The Environmental Consequences of Trade: Evidence from Subnational Trade Flows

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Abstract

The debate over the environmental consequences of free trade is not only quite heated, but also entails significant policy ramifications. The empirical difficulty with assessing this relationship is the fact that trade and environmental quality may be jointly determined, making it difficult to infer a causality. Recently, cross-sectional analysis at the country level has made use of exogenous determinants of trade to identify the causal effect of trade on the environment, finding moderate evidence of a beneficial impact of expanded trade on the environmental quality. Given the stakes involved, we revisit this finding using subnational data on 'trade' flows across US states and several measures of pollution. Our findings are striking, providing further evidence of the beneficial impact of trade.

JEL: F18, Q25
Keywords: Bilateral Trade, Environmental Quality, Pollution Haven Hypothesis

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1 Introduction

Copeland and Taylor (2004, p. 7) state that "for the last ten years environmentalists and the trade policy community have engaged in a heated debate over the environmental consequences of liberalized trade." Given the stakes involved, Taylor (2004, p. 1) argues that this constitutes "one of the most important debates in trade policy." The debate rages on, due at least in part to the dearth of empirical analyses on the *causal* effect of trade liberalization on environmental quality. While Antweiler et al. (2001), Harbaugh et al. (2002), and others provide empirical evidence of a positive *association* between trade intensity or openness and environmental quality, the treatment of trade intensity as exogenous precludes one from drawing causal inferences.[1] A recent notable exception is Frankel and Rose (2005; hereafter referred to as FR).[2] FR seek to answer the question: What is the effect of trade on the environment for a given level of per capita income? The innovation in FR is the authors' attempt to address the potential simultaneity of trade, pollution, and income by deriving instrumental variables from the extensive literatures on the so-called gravity model of bilateral trade (e.g., Deardorff 1998) and endogenous growth (e.g., Mankiw et al. 1992). To implement their solution, FR utilize a cross-section of data (from 1990) at the country level. In the end, FR conclude that there is no evidence that trade has a detrimental effect on seven measures of environmental quality.

Given the policy ramifications of such a conclusion, further analysis is warranted. In particular, we revisit the FR framework, but rather than relying on cross-country data, we utilize panel data at the subnational level from the United States. Specifically, we utilize data on shipments between US states, Gross State Product (GSP), and four types of toxic releases to construct analogous measures of trade openness, per capita income, and environmental quality at the state level for two different time periods. The data on inter- and intrastate shipments come from the US Commodity Flow Survey, conducted in 1993 and 1997, and have been utilized elsewhere to empirically assess a variety of questions concerning international trade. The pollution data are taken from the US Environmental Protection Agency's Toxic Release Inventory.

There are several advantages to using subnational data, as compared with cross-country data. First, using data from a single country ensures consistent measurement of pollution, income, and trade.[3] Second, as the sample is more homogeneous, there is less concern over the omission and/or measurement of potential

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[1] See Copeland and Taylor (2004) for a review of the literature.

[2] See also the expanded working paper version of the paper, Frankel and Rose (2002).

[3] A similar argument has been made elsewhere in the context of estimating the effects of growth on environmental quality (i.e., the Environmental Kuznets Curve) as well as estimating the determinants of bilateral trade. See, for example, Wolf (2000), Millimet et al. (2003), and Millimet and Osang (2005).

confounders such as political freedom, economic freedom, legal institutions, cultural norms, corruption, etc.[4] Third, analysis at the subnational level can partially help discern between competing hypotheses posited in FR since some do not apply to subnational level. For example, FR (p. 85) argue that gains from trade may exist due to multinational corporations bringing “clean state-of-the-art production techniques from high-standard source countries of origin to host countries.” However, such an explanation is less applicable to states within the US.

The results are striking, and broadly consonant with FR, Antweiler et al. (2001), and Harbaugh et al. (2002). In fact, the results using subnational data suggest even stronger positive effects of trade intensity on environmental quality than documented in FR using cross-sectional data at the country level. The remainder of the paper is organized as follows: Section 2 describes the empirical model and data. Section 3 presents empirical results. Section 4 concludes.

2 Empirical Methodology

2.1 Econometric Model

To investigate the effect of trade openness on environmental quality for a given level of income per capita, we begin with the following specification based on FR

$$Poll_{i,t+2} = \alpha_0 + \alpha_1 \ln(Y/Pop)_{it} + \alpha_2 \left[\ln(Y/Pop)\right]^2_{it} + \alpha_3 Trade_{it} + \alpha_4 \ln(Area/Pop)_{it} + \lambda_t + \varepsilon_{it} \tag{1}$$

where i indexes states, t indexes year, $Poll$ is a measure of pollution measured two periods ahead, Y is GSP, Pop is population, $Trade$ is a measure of trade intensity, $Area$ is size in square kilometers, λ_t is a time dummy, and ε is a mean zero error term.[5] The non-linear function of per capita GSP reflects the well-known environmental Kuznets curve (EKC); see, for instance, Grossman and Krueger (1993, 1995) and Harbaugh et al. (2002). The inclusion of land area allows for an effect of population density on environmental degradation. α_3 is the parameter of primary interest.

As noted in Copeland and Taylor (2004), FR, and elsewhere, spatial and temporal variation in trade intensity is unlikely to be exogenous. This is also likely to be the case at the subnational level. For example, Levinson (1999) examines the impact of state-level hazardous waste import taxes on interstate shipments

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[4] Even though FR rely on instrumental variables to identify the causal effect of trade openness on environmental quality, the authors do not test the validity of their instruments. The exclusion restrictions relied on for identification may be more likely to be valid using subnational data from the US.

[5] In FR (2005), pollution and the right hand side covariates are measured in the same year (1990); the working paper version (FR 2002) uses pollution measured five years ahead. Below, we discuss the results using contemporaneous specifications as well.

of hazardous waste, finding strong evidence against exogeneity. While the endogeneity of import taxes on hazardous waste may be more obvious than other impediments to trade at the subnational level (since overt barriers to interstate commerce are not permitted), less transparent state attributes are potentially correlated with both trade flows and environmental quality (e.g., infrastructure, topography, and other 'indirect' factors affecting transportation costs may affect trade flows as well as the scale of pollution-generating activity and/or damages for a given level of pollution). Moreover, FR also argue that per capita GSP should be treated as endogenous as well. State attributes such as infrastructure and topography may be correlated not just with trade flows and environmental quality, but also with income.[6] In addition, environmental regulation may lead to spurious correlation by affecting productivity, as suggested by the Porter hypothesis (Porter and van der Linde 1995), or innovation (Millimet 2003).

To cope with the possible endogeneity of the trade and per capita income variables, we instrument for these variables in equation (1) using a General Methods of Moments (GMM) approach. The instruments are equivalent to those utilized in FR. For trade intensity, we estimate a gravity model for bilateral shipments between pairs of states and form the predicted level of shipments. Next, we aggregate the predicted values across bilateral trading partners to obtain a prediction of total interstate shipments for a given state. In general, the gravity model stipulates that trade is determined by the size of trading partners (e.g., Gross Domestic Product (GDP), population, and land area) and of distance between trading partners (physical distance as well as other determinants of 'distance' such as a common border, landlocked status, common language, common currency, etc.).[7] Formally, we specify the first-stage equation as

$$\ln(\mathit{Shipments})_{ijt} = x_{ijt}\beta + u_{ijt} \tag{2}$$

where $\mathit{Shipments}_{ijt}$ is shipments from state i to state j in year t, x_{ijt} is a vector of controls corresponding to trading partners i and j in year t, and u_{ijt} is a mean zero error term. The control vector includes the (log) population of states i and j, (log) measures of how remote state i (j) are relative to all other states excluding state j (i), the (log) physical distance between the states, a dummy variable indicating whether states i and j are contiguous neighbors, a home dummy variable equal to one if $i = j$ (implying intrastate shipments), the (log) area of state i, and a time dummy.[8] Thus, we are implicitly using exogenous geographical determinants of bilateral shipments to identify the causal effect of trade intensity in (1).

For per capita GSP, the instruments are derived from the endogenous growth literature, and we utilize

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[6] For example, Henderson and Kumbhakar (2004) document positive effects of state-level public capital on GSP.

[7] Wolf (2000) provides a review of the gravity model. See also Millimet and Osang (2005).

[8] As in Wolf (2000), $\mathit{Remote}_{ij} = \sum_{k=1,k\neq j}^{48} \frac{D_{ik}}{GSP_k}$, where D is the physical difference between states. Similarly, $\mathit{Remote}_{ji} = \sum_{k=1,k\neq i}^{48} \frac{D_{jk}}{GSP_k}$. In general, a state located in the middle of a country will be less 'remote' than coastal or international border states (on average, Iowa is the least remote, while Oregon is the most remote).

two specifications for robustness. The first set of first-stage regressions follow directly from FR and are specified as

$$
\begin{aligned}
\ln(Y/Pop)_{it} &= \delta_{11}\ln\widehat{(Y/Pop)}_{it} + \delta_{12}\ln\widehat{(Y/Pop)}^{2}_{it} + \delta_{13}\ln(Area/Pop)_{it} + \lambda_t + \upsilon_{1it} && (3)\\
[\ln(Y/Pop)]^2_{it} &= \delta_{21}\ln\widehat{(Y/Pop)}_{it} + \delta_{22}\ln\widehat{(Y/Pop)}^{2}_{it} + \delta_{23}\ln(Area/Pop)_{it} + \lambda_t + \upsilon_{2it} && (4)
\end{aligned}
$$

where $\ln\widehat{(Y/Pop)}_{it}$ is the fitted value from the regression

$$\ln(Y/Pop)_{it} = \pi_0 + \pi_1 Trade_{it} + \pi_2\ln(Y/Pop)_{i,t-k} + \pi_3\ln(Pop)_{it} + \pi_4 PopGrowth_{it} + \lambda_t + \widetilde{\upsilon}_{it}, \quad (5)$$

k is the length of the lag, $PopGrowth_{it}$ is the rate of population growth, $\widetilde{\upsilon}_{it}$ is a mean zero error term, and all other terms are previously defined.[9] The inclusion of trade intensity as a covariate implies that equation (5) must also be estimated using instrumental variables (via GMM), where the instrument is based on the gravity model discussed above. Although a bit unconventional, in the end the FR methodology reduces to the estimation of (1), using predicted trade (from the gravity model) and predicted per capita income and its quadratic as instruments. Thus, the model is exactly identified.

As a more conventional alternative, we specify the first-stage regressions for GSP and GSP squared as the following reduced forms

$$
\begin{aligned}
\ln(Y/Pop)_{it} &= z_{it}\gamma_{11} + \gamma_{12}\ln(Area/Pop)_{it} + \lambda_t + \varsigma_{1it} && (6)\\
[\ln(Y/Pop)]^2_{it} &= z_{it}\gamma_{21} + \gamma_{22}\ln(Area/Pop)_{it} + \lambda_t + \varsigma_{2it} && (7)
\end{aligned}
$$

where z_{it} includes predicted trade (from the gravity model), lagged per capita income, (log) population, the growth rate of population, each term squared, and a complete set of interactions, ς_{kit}, $k = 1, 2$, are mean zero error terms, and all else is previously defined. While the difference in the two approaches may not be of much consequence, the second approach yields an overidentified model that easily enables one to compute standard overidentification tests of instrument validity.

As a final sensitivity analysis, we take advantage of the panel nature of our data and re-estimate equation (1) in first-differences, thereby removing unobserved, time invariant state-level attributes. Specifically, if one decomposes the error term in (1) as $\varepsilon_{it} = \mu_i + \widetilde{\varepsilon}_{it}$, where μ_i are state effects, then we can re-write equation (1) as

$$\Delta Poll_i = \widetilde{\alpha}_0 + \alpha_1\Delta\ln(Y/Pop)_{it} + \alpha_2\Delta\left[\ln(Y/Pop)\right]^2_{it} + \alpha_3\Delta Trade_{it} + \alpha_4\Delta\ln(Area/Pop)_{it} + \Delta\widetilde{\varepsilon}_{it} \quad (8)$$

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[9] Note, the inclusion of predicted log per capita income, its quadratic, log per capita area, and the time effects in both first-stage regressions (3) and (4) follows from the convention that all exogenous variables be included in each first-stage regression.

Equation (8) is still estimated using instrumental variables (via GMM; referred to hereafter as GMM-FD). However, the benefit of first-differencing is the increased likelihood that the identifying exclusion restrictions are valid.

2.2 Data

The data come from several different sources. The pollution data are obtained from the US EPA's Toxic Release Inventory (TRI). With the passage of the Emergency Planning and Community Right-to-Know Act (EPCRA) in 1986, manufacturing facilities (designated as Standard Industrial Classification (SIC) 20 – 39) are required to release information on the emission of over 650 toxic chemicals and chemical categories. Any facility which produces or processes more than 25,000 pounds or uses more than 10,000 pounds of any of the listed toxic chemicals must submit a TRI report (US EPA 1992). For the purposes of the current analysis, the data are aggregated to the state level.

While the data are available at the chemical level, the data are also aggregated into several broad categories: air, land, water, and underground releases (see Appendix A for definitions). In the majority of studies utilizing the TRI data, these four pollution categories are aggregated together as well (referred to as 'total' releases). Although these aggregations give equal weight to each chemical, some studies have been concerned about forming new aggregates, weighting each chemical by a measure of toxicity (Brooks and Sethi 1997; Arora and Cason 1995). However, as reported by the EPA, most of the widely used chemicals do not vary significantly in their toxicity and many of the less toxic chemicals have not been assigned risk scores by the EPA (Arora and Cason 1999; US EPA 1989). Nonetheless, Arora and Cason (1995) perform their analysis weighting each chemical equally as well as weighting chemicals by risk scores (when available). The authors find their results to be robust to the choice of aggregation scheme. Thus, we follow Maasoumi and Millimet (2005) and others, assigning equal weight to each chemical.

Given the timing of the data on state-to-state shipments (discussed below), we utilize the TRI data from the years 1993, 1995, 1997, and 1999; 1995 and 1999 (1993 and 1997) when pollution is measured two periods ahead (contemporaneously). Moreover, for each category of toxic releases (air, water, land, underground, and total), we utilize three measures of pollution as the dependent variable: aggregate, per capita, and per area (i.e., scaled by the land area of the state).

Before proceeding, it is worth mentioning that the list of chemicals firm are required to report under EPCRA has evolved over time. Firms were required to report the release of 337 chemicals during the first year, 1988, of which 299 were deemed 'core' chemicals.[10] Under EPCRA any citizen has the right to

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[10] For a list of the original core chemicals, see http://www.epa.gov/triexplorer/list-chemical-core-88.htm.

petition the EPA to add or remove chemicals from the required list. While minor additions and deletions are made virtually every year, 286 new chemicals were added beginning in 1995. To capture the increase in pollution that occurs over time simply due to the expansion in covered chemicals, the time dummy is included in equation (1).

The inter- and intrastate shipments data are from the 1993 and 1997 Commodity Flow Survey (CFS), collected by the Bureau of Transportation Statistics within the US Department of Transportation. The CFS is designed to provide data on the flow of goods and materials by mode of transport. The CFS tracks all shipments – measured in dollars and in tons – between establishments by mode of transportation: rail, truck, air, water, and pipeline. The survey covers 25 two-digit SIC industries (codes 10 (except108), 12 (except 124), 14 (except) 148, 20-26, 27 (except 279), 28-39, 41, and 50) and two three-digit SIC industries (codes 596 and 782). Samples of 200,000 (1993 CFS) and 100,000 (1997 CFS) domestic establishments randomly selected from a universe of about 800,000 establishments engaged in mining, manufacturing, wholesale, auxiliary establishments (warehouses) of multi-establishment companies, and some selected activities in retail and service were used. Total shipments from one state to another (or within state) are reported.

The public-use CFS data are used in Wolf (2000), Anderson and van Wincoop (2003), Millimet and Osang (2005), and subsequent authors to study the role of borders on bilateral shipment patterns. However, there are important limitations of the public-use CFS data worth noting. First, the commodity flow data measure all shipments: intermediate and final. For example, a product may be shipped from a manufacturing plant to a warehouse and from there to a retailer; both shipments would be reflected in the CFS. In addition, goods shipped to harbors that are then to be exported are also included in the CFS. To deal with these inconsistencies, Anderson and van Wincoop (2003) attempt to eliminate wholesale shipments by multiplying all bilateral shipment values from the CFS by a constant factor equal to the ratio of total US merchandise trade to total US shipments as measured by the CFS. Employing the private-use CFS data, Hillberry and Hummels (2003) find that wholesale shipments are less likely to cross state borders. Because wholesale shipments are highly localized, Anderson and van Wincoop's (2003) adjustment using a fixed scalar may result in overvaluing (undervaluing) short (long) shipments. Given this caveat and the fact that the influence of intermediate shipments is less problematic in our case, we simply utilize the original CFS data in the analysis below.[11]

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[11] In particular, it is worth recalling that adjustment of a covariate by a constant factor will affect the estimated coefficient, but not inference regarding the statistical significance of the coefficient (i.e., the t-statistic does not change). Thus, one should be cautious interpreting the magnitude of our results, but not the direction and statistical significance.

With the CFS data in hand, we define trade intensity in equation (1) as

$$Trade_{it} = \frac{\sum_{j,i \neq j} (Shipments_{ijt} + Shipments_{jit})}{\sum_j Shipments_{ijt}} \tag{9}$$

where the numerator reflects the sum of 'exports' plus 'imports' and the denominator is the sum or 'exports' plus intrastate shipments. For the remaining variables, data on GSP come from the US Bureau of Economic Analysis (BEA), while state population and land area are from the Statistical Abstract of the United States (various editions). The measure of distance used in the first-stage gravity model, equation (2), is borrowed from Wolf (2000) and Millimet and Osang (2005). Summary statistics are provided in Table 1.

3 Results

3.1 First-Stage Results

Tables 2 and 3 report the first-stage results corresponding to equations (2) and (5). The results from the first-stage gravity model (Table 2) are similar to those reported in Wolf (2000) and Millimet and Osang (2004). In nearly all cases, the geographic variables are highly significant determinants of inter- and intrastate shipments, both economically and statistically. The results from the first-stage GSP model (Table 3) also are consonant with the existing literature.[12] Specifically, we find a statistically and economically significant, positive impact of trade intensity and lagged GSP, as well as population, on current GSP.

3.2 Baseline Specification

The baseline results corresponding to the estimation of α_3 in equations (1) and (8) are reported in Tables 4-6.[13] The models in Table 4 measures the dependent variables as aggregate toxic releases; the models in Tables 5 and 6 use per capita toxic releases and per area toxic releases (releases per square kilometer), respectively. In all cases, pollution is measured two years ahead. Note that the first-stage regressions are identical across all three tables, as well as across the different categories of toxic releases within each table.

Each table reports the OLS and GMM estimates of equation (1), as well as the GMM-FD estimates of equation (8). Furthermore, we report several diagnostic tests for the GMM and GMM-FD models. We report three tests for weak instruments: F-tests of the joint significance of the instruments in each first-stage regression, Shea's (1997) partial R^2 for each first-stage regression, and Anderson's underidentification test (see Hall et al. 1996). We also report the Anderson-Rubin test that the three endogenous variables

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[12] See, for example, Frankel and Romer (1999) and Edwards (1993) for a review.

[13] The full set of results are available upon request.

– trade intensity, per capita GSP, and per capita GSP squared – are jointly statistically significant. The benefit of the test is that it is robust to the presence of weak instruments (see Dufour 2003).

For the GMM estimates of (1), the first-stage regressions appear sound in terms of the identifying power of the instruments (recall, the first-stage regressions are identical in Tables 4-6). Specifically, the F-tests easily reject the null that the instruments are statistically insignificant in each first-stage regression ($p = 0.00$ in all three cases), the partial R^2's are 0.09 or larger, and the Anderson test easily rejects the null of underidentification ($p = 0.00$). However, the GMM-FD estimates are less reliable as the instruments are not statistically significant according to the F-tests in the two per capita income equations ($p = 0.13$ and $p = 0.14$), and the Anderson underidentification test fails to reject the null ($p = 0.29$).

Turning to the OLS estimates of α_3, we find several instances of negative and statistically significant point estimates (at at least the 90% confidence level) in Tables 4-6; there are no instances of a statistically significant, positive coefficient on trade intensity. In particular, we find that greater trade intensity is associated with lower levels of aggregate total, air, and water releases (Table 4), per capita underground releases (Table 5), and per area underground releases (Table 6). When trade intensity and the per capita income variables are treated as endogenous, we find three instances of negative and statistically significant effects of trade intensity on pollution: aggregate air releases (Table 4), and per capita air and underground releases (Table 5). We also find one instance of a statistically significant, positive impact: per capita land releases (Table 5). The remainder are statistically insignificant at conventional levels. Lastly, while the GMM-FD results should be view skeptically, it is worth noting that in all cases the point estimates are statistically insignificant. Thus, according to the baseline specification, there is little evidence of a harmful effect of trade on pollution, and moderate evidence of a beneficial impact.

3.3 Sensitivity Analysis

To assess the robustness of the previous results, we conduct two sensitivity analyses. First, as discussed above, we re-estimate the models using a more traditional reduced form specification for the first-stage regressions for per capita income and per capita income squared, as shown in equations (6) and (7). This yields an overidentified model, allowing us to compute Hanson's overidentification test. Second, we re-estimate the previous baseline specifications, as well as the models using our alternative instrument set, measuring the dependent variable at time t rather than $t+2$. This contemporaneous specification conforms to the published results in FR.

3.3.1 Alternative Instrument Set

The results using pollution still measured two periods ahead, but relying on our alternative instrument set, are displayed in Tables 7-9. As in the baseline specification, the first-stage models are identical across all three tables and all models within each table. The overidentification test is, however, unique to each model.

In terms of the tests for weak instruments, the models appear more sound than in the previous baseline case. In both the GMM and GMM-FD models, the F-tests for joint significance of the instruments always reject the null at the $p = 0.00$ level, the partial R^2 are 0.22 or higher, and then Anderson underidentification test rejects the null in both cases (GMM: $p = 0.03$; GMM-FD: $p = 0.07$). Finally, there is no instance where the Hanson overidentification test rejects the null at the $p < 0.10$ level. Thus, using our alternative instrument set, the GMM and the GMM-FD results appear reliable.

In terms of the impact of trade intensity, we find five instances where the GMM estimate is negative and statistically significant: aggregate total, air, and water releases (Table 7), and per capita total and air releases (Table 8). Furthermore, taking advantage of our panel data, we find four instances where the GMM-FD estimate is negative and statistically significant: aggregate air releases (Table 7), per capita air releases (Table 8), and per area total and air releases (Table 9).There are no instances of a positive and statistically significant effect of trade intensity in Tables 7-9. Overall, then, the results confirm the baseline results of at worst no harmful effect of trade on the environment, and moderate evidence of a beneficial impact.

3.3.2 Contemporaneous Specification

As our final sensitivity analysis, we replicate Tables 4-9 except now the dependent variable is measured contemporaneously. The results are presented in Appendix B, Tables B1-B6. Comparing Tables 4-6 with Tables B1-B3, we find very few changes of note. In terms of the OLS results, the previous negative and statistically significant coefficients on trade intensity using aggregate water releases (Table 4) and per area underground releases (Table 6) are no longer statistically significant, although the point estimates continue to be negative. The remaining three negative and statistically significant coefficients found previously (Table 4: aggregate total and air releases; Table 5: per capita underground releases) remain so. Moreover, as before, none of the point estimates are positive and statistically significant.

In terms of the GMM results, the three negative and statistically significant coefficients found previously (Table 4: aggregate air releases; Table 5: per capita air, and underground releases), and one positive and statistically significant coefficient (Table 5: per capita land releases) are qualitatively unchanged. However, we now obtain two additional negative and statistically significant point estimates (Table B1: aggregate underground releases; Table B3: per area underground releases). Lastly, we note that the GMM-FD results, although viewed skeptically, continue to all be statistically insignificant.

Turning to the GMM-FD results, we first observe that the Hansen overidentification continues to fail to reject the validity of the instruments at at least the $p < 0.10$ confidence level. In terms of the point estimates, three of the four previous negative and statistically significant coefficients remain so (Table 7: aggregate air releases; Table 8: per capita air releases; Table 9: per area air releases). The impact of trade intensity on per area total releases (Table B6), while continuing to be negative, is no longer statistically significant. However, the impact of trade intensity on aggregate total releases (Table B4) is now negative and statistically significant. Finally, we now also document a positive and statistically significant impact of trade intensity on aggregate, per capita, and per area land releases in Tables B4-B6. As such, there does appear to be a statistically significant short-run effect of trade intensity on land releases, although it is relatively short-lived, and trade intensity overall has either no effect or a beneficial impact on total releases.

4 Conclusion

The debate over the environmental consequences of free trade is not only quite heated, but its resolution will significantly affect policy decisions. However, a consensus has not been forthcoming, given the difficulty with assessing the empirical relationship between trade openness and environmental quality. This difficulty arises because trade patterns, environmental quality, as well as income, may be jointly determined, making causal inferences problematic. Recently, however, Frankel and Rose (2005) significantly advanced the debate through the use of exogenous determinants of trade and per capita income to identify the causal effect of trade on the environment. Using cross-sectional data from 1990 at the country level, the authors find moderate evidence of a beneficial impact of expanded trade on the environmental quality. Revisiting the authors methodology, except using panel data on flows of shipments across US states, we obtain similar, if not stronger, evidence of a beneficial impact of trade on pollution levels.

The confirmation of Frankel and Rose's results using panel data at the subnational level is significant, as subnational data confers several advantages over cross-country data. First, use of data from one country helps ensure consistent measurement of the variables. Second, the greater homogeneity across US states – as opposed to across countries – increases the likelihood that the exogenous variation in trade flows and per capita income used to identify the causal effects is, in fact, exogenous. Third, panel data, which is hard to obtain for a large sample of countries, is available at the subnational level for the US, allowing one to control for time invariant, state unobservables. That being said, the US subnational data is not without its own potential shortcomings. As such, future work should continue to assess the causal relationship between trade and environmental quality using alternative data sets and exploiting alternative sources of exogenous variation in trade patterns and income to ensure the robustness of the findings reported herein and in Frankel and Rose.

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A Appendix

A.1 Pollution Definitions

Definitions of the various pollution categories (available at http://www.scorecard.org).

- **Air Releases**

Total releases to air include all TRI chemicals emitted by a plant from both its smoke stack(s) as well "fugitive" sources (such as leaking valves).

Stack Air Releases. Releases to air that occur through confined air streams, such as stacks, vents, ducts or pipes. Sometimes called releases from a point source.

*Fugitive Air Releases***.** Releases to air that do not occur through a confined air stream, including equipment leaks, evaporative losses from surface impoundments and spills, and releases from building ventilation systems. Sometimes called releases from nonpoint sources.

- **Water Releases**

Releases to water include discharges to streams, rivers, lakes, oceans and other bodies of water. This includes releases from both point sources, such as industrial discharge pipes, and nonpoint sources, such as stormwater runoff, but not releases to sewers or other off-site wastewater treatment facilities. It includes releases to surface waters, but not ground water.

- **Land Releases**

Land releases include all the chemicals disposed on land within the boundaries of the reporting facility, and can include any of the following types of on-site disposal:

RCRA Subtitle C Landfills Wastes which are buried on-site in landfills regulated by RCRA Subtitle C.

Other On-site Landfills Wastes which are buried on-site in landfills that are not regulated by RCRA.

Land Treatment/Application Farming Wastes which are applied or incorporated into soil.

Surface Impoundments Surface impoundments are uncovered holding ponds used to volatilize (evaporate wastes into the surrounding atmosphere) or settle waste materials.

Other Land Disposal Other forms of land disposal, including accidental spills or leaks.

- **Underground Injection**

Underground injection releases fluids into a subsurface well for the purpose of waste disposal. Wastes containing TRI chemicals are injected into either Class I wells or Class V wells:

Class I Injection Wells Class I industrial, municipal, and manufacturing wells inject liquid wastes into deep, confined, and isolated formations below potable water supplies.

Other Injection Wells Include Class II, III, IV, and V wells. Class II oil- and gas-related wells re-inject produced fluids for disposal, enhanced recovery of oil, or hydrocarbon storage. Class III wells are associated with the solution mining of minerals. Class IV wells may inject hazardous or radioactive fluids directly or indirectly into underground sources of drinking water (USDW), only if the injection is part of an authorized CERCLA/RCRA clean-up operation. Class V wells are generally used to inject non-hazardous wastes into or above an underground source of drinking water. Class V wells include all types of injection wells that do not fall under I – IV. They are generally shallow drainage wells, such as floor drains connected to dry wells or drain fields.

B Appendix

Table B1. Impact of Trade Intensity on Current Aggregate Toxic Releases

	Total		Air		Water		Underground		Land	
	Coeff	**SE**	**Coeff**	**SE**	**Coeff**	**SE**	**Coeff**	**SE**	**Coeff**	**SE**
OLS	**-1.01E+08**	5.51E+07	**-3.94E+07**	1.83E+07	-1.47E+07	1.17E+07	-3.72E+07	2.58E+07	2.02E+05	7.00E+06
GMM	-1.28E+08	8.04E+07	**-7.19E+07**	2.84E+07	-1.83E+07	1.77E+07	**-6.81E+07**	3.61E+07	1.58E+07	1.27E+07
Anderson-Rubin Test of Joint Significance of Endog. Vars.	$\chi^2(1) = 4.74$ [p=0.19]		$\chi^2(1) = 9.02$ [p=0.03]		$\chi^2(1) = 1.27$ [p=0.74]		$\chi^2(1) = 4.21$ [p=0.24]		$\chi^2(1) = 6.65$ [p=0.08]	
F-test of Joint Significance of Instruments	[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]	
Shea's Partial R^2	0.27, 0.09 0.09		0.27, 0.09 0.09		0.27, 0.09 0.09		0.27, 0.09 0.09		0.27, 0.09 0.09	
Anderson Underidentification Test	$\chi^2(1) = 8.45$ [p=0.00]		$\chi^2(1) = 8.45$ [p=0.00]		$\chi^2(1) = 8.45$ [p=0.00]		$\chi^2(1) = 8.45$ [p=0.00]		$\chi^2(1) = 8.45$ [p=0.00]	
GMM-FD	2.69E+08	6.51E+08	-3.40E+07	5.21E+07	1.42E+08	3.46E+08	1.19E+08	2.85E+08	1.58E+07	2.77E+07
Anderson-Rubin Test of Joint Significance of Endog. Vars.	$\chi^2(1) = 2.19$ [p=0.53]		$\chi^2(1) = 2.62$ [p=0.45]		$\chi^2(1) = 1.49$ [p=0.68]		$\chi^2(1) = 2.32$ [p=0.51]		$\chi^2(1) = 2.55$ [p=0.47]	
F-test of Joint Significance of Instruments	[p=0.00, 0.13, 0.14]		[p=0.00, 0.13, 0.14]		[p=0.00, 0.13, 0.14]		[p=0.00, 0.13, 0.14]		[p=0.00, 0.13, 0.14]	
Shea's Partial R^2	0.10, 0.24, 0.26		0.10, 0.24, 0.26		0.10, 0.24, 0.26		0.10, 0.24, 0.26		0.10, 0.24, 0.26	
Anderson Underidentification Test	$\chi^2(1) = 1.11$ [p=0.29]		$\chi^2(1) = 1.11$ [p=0.29]		$\chi^2(1) = 1.11$ [p=0.29]		$\chi^2(1) = 1.11$ [p=0.29]		$\chi^2(1) = 1.11$ [p=0.29]	

NOTES:

1. N = 96 in each model. Clustered standard errors reported.
2. Additional controls include income, income squared, per capita area, and a year dummy (OLS and GMM only).
3. Trade intensity, ln(per capita GSP), and ln(per capita GSP) squared are instrumented for using predicted trade intensity, predicted ln(per capita GSP), and predicted ln(per capita GSP) squared.
4. Numbers for the F-tests and R^2 correspond to trade intensity, ln(per capita GSP), and ln(per capita GSP) squared, respectively.
5. Bold indicates statistical significance at at least the $p < 0.10$ level.

Table B2. Impact of Trade Intensity on Current Per Capita Toxic Releases

	Total		Air		Water		Underground		Land	
	Coeff	SE	Coeff	SE	Coeff	SE	Coeff	SE	Coeff	SE
OLS	-7.62	6.76	-1.60	2.22	-2.71	2.67	**-4.95**	2.68	2.15	4.08
GMM	-12.40	13.03	**-10.72**	4.63	-3.42	4.06	**-14.42**	6.76	**13.35**	6.92
Anderson-Rubin Test of Joint Significance of Endog. Vars.	$\chi^2(1) = 3.62$ [p=0.31]		$\chi^2(1) = 13.70$ [p=0.00]		$\chi^2(1) = 1.69$ [p=0.64]		$\chi^2(1) = 25.50$ [p=0.00]		$\chi^2(1) = 6.29$ [p=0.10]	
F-test of Joint Significance of Instruments	[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]	
Shea's Partial R^2	0.27, 0.09 0.09		0.27, 0.09 0.09		0.27, 0.09 0.09		0.27, 0.09 0.09		0.27, 0.09 0.09	
Anderson Underidentification Test	$\chi^2(1) = 8.45$ [p=0.00]		$\chi^2(1) = 8.45$ [p=0.00]		$\chi^2(1) = 8.45$ [p=0.00]		$\chi^2(1) = 8.45$ [p=0.00]		$\chi^2(1) = 8.45$ [p=0.00]	
GMM-FD	75.43	157.48	-20.70	29.65	38.82	90.80	44.60	71.27	4.30	9.48
Anderson-Rubin Test of Joint Significance of Endog. Vars.	$\chi^2(1) = 5.18$ [p=0.16]		$\chi^2(1) = 10.87$ [p=0.01]		$\chi^2(1) = 1.70$ [p=0.64]		$\chi^2(1) = 8.01$ [p=0.05]		$\chi^2(1) = 1.59$ [p=0.66]	
F-test of Joint Significance of Instruments	[p=0.00, 0.13, 0.14]		[p=0.00, 0.13, 0.14]		[p=0.00, 0.13, 0.14]		[p=0.00, 0.13, 0.14]		[p=0.00, 0.13, 0.14]	
Shea's Partial R^2	0.10, 0.24, 0.26		0.10, 0.24, 0.26		0.10, 0.24, 0.26		0.10, 0.24, 0.26		0.10, 0.24, 0.26	
Anderson Underidentification Test	$\chi^2(1) = 1.11$ [p=0.29]		$\chi^2(1) = 1.11$ [p=0.29]		$\chi^2(1) = 1.11$ [p=0.29]		$\chi^2(1) = 1.11$ [p=0.29]		$\chi^2(1) = 1.11$ [p=0.29]	

NOTES:

1. Bold indicates statistical significance at at least the $p < 0.10$ level.
2. See Table B1.

Table B3. Impact of Trade Intensity on Current Per Area Toxic Releases

	Total		**Air**		**Water**		**Underground**		**Land**	
	Coeff	**SE**	**Coeff**	**SE**	**Coeff**	**SE**	**Coeff**	**SE**	**Coeff**	**SE**
OLS	-22.15	271.18	155.57	105.27	-87.59	103.60	-136.00	92.28	7.28	28.28
GMM	-89.35	504.61	-79.76	200.60	-57.20	159.11	**-337.22**	195.37	70.61	51.01
Anderson-Rubin Test of Joint Significance of Endog. Vars.	$\chi^2(1) = 0.07$ [p=1.00]		$\chi^2(1) = 0.96$ [p=0.81]		$\chi^2(1) = 3.36$ [p=0.34]		$\chi^2(1) = 4.16$ [p=0.25]		$\chi^2(1) = 3.91$ [p=0.27]	
F-test of Joint Significance of Instruments	[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]	
Shea's Partial R^2	0.27, 0.09 0.09		0.27, 0.09 0.09		0.27, 0.09 0.09		0.27, 0.09 0.09		0.27, 0.09 0.09	
Anderson Underidentification Test	$\chi^2(1) = 8.45$ [p=0.00]		$\chi^2(1) = 8.45$ [p=0.00]		$\chi^2(1) = 8.45$ [p=0.00]		$\chi^2(1) = 8.45$ [p=0.00]		$\chi^2(1) = 8.45$ [p=0.00]	
GMM-FD	-196.92	4464.58	-1966.27	2039.72	1612.37	3524.89	433.13	1585.24	175.16	270.94
Anderson-Rubin Test of Joint Significance of Endog. Vars.	$\chi^2(1) = 4.10$ [p=0.25]		$\chi^2(1) = 15.63$ [p=0.00]		$\chi^2(1) = 2.56$ [p=0.47]		$\chi^2(1) = 2.18$ [p=0.54]		$\chi^2(1) = 2.86$ [p=0.41]	
F-test of Joint Significance of Instruments	[p=0.00, 0.13, 0.14]		[p=0.00, 0.13, 0.14]		[p=0.00, 0.13, 0.14]		[p=0.00, 0.13, 0.14]		[p=0.00, 0.13, 0.14]	
Shea's Partial R^2	0.10, 0.24, 0.26		0.10, 0.24, 0.26		0.10, 0.24, 0.26		0.10, 0.24, 0.26		0.10, 0.24, 0.26	
Anderson Underidentification Test	$\chi^2(1) = 1.11$ [p=0.29]		$\chi^2(1) = 1.11$ [p=0.29]		$\chi^2(1) = 1.11$ [p=0.29]		$\chi^2(1) = 1.11$ [p=0.29]		$\chi^2(1) = 1.11$ [p=0.29]	

NOTES:

1. Bold indicates statistical significance at at least the $p < 0.10$ level.
2. See Table B1.

Table B4. Impact of Trade Intensity on Current Aggregate Toxic Releases: Alternative Instrument Set

	Total		Air		Water		Underground		Land	
	Coeff	**SE**	**Coeff**	**SE**	**Coeff**	**SE**	**Coeff**	**SE**	**Coeff**	**SE**
GMM	**-1.48E+08**	5.10E+07	**-8.67E+07**	2.15E+07	**-9.14E+06**	4.33E+06	-1.11E+07	1.67E+07	-8.81E+05	6.86E+06
Anderson-Rubin Test of Joint Significance of Endog. Vars.	$\chi^2(1) = 74.37$ [p=0.00]		$\chi^2(1) = 139.03$ [p=0.00]		$\chi^2(1) = 9.88$ [p=0.77]		$\chi^2(1) = 13.14$ [p=0.52]		$\chi^2(1) = 62.16$ [p=0.00]	
F-test of Joint Significance of Instruments	[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]	
Shea's Partial R^2	0.51, 0.22, 0.22		0.51, 0.22, 0.22		0.51, 0.22, 0.22		0.51, 0.22, 0.22		0.51, 0.22, 0.22	
Anderson Underidentification Test	$\chi^2(1) = 22.47$ [p=0.03]		$\chi^2(1) = 22.47$ [p=0.03]		$\chi^2(1) = 22.47$ [p=0.03]		$\chi^2(1) = 22.47$ [p=0.03]		$\chi^2(1) = 22.47$ [p=0.03]	
Hansen Overidentification Test	[p=0.17]		[p=0.14]		[p=0.60]		[p=0.79]		[p=0.15]	
GMM-FD	**-2.66E+08**	1.44E+08	**-2.79E+07**	9.82E+06	3.29E+06	7.13E+06	-1.14E+07	1.26E+07	**1.59E+07**	6.27E+06
Anderson-Rubin Test of Joint Significance of Endog. Vars.	$\chi^2(1) = 27.77$ [p=0.02]		$\chi^2(1) = 52.61$ [p=0.00]		$\chi^2(1) = 5.33$ [p=0.98]		$\chi^2(1) = 33.37$ [p=0.00]		$\chi^2(1) = 36.80$ [p=0.00]	
F-test of Joint Significance of Instruments	[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]	
Shea's Partial R^2	0.66, 0.39, 0.39		0.66, 0.39, 0.39		0.66, 0.39, 0.39		0.66, 0.39, 0.39		0.66, 0.39, 0.39	
Anderson Underidentification Test	$\chi^2(1) = 19.98$ [p=0.07]		$\chi^2(1) = 19.98$ [p=0.07]		$\chi^2(1) = 19.98$ [p=0.07]		$\chi^2(1) = 19.98$ [p=0.07]		$\chi^2(1) = 19.98$ [p=0.07]	
Hansen Overidentification Test	[p=0.82]		[p=0.39]		[p=0.76]		[p=0.84]		[p=0.80]	

NOTES:

1. Trade intensity, ln(per capita GSP), and ln(per capita GSP) squared are instrumented for using predicted trade intensity, predicted openness squared, ln(population), ln(population) squared, population growth, population growth squared, lagged ln(per capita GSP), lagged ln(per capita GSP) squared, and a full set of interactions (excluding the quadratic terms).
2. Bold indicates statistical significance at at least the $p < 0.10$ level.
3. See Table B1.

Table B5. Impact of Trade Intensity on Current Per Capita Toxic Releases: Alternative Instrument Set

	Total		Air		Water		Underground		Land	
	Coeff	SE	Coeff	SE	Coeff	SE	Coeff	SE	Coeff	SE
GMM	**-12.43**	3.18	**-6.61**	3.31	-0.48	0.90	**-2.49**	1.50	2.84	2.61
Anderson-Rubin Test of Joint Significance of Endog. Vars.	$\chi^2(1) = 136.60$ [p=0.00]		$\chi^2(1) = 122.91$ [p=0.00]		$\chi^2(1) = 6.47$ [p=0.95]		$\chi^2(1) = 734.33$ [p=0.00]		$\chi^2(1) = 56.53$ [p=0.00]	
F-test of Joint Significance of Instruments	[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]	
Shea's Partial R^2	0.51, 0.22, 0.22		0.51, 0.22, 0.22		0.51, 0.22, 0.22		0.51, 0.22, 0.22		0.51, 0.22, 0.22	
Anderson Underidentification Test	$\chi^2(1) = 22.47$ [p=0.03]		$\chi^2(1) = 22.47$ [p=0.03]		$\chi^2(1) = 22.47$ [p=0.03]		$\chi^2(1) = 22.47$ [p=0.03]		$\chi^2(1) = 22.47$ [p=0.03]	
Hansen Overidentification Test	[p=0.28]		[p=0.19]		[p=0.94]		[p=0.65]		[p=0.16]	
GMM-FD	-3.97	6.28	**-5.60**	1.67	-0.16	2.33	-2.11	2.83	**4.29**	2.44
Anderson-Rubin Test of Joint Significance of Endog. Vars.	$\chi^2(1) = 17.94$ [p=0.21]		$\chi^2(1) = 50.31$ [p=0.00]		$\chi^2(1) = 4.05$ [p=1.00]		$\chi^2(1) = 88.57$ [p=0.00]		$\chi^2(1) = 75.17$ [p=0.00]	
F-test of Joint Significance of Instruments	[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]	
Shea's Partial R^2	0.66, 0.39, 0.39		0.66, 0.39, 0.39		0.66, 0.39, 0.39		0.66, 0.39, 0.39		0.66, 0.39, 0.39	
Anderson Underidentification Test	$\chi^2(1) = 19.98$ [p=0.07]		$\chi^2(1) = 19.98$ [p=0.07]		$\chi^2(1) = 19.98$ [p=0.07]		$\chi^2(1) = 19.98$ [p=0.07]		$\chi^2(1) = 19.98$ [p=0.07]	
Hansen Overidentification Test	[p=0.61]		[p=0.51]		[p=0.92]		[p=0.78]		[p=0.56]	

NOTES:

1. Bold indicates statistical significance at at least the $p < 0.10$ level.
2. See Table B4.

Table B6. Impact of Trade Intensity on Current Per Area Toxic Releases: Alternative Instrument Set

	Total		**Air**		**Water**		**Underground**		**Land**	
	Coeff	**SE**	**Coeff**	**SE**	**Coeff**	**SE**	**Coeff**	**SE**	**Coeff**	**SE**
GMM	-81.82	148.40	4.51	81.89	-3.57	26.93	-96.20	72.84	44.42	29.54
Anderson-Rubin Test of Joint Significance of Endog. Vars.	$\chi^2(1) = 32.44$ [p=0.00]		$\chi^2(1) = 98.86$ [p=0.00]		$\chi^2(1) = 10.15$ [p=0.75]		$\chi^2(1) = 12.02$ [p=0.61]		$\chi^2(1) = 69.72$ [p=0.00]	
F-test of Joint Significance of Instruments	[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]	
Shea's Partial R^2	0.51, 0.22, 0.22		0.51, 0.22, 0.22		0.51, 0.22, 0.22		0.51, 0.22, 0.22		0.51, 0.22, 0.22	
Anderson Underidentification Test	$\chi^2(1) = 22.47$ [p=0.03]		$\chi^2(1) = 22.47$ [p=0.03]		$\chi^2(1) = 22.47$ [p=0.03]		$\chi^2(1) = 22.47$ [p=0.03]		$\chi^2(1) = 22.47$ [p=0.03]	
Hansen Overidentification Test	[p=0.70]		[p=0.77]		[p=0.94]		[p=0.66]		[p=0.19]	
GMM-FD	-311.28	420.31	**-235.16**	132.34	62.89	75.57	-101.04	86.16	**78.90**	32.25
Anderson-Rubin Test of Joint Significance of Endog. Vars.	$\chi^2(1) = 10.65$ [p=0.71]		$\chi^2(1) = 68.40$ [p=0.00]		$\chi^2(1) = 7.9$ [p=0.89]		$\chi^2(1) = 8.91$ [p=0.84]		$\chi^2(1) = 15.90$ [p=0.32]	
F-test of Joint Significance of Instruments	[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]	
Shea's Partial R^2	0.66, 0.39, 0.39		0.66, 0.39, 0.39		0.66, 0.39, 0.39		0.66, 0.39, 0.39		0.66, 0.39, 0.39	
Anderson Underidentification Test	$\chi^2(1) = 19.98$ [p=0.07]		$\chi^2(1) = 19.98$ [p=0.07]		$\chi^2(1) = 19.98$ [p=0.07]		$\chi^2(1) = 19.98$ [p=0.07]		$\chi^2(1) = 19.98$ [p=0.07]	
Hansen Overidentification Test	[p=0.78]		[p=0.54]		[p=0.42]		[p=0.89]		[p=0.68]	

NOTES:

1. Bold indicates statistical significance at at least the $p < 0.10$ level.
2. See Table B4.

Table 1. Summary Statistics

Variable	Mean	Std. Deviation	Years
Per Capita GSP (Current)	17105.37	2766.42	1993, 1997
Per Capita GSP (Initial)	14106.34	2420.61	1977, 1980
Population	5497975	5855139	1993, 1997
Populatin Growth	0.01	0.01	1993, 1997
Per Capita Area	0.07	0.11	1993, 1997
Trade Intensity	1.30	0.23	1993, 1997
Predicted Trade Intensity	1.40	0.55	1993, 1997
Aggregate Toxic Releases			
Total	58000000	70900000	1993, 1997
Total	50349210	52988089	1995, 1999
Air	29200000	28400000	1993, 1997
Air	26637327	26347185	1995, 1999
Water	5319773	22200000	1993, 1997
Water	4641732	7503183	1995, 1999
Underground	8288987	28400000	1993, 1997
Underground	4657555	16781199	1995, 1999
Land	7101876	10900000	1993, 1997
Land	6602943	10728116	1995, 1999
Per Capita Toxic Releases			
Total	13.36	14.95	1993, 1997
Total	11.36	10.36	1995, 1999
Air	6.34	6.35	1993, 1997
Air	5.71	5.36	1995, 1999
Water	1.15	5.07	1993, 1997
Water	0.97	1.36	1995, 1999
Underground	1.77	5.85	1993, 1997
Underground	0.88	2.98	1995, 1999
Land	2.59	7.27	1993, 1997
Land	2.39	7.23	1995, 1999
Per Area Toxic Releases			
Total	524.76	593.02	1993, 1997
Total	447.49	421.97	1995, 1999
Air	286.59	270.94	1993, 1997
Air	251.21	232.25	1995, 1999
Water	53.82	199.18	1993, 1997
Water	47.83	74.22	1995, 1999
Underground	48.97	173.19	1993, 1997
Underground	23.50	75.85	1995, 1999
Land	43.55	58.11	1993, 1997
Land	39.61	55.56	1995, 1999

Table 2. Gravity Equation Results (OLS Estimates)

	Coefficient	**Robust Standard Error**
ln(Distance)	**-0.90**	0.02
ln(Population_1)	**1.08**	0.01
ln(Population_2)	**1.06**	0.01
ln(Remoteness_1)	0.10	0.09
ln(Remoteness_2)	**0.77**	0.09
North_1 (1 = Yes)	**0.18**	0.06
North_2 (1 = Yes)	**0.02**	0.05
South_1 (1 = Yes)	**-0.27**	0.04
South_2 (1 = Yes)	**-0.28**	0.04
East_1 (1 = Yes)	**-0.41**	0.06
East_2 (1 = Yes)	**-0.44**	0.04
1997 Dummy	**0.35**	0.04
Border (1 = Yes)	**0.73**	0.05
ln(Area)	**-0.10**	0.02
Home Dummy	**1.56**	0.10
Constant	-18.68	0.32

NOTES:

1. $N = 4228$
2. $R^2 = 0.88$
3. Bold indicates statistical significance at at least the $p < 0.10$ level.

Table 3. Determinants of GSP (GMM Estimates).

	Coefficient	Robust Standard Error
Trade Intensity	**0.27**	0.11
ln(Population)	**0.06**	0.02
ln(Lagged GSP)	**0.62**	0.09
Population Growth	-1.54	1.35
1997 Dummy	**0.10**	0.01
Anderson-Rubin Test of Significance of Endogenous Variable	$\chi^2(1) = 6.36$ [p=0.01]	
F-test of Joint Significance of Instrument	F(1,47) = 102.50 [p=0.00]	
Shea's Partial R^2	0.58	
Anderson Underidentification Test	$\chi^2(1) = 83.61$ [p=0.00]	

NOTES:
1. $N = 96$
2. Openness instrumented for using predicted openness
3. Bold indicates statistical significance at at least the $p < 0.10$ level.

Table 4. Impact of Trade Intensity on Future Aggregate Toxic Releases

	Total		Air		Water		Underground		Land	
	Coeff	**SE**	**Coeff**	**SE**	**Coeff**	**SE**	**Coeff**	**SE**	**Coeff**	**SE**
OLS	**-7.85E+07**	4.61E+07	**-3.81E+07**	1.83E+07	**-8.78E+06**	5.19E+06	-2.51E+07	1.82E+07	1.41E+06	7.08E+06
GMM	-8.24E+07	6.85E+07	**-6.77E+07**	2.75E+07	-3.78E+06	4.46E+07	-4.07E+07	2.58E+07	1.62E+07	1.30E+07
Anderson-Rubin Test of Joint Significance of Endog. Vars.	$\chi^2(1)$ =5.70 [p=0.13]		$\chi^2(1)$ = 8.86 [p=0.03]		$\chi^2(1)$ = 1.08 [p=0.78]		$\chi^2(1)$ = 2.74 [p=0.43]		$\chi^2(1)$ = 7.87 [p=0.05]	
F-test of Joint Significance of Instruments	[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]	
Shea's Partial R^2	0.27, 0.09, 0.09		0.27, 0.09, 0.09		0.27, 0.09, 0.09		0.27, 0.09, 0.09		0.27, 0.09, 0.09	
Anderson Underidentification Test	$\chi^2(1)$ = 8.45 [p=0.00]		$\chi^2(1)$ = 8.45 [p=0.00]		$\chi^2(1)$ = 8.45 [p=0.00]		$\chi^2(1)$ = 8.45 [p=0.00]		$\chi^2(1)$ = 8.45 [p=0.00]	
GMM-FD	4.01E+07	1.08E+08	-2.35E+07	3.71E+07	5.19E+06	2.44E+07	3.00E+07	6.24E+07	1.97E+07	2.43E+07
Anderson-Rubin Test of Joint Significance of Endog. Vars.	$\chi^2(1)$ = 4.26 [p=0.23]		$\chi^2(1)$ = 1.40 [p=0.71]		$\chi^2(1)$ = 3.31 [p=0.35]		$\chi^2(1)$ = 1.38 [p=0.71]		$\chi^2(1)$ = 6.51 [p=0.09]	
F-test of Joint Significance of Instruments	[p=0.00, 0.13, 0.14]		[p=0.00, 0.13, 0.14]		[p=0.00, 0.13, 0.14]		[p=0.00, 0.13, 0.14]		[p=0.00, 0.13, 0.14]	
Shea's Partial R^2	0.10, 0.24, 0.26		0.10, 0.24, 0.26		0.10, 0.24, 0.26		0.10, 0.24, 0.26		0.10, 0.24, 0.26	
Anderson Underidentification Test	$\chi^2(1)$ = 1.11 [p=0.29]		$\chi^2(1)$ = 1.11 [p=0.29]		$\chi^2(1)$ = 1.11 [p=0.29]		$\chi^2(1)$ = 1.11 [p=0.29]		$\chi^2(1)$ = 1.11 [p=0.29]	

NOTES:

1. Dependent variable is measured two years forward. N = 96 in each model. Clustered standard errors reported.
2. Additional controls include income, income squared, per capita area, and a year dummy (OLS and GMM only).
3. Trade intensity, ln(per capita GSP), and ln(per capita GSP) squared are instrumented for using predicted trade intensity, predicted ln(per capita GSP), and predicted ln(per capita GSP) squared.
4. Numbers for the F-tests and R^2 correspond to trade intensity, ln(per capita GSP), and ln(per capita GSP) squared, respectively.
5. Bold indicates statistical significance at at least the $p < 0.10$ level.

Table 5. Impact of Trade Intensity on Future Per Capita Toxic Releases

	Total		Air		Water		Underground		Land	
	Coeff	**SE**	**Coeff**	**SE**	**Coeff**	**SE**	**Coeff**	**SE**	**Coeff**	**SE**
OLS	-3.84	4.67	-2.14	2.08	-0.76	0.61	**-2.95**	1.52	2.05	4.22
GMM	-3.60	9.50	**-9.20**	4.17	0.20	1.45	**-9.94**	5.38	**13.13**	7.83
Anderson-Rubin Test of Joint Significance of Endog. Vars.	$\chi^2(1) = 1.47$ [p=0.69]		$\chi^2(1) = 15.88$ [p=0.00]		$\chi^2(1) = 3.71$ [p=0.30]		$\chi^2(1) = 25.49$ [p=0.00]		$\chi^2(1) = 5.33$ [p=0.15]	
F-test of Joint Significance of Instruments	[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]	
Shea's Partial R^2	0.27, 0.09, 0.09		0.27, 0.09, 0.09		0.27, 0.09, 0.09		0.27, 0.09, 0.09		0.27, 0.09, 0.09	
Anderson Underidentification Test	$\chi^2(1) = 8.45$ [p=0.00]		$\chi^2(1) = 8.45$ [p=0.00]		$\chi^2(1) = 8.45$ [p=0.00]		$\chi^2(1) = 8.45$ [p=0.00]		$\chi^2(1) = 8.45$ [p=0.00]	
GMM-FD	4.97	19.09	-9.03	14.03	1.94	7.99	4.69	9.44	9.54	11.69
Anderson-Rubin Test of Joint Significance of Endog. Vars.	$\chi^2(1) = 6.69$ [p=0.08]		$\chi^2(1) = 1.63$ [p=0.65]		$\chi^2(1) = 2.66$ [p=0.45]		$\chi^2(1) = 2.45$ [p=0.48]		$\chi^2(1) = 5.09$ [p=0.17]	
F-test of Joint Significance of Instruments	[p=0.00, 0.13, 0.14]		[p=0.00, 0.13, 0.14]		[p=0.00, 0.13, 0.14]		[p=0.00, 0.13, 0.14]		[p=0.00, 0.13, 0.14]	
Shea's Partial R^2	0.10, 0.24, 0.26		0.10, 0.24, 0.26		0.10, 0.24, 0.26		0.10, 0.24, 0.26		0.10, 0.24, 0.26	
Anderson Underidentification Test	$\chi^2(1) = 1.11$ [p=0.29]		$\chi^2(1) = 1.11$ [p=0.29]		$\chi^2(1) = 1.11$ [p=0.29]		$\chi^2(1) = 1.11$ [p=0.29]		$\chi^2(1) = 1.11$ [p=0.29]	

NOTES:

1. Bold indicates statistical significance at at least the $p < 0.10$ level.
2. See Table 4.

Table 6. Impact of Trade Intensity on Future Per Area Toxic Releases

	Total		Air		Water		Underground		Land	
	Coeff	**SE**	**Coeff**	**SE**	**Coeff**	**SE**	**Coeff**	**SE**	**Coeff**	**SE**
OLS	140.49	211.59	109.85	100.15	17.90	33.22	**-80.48**	47.75	12.55	26.61
GMM	332.15	429.08	-75.67	188.65	134.25	100.20	-148.50	103.91	70.81	49.63
Anderson-Rubin Test of Joint Significance of Endog. Vars.	$\chi^2(1) = 1.09$ [p=0.78]		$\chi^2(1) = 0.58$ [p=0.90]		$\chi^2(1) = 3.21$ [p=0.36]		$\chi^2(1) = 3.06$ [p=0.38]		$\chi^2(1) = 5.82$ [p=0.12]	
F-test of Joint Significance of Instruments	[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]	
Shea's Partial R^2	0.27, 0.09, 0.09		0.27, 0.09, 0.09		0.27, 0.09, 0.09		0.27, 0.09, 0.09		0.27, 0.09, 0.09	
Anderson Underidentification Test	$\chi^2(1) = 8.45$ [p=0.00]		$\chi^2(1) = 8.45$ [p=0.00]		$\chi^2(1) = 8.45$ [p=0.00]		$\chi^2(1) = 8.45$ [p=0.00]		$\chi^2(1) = 8.45$ [p=0.00]	
GMM-FD	-1561.46	1269.56	-1757.46	1699.95	40.20	192.58	98.02	263.58	174.31	242.89
Anderson-Rubin Test of Joint Significance of Endog. Vars.	$\chi^2(1) = 10.07$ [p=0.02]		$\chi^2(1) = 14.17$ [p=0.00]		$\chi^2(1) = 0.35$ [p=0.95]		$\chi^2(1) = 1.53$ [p=0.67]		$\chi^2(1) = 4.79$ [p=0.19]	
F-test of Joint Significance of Instruments	[p=0.00, 0.13, 0.14]		[p=0.00, 0.13, 0.14]		[p=0.00, 0.13, 0.14]		[p=0.00, 0.13, 0.14]		[p=0.00, 0.13, 0.14]	
Shea's Partial R^2	0.10, 0.24, 0.26		0.10, 0.24, 0.26		0.10, 0.24, 0.26		0.10, 0.24, 0.26		0.10, 0.24, 0.26	
Anderson Underidentification Test	$\chi^2(1) = 1.11$ [p=0.29]		$\chi^2(1) = 1.11$ [p=0.29]		$\chi^2(1) = 1.11$ [p=0.29]		$\chi^2(1) = 1.11$ [p=0.29]		$\chi^2(1) = 1.11$ [p=0.29]	

NOTES:

1. Bold indicates statistical significance at at least the *p* < 0.10 level.
2. See Table 4.

Table 7. Impact of Trade Intensity on Future Aggregate Toxic Releases: Alternative Instrument Set

	Total		Air		Water		Underground		Land	
	Coeff	**SE**	**Coeff**	**SE**	**Coeff**	**SE**	**Coeff**	**SE**	**Coeff**	**SE**
GMM	**-1.04E+08**	4.10E+07	**-7.32E+07**	2.01E+07	**-5.34E+06**	3.98E+06	-7.24E+06	8.75E+06	-4.73E+06	6.64E+06
Anderson-Rubin Test of Joint Significance of Endog. Vars.	$\chi^2(1) = 100.95$ [p=0.00]		$\chi^2(1) = 140.36$ [p=0.00]		$\chi^2(1) = 39.23$ [p=0.00]		$\chi^2(1) = 11.66$ [p=0.63]		$\chi^2(1) = 43.62$ [p=0.00]	
F-test of Joint Significance of Instruments	[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]	
Shea's Partial R^2	0.51, 0.22, 0.22		0.51, 0.22, 0.22		0.51, 0.22, 0.22		0.51, 0.22, 0.22		0.51, 0.22, 0.22	
Anderson Underidentification Test	$\chi^2(1) = 22.47$ [p=0.03]		$\chi^2(1) = 22.47$ [p=0.03]		$\chi^2(1) = 22.47$ [p=0.03]		$\chi^2(1) = 22.47$ [p=0.03]		$\chi^2(1) = 22.47$ [p=0.03]	
Hansen Overidentification Test	[p=0.17]		[p=0.13]		[p=0.53]		[p=0.70]		[p=0.20]	
GMM-FD	-1.13E+07	1.23E+07	**-3.22E+07**	9.23E+06	-4.03E+05	2.64E+06	-1.58E+05	2.71E+06	9.99E+06	7.37E+06
Anderson-Rubin Test of Joint Significance of Endog. Vars.	$\chi^2(1) = 34.23$ [p=0.00]		$\chi^2(1) = 47.25$ [p=0.00]		$\chi^2(1) = 12.09$ [p=0.60]		$\chi^2(1) = 18.70$ [p=0.18]		$\chi^2(1) = 72.54$ [p=0.00]	
F-test of Joint Significance of Instruments	[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]	
Shea's Partial R^2	0.66, 0.39, 0.39		0.66, 0.39, 0.39		0.66, 0.39, 0.39		0.66, 0.39, 0.39		0.66, 0.39, 0.39	
Anderson Underidentification Test	$\chi^2(1) = 19.98$ [p=0.07]		$\chi^2(1) = 19.98$ [p=0.07]		$\chi^2(1) = 19.98$ [p=0.07]		$\chi^2(1) = 19.98$ [p=0.07]		$\chi^2(1) = 19.98$ [p=0.07]	
Hansen Overidentification Test	[p=0.45]		[p=0.45]		[p=0.93]		[p=0.86]		[p=0.73]	

NOTES:

1. Trade intensity, ln(per capita GSP), and ln(per capita GSP) squared are instrumented for using predicted trade intensity, predicted openness squared, ln(population), ln(population) squared, population growth, population growth squared, lagged ln(per capita GSP), lagged ln(per capita GSP) squared, and a full set of interactions (excluding the quadratic terms).

2. Bold indicates statistical significance at at least the $p < 0.10$ level.

3. See Table 4.

Table 8. Impact of Trade Intensity on Future Per Capita Toxic Releases: Alternative Instrument Set

	Total		**Air**		**Water**		**Underground**		**Land**	
	Coeff	**SE**	**Coeff**	**SE**	**Coeff**	**SE**	**Coeff**	**SE**	**Coeff**	**SE**
GMM	**-7.90**	4.61	**-5.70**	2.71	-0.37	0.35	-0.87	1.25	1.27	2.75
Anderson-Rubin Test of Joint Significance of Endog. Vars.	$\chi^2(1) = 216.35$ [p=0.00]		$\chi^2(1) = 156.68$ [p=0.00]		$\chi^2(1) = 33.12$ [p=0.00]		$\chi^2(1) = 3632.29$ [p=0.00]		$\chi^2(1) = 47.74$ [p=0.00]	
F-test of Joint Significance of Instruments	[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]	
Shea's Partial R^2	0.51, 0.22, 0.22		0.51, 0.22, 0.22		0.51, 0.22, 0.22		0.51, 0.22, 0.22		0.51, 0.22, 0.22	
Anderson Underidentification Test	$\chi^2(1) = 22.47$ [p=0.03]		$\chi^2(1) = 22.47$ [p=0.03]		$\chi^2(1) = 22.47$ [p=0.03]		$\chi^2(1) = 22.47$ [p=0.03]		$\chi^2(1) = 22.47$ [p=0.03]	
Hansen Overidentification Test	[p=0.22]		[p=0.17]		[p=0.36]		[p=0.85]		[p=0.24]	
GMM-FD	1.73	3.92	**-4.67**	1.84	-0.12	0.74	0.04	0.23	3.18	2.49
Anderson-Rubin Test of Joint Significance of Endog. Vars.	$\chi^2(1) = 21.06$ [p=0.10]		$\chi^2(1) = 55.39$ [p=0.00]		$\chi^2(1) = 8.75$ [p=0.85]		$\chi^2(1) = 39.89$ [p=0.00]		$\chi^2(1) = 26.18$ [p=0.02]	
F-test of Joint Significance of Instruments	[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]	
Shea's Partial R^2	0.66, 0.39, 0.39		0.66, 0.39, 0.39		0.66, 0.39, 0.39		0.66, 0.39, 0.39		0.66, 0.39, 0.39	
Anderson Underidentification Test	$\chi^2(1) = 19.98$ [p=0.07]		$\chi^2(1) = 19.98$ [p=0.07]		$\chi^2(1) = 19.98$ [p=0.07]		$\chi^2(1) = 19.98$ [p=0.07]		$\chi^2(1) = 19.98$ [p=0.07]	
Hansen Overidentification Test	[p=0.60]		[p=0.74]		[p=0.66]		[p=0.69]		[p=0.84]	

NOTES:

1. Bold indicates statistical significance at at least the $p < 0.10$ level.
2. See Table 7.

Table 9. Impact of Trade Intensity on Future Per Area Toxic Releases: Alternative Instrument Set

	Total		Air		Water		Underground		Land	
	Coeff	**SE**	**Coeff**	**SE**	**Coeff**	**SE**	**Coeff**	**SE**	**Coeff**	**SE**
GMM	-56.48	138.65	-29.05	72.63	10.44	22.84	-37.97	27.40	35.39	25.50
Anderson-Rubin Test of Joint Significance of Endog. Vars.	$\chi^2(1)$ =34.04 [p=0.00]		$\chi^2(1)$ = 70.88 [p=0.00]		$\chi^2(1)$ = 35.04 [p=0.00]		$\chi^2(1)$ = 10.21 [p=0.75]		$\chi^2(1)$ = 47.01 [p=0.00]	
F-test of Joint Significance of Instruments	[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]	
Shea's Partial R^2	0.51, 0.22, 0.22		0.51, 0.22, 0.22		0.51, 0.22, 0.22		0.51, 0.22, 0.22		0.51, 0.22, 0.22	
Anderson Underidentification Test	$\chi^2(1)$ = 22.47 [p=0.03]		$\chi^2(1)$ = 22.47 [p=0.03]		$\chi^2(1)$ = 22.47 [p=0.03]		$\chi^2(1)$ = 22.47 [p=0.03]		$\chi^2(1)$ = 22.47 [p=0.03]	
Hansen Overidentification Test	[p=0.30]		[p=0.67]		[p=0.33]		[p=0.68]		[p=0.13]	
GMM-FD	**-305.83**	126.33	**-278.36**	115.49	12.50	25.22	-0.40	11.19	42.89	35.82
Anderson-Rubin Test of Joint Significance of Endog. Vars.	$\chi^2(1)$ = 50.94 [p=0.00]		$\chi^2(1)$ = 39.69 [p=0.00]		$\chi^2(1)$ = 11.74 [p=0.63]		$\chi^2(1)$ = 15.01 [p=0.38]		$\chi^2(1)$ = 33.00 [p=0.00]	
F-test of Joint Significance of Instruments	[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]		[p=0.00, 0.00, 0.00]	
Shea's Partial R^2	0.66, 0.39, 0.39		0.66, 0.39, 0.39		0.66, 0.39, 0.39		0.66, 0.39, 0.39		0.66, 0.39, 0.39	
Anderson Underidentification Test	$\chi^2(1)$ = 19.98 [p=0.07]		$\chi^2(1)$ = 19.98 [p=0.07]		$\chi^2(1)$ = 19.98 [p=0.07]		$\chi^2(1)$ = 19.98 [p=0.07]		$\chi^2(1)$ = 19.98 [p=0.07]	
Hansen Overidentification Test	[p=0.31]		[p=0.79]		[p=0.80]		[p=0.83]		[p=0.82]	

NOTES:

1. Bold indicates statistical significance at at least the $p < 0.10$ level.

2. See Table 7.