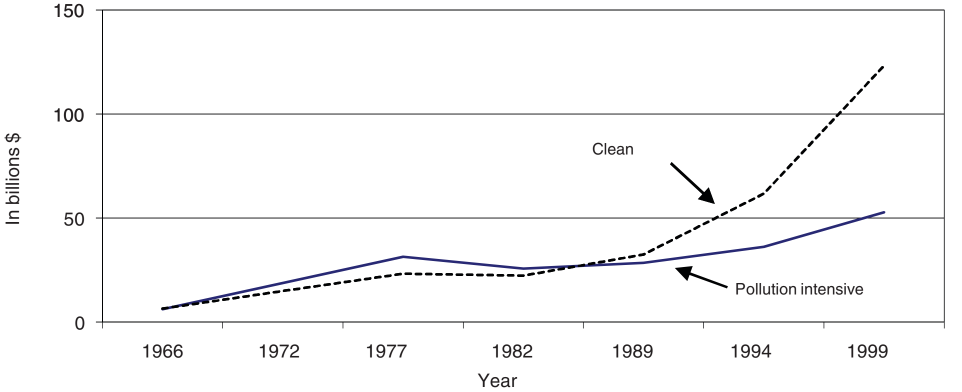

Figure 1B. Foreign Assets in Manufacturing Excluding High Income, OECD Nations, by Industrial Pollution Status

Source: Author calculation from BEA Investment Survey (estimated 1972).

response to regulation, as other firms tend to have such high barriers to foreign production that realistic levels of regulation may never cause them to produce abroad.

Figures 1A and 1B graph the foreign assets allocated to manufacturing by US based multinationals overall and excluding high-income, OECD countries for the years 1966–1999.[18] The figures split foreign assets by pollution-intensive industries versus clean industries. After 1982, foreign assets in clean industries grew at a relatively faster rate. This is not surprising, as it has been suggested that, due to the nature of their technologies, industries with the largest pollution abatement costs

[18] I use the World Bank definition for high income, OECD country.

also happen to be the least footloose (Ederington, Levinson, and Minier 2005). The figures illustrate that the trends in FDI for pollution intensive and clean industries differ, implying that an analysis simply comparing the effect of environmental regulations on FDI across industries may suffer from bias associated with these trends.

Plant Data.—To assess the level of environmental regulation a firm faces in the US, I exploit variation in the location and the industry of a firm's US manufacturing facilities. Therefore, data on the domestic plants of multinationals are necessary for the identification strategy. The Census Bureau's Census of Manufacturing is the most comprehensive facility level data collected, but it was unavailable for this study. Instead, I obtained data from a yearly series of print manufacturing directories entitled "*Marketing Economics Key Plants*" (various years). The directories include 10 percent of US facilities (about 40,000 facilities per year), which account for approximately 80 percent of value added in US manufacturing. I manually matched the firms in the BEA foreign investment data to these detailed US manufacturing facility data.

The patterns in the Marketing Economics sample are quite similar to patterns in other US manufacturing facility data. Although the County Business Patterns data include many more plants, the two datasets exhibit near identical patterns in industrial composition and in the percentage of emitting plants that reside in nonattainment counties. In addition, though the Marketing Economics sample only includes large plants (100 or more employees), it should still provide an accurate picture of the number of a firm's plants that were significantly affected by regulation: Becker and Henderson (2000) provide anecdotal evidence that the inspection and enforcement activities of the CAAA centered on large plants.

For each manufacturing plant in the Marketing Economics directories, I coded the firm name, state code, county code, SIC code, and approximate employment. Next, each firm-year observation in the BEA data was manually matched to the US manufacturing facilities that the firm operated at the time of the previous benchmark survey. Firms in the 1999 survey were matched to plant data in 1994, firms in the 1994 survey were matched to plant data in 1989, etc.[19] Changes in company names and subsidiaries were tracked using a series of print and electronic sources.[20] Despite the interest in understanding the interaction between manufacturing patterns in the United States and outbound FDI, this is, to my knowledge, the first time the BEA's outbound FDI dataset has been linked to detailed information on the location of the multinationals' manufacturing facilities within the United States.

Firms indicating that their primary SIC code was either banking or services were eliminated from the analysis. Out of the remaining firms, 67 percent (2,235) were matched to at least one manufacturing plant.[21] The final sample was drawn from these 2,235 firms.

[19] There are two exemptions from this rule. Firms in the 1977 dataset were matched to the 1966 plant directory, but if a firm had no plants listed in the 1966 plant directory, the firm was matched to its corresponding 1972 plants—the first effective year of the regulation. Second, the directories began in 1966, and, as a result, firms in 1966 were matched to their 1966 plant data in order to obtain data for county and industry codes.

[20] For example, from Hoover's Online Premium Directory, Moody's Industrials, firm Web sites, Lexus-Nexus, etc.

[21] The majority of unmatched firms listed their primary SIC codes as nonmanufacturing.

Regulation Data.—The attainment/nonattainment data are taken from the Code of Federal Regulations and the EPA's national pollution monitoring network.[22] All US counties are considered to be in "attainment" prior to 1972, because the CAAA were not fully enforced until late 1971. For all years between 1972 and 1977, a county is labeled as nonattainment if it had a pollution monitoring reading that exceeded the relevant federal standard in the appropriate year. Since the EPA has not maintained historical records of the designations prior to 1978, these data provide the closest approximation of nonattainment designation in this period. After 1978, the data are taken directly from the Code of Federal regulations.[23]

Figure 2A plots the number of counties with a nonattainment designation for each pollutant over time. Vertical lines indicate years for which investment data (described below) are available. The figure clearly illustrates that the ozone (O_3) regulatory program was the most pervasive, followed by particulate matter (PM). The number of nonattainment counties peaked in the late 1970s–early 1980s, due to factors such as the deterioration of air quality in attainment counties and the EPA's increasing awareness of which counties exceeded federal standards. With the exception of small increases in the number of nonattainment counties in the early 1990s, the number of nonattainment counties has steadily declined after 1980.[24]

Figure 2B plots the number of counties that experienced a change in status over the following year. In addition to being the period in which regulation was most pervasive, the 1970s to early 1980s also saw the greatest county-level fluctuations in nonattainment status. For example, prior to 1985, approximately 110 counties experienced a change in ozone designation over the previous year. This number fell to 45 during the subsequent period.

B. *Empirical Strategy*

This paper employs a modified differences-in-differences approach to determine the effect of CAAA regulation on the foreign manufacturing operations of US based multinationals. In particular, I test whether firms were more likely to increase foreign production within an industry if a large share of their US manufacturing facilities (in that industry) were regulated.

The Simple Case.—I start by discussing a simple case, where each firm has only one plant, operates in one US county, and manufactures in one industry. In this case, a firm "f" is regulated under the CAAA if its plant is both located in a nonattainment county "c" for a given pollutant "z" and actually emits that pollutant. "z" belongs to the set of criteria pollutants (CO, O, SO_2, PM). As I lack data on each plant's emissions, I follow Greenstone (2002) and classify a plant as an emitter of pollutant "z" if

[22] Greenstone (2002) generously provided these data.

[23] The 1972–1977 estimated data are an underestimate of the scope of the regulations. Many counties lacked pollution monitoring equipment. In this case, a county was labeled as in "attainment." In the robustness section (Section IIIF), I explore the sensitivity of the results to the estimated data. As a preview, the results remain unchanged.

[24] Prior to 1979, the ozone standard prohibited the second highest daily maximum concentration from exceeding 0.08 parts per million. In 1979, the standard dropped to 0.12, partly explaining the subsequent decline in ozone-nonattainment counties.

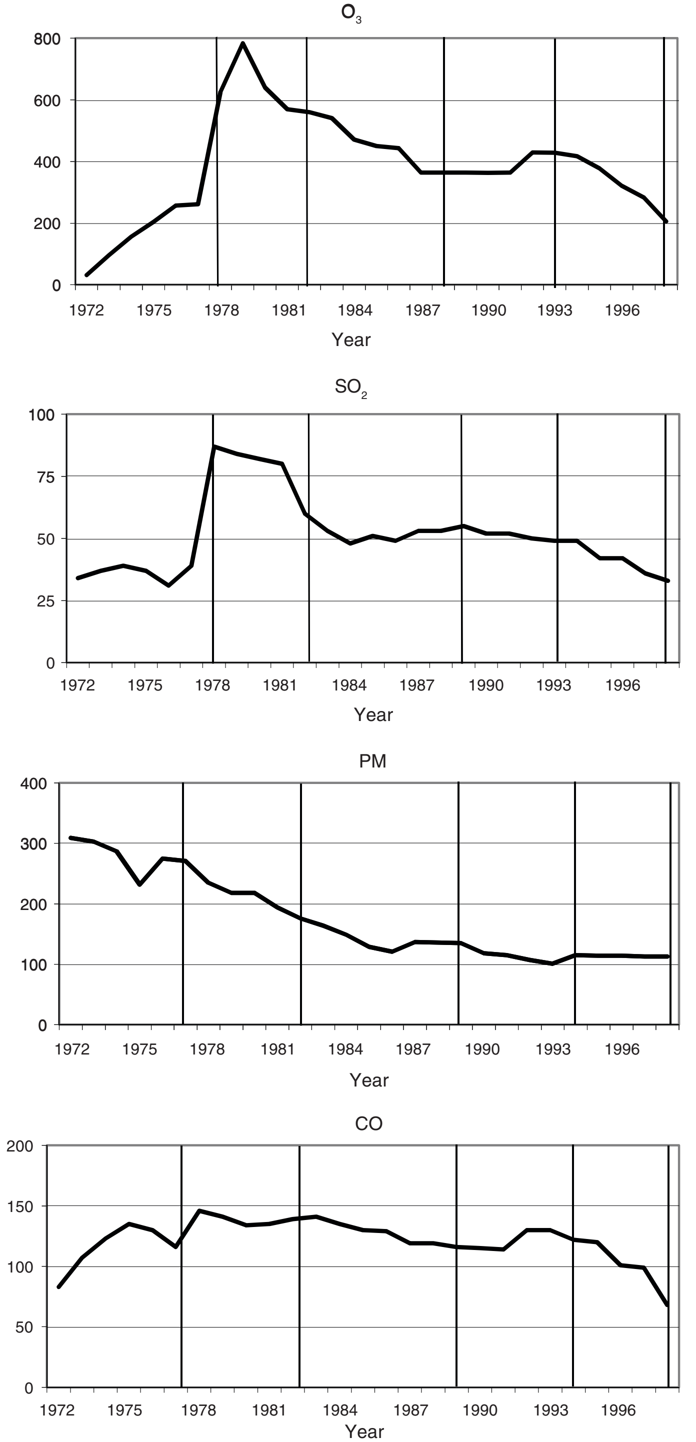

Figure 2A. Number of Counties with Nonattainment Status, by Pollutant

Notes: Data are from the EPA Greenbook, EPA Pollution Monitoring Network (courtesy of Greenstone). The bars correspond to BEA Benchmark Survey Years.

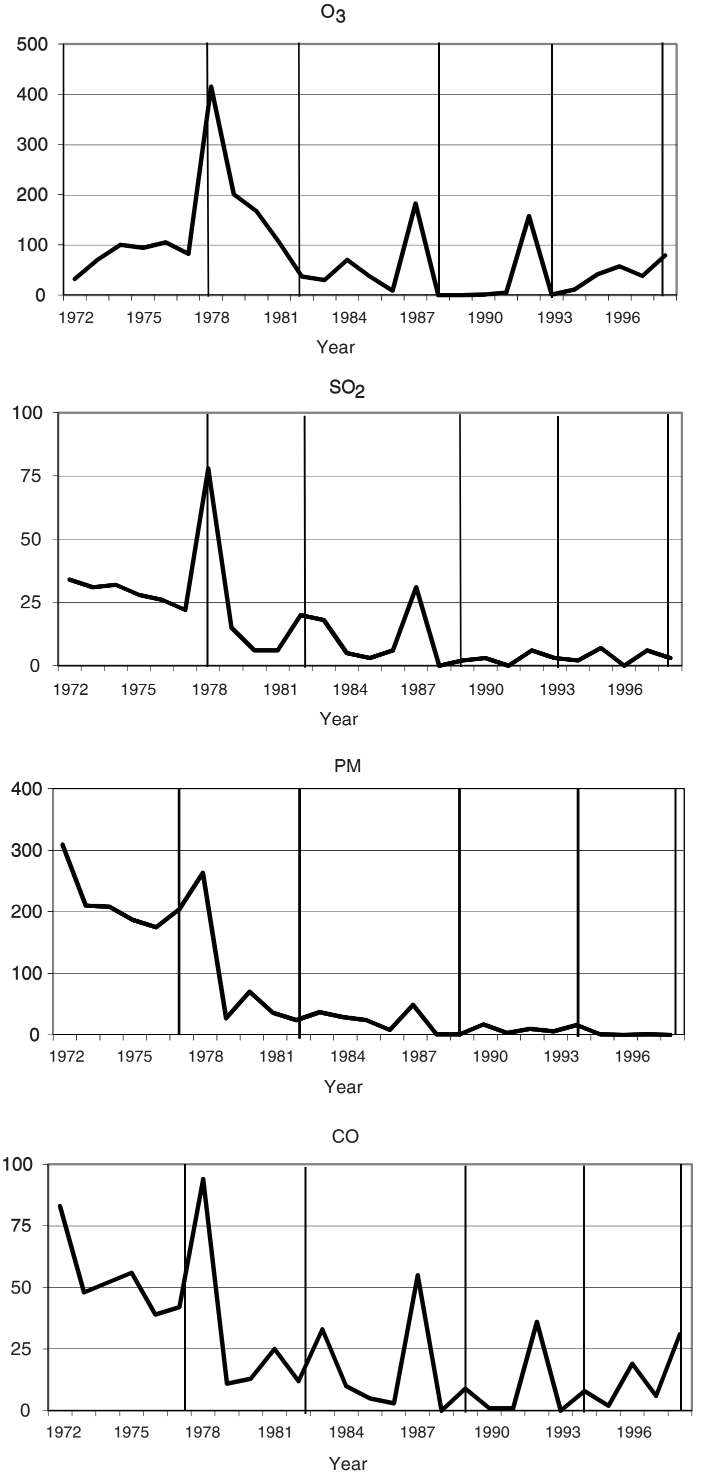

Figure 2B. Number of Counties with a Change in Status, by Pollutant

Notes: Data come from the EPA Greenbook, EPA Pollution Monitoring Network (courtesy of Greenstone). The bars correspond to BEA Benchmark Survey Years.

Table 1—Which Industries Emit Which Pollutants?

Industry (SIC code)	O_3	SO_2	PM	CO
Fabricated metals (34)	x			
Inorganic chemicals (2812-9)		x		
Iron and steel (3312-3, 3321-5)	x	x	x	x
Lumber and wood products (24)			x	
Motor vehicles, bodies and parts (371)	x			
Nonferrous metals (333-4)		x		x
Organic chemicals (2861-9)	x			
Petroleum refining (2911)	x	x		x
Printing (2711-89)	x			
Pulp and paper (2611-31)	x	x	x	x
Rubber and misc. plastic products (30)	x			
Stone, clay, glass, and concrete (32)	x	x	x	
Percent of industrial emissions accounted for	80.7	91.2	71.90	84.8

Note: Data from EPA Sector Notebooks (1995) and Greenstone (2002).

it falls within an industry (where industry is denoted as "i") that contributed 7 percent or more to total industrial emissions of the pollutant (see Table 1).[25]

Of course, comparing "regulated" firms (heavily emitting firms located in nonattainment counties) with "nonregulated" firms may capture factors other than the regulation. Specifically, firms located in nonattainment counties may be different than those located in attainment counties, and similarly, firms that belong to heavily polluting industries may be different than those in clean industries. However, the structure of the regulation allows me to control for these two factors. First, clean firms exist in both nonattainment and attainment counties, and clean firms are not subject to regulation. Thus, I can compare the outcomes of clean firms located in nonattainment counties to those located in attainment counties to estimate the effect of belonging to a nonattainment county that is independent of the regulation effect. Second, attainment counties include both clean and dirty firms, allowing me to estimate the effect of belonging to a dirty industry relative to a clean industry when no regulation exists. By differencing out these two effects, I can isolate the true regulation effect.

In a regression framework, this results in a traditional difference in differences model:

$$Y_{fic} = \beta_0 + \beta_1 Emit_{fic} + \beta_2 Non_{fic} + \beta_3 Emit_{fic} \times Non_{fic} + \varepsilon_{fic}, \tag{1}$$

where Y_{fic} is the FDI for firm f, $Emit_{fic}$ is an indicator variable for a heavy polluter, Non_{fic} is an indicator variable for being located in a nonattainment county. The coefficient of interest is β_3, which captures the variation in foreign production specific to firms in domestic, polluting industries (relative to nonpolluters) in nonattainment counties (relative to attainment ones). A set of industry and county fixed effects can

[25] Using this rule, US plants manufacturing in emitting industries collectively account for between 72 percent and 91 percent of the total US industrial emissions of each criteria pollutant.

replace $Emit_{fic}$ and Non_{fic} to more flexibly estimate their respective effects on FDI. If multiple years of data are available, firm fixed effects can also be added to the model to control for firm-level heterogeneity.

This simple case is not realistic. In any given year, a firm may operate in multiple US counties (on average, multinationals in the sample manufacture in six US counties per year), and may also operate in multiple industries. Thus, I now turn to a more nuanced empirical model that incorporates these facts.

The Modified Differences-in-Differences Approach.—I organize the data at the level of a firm *f* in an industry *i* at time *t*. For each firm-industrial segment, I compute the percentage of plants that were effectively regulated under the CAAA in year *t* for pollutant *z*. Practically, I first define a plant "*p*" as regulated for any pollutant if the following condition is satisfied:

$$\left(\sum_{z} Ind_{pctiz} \times Nonattain_{pctiz}\right) > 0,$$

where Ind_{pctiz} takes the value of one if the plant belongs to an industry in the US that is a heavy emitter of pollutant *z*, and $Nonattain_{pctiz}$ takes the value of one if the plant belongs to a county that is in nonattainment for *z*. Then, to create the measure of regulation (Reg_{fit}), I sum the number of regulated US plants and divide this by the number of a firm's US plants in that industry (N_{fit}):

$$Reg_{fit} = \frac{1}{N_{fit}} \times \left(\sum_{p=1}^{N_{fit}} 1\left(\sum_{z}\left(Ind_{pctiz} \times Nonattain_{pctiz}\right)\right)\right) \times 100,$$

where 1() is an indicator function that takes the value of 1 if the US plant faces regulation for at least one pollutant.

I then specify the baseline empirical specification as follows:

$$(2)\ Y_{fit} = \beta_0 + \beta_1 Ind_{fi(t-k)} + \beta_2 Non_{fi(t-k)} + \beta_3 Reg_{fi(t-k)} + \alpha_{fi} + \delta_{ft} + \eta_{it} + \varepsilon_{fit},$$

where $(t-k)$ indexes the most recent year for which FDI data was available. Y_{fit} is a measure of a firm's direct foreign production within an industrial segment (including capital stock, output, and sales).[26] $Reg_{fi(t-k)}$ is the lagged regulation measure. ε_{fit} is the stochastic error term, which is clustered at the industry-county-year level.[27]

[26] The regressions were run on the level of assets, and the mean elasticity of regulation is presented. Transforming the data by the log function would constrain the effect of regulation to be proportional to the firm's foreign assets, ensuring that the magnitude of the regulation effect was not simply driven by the largest firms. However, the data include a large fraction of zeros for years in which the firms did not invest abroad in an industry, and therefore, the log function is not appropriate.

[27] There are two issues to note regarding the clustering. First, it is not necessarily clear how to cluster in this case, as the firm-industry segments may be in multiple counties in multiple years. To be conservative, I use the county in which there are the most employees. Second, while this method of clustering allows for correlations between firms that are facing the same type of regulation in a county, it imposes the assumption of no auto-correlation between years. However, it is not clear that autocorrelation is an issue in this case as it is in the standard difference-in-difference model. The inclusion of both firm-year and industry-year effects should absorb much of the time variation.

Analogous to the simple case, the regulation variable captures the true effect of regulation, whether the firm-industry has plants that are located in nonattainment counties, and whether the firm-industry manufactures in a dirty industry at home. To difference out these effects, I include two sets of variables. First, I include $Ind_{fi(t-k)}$, which is a vector of "industries at home" dummy variables that indicate whether a firm manufactured within a domestic industry in a given year interacted with year. These variables capture shocks common to firms manufacturing in a particular US industry. Second, I include $Non_{fi(t-k)}$, which is a vector of variables that give the proportion of a firm's US manufacturing facilities, in an industrial segment, that are located in a nonattainment county, by year.[28] $Non_{fi(t-k)}$ parametrically controls for the main effect of manufacturing in a nonattainment county. This is especially important because operating within a nonattainment county may affect FDI independently of regulation if counties in nonattainment systematically differ from those in attainment (for example, counties that are in nonattainment differ from those in attainment in observable characteristics such as rates of unionization and average education level). It is important to note that $Non_{fi(t-k)}$ constrains the main effect of manufacturing in a nonattainment county to be identical across counties. I would ideally relax this restriction and include a vector of time varying, county fixed effects. However, given the number of observations, I cannot control for the ensuing 18,000 county-year fixed effects. Nonetheless, I believe that this restriction should not alter the results. First, since the emission standards (and basic policy implementation) are the same for each nonattainment county, the main threat to the estimation strategy comes from differences in trends between firms manufacturing in nonattainment and attainment counties, not between particular counties. Second, controlling for the main effect of counties (not interacted by year) does not significantly alter the coefficients of interest. Third, the inclusion of firm-industry effects (discussed below) should also capture a significant portion of the variation across counties.

The panel structure of the data allows for additional controls that purge the regulation effect of bias associated with industry and firm specific trends, which may be correlated with regulation. Specifically, I include firm by industry (α_{fi}), industry by year (η_{it}), and firm by time (δ_{ft}) fixed effects. The inclusion of industry by year fixed effects (η_{it}) removes shocks to FDI that are common to all firms investing abroad within an industry in a particular year. Including industries by year fixed effects is especially important if certain industries increased FDI during this period for reasons unrelated to environmental regulation (e.g., the US automobile industry significantly shifted production to Mexico after NAFTA).

Firm-by-year fixed effects (δ_{ft}) remove the mean FDI across all of a firm's industrial segments in a particular year. This controls for unobserved factors that equally affect FDI across a firm's polluting and nonpolluting segments (e.g., a change in a firm's credit ratings or senior management).

Finally, firm-by-industry fixed effects (α_{fi}), absorb the unobserved heterogeneity in the determinants to FDI that are common to a particular industry within a given firm. In effect, this allows a firm-industry that is unregulated in one period to act as

[28] $Non_{fi(t-k)}$ is defined as $(1/N_{fi(t-k)}) \times \left(\sum_{p=1}^{N_{fi(t-k)}} 1\left(\sum_{z} Nonattain_{pctiz}\right)\right) \times 100$.

a comparison group for itself when regulated in other periods. These controls are important if we believe that a firm-industry's exposure to regulation is potentially correlated with factors inherent to a firm-industry (such as technology or size).

The parameter of interest, β_3, measures the effect of increasing a firm-industry's percentage of regulated, domestic plants on its FDI level.[29] Note several core assumptions implicit in the construction of Reg_{fit}, which may affect the interpretation of the coefficient. First, Reg_{fit} restricts the effect of regulation in nonemitting industries to be zero. As a result, the estimated regulation effect heavily relies on the cutoff used to divide industries into the emitting and nonemitting categories. The sensitivity of the result to the 7 percent cutoff is explored in Section IIID. Second, since I count each plant only once in Reg_{fit}, I implicitly assume that the average costs of regulation are identical for each plant, regardless of the number of pollutants for which the plant faces regulation. Furthermore, I weigh each pollutant equally in Reg_{fit}. Thus, I assume that the average compliance costs of regulation are identical for each pollutant. Section IIID relaxes both these assumptions by allowing each of the four regulatory programs to impact foreign production separately. Finally, I assume that each plant affects a firm's foreign investment decisions regardless of individual characteristics of the plant (plant size, age of the plant). In Section IIIF, I construct an alternative measure of a firm's exposure to regulation as a function of plant characteristics.

Finally, note that for ease of interpretation, I have also included the elasticity of the FDI response to the regulations, i.e., the percentage change in the sample-wide average FDI associated with a one percent increase in regulation.

C. *Descriptive Statistics*

Descriptive statistics are provided in Table 2. All monetary variables are in thousands of 1982 dollars. The analysis in this paper used 56,385 firm by industry by year observations from 2,235 firms. If a firm never manufactured in an industry at home nor abroad, I exclude the firm-industry from the analysis, causing the number of observations included per firm to vary. However, this exclusion should not significantly alter the results, as the estimated coefficient on regulation $(Reg_{fi(t-k)})$ is conditional on having operated at least one US plant within an industry in a given year $(Ind_{fi(t-k)})$.

The first two columns of Table 2 include FDI in all countries, while the second two columns exclude FDI to high-income, OECD nations. Several key patterns emerge from the table. First, the average level of multinational activity in high-income countries dwarfs the activity in other nations. For example, the average firm-industry's foreign assets that are in low-income countries (7,612) is less than one-quarter of all foreign assets (37,118). Second, a firm-industry that holds assets abroad in a given year is more likely to have been regulated in the past (7 percent of plants regulated) than the overall average (6 percent). However, because of the substantial variation

[29] Since foreign capital is likely underestimated for capital intensive industries, and such industries are also more likely to be more pollution intensive and more responsive to environmental regulations, this suggests that the measurement error in the dependent variable may be negatively correlated with the regulation measure. As such, this would bias the estimated regulation effect downward.

Table 2—Descriptive Statistics of Key Variables

Variable	All foreign affiliates: Overall (1)	All foreign affiliates: Conditional on foreign assets>0 (2)	Excluding affiliates in high income, OECD nations: Overall (3)	Excluding affiliates in high income, OECD nations: Conditional on foreign assets>0 (4)
Foreign assets	37,118	162,885	7,612	33,403
	(451,013)	(933,916)	(103,110)	(214,000)
Plant, property and equipment	12,148	53,309	2,678	11,753
	(172,855)	(359,069)	(38,875)	(80,781)
Costs of goods and services	45,903	201,436	9,085	39,866
	(728,007)	(1,514,785)	(149,734)	(311,713)
Gross product	14,149	62,092	3,378	14,824
	(340,721)	(711,683)	(238,336)	(499,117)
Sales from foreign affiliates to US firm	8,109	36,193	2,865	12,801
	(307,384)	(649,205)	(26,0066)	(549,817)
Sales from foreign affiliates to US	13,216	57,995	2900	12943
	(320,534)	(669,544)	(259,804)	(549,257)
Firm by industry regulation (Reg_{fit})	5.99	7.16	5.99	7.16
	(22.24)	(22.76)	(22.24)	(22.76)
Firm by industry regulation: CO_{fit}	0.48	0.49	0.48	0.49
	(6.02)	(5.10)	(6.02)	(5.10)
Firm by industry regulation: O_{fit}	5.35	6.33	5.35	6.33
	(21.10)	(21.53)	(21.10)	(21.53)
Firm by industry regulation: SO_{fit}	0.39	0.53	0.39	0.53
	(5.38)	(5.59)	(5.38)	(5.59)
Firm by industry regulation: PM_{fit}	0.93	0.94	0.93	0.94
	(8.65)	(7.69)	(8.65)	(7.69)

Notes: The level of observation is a firm by industry by year (for 2,235 firms). Columns 1 and 3 have 56,385 firm by industry by year observations, while columns 2 and 4 have 12,385 observations. Outcome variables are constructed from the BEA Direct Foreign Investment Benchmark Surveys for 1966–1999. All outcome variables are in real thousands of 1982 US dollars (deflated using US industry PPI from Federal Reserve Bank of St. Louis FRED II) Definition of "high income, OECD" comes from the World Bank. Standard deviations of the means are in parenthesis.

in the regulation variable, I cannot reject the hypothesis that this difference is zero. Finally, the ozone program was most pervasive, and, therefore, it follows that the average firm-industry is disproportionately regulated for ozone (5.35 percent).

III. Regression Results

A. *Primary Results*

Table 3 gives the results from estimating equation 2, over the 1966–1999 time period. In columns 1–4, the foreign assets of a firm, by industry, by year, is the dependent variable, while various measures of assets, income, and sales are the dependent variable in columns 5–9. The main coefficient of interest, β_3, is presented; a positive value of β_3 implies that a firm increased its foreign assets in response to CAAA regulation. The columns correspond to specifications that include different sets of controls. The exact controls are noted at the bottom of the table. As the regulation effects are derived from the interaction of manufacturing in a heavily polluing industry in the United States and residing in a nonattainment county, the

Table 3—Regression Results, Firm by Industry Level Data

	Assets			Plant, property and equip.	Costs of goods and services	Gross product	Sales, US parent firm	Sales, US
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Firm by industry regulation (Reg_{fit})	735.3	319.9	329.9	125.9	702.1	290.9	131.4	99.7
	(261.9)	(140.3)	(171.5)	(74.8)	(313.0)	(125.7)	(84.4)	(80.3)
Mean elasticity	2.0	0.9	0.9	2.0	1.5	2.1	1.6	0.8
Industry at home, by year	x	x	x	x	x	x	x	x
Nonattainment, by year	x	x	x	x	x	x	x	x
Firm by industry		x	x	x	x	x	x	x
Firm by year			x	x	x	x	x	x
Industry by year			x	x	x	x	x	x

Notes: The entries are from regressions where the dependent variable is the listed variable of a firm in an industry "*i*" at time "*t*" (56,385 observations for 2,235 firms). All regressions are computed using the two-way effects model. Standard errors are adjusted for the correct degrees of freedom, and also are clustered at the industry-county-year level.

main effects of manufacturing in a domestic industry $(Ind_{fi(t-k)})$ and manufacturing in a nonattainment county $(Non_{fi(t-k)})$ are always included.

The column 1 specification presents the estimated regulation effect from exploiting the pooled cross-sectional variation in the data. In other words, I exclude firm-by-industry, industry-by-year, and firm-by-year fixed effects. The estimated effect of regulation is large (735.35) and significant at the 1 percent level.[30] However, in this specification, the estimated regulation effect may simply capture the difference in FDI between firms. For example, suppose that larger firms are more likely to be regulated and more likely to manufacture abroad. Then, the estimated coefficient would potentially confound the regulation effect with firm size.

In the specification reported in column 2, I take advantage of the panel structure of the data and include firm-by-industry fixed effects. The estimate of β_3 falls from 735 in column 1 to 320 in column 2. This difference suggests that firm specific factors are an important determinant of FDI, and therefore, estimates of the regulation effect using cross-sectional data may overstate the effect of environmental regulation on FDI.

Column 3 reports results from including industry-by-year, firm-by-industry, and firm-by-year fixed effects.[31] In this specification, the coefficient estimate on regulation is purged of possible sources of bias associated with transitory shocks to an industry, inherent firm-by-industry characteristics, and transitory shocks to a firm. The estimate of β_3, which is similar to that in column 2, indicates that a 1 percentage point increase in the lagged percentage of plants regulated in an industry leads to a $329,000 increase in a firm's stock of foreign assets in that industry (significant at the 10 percent level).[32]

[30] Constraining the effect of the industries at home and nonattainment variables to be constant over time produced similar results to Table 3, but they are omitted for brevity. These results can be obtained from the author upon request.

[31] For computational ease, the data are demeaned by two sets of fixed effects. The standard errors are adjusted to account for the correct degrees of freedom.

[32] Note that this effect includes the effect of regulation both being turned on and turned off. If the regulation remains turned on, the regulation effect remains positive and significant. This suggests that the changes may be

This corresponds to a 0.9 percent increase in foreign assets for the average firm-industry. To put these numbers into context, suppose that the average level of regulation is imposed upon a previously unregulated firm-industry (i.e., 6 percent of a firm-industry's plants are now regulated). The model predicts that the firm would increase its foreign assets in that industrial segment by 5.3 percent.[33]

Columns 4–8 of Table 3 document the effect of the CAAA regulation on several selected measures of foreign production. These columns present the results from the specification that controls for firm-by-industry, firm-by-year, and industry-by-year fixed effects.

Column 4 reports the estimation results for an alternative measure of a firm's capital stock: plant, property, and equipment (PPE). In addition to including the physical capital stock of the foreign affiliate, the asset variable includes the affiliate's equity investments in other firms. In contrast, the PPE measure only includes the physical capital stock (land, machinery, etc.), perhaps providing a less noisy measure of foreign production activities. The coefficient on regulation is positive (125) and significant at the 10 percent level.

Next, I investigate the effect of regulation on a multinational's foreign output. Although changes in a firm's foreign capital stock may provide evidence on permanent changes in foreign production, they may not capture transitory changes in foreign manufacturing during a given year. Suppose that a firm's manufacturing facility operates at less than full capacity.[34] A firm may, thus, increase production by more fully utilizing existing capital structures, rather than investing in new equipment. In this case, using the foreign capital stock as a measure of foreign production would cause a downward biased measure of the regulation effect. In addition, the assets and PPE variables are recorded through a book value system. This system permanently records the value of an investment at its purchase price, and the value is never updated to reflect inflation or changes in the goods market value. Since this system overstates the relative contribution of a recent investment (which is entered in current dollars), the increase in foreign capital as a fraction of total capital may be an upwardly biased measure of current production levels. A firm's foreign output does not suffer from either bias, and, therefore, may provide a better measure of transitory changes in production.

Columns 5 and 6 report the estimation results for two measures of foreign output: the real costs of foreign goods and services and the real foreign gross product, respectively.[35] The estimated regulation effect, β_3 is positive and significant at the 5 percent level (point estimates of 702 and 290, and mean elasticities of 1.5 and 2.1,

permanent, i.e., once a firm shifts production abroad it does not shift back if regulations are relaxed.

[33] The regulation measure in Table 3 assumed that only regulations from the year of the last investment survey affected the FDI decisions of firms (for example, regulation in 1977 affected investment in 1982, but regulation in 1978–1981 did not). I made this assumption because there are typically delays in enforcement activities when a county falls into nonattainment, and there may also be a delayed response of investment to regulation. Eli Berman and Linda T. M. Bui (1998) document that the plant level regulations associated with nonattainment status often set compliance dates a number of years in advance. Alternatively, I construct the average level of regulation (weighed by year) during the period prior to the investment, and determine whether this new regulation measure impacts foreign assets. The point estimates are not substantially different than those presented in Table 3, columns 1–5.

[34] It has been well documented that many plants operate under capacity, and that capacity utilization movements are not random, but can be viewed as systematic results of a rational economic optimization process undertaken by the firm (Ernst R. Berndt and Catherine J. Morrison 1981).

[35] Note that gross product is a measure of value added, and not gross output.

respectively). This implies that imposing the mean level of firm-by-industry regulation causes the average firm to increase its foreign output (as measured by the costs of goods and services) by roughly 9 percent within a polluting industry.

In column 7, I test whether a firm increases imports from its foreign affiliates in response to tougher environmental regulation. A firm may utilize FDI as a means of penetrating a local market, or, alternatively, to produce goods for export. In the context of this study, it is interesting to understand whether the United States was the final destination of the additional foreign goods produced in response to regulation, and whether imports substituted for domestic production. It is worth mentioning that although a foreign affiliate can export directly to other companies within the United States, roughly one-third of world trade is intra-firm trade (Pol Antras 2003) and, in our particular sample, sales to the US parent firm account for 62 percent of all sales to the United States. As such, this is an important indicator of whether a firm substitutes foreign goods for its own domestic production. The effect of regulation on intra-firm trade is positive (131) and economically significant. A 1 percentage point increase in regulation leads to a 1.6 percent increase in imports by the average firm-by-industry. However, the estimate is not statistically significantly different than zero. Finally, column 8 reports the estimation result where the real sales from the foreign affiliate to the United States, through any firm, is the dependent variable. The coefficient is positive (99), but not statistically significant.

B. *Patterns of Movement Abroad*

Section IIIA concluded that the CAAA regulation led to a 5.3 percent increase in assets and a 9 percent increase in output. This, perhaps, suggests that firms have increased capacity at existing plants in response to regulation, rather than creating new investments abroad. In this section, I more formally explore the forms of investment undertaken by regulated firms.

Increases in foreign manufacturing can take two forms. First, regulation may cause firms to invest abroad for the first time or to create a new manufacturing plant. However, suppose a firm believes that the regulation may be temporary, or suppose the fixed costs of moving are high. Under these scenarios, it may not be worthwhile for a firm to begin investing abroad due to the regulation. Instead, if a firm has a plant that is operating under capacity, the firm may choose to simply increase output. In column 1 of Table 4, I present the effect of regulation on a firm's decision to start a new investment. Regulation appears to have no effect. In column 2, I report the estimated effect of domestic regulation on foreign assets, conditional on having invested abroad in a given year. The coefficient estimate is positive and large, and significant at the 10 percent level.

If we believe that firms that have excess capacity abroad are more likely to increase foreign manufacturing in response to regulation, we might expect that larger firms would be more likely to respond relative to smaller firms. Thus, I interact the regulation variable with an indicator variable for whether the firm is above median size (where size is measured as the number of US plants in the previous period). The results are presented in column 3. Larger firms are significantly more likely to respond to regulation relative to smaller firms. In fact, large firms account for most of the regulation effect.

Table 4—Patterns of Movement Abroad

	Dummy for new investment	Foreign assets if > 0	Foreign assets	Number of countries with investments
	(1)	(2)	(3)	(4)
Firm by industry regulation (Reg_{fit})	0.0	1,024.1	−242.1	0.0
	(0.0)	(610.7)	(104.0)	(0.0)
Firm by industry regulation (Reg_{fit}) × Large Firm			685.5	
			(205.7)	

Notes: The entries are from regressions where the dependent variable is the listed variable of a firm in an industry "*i*" at time "*t*." All regressions are computed using the two-way effects model. Standard errors are adjusted for the correct degrees of freedom, and also are clustered at the industry-county-year level. All regressions include fixed effects for industry at home, by year; nonattainment, by year; firm by industry; firm by year; and industry by year. In columns 1, 3, and 4, the number of observations is 56,385. In column 2, the number of observations is 12,587.

Finally, I determine whether regulated firms invest abroad in a greater number of countries (column 4). Once again, if we believe that firms simply increase manufacturing at existing plants in response to regulation, we would not expect regulation to affect the number of countries a firm invests in. The data support this hypothesis.

C. *The Relative Impacts of Regulation on FDI to Developing Countries*

Opponents of US environmental regulation fear that regulation forces firms to shift manufacturing to developing countries, which are generally less able or less willing to impose tough environmental policies (pollution havens or "race to the bottom" effects). If this concern is justified, US environmental policies may have significant distributional impacts, as both pollution and jobs shift to developing nations.

Economic theory, however, does not necessarily predict that firms will disproportionately increase investment in developing nations. The regulations do not alter conditions (interest rates, costs) across foreign nations, and therefore, at the margin, we would not automatically expect a change in the distribution of a firm's foreign portfolio. Furthermore, even if the regulations motivate a firm to invest in countries with weaker standards, the firm may not necessarily increase production in a developing country. A firm's location choice depends upon a variety of factors that affect the business environment, of which environmental law is only one. For example, a firm that requires a flexible workforce might not invest in a country that has the weakest environmental laws if it also has the most rigid labor laws. Moreover the fact that we find that firms are not investing in more countries in response to regulation, and, instead, just increase production at existing plants, suggests that firms do not choose to *enter* a developing market in response to regulation.[36]

[36] The empirical evidence on whether multinationals invest in developing nations to exploit weaker environmental policies is mixed. Shanti Gamper-Rabindran and Shreyasi Jha (2004) show that after India's 1991 liberalization, there were greater inflows of FDI into dirty industries relative to cleaner ones. On the other hand, Eskeland and Harrison (1997) find little evidence that foreign investors are concentrated in dirty sectors, and show that foreign plants are actually more energy efficient than domestic plants in Mexico, Venezuela, Morocco, and Côte d'Ivoire.

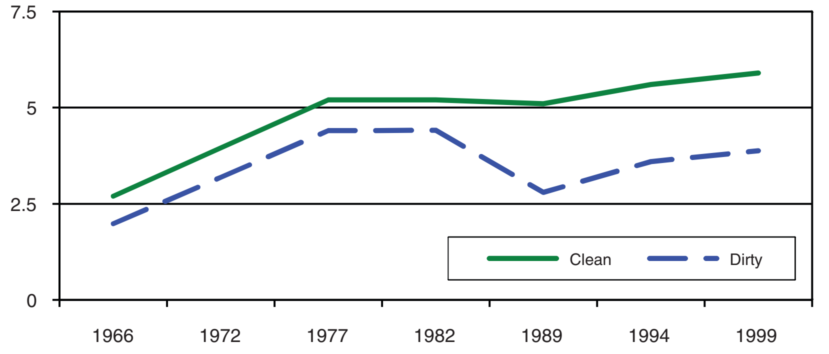

Figure 3. Ratio of Foreign Assets in Developing Countries to Total

In Figure 3, I plot the average ratio of foreign assets in developing nations to total foreign assets, by polluting and clean industries. For all years, the ratio is higher for clean industries. There is no discernible change in the difference in ratios over time, confirming Eskeland and Harrison's (1997) result that dirty US industries are not disproportionately increasing their concentration in developing countries.

Table 5 presents a formal test of whether multinationals disproportionately increase FDI to the developing world in response to regulation. I reestimate equation (2) with the ratio of FDI in less developed countries to total FDI as the dependent variable.[37] For each outcome measure, the mean of the dependent variable is listed in brackets at the top of the table. Across all outcomes, the results are indistinguishable from zero, implying that the share of a firm's investment in poorer countries is not determined by US environmental regulations.

D. *Individual Pollutants*

If abatement costs vary by pollutant, each pollutant-specific regulatory program (CO, O_3, SO_2, and PM) should have a distinct effect on FDI. In particular, one would expect FDI to disproportionately increase in response to the regulation of pollutants with high marginal abatement costs.

Unfortunately, it is difficult to measure marginal abatement costs by pollutant. In general, abatement cost data come from manufacturing plant surveys, but plants may be unable to separate costs by pollutant if equipment can abate multiple pollutants. Moreover, Raymond S. Hartman, David Wheeler, and Manjula Singh (1994) have documented that the marginal cost of pollution abatement varies across industry. For example, in the paper industry, the marginal cost of pollution abatement is

[37] Leslie E. Papke and Jeffrey M. Wooldridge (2008) provide an estimation technique for fractional response variables with panel data. However, the model is computationally challenging, given that fixed effects affect model employed. Excluding the firm-by-industry, firm-by-time, and industry-by-time fixed effects, the estimated coefficient of interest from the Papke and Wooldridge (2008) model is not significantly different than the estimated coefficient from OLS. Given the importance of including the fixed effects, I have presented the results of the OLS estimation.

TABLE 5—REGULATION EFFECTS ON THE RATIO OF PRODUCTION IN DEVELOPING COUNTRIES TO TOTAL FOREIGN PRODUCTION

	Foreign assets [4.37]	Plant, property and equip. [5.23]	Costs of goods and services [4.40]	Gross product [4.50]	Sales, US parent firm [2.51]	Sales, US [2.21]
	(1)	(2)	(3)	(4)	(5)	(6)
Firm by industry regulation (Reg_{fit})	0.003	0.003	0.007	0.054	−0.002	0.003
	(0.007)	(0.015)	(0.007)	(0.430)	(0.006)	(0.005)

Notes: The entries are from regressions where the dependent variable is the listed variable of a firm in an industry "*i*" at time "*t*" (56,385 observations for 2,235 firms). All regressions are computed using the two-way effects model. Standard errors are adjusted for the correct degrees of freedom, and also are clustered at the industry-county-year level. All regressions include fixed effects for industry at home, by year; nonattainment, by year; firm by industry; firm by year; and industry by year.

highest for O_3/CO (US$ (1979) 214 per ton of reduced emissions), while in the agricultural chemical industry, marginal O_3/CO abatement ($158) is cheaper than SO_2 abatement ($285). As a result, it is difficult to rank individual pollutants by their marginal abatement costs.

Other evidence suggests that the CO and O_3 programs should have relatively greater impacts. Recent evidence suggests that the CO regulatory program disproportionately retarded the growth of manufacturing (Greenstone 2002). This implies that it may be the most costly of the four regulatory regimes.

In order to estimate the separate effects of each regulatory program on foreign production, I compute the regulation variable by pollutant (Z):

$$RegZ_{fit} = \frac{1}{N_{fit}} \times \left(\sum_{p=1}^{N_{fit}} 1 \left(Ind_{pctiz} \times Nonattain_{pctiz} \right) \right) \times 100.$$

This measure is similar in attributes to Reg_{fit}, and can be interpreted as the percentage of a firm's US plants in an industrial segment that are regulated for pollutant Z.

I then estimate the effect of each pollutant-specific measure of regulation:

$$(3)\quad Y_{fit} = \beta_0 + \beta_1 Ind_{fi(t-k)} + \beta_2 NonZ_{fi(t-k)} + \beta_3 RegZ_{fi(t-k)} + \alpha_{fi} + \delta_{ft} + \eta_{it} + \varepsilon_{fit}.$$

Note that equation (3) differs from equation (2) in that $Non_{fi(t-k)}$ has been replaced by $NonZ_{fi(t-k)}$, which is defined as the percentage of plants in a nonattainment county for pollutant Z.

Columns 1–4 of Table 6 present the results from estimating equation (3) for each of the four regulatory programs. The O_3 program appears to have had the largest effect (275, significant at the 10 percent level). While the regulation effect for CO is large and positive, it is not significantly different than zero. The coefficients on regulation for the PM (column 4) and SO_2 (column 3) programs are indistinguishable from zero.

Equation (3) captures the effect of each regulatory program on FDI. However, many plants are subject to more than one of the nonattainment designations, and, as

TABLE 6—THE EFFECT OF POLLUTANT SPECIFIC REGULATORY PROGRAMS ON FOREIGN ASSETS

	(1)	(2)	(3)	(4)	(5)
Firm by industry regulation: CO_{fit}	514.8				514.9
	(439.1)				(457.6)
Firm by industry regulation: O_{fit}		275.4			267.7
		(149.1)			(146.8)
Firm by industry regulation: SO_{fit}			−139.6		−242.7
			(300.6)		(307.3)
Firm by industry regulation: PM_{fit}				−64.1	−191.0
				(80.4)	(167.0)

Notes: The entries are from regressions where the dependent variable is the listed variable of a firm in an industry "*i*" at time "*t*" (56,385 observations for 2,235 firms). All regressions are computed using the two-way effects model. Standard errors are adjusted for the correct degrees of freedom, and also are clustered at the industry-county-year level. All regressions include fixed effects for industry at home, by year; nonattainment, by year; firm by industry; firm by year; and industry by year.

such, the coefficient estimates in equation (3) may potentially confound the effects of each of the nonattainment designations. Alternatively, I estimate the effect of each regulatory program, holding constant the effect of regulation for other pollutants:

$$(4) \qquad Y_{fit} = \beta_0 + \beta_1 Ind_{fi(t-k)} + \sum_z \beta_{2z} NonZ_{fi(t-k)} + \sum_z \beta_{3z} RegZ_{fi(t-k)} + \alpha_{fi} + \delta_{ft} + \eta_{it} + \varepsilon_{fit}.$$

Column 5 presents the estimates of the coefficients of interest (β_{3CO}, β_{3O}, β_{3SO2}, β_{3PM}) from equation (4). Once again, the regulation effect for the ozone program is significant at the 10 percent level, while all other regulation effects are indistinguishable from zero. All four coefficients are jointly significant at the 10 percent level. The regulation effect for O_3 is not significantly different than the regulation effect for CO, but is significantly different than the effects for SO_2 and PM. Given that the estimates do not significantly differ from estimating the effect of each regulatory regime separately, this suggests that the marginal effect of regulation for a second pollutant is equal to the average effect of being regulated for that pollutant.

E. *Firm Level Regression*

Regulation effects calculated at the level of the firm can be informative if there are spillover effects from dirty to clean industries. Foreign investment tends to be lumpy, primarily due to the fixed costs of investing abroad. If a firm facing tougher regulation at home is more likely to pay the fixed costs of creating infrastructure abroad, it may be easier for that firm to manufacture across all industries. However, the firm-level results may be misleading if regulated firms simply shift foreign resources from clean to dirty industries. In this case, even if total foreign production remained constant, a reallocation between industries would have considerable effects on pollution patterns and welfare.

Table 7—Firm Level Regressions

	Capital stock		Output		Sales	
	Foreign assets [199,950.0] (1)	Plant, property and equip. [64,928.9] (2)	Costs of goods and services [248,742.6] (3)	Gross product [76,783.3] (4)	Sales, US parent firm [12,197.3] (5)	Sales, US [69,955.4] (6)
Firm-level regulation	616.8	336.3	1,205.2	530.7	160.0	59.1
	(421.5)	(147.9)	(694.2)	(229.6)	(183.0)	(192.7)
Mean elasticity	0.3	0.5	0.5	0.7	1.3	0.1
Industry at home, by year	x	x	x	x	x	x
Nonattain, by year	x	x	x	x	x	x
Year	x	x	x	x	x	x
Firm	x	x	x	x	x	x

Notes: The entries are from regressions where the dependent variable is the listed variable of a firm at time "*t*" (10,016 observations for 2,235 firms). Dependent variable means are listed in brackets. All standard errors are robust.

To investigate these issues, I estimate the effect of regulation on a firm's total foreign production, rather than the effect on a firm's production within an industrial segment. In particular, I fit the following equation to firm-level data:

$$Y_{ft} = \beta_0 + \beta_1 Ind^*_{f(t-k)} + \beta_2 Non^*_{f(t-k)} + \beta_3 Reg^*_{f(t-k)} + \theta_f + \upsilon_t + \varepsilon_{ft}, \quad (5)$$

where $Reg^*_{f(t-k)}$ is the lagged percentage of a firm's US plants under regulation, $Ind^*_{f(t-k)}$ is a vector of dummies that control for the firm's domestic industries, $Non^*_{f(t-k)}$ controls for the percentage of plants a firm has in a nonattainment county, θ_f is a firm fixed effect and vt is a year fixed effect. Standard errors are robustly estimated.

The results of the firm level regressions are presented in Table 7. An increase in CAAA regulation causes a significant increase in the total foreign capital stock and foreign output of a firm; the effect on sales is indistinguishable from zero.

F. *Specification Checks*

I probe the robustness of the estimates to determine the sensitivity of the results (Table 8), but I find little evidence contradicting the basic conclusions of this paper. Each cell is the coefficient estimate of β_3 from equation (2), where the outcome variable is foreign assets. All regressions include firm-by-industry, firm-by-year, and industry-by-firm fixed effects, and are therefore comparable to the results presented in Table 3, column 3.

Employment Weighted Regulation.—In constructing Reg_{fit}, I restrict the effect of regulation to be identical for each of the firm-by-industry's plants, regardless of the characteristics (such as the size) of the plant. This assumption is tenuous if,

Table 8—Specification Checks

Dependent variable: assets	Employment weighted (1)	1972 and 1977 assigned 1978 status (2)	Using lower percentage for "emitter status" (3)	Alive all years (4)
Firm by industry regulation (Reg_{fit})	393.6	307.7	332.2	450.5
	(189.0)	(177.2)	(171.8)	(231.5)

Notes: The entries are from regressions where the dependent variable is the listed variable of a firm in an industry "*i*" at time "*t*" (56,385 observations for 2,235 firms). All regressions are computed using the two-way effects model. Standard errors are adjusted for the correct degrees of freedom, and also are clustered at the industry-county-year level. All regressions include fixed effects for industry at home, by year; nonattainment, by year; firm by industry; firm by year; and industry by year.

for example, a firm finds regulation more costly when its largest plant becomes subject to regulation. Alternatively, I weight each plant by its approximate employment (E_{pit}) when constructing the regulation variable, and replace Reg_{fit} with an employment-weighted measure of regulation:[38]

$$EmpReg_{fit} = \frac{1}{\sum_{p=1}^{N_{fit}} Epit} \times \left(\sum_{p=1}^{N_{fit}} E_{pit} \times 1\left(\sum_{z} (Ind_{pctiz} \times Nonattain_{pctiz})\right)\right) \times 100.$$

The results, presented in column 1 of Table 8, remain robust. The regulation effect on foreign capital assets is positive and significant at the 5 percent level.

Estimated Regulation Data.—The EPA did not maintain data on the county-level designations between the years 1972 and 1977, and therefore, predicted data were used in the analysis for these years. However, as Figure A1 shows, the predicted data series underestimates the actual number of nonattainment counties, particularly for ozone. To ascertain the sensitivity of the results to the predicted data, I use the designation of the county in 1978 (the first year of preserved nonattainment designations) as the designation of the county in 1972 and 1977. The results presented in column 2 of Table 8 remain robust.

Lower Cutoff for Emissions Standards.—I label an industry as an "emitter" of a pollutant if the industry contributed 7 percent or more to industrial emissions of that pollutant. My analysis relies on the comparison between nonemitters and emitters, and, therefore, it is important that the assignment rule correctly classifies industries, as misclassification will bias the estimated regulation effects. In Table 8, column 3,

[38] I lack US plant-level asset data. Otherwise, I would weight each US plant by its assets when constructing the regulation variable in order to discern whether the decision to increase manufacturing abroad is a function of the size of the regulated plant.

I present the estimation of equation (2), where an industry is labeled an emitter if the industry has contributed 4.5 percent or more to industrial emissions. The results remain robust, largely because the change from the 7 percent to 4.5 percent cutoff does not cause many industries to flip from the nonemitting to emitting category.

Varying Sample Construction.—In Table 8, column 4, I reestimate equation (2) for firms that operated throughout the entire period. If the CAAA regulations caused firms to shut down, and firms that are anticipating closure make fewer foreign investments while alive, then the estimated regulation effects would be biased downward. The point estimates of regulation (column 4) are larger across all outcome measures (for example, the effect on foreign assets is now 450 versus 329 in Table 4). However, firms that operate throughout the entire period have higher mean FDI (the mean foreign assets is 44,836). As such, the mean elasticity of FDI to regulation does not differ from the full sample.

IV. Discussion

The preceding empirical work provides evidence that US-based multinationals increased FDI in response to US "clean air" policies. These findings warrant additional discussion regarding their meaning and possible welfare implications.

A. *Substitution of US Manufacturing*

The findings in this paper suggest that US multinationals may substitute foreign for domestic production in response to US regulations. However, these substitution effects are small relative to total multinational production in the United States.

I can compute the approximate percentage of US multinational activity for which this increased foreign production accounts. The analysis predicts that US multinationals will increase their foreign assets by 5.3 percent in polluting industries in response to the mean CAAA regulation. Therefore, for the year 1977, the regulations amounted to $52 billion of total foreign assets in polluting industries. This increase represents approximately 0.6 percent of the stock of multinationals' domestic assets in polluting industries.

B. *Comparison with Tax*

Regulation impacts a firm's production decisions by increasing the cost of domestic production, and can therefore be seen as a production tax. To determine whether the magnitude of the estimated regulation effect is plausible, I can compare it with a rough estimate of how an "environmental tax" would impact FDI.

The best estimates currently place US environmental compliance costs at 2 percent of the total cost of production (Jaffe et al. 1995). Prior to the passage of CAAA, the United States had little environmental regulation, and, therefore, I assume that these costs are fully attributable to the CAAA regulation. Two percent of the cost is roughly equal to 12 percent of a multinational's profits (1999 BEA data). Thus, the CAAA regulation can be viewed as equivalent to a 12 percent profit tax.

To my knowledge, an estimate of the tax elasticity of outbound investment is unavailable. Instead, I use a measure of the inward tax elasticity of investment, −0.6, from Roger H. Gordon and James R. Hines, Jr. (2002) as a proxy for the outbound elasticity. Thus, a 12 percent environmental tax is associated with a 6.8 percent increase in FDI, which is comparable in magnitude to the 5.3 percent estimate derived in this paper.

C. *Welfare Implications*

This study finds that multinationals may circumvent environmental laws by manufacturing in alternative locations. Therefore, while country-level policies may reduce local pollution, they have the potential to leave the level of global pollution unchanged (or, perversely, even increase it), and may have important distributional consequences.

However, a comprehensive study on who gains (and who loses) from these policies is complicated by several factors. First and foremost, the analysis depends on whether one takes a global or a US perspective. US environmental policy shifts manufacturing (and, therefore, pollution) abroad. Some foreign countries may tolerate higher pollution levels in order to further economic growth (Gene M. Grossman and Alan B. Krueger, 1995), and therefore, it is not obvious that countries receiving US FDI experience a welfare loss from an increased presence of dirty industries.

From a US perspective, environmental regulation reduces US pollution levels and can provide significant health benefits and general improvements in the quality of life.[39] On the other hand, these improvements may come at a substantial cost: the cost of production and employment shifting abroad, externalities from global pollution, and changes in the prices of consumer goods.

While this study aims to understand the costs of lost production, the calculated regulation effects can only be used as a guide in determining these costs. First, this study does not capture all possible changes in foreign production. For example, suppose that domestic firms cannot compete with foreign firms after regulation. Foreign goods may therefore flood the market (import substitution) causing US firms to shutdown. Second, I cannot fully predict the counterfactual. If firms would have eventually shifted production abroad even in the absence of regulation (and the regulations simply speed up the process), the ensuing welfare effects would be different than if the firms move solely in response to regulation. Finally, even if production and jobs shifted abroad, one would expect labor and capital to be reallocated within the United States. As such, the true costs of regulation depend on the adjustment costs of switching resources to other sectors.

V. Conclusions

This paper provides new evidence on the relationship between environmental regulation and FDI. I find evidence that the Clean Air Act Amendments caused US

[39] See V. Kerry Smith and Ju-Chin Huang (1995); Henderson (1996); Chay and Greenstone (2003); Janet Currie and Matthew Neidell (2004).

based multinational firms to increase their foreign production in emitting industries. In particular, my analysis predicts that multinationals increased their foreign assets by 5.3 percent and their foreign output by 9 percent in response to tougher regulation. This increase accounted for roughly 0.6 percent of the multinationals' domestic assets in polluting industries. However, contrary to common claims, I find that heavily regulated firms did not disproportionately increase foreign investment in developing countries. Note that these results pertain only to multinational firms, and not the entire universe of firms; many firms would simply never be large enough to consider manufacturing abroad.

In light of the recent debates on outsourcing, these results suggest that American environmental regulations have contributed to the flight of manufacturing. However, these findings should not be misinterpreted as a criticism of environmental law nor a call to reverse environmental policy within the United States. Extensive research has shown that these policies are effective at reducing air pollution concentrations and that cleaner air provides substantial health benefits. Thus, it is possible that the welfare gains from the shifting investment abroad may still outweigh the costs.

Appendix

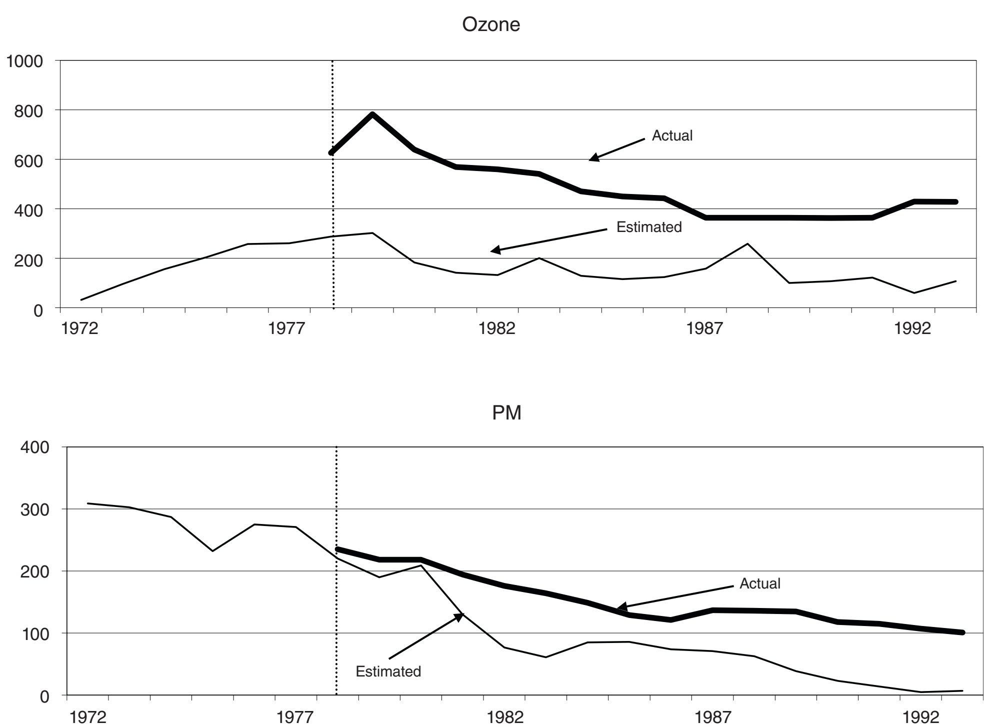

Figure A1. Comparing the Estimated versus Actual Nonattainment

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