Institutions, Comparative Advantage, and the Environment: Why are Developing Countries Polluted?*

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Abstract

This paper proposes that developing countries have high levels of air and water pollution in part because financial, judicial, and labor market institutions provide comparative advantage in clean industries. Weak institutions make countries poor and polluted; strong institutions make countries rich and clean. Strong institutions attract clean production, even conditional on environmental regulation and factor endowments. Clean industries need institutions because clean goods are complex. Cross-country differences in the composition of output between clean and dirty industries explain more of the global distribution of emissions than differences in the techniques used for production do. Partial equilibrium calculations and a quantitative general equilibrium model suggest that strengthening a country's institutions substantially decreases its pollution through relocating dirty industries abroad, though correspondingly increases pollution in other countries.

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1 Introduction

Why are poor countries polluted? Casual observation reveals that acrid air or foul rivers are common in developing country megacities, but systematic environmental differences between rich and poor countries are enormous. Figure 1 compares air and water quality between countries. Each graph shows the cross-sectional, cross-country association between ambient air or water quality and the log of GDP per capita. Poor countries have exponentially worse air and water quality than rich countries. These outcomes have large stakes—the World Health Organization (2021) estimates that ambient outdoor air pollution causes over 4 million global deaths annually, 90 percent of which occur in low- and middle-income countries.

This paper proposes a novel explanation for this pattern: financial, judicial, and labor market institutions provide comparative advantage in clean industries. I find that this explanation, in addition to existing explanations focused on environmental regulation and factor endowments, provides an important and overlooked reason why developing countries are polluted. Weak institutions make countries poor and give countries comparative advantage in polluting industries. Strong institutions make countries rich and provide comparative advantage in clean industries. I primarily define polluting industries as those with high emissions of air and water pollution per dollar of revenue, though I consider alternative definitions.[1]

Several pieces of evidence contribute to this explanation. First, countries with stronger national institutions have better ambient air and water quality. This is consistent with the paper's hypothesis that national institutions affect environmental quality though comparative advantage. It is a weak test, however, since polluted and unpolluted countries differ along dimensions besides institutions, and since institutions may affect pollution through channels besides comparative advantage.

Second, clean industries disproportionately depend on strong institutions. This finding comes from measures of the extent to which each industry depends on each institution. For example, I find that clean industries predominantly use inputs that are traded in bilateral contracts rather than in open exchanges or referenced-priced in industry catalogs, and thus clean industries disproportionately need strong judicial systems to enforce bilateral contracts. Similarly, clean industries disproportionately fund capital investment using external credit institutions like banks. These comparisons also show why institutions provide comparative advantage in clean industries—the production technology, capital structure, and volatility of clean industries disproportionately benefit from institutions.

[1] "Clean industries" in some settings denotes solar, wind, or other forms of energy generation that emit or no pollution. I use a broader interpretation of this phrase to describe any industry with relatively low pollution emissions per dollar of revenue.

Third, stronger national institutions increase the share of exports in clean industries. This provides direct evidence of comparative advantage. Trade research assesses how the interaction of a country's endowments with an industry's reliance on that endowment (e.g, the interaction of a country's capital stock with an industry's capital intensity) predicts industry-specific trade flows. I extend this approach to study how institutions affect the comparative advantage of clean industries. I report estimates from a cross-section of international trade; panel estimates comparing changes in national institutions against changes in international trade over 20 years; looking across manufacturing and all industries; comparing across 15 different measures of institutions and 8 different measures of environmental regulation; instrumenting institutions with countries' legal origins, rates of settler mortality, or population density in the year 1500; using US or multi-country data on pollution intensity; and using intra-national data across states of India.

Institutions have large estimated impacts on pollution. Institutions have comparable importance for clean industries as environmental regulation or factor endowments. Moving a country from the tenth to the ninetieth percentile of institutional quality decreases pollution by 20 percent or more. For an industry one standard deviation cleaner than average, improving an exporter's institutions by one standard deviation has a similar predicted effect on exports as decreasing tariffs by 5 to 10 percentage points. Since mean trade-weighted tariffs are around 2 percent in the US or EU, this corresponds to an enormous change in trade policy.

Why do clean industries depend disproportionately on institutions? I find broadly that clean industries depend on sophisticated, skilled, and specialized inputs, i.e., complex inputs. In regressions, these explanations statistically help account for the comparative advantage that institutions provide in clean industries.

To assess the potential role of comparative advantage, I decompose the extent to which differences in pollution emissions between countries reflect differences in the scale of total output, the composition of output across industries, and the techniques used to produce output in a given industry. For example, this decomposition asks: how would India's pollution change if India's firms used US production techniques versus if the composition of output across industries in India matched the US distribution? This resembles a decomposition commonly used in the literature studying environmental change within a country and over time, but modified to compare across countries and within a time period. Globally, I find that composition has similar or greater importance than technique in explaining international differences in environmental quality, which suggests there is scope for comparative advantage to drive international environmental patterns.

The paper's final approach uses a model of trade, pollution, and institutions to quantify how improving institutions in some countries changes pollution in all countries. I use a structural gravity model with pollution (Costinot and Rodriguez-Clare 2014; Shapiro 2021) where national institutions change a country's productivity across industries. The comparative advantage regressions of the earlier sections estimate a key parameter governing the productivity benefit of institutions.

I use the model to analyze three counterfactual scenarios. In the first, institutions in all countries change to equal the global mean institutional quality. In the second counterfactual, institutions in weak-institution countries improve to a high level. In the third counterfactual, institutions improve in Latin America, one region with especially weak institutions.

I find that all three counterfactuals decrease pollution emissions in poor countries and increase emissions in rich countries. In the first two counterfactuals, for example, pollution falls by 3 to 10 percent in Eastern Europe and Latin America but increases by 5 to 10 percent in Northern Europe, Japan and Korea. In the third counterfactual, pollution falls by 20 percent in Latin America but increases modestly in all other regions. For comparison, a 20 percent decline in pollution would be a larger decrease in particulate matter air pollution than the US experienced in the early 1980s recession, but a smaller decrease than occurred around the 1970 US Clean Air Act Amendments (Chay and Greenstone 2003*a*,*b*).

To clarify the paper's main ideas, consider a simple example. The Fluid Pumps industry, which builds hydraulic and pneumatic pumps used in industrial machines, emits little air or water pollution. The Gypsum Products industry, which produces wallboard and plaster, emits high levels of air and water pollution.

The cleaner industry in this example depends more on each type of institution. The cleaner (pumps) industry needs strong financial institutions, since it has modest annual cash flow relative to its capital investments. The pumps industry also relies on judicial institutions, since it mainly uses specialized inputs like machines that require bilateral contracts with suppliers. Finally, the pumps industry depends on flexible labor market institutions, since its annual sales change substantially in most years, which can require hiring or firing workers. In comparison, the dirtier (gypsum) industry relies less on financial institutions, since it has high cash flow relative to capital investments. The dirtier gypsum industry primarily uses homogeneous inputs like coal, stone, and paperboard, which are traded on exchanges or through industry publications. Finally, the dirtier (gypsum) industry relies less on flexible labor market institutions, since its firms have relatively steady mean annual sales.[2]

This paper essentially combines three ideas that I believe are each fairly uncontroversial, but that together imply that institutions help explain international differences in environmental quality. First, comparative advantage drives international trade. This reflects a core principle of trade

[2]This example discusses the 2012 NAICS industry codes 333996 and 327420.

research, including Ricardian models, Heckscher-Ohlin models, and others. Second, institutions provide a source of comparative advantage. This reflects many papers, methods, and data (e.g., Nunn 2007; Levchenko 2007; Costinot 2009; Chor 2010; Boehm 2022). Third, industries that need strong institutions are clean. I provide the first test and evidence of the third channel. I emphasize that it describes correlation but need not analyze causation—given the finding that institutions drive comparative advantage, the key question is whether the industries that benefit from institutions are relatively clean. While I provide additional analysis and evidence beyond these three steps, the simplicity of this logic I believe suggests that this paper's conclusions rest on mostly well-known premises.

This paper departs from existing literature in several ways. I believe it is the first comprehensive analysis of how institutions contribute to international differences in environmental quality through comparative advantage. This provides a new mechanism underlying the relationship between international trade and the environment. Existing research on trade and the environment focuses on environmental regulation and endowments of capital and labor as the main drivers of international differences in environmental quality (Antweiler, Copeland and Taylor 2001).[3] The idea that regions may use weak levels or enforcement of environmental policy to attract dirty industries (the "Pollution Havens Hypothesis") is among the most influential ideas in research on trade and the environment, and I build on literature seeking to understand the limited empirical support for this Hypothesis (Cherniwchan, Copeland and Taylor 2017).[4] The Environmental Kuznets Curve literature (Grossman and Krueger 1995) proposes that a country's pollution has an inverted U-shaped relationship to income per capita. Interpretations of that pattern attribute it to consumer preferences, structural transformation from agriculture to manufacturing to services, increasing returns to pollution abatement, or voting rules that determine environmental regulation, among others (Arrow et al. 1995; Stokey 1998; Andreoni and Levinson 2001; Jones and Manuelli 2001). The evidence for the inverted-U pattern is mixed (Stern 2017), and international comparisons of pollution find higher levels in developing countries for at least some pollutants (Greenstone and Hanna 2014; Jayachandran 2022). Andersen (2016; 2017) finds that ambient air pollution declines when a country creates

[3]A few papers refer to environmental regulation, and Jones and Manuelli (2001) theoretically analyze voting rules, as types of institutions. I use "institutions" to refer to judicial, financial, and labor market institutions, which I distinguish from environmental regulation, though I carefully compare them.

[4]Given the importance of the Pollution Havens Hypothesis, a brief history is informative and I do not think is available elsewhere. The first published mention of "pollution havens" appears to be from the late 1960s, in discussions of how US states used weak environmental policy to attract industrial activity (Hughes 1967; Lieber 1968; Metzler 1968). Russell and Landsberg's (1971) paper in *Science* popularized use of the phrase to describe international industry relocation. The pollution havens "hypothesis" was introduced in the early 1990s around environmental debates involving the North American Free Trade Agreement (Molina 1993; Birdsall and Wheeler 1993; Harrison 1994).

a credit bureau and that US manufacturing firms with better credit ratings have lower pollution emissions.

Unlike much research at the intersection of development and environment, which focuses on demand-side reasons like income or preferences for why poor countries have more pollution (Greenstone and Jack 2015), I focus on how comparative advantage instead represents a supply-side story wherein providing environmental quality is more costly in countries with weak institutions. Classic work emphasizes that property rights over natural resources like timber or groundwater increase investment in those resources, since owners benefit from the resources' long-run value, though does not attribute environmental benefits of institutions to comparative advantage (Coase 1960; Chichilnisky 1994).

Parts of this paper seek to distinguish how environmental regulation versus institutions drive location choices of dirty industries. Environmental regulation takes many forms, which can be challenging to quantify as a single national measure. I build on existing work, which typically focuses on one or a few measures of regulation, by compiling eight data series with country-level measures of environmental regulation, which I analyze individually and also aggregate via principal components and averaging z-scores. The eight data series measure the level of ambient air quality standards for particulate matter and sulfur dioxide; executives' perceptions of environmental regulation enforcement and stringency; participation in international environmental treaties; standards for lead in gasoline and sulfur in diesel; and environmental taxes as a share of GDP. While no one of these alone provides a perfect measure of regulation, together they provide a more complete picture than has been previously available.

This paper also shows that approaches in the trade literature used to study comparative advantage can shed light on environmental quality. Research has studied how capital, skills, and institutions drive international specialization (Rajan and Zingales 1998; Romalis 2004; Nunn 2007; Chor 2010; Cuñat and Melitz 2012). Broner, Bustos and Carvalho (2011) find that environmental regulation discourages dirty production, though do not examine how institutions affect dirty industries. A broad body of research on institutions recognizes that firms can respond to weak contracting environments through vertical integration (Grossman and Hart 1986; Hart and Moore 1990; Antras 2003); one could interpret this paper's estimates as net of any such firm adaptive responses.

Finally, I provide what I believe is the first decomposition of how scale, composition, and technique explain cross-country differences in environmental quality. The results of this decomposition differ from the prevailing view that composition is an unimportant channel for understanding broad global environmental patterns. Following Grossman and Krueger (1993) and then Copeland and

Taylor (1994), research has asked whether changes in the scale of production, the composition of production across industries, or the techniques used to produce goods within industries most accounts for differences in environmental quality. Recent analyses of the US, EU, and Canada with national data, and dozens of other countries in a multi-region input-output database, typically find that technique, rather than composition, explains most differences in environmental quality within a country and over time (Grether, Mathys and de Melo 2009; Levinson 2009; Brunel 2016; Shapiro and Walker 2018; Copeland, Shapiro and Taylor 2022). Because standard Heckscher-Ohlin models predict that comparative advantage would primarily cause differences in environmental quality through composition, some work proposes based on this empirical finding that canonical theories of comparative advantage do not provide the most compelling explanation for international differences in environmental quality. While those findings account for environmental change within a country and over time, this paper instead provides such a comparison between countries within a year, and finds a more important role for composition effects. It is unclear why existing work has applied this decomposition to the time series within a country rather than the cross-section across countries; the recent availability and limited environmental applications of global multi-region input-output tables in environmental economics may contribute.

The paper proceeds as follows. Section 2 describes the data. Section 3 provides broad cross-country and cross-industry comparisons. Section 4 estimates patterns of comparative advantage. Section 5 provides a decomposition of scale, composition, and technique. Section 6 describes analysis from a quantitative model. Section 7 concludes. Because the sections use a range of methods, I discuss econometrics and theory in each section separately.

2 Data

Appendix Table 1 summarizes variables and data and Appendix A provides additional details. I scale all environmental variables so more positive values represent better environmental quality.

2.1 Country Variables

I use country-level measures of each institution for the year 2012 or closest available year.[5] I re-scale each measure of institutions to z-scores, with a higher value denoting better institutions. Appendix A.1 describes many alternative measures of institutions and environmental regulation for sensitivity analyses.

[5]I use 2012 since several data come from the US Economic Census, collected in years ending in 2 and 7.

I use standard data to measure each institution (Rajan and Zingales 1998; Romalis 2004; Nunn 2007; Chor 2010; Cuñat and Melitz 2012; Manova 2013). I measure financial institutions as the ratio of private credit by deposit and money institutions to GDP, as reported in the World Bank's Financial Structure Database. I measure judicial institutions from the World Bank's Rule of Law index for the year 2012, which seeks to capture the "quality of contract enforcement, property rights, the police, and the courts, as well as the likelihood of crime and violence" (Kaufmann, Kraay and Mastruzzi 2011, p. 223). I measure labor market institutions from the Heritage Foundation (2021)'s labor market freedom index, which reflects hindrance to hiring workers; rigidity of hours; difficulty firing redundant employees; legally mandated notice period; mandatory severance pay; and the ratio of the minimum wage to the mean value added per worker. Sensitivity analyses seek to distinguish two broad concepts of property rights institutions: constraints on the executive, which protect against expropriation, corruption, and other powers of government and elites; and contracting institutions, which secure transactions between citizens (Acemoglu and Johnson 2005).

Labor market institutions can represent two contrasting concepts. The first, which I analyze, describes a labor market's flexibility. The second concept is the presence of a strong social safety net. I can quantify the extent to which each industry benefits from flexibility, according to the volatility of the firms' sales (Cuñat and Melitz 2012). I do not analyze the safety nets measure of labor market institutions because it is less feasible to estimate how each industry depends on safety nets.

I use eight different measures of environmental regulation for each country. To calculate my main measure of a country's environmental regulation, I calculate the first principal component of the measures with the fewest missing country values. I also report a sensitivity analysis that transforms each variable to z-scores, then averages across the measures of environmental regulation for each country. Additionally, I report estimates controlling for each of the eight measures of regulation separately.

The eight environmental regulation measures are as follows. I use data from the World Economic Forum (2013), which surveys executives about environmental policy enforcement in each country, on a scale from 1 (most lax) to 7 (most enforced), and another survey item about environmental policy stringency. I also use information on the number of environmental treaties each country has signed (World Economic Forum 2013), the ratio of environmental tax revenue to GDP (IMF 2022), the 24-hour numerical air quality standards for particulate matter and sulfur dioxide (Joss et al. 2017 in the US, these are called National Ambient Air Quality Standards)[6], lead content standards for

[6]These are the two sets of air quality standards with the fewest missing values across countries in Joss et al. (2017).

gasoline (Broner, Bustos and Carvalho 2011), and sulfur content standards for diesel (UNEP 2022). The principal components measure combines the diesel sulfur standard, environmental regulation stringency, environmental regulation enforcement, and environmental treaties.

I measure factor endowments from standard data. I measure capital endowments as the log of the value of a country's capital stock per worker, and skill endowments as the Penn World Tables calculation of a country's human capital index (Feenstra, Inklaar and Timmer 2021).

A few estimates use ambient pollution levels. I use air pollution data from the World Health Organization, which records the national urban mean of particulate matter smaller than 10 micrometers (PM_{10}), averaged over 2007-2016.[7] I use measures of biochemical oxygen demand, which provides a common omnibus measure of water quality (Keiser and Shapiro 2019), from the Global Environmental Monitoring System for freshwater (GEMStat). These measures of ambient pollution are mostly available for high- and middle-income countries, and fewer of the poorest countries.

Appendix Table 2, Panel A, shows pairwise correlations between country characteristics. Financial and judicial institutions have a strong positive correlation. Labor market institutions have weaker correlation with the other institutions. Countries with stronger institutions have greater capital and skill endowments, though these relationships vary across factors and institutions. Environmental regulation has a positive correlation with institutions, capital, and skills. Most regressions control for environmental regulation and factors separately from institutions.

2.2 Industry Variables

I measure most industry variables for about 350 U.S. 6-digit North American Industry Classification System (NAICS) manufacturing industries in 2012, since the U.S. has higher-quality establishment-level pollution emissions and other data and more industry detail than most countries. I focus on manufacturing since the measures of capital and skills are from the US Census of Manufactures, and to limit concern that discovery and exports of natural resources from the mining sector could directly influence institutions through the "resource curse." Some sensitivity analyses include all industries and not just manufacturing. Applying U.S. pollution rates globally requires the assumption that U.S. industry values represent those values for other countries. This does have the benefit of ensuring these rates are exogenous to conditions in other countries. Given potential bias from assuming that US pollution rates represent all countries (Ciccone and Papaioannou 2023), I also report estimates from Exiobase, which allow industry characteristics including air pollution emission rates to differ by country and industry, and hence avoid the aforementioned assumption that U.S. industry values

[7] PM_{10} is a widely available measure of small particles; measures of even smaller particles ($PM_{2.5}$) are typically estimated to damage health more, but are measured in fewer countries.

represent other countries. Exiobase seeks to measure pollution comparably and flexibly across countries and industries (Stadler et al. 2018).

I use common measures of each industry's factor and institution intensity (Rajan and Zingales 1998; Romalis 2004; Nunn 2007; Chor 2010; Cuñat and Melitz 2012). Measures of each industry's dependence on capital and skills are straightforward. I measure an industry's dependence on financial institutions as the share of the industry's capital expenditures that internal cash flow do not support, using Compustat North America data. I measure an industry's dependence on judicial institutions as the share of the industry's inputs, measured from input-output tables, that are not traded on open markets or reference priced (Rauch 1999). This is also positively correlated with the prevalence of contract litigation (Boehm 2022). I measure an industry's dependence on labor market institutions as the standard deviation of within-firm sales growth, using Compustat data, weighted across firms by each firm's employment.

I measure each industry's clean index from data on air and water pollution emissions. I analyze air and water pollution because they can have large local welfare effects, are the focus of the trade-environment literature, and are feasible to attribute to individual industries. I measure the short tons of air pollution emitted from the 2011 National Emissions Inventory, a comprehensive plant-level emissions dataset collected by the U.S. Environmental Protection Agency. I consider the five "criteria" pollutants that are most widely measured and the focus of regulation: carbon monoxide, nitrogen oxides, particulate matter smaller than 2.5 micrometers, sulfur dioxide, and volatile organic compounds. For each pollutant, I calculate log emissions per dollar of revenue. I measure revenues from the 2012 Census of Manufactures. I measure an industry's air pollution rate as the first principal component of the five log pollutant-specific rates. For water pollution, I measure the log of the total pounds of emissions from the Discharge Monitoring Reports of the US Environmental Protection Agency (EPA) per dollar of revenue (USEPA 2020). I measure an industry's clean index as minus one times the first principal component of the air and water pollution emission rates. I report sensitivity analyses using country×industry data from Exiobase, which measures air but not water pollution, and using the Leontief Inverse matrix to account for emissions embodied in value chains of each industry, including electricity.

Appendix Table 2, Panel B, shows pairwise correlations between industry characteristics. Dependence on judicial and financial institutions have a positive correlation. Dependence on judicial and labor market institutions are independent. Factor intensities have limited correlation. The last row of Appendix Table 2 shows that clean industries have stronger dependence on institutions, lower capital intensity, and higher skill intensity.

2.3 Other Variables

I measure bilateral trade from the *Base pour l'Analyse du Commerce International* (BACI), created by the *Centre d'Etudes Prospectives et d'Informations* (CEPII). I aggregate data to 134 individual countries with non-missing values of key variables, plus one rest-of-world region. I concord these data to distinguish over 350 six-digit NAICS industries.

I use applied tariff rate data from CEPII's Market Access Map (Macmap) database, which accounts for regional and free trade agreements, tariff rate quotas, and other detailed tariff characteristics. Applied tariffs represent the statutory tariff rate, which is weakly less than preferential (Most Favored Nation) tariffs. A 2-digit Harmonized System (HS) code version is online; I purchased the 6 digit HS code version (Guimbard et al. 2012).

I use data from Exiobase, version 3.8.1, industry-by-industry data (Stadler et al. 2018), to separate scale, composition, and technique. Exiobiase is a multi-region input-output table, like the World Input Output Database or Eora. I use Exiobase since it has 163 industries, much more than other world input-output tables. Exiobase distinguishes 49 countries, including several rest-of-world aggregates, spanning the global economy. I also estimate the quantitative model using trade, production, and air pollution data from Exiobase aggregated to 10 regions and 21 industries. The quantitative model uses sector-specific trade elasticities aggregated across four studies (Caliendo and Parro 2015; Shapiro 2016; Giri, Yi and Yilmazkuday 2020; Bagwell, Staiger and Yurukoglu 2021; see also discussion of measures and aggregation in Bartelme et al. (2021) and Shapiro (2021)).

I report one analysis of state-year production in India. These estimates use production microdata from India's 2015-2016 Annual Survey of Industry. The dependent variable in regressions measures gross sales. I measure institutions according to existing measures (Dougherty 2009; Boehm and Oberfield 2020).

3 Cross-Country and Cross-Industry Comparisons

3.1 Cross Country Comparisons

I first report a cross-sectional estimate of whether countries with strong institutions have better environmental quality:

$$Z_i = \rho_0^C + \rho_1^C I_i + \epsilon_i \tag{1}$$

Here Z_i measures ambient air or water quality in country i and I represents the country's institutional quality. Equation (1) provides a weak test of whether institutions affect pollution through comparative advantage. It is weak in part since it represents a cross-section of countries and since institutions are correlated with other variables influencing pollution. Additionally, equation (1) provides no evidence on whether institutions affect pollution through comparative advantage or other channels.

Figure 2 shows binned scatter plots of the quality of a country's environment versus its institutions, as in equation (1). Each observation underlying a graph represents a country. In each graph, the blue dots represent mean values within 15 equal-sized bins and the red line shows the linear trend. The y-axis in the graphs on the left describes ambient air quality, and for graphs on the right it describes water quality. The x-axis measures institutional quality in z-scores. The top two graphs describe financial institutions, the middle two describe judicial institutions, and the bottom two describe labor market institutions.

Figure 2 shows that countries with stronger institutions have better air and water quality. All these relationships have positive slopes. Some relationships, like for air quality and financial or judicial institutions, are roughly linear. Others are less clear. Panel E, but not other graphs, has a slight U shape reminiscent of the Environmental Kuznets Curve literature (Grossman and Krueger 1995).

Table 1 shows regressions of country ambient environmental quality on national institutions, as in equation (1). Panel A describes air quality and Panel B describes water quality. The first three columns show financial, judicial, and labor market institutions. Column (4) shows an index of a country's institutions, measured as the first principal component of financial, judicial, and labor market institutions. For comparison, column (5) shows the association with a country's environmental regulation. All these table entries are beta coefficients, so represent the difference in air or water quality in standard deviations for countries with one standard deviation better institutional quality.

All associations in Table 1 are positive, indicating that countries with stronger institutions have better environmental quality. The coefficients in the first two columns have large magnitude, and imply that a country with one standard deviation better financial or judicial institutions has 0.6 standard deviations better air quality and 0.3 standard deviations better water quality. Column (3) shows that countries with better labor market institutions have slightly better air and water quality, but the magnitude is smaller and statistically insignificant. The smaller association for labor market institutions may reflect the two somewhat opposite definitions of labor market institutions discussed in Section 2.1. Column (4) shows that countries with one standard deviation better institutions overall have 0.3 to 0.5 standard deviations better environmental quality. Comparing columns (4) and (5) shows that environmental regulation and institutions have comparable magnitude associations with air and water quality.

Appendix Table 3 examines the pollution content of exports rather than ambient environmental quality. It also suggests that countries with stronger institutions have better environmental quality. For each country, it calculates the clean index of exports as the mean clean index across industries within a country, weighted by each industry's exports. A country with one standard deviation stronger institutions has 0.4 standard deviations cleaner exports. A country's institutions and environmental regulation have similar associations with the mean clean index of a country's exports.

3.2 Cross Industry Comparisons

I now measure the cross-sectional relationship of each industry's dependence on institutions with what I call the industry's clean index—how little air and water pollution industry s emits per dollar of sales:

$$Z_s = \rho_0^I + \rho_1^I I_s + \epsilon_s \tag{2}$$

I measure Z_s as negative one times the first principal component of log air pollution per dollar and log water pollution per dollar. The term I_s represents the extent to which industry s depends on institutions. As discussed in Section 2.2, for the example of judicial institutions, I_s represents the share of inputs for industry s that are differentiated and so depend on contracts. Finding $\rho_1^I > 0$ would imply that clean industries depend more on institutions, so institutions can provide comparative advantage in clean industries. Equation (2) is descriptive and not causal—it asks whether an industry's clean index is correlated with dependence on institutions.

Before estimating equation (2), Table 2 describes the five cleanest manufacturing industries (Panel A) and five dirtiest manufacturing industries (Panel B). While Table 2 only provides anecdotal comparisons, it previews the general finding that cleaner industries depend more on stronger institutions. Table 2 uses only US data and thus holds national institutions and environmental regulation fixed. Panel A shows that clean industries depend on strong institutions. Column (1) shows that the fluid power pumps and motors industry is 2.4 standard deviations cleaner than the mean industry. Columns (2) through (4) show that this industry depends 1.5 standard deviations more than the mean manufacturing industry does on financial institutions, 0.7 standard deviations more on strong judicial institutions, and 0.9 standard deviations more on flexible labor market institutions.

Panel B of Table 2 shows that dirty industries depend relatively less on institutions. Gypsum product manufacturing, one of the dirtiest manufacturing industries, depends on financial institutions 0.6 standard deviations less than the mean manufacturing industry does. The gypsum products industry also depends on judicial institutions 1.2 standard deviations less than the mean manufacturing industry does, and also depends on labor market institutions 1.2 standard deviations less than the mean industry does.

Column (5) of Table 2 shows mostly positive values for clean industries in Panel A, indicating that they depend more than average on institutions; but negative values for dirty industries in Panel B, indicating that they depend less than average on institutions. On average, the cleanest industries in Table 2 depend 1.9 standard deviations more on institutions than the dirtiest industries do.

Figure 3 shows binned scatter plots describing the relationship between an industry's clean index and its dependence on institutions. Each observation underlying a graph represents one industry. Each blue circle shows the mean for one of 15 evenly-sized bins and the red line shows the linear trend.

The upward-sloping lines in Figure 3 imply that cleaner industries depend more on stronger institutions. Panel A shows that industries that depend relatively more on financial institutions, and thus rely more on external finance and less on free cash flow for their capital investments, are cleaner. Panel B shows that industries which use inputs that are differentiated, and thus depend more on strong judicial institutions, are cleaner. Panel C shows that industries which have volatile sales, and thus may more often seek to hire and fire workers so benefit from flexible labor market institutions, are cleaner. The coefficients in the graphs, corresponding to equation (2), show that the magnitudes of these associations range from 0.14 for labor market institutions to 0.49 for judicial institutions.

4 Regressions: Direct Tests of Comparative Advantage

4.1 Comparative Advantage in All Industries

Methods

I now test whether countries with strong institutions concentrate exports more in clean industries. As Section 6 will discuss, multi-sector Ricardian trade models lead to the following "gravity" equation for international trade (Eaton and Kortum 2002; Costinot, Donaldson and Komunjer 2012; Costinot and Rodriguez-Clare 2014):

$$X_{ij,s} = \xi \frac{T_{i,s}(c_{i,s}\phi_{ij,s})^{-\theta_s}}{(P_{j,s})^{-\theta_s}} X_{j,s} \tag{3}$$

Here $X_{ij,s}$ is the value of bilateral trade from origin country i to destination country j in industry s, $T_{i,s}$ is the level of technology in the exporter and industry, and $c_{i,s}$ is the unit production cost. The full trade cost is $\phi_{ij,s} \equiv \tau_{ij,s}(1 + t_{ijs})$. Goods face iceberg trade costs $\tau_{ij,s} \geq 1$, where τ goods must be shipped for one to arrive, and tariffs $t_{ij,s}$. The elasticity of bilateral trade flows with respect to trade costs, θ_s, is also called the trade elasticity. The importer×industry price index is $P_{j,s}$. The importer's expenditure on goods from industry s is $X_{ij,s}$. The term ξ represents a constant function of model parameters.

To link equation (3) to country endowment×industry characteristic regressions, I make the following assumptions:

$$lnX_{j,s} - \theta_s lnP_{j,s} = \zeta_{j,s} \tag{4}$$

$$lnT_{i,s} = \alpha E_i I_s + \sum_f \beta_f E_i^f I_s^f + \pi R_i Z_s + \omega_{i,s} \tag{5}$$

$$ln\xi - \theta_s lnc_{i,s} - \theta_s ln\phi_{ij,s} = \gamma t_{ij,s} + \eta_{ij} + \omega_{ij,s} \tag{6}$$

$$\epsilon_{ij,s} = \omega_{i,s} + \omega_{ij,s} \tag{7}$$

Equation (4) states that the importer×industry fixed effects $\zeta_{j,s}$ equal the difference of importer×industry log expenditure and scaled prices. Equation (5) states that a country×sector's productivity reflects the interactions of endowments and industry characteristics, plus a stochastic term $\omega_{i,s}$. Equation (6) states that tariffs, bilateral fixed effects η_{ij}, and the error $\omega_{ij,s}$ capture the effects of unit production costs and trade frictions. In these equations, E_i represents the quality of institutions in exporter i, E_i^f is a country's endowment of factor f, I_s^f is the dependence of industry s on factor f, R_i is the stringency of environmental regulation, and Z_s is the clean industry index. Other variables are as defined earlier. The left-hand side of equations (4) through (7) describe components of equation (3). The right-hand side of these equations describe variables, parameters, and fixed effects that either data report or regressions can estimate. I do not include ad valorem measures of non-tariff barriers since they are generally available at the importer×industry level but do not differ by exporter, and thus are perfectly collinear with the fixed effects $\zeta_{j,s}$ (Kee, Nicita and Olarreaga 2009; Shapiro 2021).

Equations (4) through (7) link country endowment×industry intensity terms in data like $E_i I_s$ to country×industry terms in the model like $T_{i,s}$. This connection makes sense—institutions E_i effectively improve a country's technology in industries I_s that benefit from institutions.[8]

[8] Equation (5) includes factors E_i^f. Alternatively, one could describe a model with multiple factors. Equations (4)-(7) use a single factor since they provide simple conditions for a gravity model to generate the endowment×industry intensity variables in the literature.

Under assumptions (4) through (7), equation (3) becomes the following:

$$lnX_{ij,s} = \alpha E_i I_s + \sum_f \beta_f E_i^f I_s^f + \pi R_i Z_s + \gamma t_{ij,s} + \zeta_{j,s} + \eta_{ij} + \epsilon_{ij,s} \quad (8)$$

Many trade papers report a test for comparative advantage which interacts an exporter's endowments with an industry's characteristics, like equation (8). Equations (4) through (7) describe one way to derive such an equation from a Ricardian trade model. The coefficient α reflects comparative advantage due to institutions, β_f reflects comparative advantage due to factor endowments, and π reflects comparative advantage due to environmental regulation.

A few aspects of equation (8) are worth noting. This equation describes one variable representing an industry's dependence on institutions, but I also report estimates separating financial, judicial, and labor market institutions. Factors E_i^f include a country's capital-labor ratio and skills. Regressions allow clustering of standard errors by country pair. I show standardized beta coefficients to facilitate comparison of magnitudes across variables. I also report Poisson pseudo-maximum likelihood (PPML) versions of equation (8), in part to address possible bias from excluding the log of zero trade flows (Silva and Tenreyro 2006). Even if some country endowments affect others, e.g., if institutions affect factor endowments or environmental regulation, one can take the usual interpretation of equation (8) as reflecting effects of one country endowment conditional on others. For example, one could think of comparing countries with similar quality institutions but different stringency of environmental regulation.

Equation (8) and extensions to it in the rest of this section deal with three possible econometric issues. First, institutions may be measured with error. Second, institutions may be correlated with other country characteristics. Third, trade and production may affect institutions. I use many approaches to addressing these potential concerns—I compare across different measures of institutions, construct an index of institutions, use multiple predetermined instruments for institutions, focus on interactions of a country's institutions with an industry's characteristics, exploit variation in institutions across time within a country and across states within a country, and others.

Results

Table 3, Panel A, examines comparative advantage in a standard trade setting, with estimates corresponding to equation (8). The first four columns study comparative advantage due to institutions. For example, column (1) analyzes the interaction of a country's financial institutions with an industry's dependence on financial institutions. Column (5) considers the interaction of a country's environmental regulation and an industry's clean index. Columns (6) and (7) estimate comparative advantage due to factors of production. Column (8) studies applied tariff rates. Columns (9) and (10) consider all these explanations at once.

Table 3, Panel A, shows that most institutions and factors provide comparative advantage, and tariffs discourage trade. This echoes existing work, though incorporates environmental regulation. Column (1) shows that countries with strong financial institutions export relatively more in industries that depend on financial institutions. The coefficient approximately indicates that for an industry that depends one standard deviation more than average on financial institutions, improving a country's endowment of financial institutions by one standard deviation increases log exports by 0.019 standard deviations. This indicates that financial institutions provide a source of comparative advantage. Columns (2) through (4) show that similar patterns hold for other institutions. Column (5) shows that environmental regulation provides a source of comparative advantage in clean industries, which supports the Pollution Haven Hypothesis. Capital has less importance on its own, though is more important in the pooled regressions of columns (9) and (10). Column (7) shows a similar pattern for skills. Column (8) finds that tariffs discourage trade.

Because Table 3 shows standardized beta coefficients, we can compare the coefficients' magnitudes. Consistent with Heckscher-Ohlin models, the largest source of comparative advantage in the pooled regression of columns (9)-(10), Panel A, is a country's skill endowment. As noted earlier, capital matters less. In all these estimates, institutions have larger predictive power for trade than environmental regulation does. The importance of environmental regulation here nonetheless suggests that the Pollution Havens Hypothesis is important to understanding trade and comparative advantage broadly.

The modest estimated effect of the capital/labor ratio in Table 3, column (6), initially appears at odds with Heckscher-Ohlin theory. One explanation for the small estimated effect of the capital/labor ratio is the lack of control for environmental regulation, since polluting industries have high capital/labor ratios. For example, adding the environmental regulation endowment×intensity variable to the specification of Table 3, column (6), increases the coefficient on the capital/labor ratio term to become much larger and statistically distinguishable from zero. The larger estimate for the capital/labor ratio in columns (9)-(10) is also consistent with this explanation. Thus, while Table 3 just shows standard trade analysis not primarily focused on the environment, it underscores the relevance of environmental policy in explaining comparative advantage overall.

4.2 Comparative Advantage in Clean Industries

Methods

The findings in Section 4.1 and previous literature that institutions provide an important source of comparative advantage, and in Section 3.2 that the industries that benefit from institutions are clean, together suggest that institutions provide comparative advantage in clean industries. I also report the following more direct test of this hypothesis:

$$lnX_{ij,s} = \alpha^C E_i Z_s + \sum_f \beta_f^C E_i^f I_s^f + \pi^C R_i Z_s + \gamma^C t_{ij,s} + \zeta_{j,s}^C + \eta_{ij}^C + \epsilon_{ij,s}^C \tag{9}$$

Equation (9) tests whether countries with strong institutions export more in clean industries. It resembles the canonical gravity equation (8), except it interacts institutions with an industry's clean index Z_s, rather than an industry's dependence on institutions I_s. The coefficient α^C represents the average increase in log exports for an exporter with institutional quality E_i in an industry with clean index Z_s. The country-pair fixed effects η_{ij}^C adjust for the level effects of the exporter's institutional quality. The destination×sector fixed effects $\zeta_{j,s}^C$ adjust for level effects of the industry's clean index Z_s. The coefficient θ reflects only the interaction of a country's institutional quality and an industry's clean index.

Results

Figure 4 graphs raw data. Each graph describes three variables: the horizontal axis describes an industry's clean index; the vertical axis plots a country's exports in each industry, normalized to mean zero; and the two lines describe countries with strong versus weak institutions. Figure 4 shows that countries with strong institutions specialize in cleaner industries. Panel A describes two example countries: Tajikistan, with weak institutions; and Switzerland, with strong institutions. I plot a nonparametric local linear regression across industries within each country or group of countries. The upward-sloping dashed line in Panel A indicates that Switzerland exports more in clean than dirty industries. The relationship of Swiss exports to an industry's clean index is monotone and approximately linear. The downward-sloping solid line in Panel A indicates that Tajikistan exports relatively less in clean industries. The difference in exports between clean and dirty industries here is economically large.

Figure 4, Panel B, finds similar patterns for all countries. I separate countries into two groups: the dashed red line describes countries with stronger national institutions than the median country; the solid blue line describes countries with weaker institutions than the median country. The

X-shaped figure in the global graph in Panel B echoes the shape of the two-country graph in Panel A—countries with strong institutions specialize in clean industries, and countries with weak institutions specialize in dirty industries. In Panel B, the relationship between log exports and an industry's clean index is approximately linear within each country group. Appendix Figure 1 shows qualitatively similar patterns in two theoretically-derived measures of revealed comparative advantage (Balassa 1965, Costinot, Donaldson and Komunjer 2012).

Table 3, Panel B, estimates equation (9). Columns (1) through (3) consider each type of institution separately. Column (4) analyzes the index combining all three types of institutions. Columns (5) and (6) pool these estimates and control for tariffs and comparative advantage due to environmental regulation and factor endowments.

Table 3, Panel B, finds that countries with strong institutions specialize in clean industries. Most estimates for institutions are positive and statistically distinguishable from zero at high confidence. The estimates separating institutions in columns (1) through (3) and pooling them in column (5) suggest that financial institutions provide a larger source of comparative advantage in clean industries than judicial or labor market institutions do. Column (6) shows that for an industry one standard deviation cleaner than the mean, a country with one standard deviation stronger institutions has about 4 percent of a standard deviation higher log exports. Column (6) also finds that for clean industries, institutions drive comparative advantage more than environmental policy does. Column (6) supports the Pollution Havens Hypothesis by finding that environmental regulation drives specialization in clean industries. It also finds that institutions are at least as important as environmental regulation to explaining countries' specialization in clean versus industries. The literature on trade and the environment focuses on how environmental regulation affects location choices of clean industries and generally abstracts from institutions. Findings like these patterns in Table 3 drive one of this paper's main ideas, that financial, judicial, and labor market institutions also substantially drive location choices of clean versus dirty industries.

The cost structure of industries provides one reason why institutions could play a quantitatively larger role in location choices of clean versus industries than environmental policy does. Survey data, model-based estimates, and productivity regressions suggest that for the dirtiest manufacturing industries, environmental regulation increases costs by up to a few percent (Becker and Shadbegian 2005; Greenstone, List and Syverson 2012; Shapiro and Walker 2018). By contrast, through changing the productivity of using intermediate goods or factors, institutions have potential to change a large majority of a firm's cost structure.

We can interpret the estimates in Table 3 in two other ways. One investigates how changing the quality of a country's institutions from the tenth to the ninetieth percentile of institutional quality would affect emissions. I calculate a country's baseline environmental quality as $Z = \sum_{j,s} X_{ijs} Z_s$, and counterfactual environmental quality as

$$Z' = \sum_{j,s} [X_{ijs} Z_s + e^{\hat{\alpha}^C Z_i [E^e_{0.9} - E^e_{0.1}]} Z_s] \tag{10}$$

Here $\hat{\alpha}$ is from equation (9), $E^e_{0.9}, E^e_{0.1}$ are the ninetieth and tenth percentile of institutional quality, and I calculate the proportional change in pollution due to changing institutions as $(Z'/Z - 1)$.[9] The fitted effect row at the bottom of Table 3, Panel B, columns (5) and (6), suggests that this counterfactual would decrease a country's emissions by about 25 percent. This large decline would imply that institutions substantially drive environmental quality.

This calculation requires strong caveats. It includes only emissions from traded manufacturing goods, so abstracts from other tradable goods and from polluting non-tradable goods like domestic transportation and home heating. It assumes that other sources of technology, factors, and other determinants of specialization are fixed, and that institutions have log-linear effects. It also comes from a partial equilibrium calculation, which abstracts from changes in wages or prices. The quantitative model in Section 6 helps relax these assumptions.

A second interpretation of Panel B of Table 3, column (6), recognizes that the coefficient on institutions is about 80 percent as large as the tariff coefficient. Globally, one standard deviation of tariffs is 9 percentage points weighted by trade value and 15 percentage points unweighted. Hence, for an industry one standard deviation cleaner than average, improving institutions by one standard deviation would increase exports by about the same amount as decreasing tariffs by 7 to 12 percentage points. This would be similar to ending a trade war or granting a country Most Favored Nation status, and implies that institutions have as large effects on clean industries as enormous changes in trade policy have.

4.3 Alternative Research Designs

I now discuss several alternative versions of these estimates, which both help clarify the economics and the potential importance of some of the econometric challenges mentioned in Section 4.1. Table 4, Panel A, reports baseline estimates controlling for institutions, factors, environmental regulation, and tariffs.

[9] Practically, I measure the tenth percentile of institutions as the mean institution index for countries between the fifth and fifteenth percentile of that index, and the ninetieth percentile as the mean institution index for countries between the eighty-fifth and ninety-fifth percentile of that index.

Instrumental Variables Estimates

I also report estimates that instrument for a country's institutions, with the following first-stage:

$$E_i I_s = \sum_o \alpha_o^F L_{i,o} I_s + \sum_f \beta_f^F E_i^f I_s^f + \pi^F R_i Z_s + \gamma^F t_{ij,s} + \zeta_{j,s}^F + \eta_{ij}^F + \epsilon_{ij,s}^F \tag{11}$$

I instrument the interaction of a country's institutions and an industry's dependence on institutions, $E_i I_s$, with the interaction of indicators for the origin o of a country's legal system and an industry's clean index. Here L_i^o is an indicator for whether the legal system of exporter i originates in country o, measured from La Porta et al. (2012). Equation (8) represents the structural or second stage. The estimates include four interactions, for British common law, French civil law, German civil law, or Socialist legal origin (Scandinavian civil law is the reference category). I also report estimates that use settler mortality or population density in the year 1500 as instrumental variables (IV) for institutions, and estimates that use multiple instruments to separate the roles of property rights institutions that constraint executive power versus institutions improving contract security (Acemoglu and Johnson 2005).

Legal origins are widely used as instruments in research on institutions, with the motivation that legal origins determine contract enforcement, judicial quality, and financial systems (Djankov et al. 2003; Acemoglu and Johnson 2005; Lerner and Schoar 2005; Nunn 2007). Scholars have debated the interpretation and importance of a country's legal origins (La Porta, Lopez de Silanes and Shleifer 2008). Used as an instrument, I assume that legal origins predict institutions (testable with the first stage); I also assume that legal origins, interacted with the clean index, affect trade only through the interactions of institutions and the clean index, conditional on the other controls. The estimates using settler mortality or year 1500 population density involve analogous assumptions.

Appendix Table 4 shows the first-stage estimates. Columns (1) through (4) study comparative advantage in all industries, which provides a first stage for equation (8); columns (4) through (8) examine comparative advantage in clean industries, which provides a first stage for equation (9). Legal origins provide strong instruments, with first-stage F statistics for the institutions index of 164 to 214. The instruments are also strong for each type of institutions individually. Relative to Scandinavian legal origins (the reference category), British legal origins predict the strongest institutions.

Table 4, Panel B, shows second-stage instrumental variables (IV) estimates that use legal origins interactions as instruments. While some IV estimates moderately exceed corresponding OLS estimates, for the comparative advantage of institutions in clean industries in column (8), the OLS and IV estimates are similar, with an OLS estimate of 0.40 (0.003) and IV estimate of 0.048 (0.005).

Given the complexity of measuring institutions, measurement error is a plausible explanation for why some IV magnitudes modestly exceed OLS magnitudes. Qualitatively, however, the instrumental variables and OLS regressions imply similar conclusions.

Panel Data Estimates

I use panel data over the period 1996-2015 to test whether clean exports increase more in countries where institutions improve:

$$lnX_{ij,sy} = \alpha^P E_{i,y} Z_s + \sum_f \beta_f^P E_{i,y}^f I_s^f + \zeta_{j,sy}^P + \eta_{ij,y}^P + \epsilon_{ij,sy}^P \quad (12)$$

Here trade flows X, institutions E, factors E^f, and the fixed effects ζ and η vary by year y. I assume the clean industry index Z, factor intensities I_s^f, and tariffs t are time-invariant, due to limited data availability for the full panel. The comparative advantage parameter α^P is identified from differences in institutional quality within a country, interacted within an industry's clean index. One motivation for these estimates is that a country's institutions could correlate with time-invariant country characteristics, such as geography, which differentially encourage specialization in clean industries.

I also estimate a long-differenced version of equation (12), which is restricted to the first and last years of data. This may provide a more accurate estimate than the full panel regression for two reasons. Because institutions may be measured with error, panel estimates like equation (12) can exacerbate attenuation bias due to measurement error (Griliches and Hausman 1986). Additionally, institutions can change gradually, and trade may respond gradually to institutions. Cross-sectional estimates like equation (9) obtain a long-run relationship between institutions and trade, while panel data estimates like equation (12) estimate the short-run relationship. The long-differenced estimate obtains medium-run estimates.

Although a country's institutions have path dependence, the mean country has large changes in institutions over 20 years, which suggests that changing institutions has scope to affect pollution. Between 1996 and 2015, the absolute value of institutions in the mean country changed by half a standard deviation.[10] Institutions improved in about two-thirds of countries and worsened in a third of countries. The rate of change was slightly lower for judicial institutions and slightly higher for labor market institutions. For comparison, in the mean country between 1996 and 2015, the

[10]This statistic reports the mean across countries of $|E_{i,2015} - E_{i,1996}|$,where $E_{i,y}$ is a measure of institutions or factor endowments in country i and year y. For comparability with most of the paper, these values are normalized to have mean zero and standard deviation one in the year 2012.

absolute value of capital and skill endowments changed by a similar amount—0.6 and 0.4 standard deviations.

Figure 5 shows panel graphs relating changes in trade over 20 years to changes in institutions. For example, Rwanda had among the most rapid improvements in institutions in this period, while Egypt had among the most rapid deterioration of institutions. This graph divides countries into two groups: countries where institutions improve and countries where institutions worsen. For each industry, I calculate the share of global exports from each group of countries in 1996 and in 2015. I then plot a nonparametric regression of the change over time in these shares for each country×industry.

Figure 5 shows that countries where institutions improve have faster export growth in all industries, since the solid blue line lies above the x-axis. Countries where institutions worsen have slower export growth in all industries, since the dashed red line lies below the x-axis. The slopes show that countries where institutions improve disproportionately increase exports in clean industries. Countries with improving institutions increase their share of world exports for clean industries by about 20 percentage points. Those countries increase their share of world exports for the dirtiest industries by only 1-2 percentage points. Countries where institutions worsen hardly change their share of world exports in dirty industries, but substantially decrease their export share in clean industries.

Table 4, Panels C and D, exploit panel variation in institutions, capital, labor, and other variables within a country and over 20 years, corresponding to equation (12). Panel C uses all years of data. If institutions are measured with error, panel estimates can exacerbate attenuation bias (Griliches and Hausman 1986). Panel D therefore includes only the first and last years of data, and thus provides a long-differenced estimate.

The panel data estimate obtains precise results, with smaller magnitudes in the full panel but larger magnitudes in the long-differenced estimates. In column (8) of Table 4, Panels C and D, the comparative advantage that institutions provide in clean industries is 0.040 (0.003) in the baseline estimates, 0.013 (.001) in the full panel estimates, and 0.061 (0.008) in the long-differenced estimates. The smaller magnitude of the full panel versus long difference is consistent with measurement error in institutions. It is also consistent with the possibility that trade responds gradually to institutions.

Cross-State, Intranational Institutions

I also compare institutions across states within a single country, India. Some determinants of specialization vary across countries in ways that are difficult to observe. Comparing across states within a country helps address that challenge, since it effectively holds other national variables fixed.

India is a useful setting for such an analysis since India's credit, judicial, and labor institutions vary considerably across states, and existing work has measured them. For this analysis I use production data to estimate the following test:

$$lnX_{is} = \alpha^I E_i I_s + \sum_f \beta_f^I E_i^f I_s^f + \pi^I R_i Z_s + \eta_i^I + \zeta_s^I + \epsilon_{i,s}^I$$

Table 4, Panel E, estimates comparative advantage due to institutions across states in India. Columns (1)-(4) find that judicial and labor institutions, though not financial institutions, provide comparative advantage overall. Columns (5) through (8) estimate that these institutions provide comparative advantage in clean industries. The magnitude of the overall comparative advantage of institutions in column (4), and the comparative advantage that institutions provide in clean industries in column (8), are both moderately larger than the global estimate from Panel A. The global and intra-national India estimates differ in several ways, including the use of trade versus production data and using different measures of institutions. While this makes it difficult to provide a perfect apples-to-apples comparison, the magnitudes of baseline estimates in Panel A versus these India estimates in Panel E at least do not support the concern that the global estimates of institutions' comparative advantage is due to unobserved country-level variables that are correlated with institutions.

4.4 Sensitivity Analyses

Appendix Table 5 obtains similar estimates of the comparative advantage equations (8) and (9) using different measures of environmental regulation. Row 1 measures environmental regulation in each country as the mean of the z-scores of each of the eight measures of environmental regulation. Rows 2-9 examine one measure of environmental policy per row. Across these nine different ways of measuring environmental regulation, these county institutions×clean industry interactions have coefficients between 0.03 and 0.06, and are statistically distinct from zero at 99 percent confidence. The estimates of the importance of regulation itself are more variable across measures of regulation, consistent with the rationale for aggregating across these measures in the main results.

Appendix Table 6 obtains qualitatively similar estimates from different measures of each institution; the Appendix describes the associated data sources. I consider 3 alternative measures of financial institutions, 4 alternative measures of judicial institutions 5 alternative measures of labor market institutions, and 9 estimates comparing measures of property rights institutions, one based on whether a system constrains executive power and one based on the effectiveness of contracting institutions. In line with Acemoglu and Johnson (2005), I show institutions on their own and instrumented by colonial settler mortality, population density in the year 1500, legal origins, or combinations of the three.

In column (1) of Appendix Table 6, most of these 21 estimates imply that institutions provide a source of comparative advantage overall. A couple estimates which simultaneously control and instrument for constraint on the executive and contracting institutions have more sensitive results, reflecting the complexity of separating comparative advantage due to these two distinct interpretations of property rights. In column (2), most measures of institutions provide comparative advantage in clean industries. Estimates in rows 13-22 seeking to unbundle institutions suggest that contracting institutions, more than institutions constraining executive power, drive comparative advantage in clean industries, which makes sense and fits with the interpretation of judicial institutions in the rest of the paper.

Appendix Table 7 uses other data sources and econometric assumptions. I report estimates controlling for all three types of institutions at once; including non-manufacturing industries; replacing the bilateral fixed effects with bilateral distance, common language, and other standard gravity variables from CEPII; using PPML; using Exiobase; measuring pollution in the entire value chain via the Leontief Inverse matrix; and replacing the continuous clean index with an indicator for not being among the dirtiest 10 percent of industries. The "dirtiest industries" indicator follows the Pollution Havens Hypothesis literature, which typically focuses on the dirtiest set of industries rather than using a continuous clean industry index. The qualitative patterns across these different estimates are similar. The interaction term for strong country institutions×clean industry ranges from 0.04 to 0.06 and is generally precise. The largest point estimates are from using PPML and Exiobase.

I also briefly discuss how institutions affect clean production techniques within an industry. This paper primarily studies how institutions affect the composition of a country's production between clean versus dirty industries. Institutions could also affect pollution through channels like changing intermediate goods as a share of costs or changing the types of intermediate goods a firm purchases. The effect of institutions on a country×industry's clean index has ambiguous sign. For example, better institutions could move firms from cleaner inputs like labor towards potentially dirtier inputs like intermediate goods (e.g., energy and chemicals). Alternatively, better institutions could make firms substitute from dirtier to cleaner intermediate goods.

Much of this paper measures how institutions affect composition and comparative advantage by interacting industry intensities and country endowments. Because this approach cannot test how institutions affect technique within an industry, I simply relate cross-country differences in the clean index within industries to cross-country differences in institutions, which requires stronger identifying assumptions. Given these important caveats, Appendix Table 7, row 9, estimates an imprecise zero effect of institutions on clean production techniques for a country×industry. This regression controls for environmental regulation, factor endowments, and industry fixed effects, so represents the relationship of institutions to an industry's clean index, conditional on these variables. The negative sign suggests that countries with better institutions tend to have less clean production techniques within an industry, although the wide confidence interval fails to reject zero or modest but economically important magnitudes. I conclude that this paper's setting has power and a research design that are not ideally suited to test the effect of institutions on clean production techniques within an industry, which I leave as an important question for future work. Hence the remainder of the analysis maintains the paper's general focus on effects of institutions through comparative advantage.

4.5 Explanations

The previous results provide evidence that clean industries depend on strong institutions. They do not, however, explain why. Table 5 uses information on many industry characteristics to provide some insight. These are primarily variables relevant to political economy and found to influence trade policy (Rodrik 1995; Shapiro 2021). I first regress an industry's clean index on other industry characteristics, one at a time:

$$Z_s = \rho_0^W + \rho_1^W W_s + \epsilon_s^W \tag{13}$$

This comparison indicates which industry characteristics W are correlated with being clean. I then adapt equation (2) by assessing how controlling for one industry characteristic changes the association of the clean index with an industry's dependence on institutions:

$$Z_s = \rho_0^{IW} + \rho_1^{IW} I_s + \rho_2^{IW} W_s + \epsilon_s^{IW} \tag{14}$$

The additional control W_s varies by regression. I investigate how each control variable W_s changes the estimated association of institutional dependence and the clean industry index. Finally, I adapt equation (9) by controlling for the interaction of one additional industry characteristic W_s with a country's institutional quality E_i:

$$lnX_{ijs} = \alpha^W E_i Z_s + \alpha^W E_i W_s + \sum_f \beta_f^W E_i^f I_s^f + \pi^W R_i Z_s + \gamma^W t_{ijs} + \zeta_{js}^W + \eta_{ij}^W + \epsilon_{ijs}^W \tag{15}$$

Table 5, column (1), shows that clean and dirty industries differ on many dimensions. Clean industries have more specialized, sophisticated, and skilled inputs. Specifically, clean industries have lower cost shares of energy and raw materials, are less upstream, have more differentiated products (higher inverse export supply elasticity), and have lower shipping costs. The explanatory variables are in z-scores so their magnitudes are comparable. The strongest associations with an industry's clean index are its raw materials share and its shipping cost.

Table 5, columns (2) through (4), assess whether these characteristics account for the relationship between an industry's dependence on institutions and its clean index, as in equation (14). They show that differentiated, processed, and downstream industries are clean and depend on institutions. The most important industry characteristics here are the industry's raw materials share, its upstreamness, its workers' education, and its product shipping costs. No one industry characteristic alone fully accounts for the association between an industry's institutional dependence and its clean index, though all these characteristics together do, as indicated by the small magnitudes in the final "all at once" row.

Column (5) of Table 5 estimates equation (15). The last row of Table 5 controls for all these variables at the same time. No single variable completely accounts for the comparative advantage that strong institutions provide in clean industries. An industry's raw materials share accounts for a fifth of the comparative advantage of clean industries; the shipping cost accounts for half; and including all variables together account for about 40 percent of this comparative advantage.

In studying trade policy and CO_2, a single industry characteristic, upstreamness, primarily accounts for the lower trade protection of dirty industries (Shapiro 2021). This is not the case here—many variables together account for the reason why countries with strong institutions specialize in clean industries. The most important variables reflect the idea that clean industries are specialized, skilled, and downstream, or in one word, complex. One possible reason for the difference between the analysis of trade policy and CO_2 versus this paper is that the local pollutants studied here depend on end-of-pipe pollution control technology, which varies substantially and idiosyncratically across industries based on many forces. CO_2, by contrast, has no economically viable end-of-pipe abatement technology, and depends only on energy inputs, which vary more systematically across industries.

5 Decomposing Scale, Composition, and Technique

The previous sections suggest that institutions improve environmental quality partly through comparative advantage, and that differences in the composition of clean versus dirty production between countries help explain the global distribution of environmental quality. This finding contrasts with prevailing results from research on trade and the environment, which finds that the technique of producing goods within an industry, rather than the composition of output across industries, accounts for most differences in environmental quality (Levinson 2009; Grether, Mathys and de Melo 2009; Shapiro and Walker 2018; Brunel 2016; Copeland, Shapiro and Taylor 2022). Existing literature, however, compares pollution within a country and over time. Here I adapt decompositions used in that work to instead compare pollution between countries and within time. For example, rather than studying the extent to which scale, composition, and technique explain the change in US pollution emissions between 1990 and 2008, aas previous work as done, I ask to what extent scale, composition, and technique explain the difference in pollution emissions from India versus the US.

I apply the following decomposition. Let $\mathcal{E}$ denote a country's total pollution emissions, which equal the sum of industry-specific emissions $\mathcal{E}_s$ across all industries in the economy, including both manufacturing and non-manufacturing industries. An industry's emissions equal the product of sales x_s and emissions per dollar of sales, $e_s = \mathcal{E}_s/x_s$. We can equivalently write an industry's sales as $X\kappa_s$, where κ_s is the share of the economy's sales from industry s:

$$\mathcal{E} = \sum_s \mathcal{E}_s = \sum_s x_s e_s = X \sum_s \kappa_s e_s \tag{16}$$

Totally differentiating then dividing by $\mathcal{E}$ yields

$$\frac{d\mathcal{E}}{\mathcal{E}} = \frac{dX}{X} + \frac{d\kappa}{\kappa} + \frac{de}{e} \tag{17}$$

The first term on the right-hand side of equation (17) represents the scale effect, the second represents the composition effect, and third the technique effect.

Research typically takes equation (17) to data by measuring emission rates e_s for each industry in a reference year, then projecting those rates onto future years within a country. I instead take emission rates for each industry in a reference country r. I project those rates onto the same industry in other countries to distinguish scale, composition, and technique effects. I implement this comparison for each country i separately:

$$Scale_{i,r} = \frac{\sum_s x_{is}}{\sum_s x_{rs}} \tag{18}$$

$$Composition_{i,r} = \frac{\sum_s \kappa_{is} e_{rs}}{\sum_s \kappa_{rs} e_{rs}} = \frac{\sum_s \kappa_{is} e_{rs}}{Z_r/X_r} \tag{19}$$

$$Technique_{i,r} = \frac{\sum_s \kappa_{is} e_{is}}{\sum_s \kappa_{is} e_{rs}} = \frac{Z_i/X_i}{\sum_s \kappa_{is} e_{rs}} \tag{20}$$

Here r indexes a reference country, x_{is} represents the gross output of focal country i in industry s, κ_{is} represents the share of country i's gross output from industry s, and e_{is} are emissions per dollar of gross output. In presenting these numbers, I subtract one from each equation, so they can be interpreted as the percentage change relative to the reference country. Appendix C derives these equations from those used in the literature comparing within a country and over time.

The scale effect in equation (18) equals the percentage difference in gross output between country i and reference country r. This describes how emissions would change if country i instead had the total output of country r, but the allocation of output across industries and emissions per unit output within an industry were fixed.

The composition effect in equation (19) equals the difference in emission rates between countries i and r due to their difference in the share of output κ from each industry. Composition weights output shares by the reference rates, e_{rs}. I use these weights since they are common in the literature comparing environmental change within a country and over time (Appendix C).

The technique effect equals the difference in emission rates between countries i and r due to their difference in emission rates e from each industry. Equation (20) uses output weights from the focal country κ_{is} for consistency with the literature (Appendix C), though again below I report the distribution of results from possible alternatives. To help assess the relative importance of composition versus technique overall, I report the absolute value of the technique effect and the absolute value of the composition effect. To compare them, I present the ratio $|Composition|/(|Composition| + |Technique|)$.

Consider the example of sulfur oxides emissions in India and the the US. Using Exiobase data, the scale effect from equation (18) indicates that India produced 87 percent less output than the US. Sulfur oxides emissions, however, were 12 percent higher in India than the US. The composition effect from equation (19) indicates that India emitted 162 percent more sulfur oxides than the US did because a larger share of India's output comes from dirtier industries. The technique effect from equation (20) indicates that India produced 216 percent more pollution than the US because a given industry emits relatively more pollution per dollar of gross output in India than in the US does. Thus, although India produces less output than the US economy (scale), it emits more sulfur both because it is more concentrated in polluting industries (composition) and because a given industry emits more pollution in India (technique). Here, composition accounts for 43 percent (=162/(162+216)) of the composition+technique total.

Table 6 provides such comparisons for all countries and pollutants, using the US as reference country. Row 1 shows that the mean country has 72 percent lower total pollution emissions than the US. Row 2 shows that the mean country has 90 percent lower gross output than the US does. Row

3 shows that the composition of output across industries in the mean country increases emissions 175 percent relative to the US, i.e., most countries produce dirtier types of goods than the US does. Row 4 shows that the technique effect for the mean country does not substantially change emissions relative to the US, i.e., some countries use cleaner techniques and others dirtier, but the mean is comparable. While some countries have a positive composition effect (dirtier than the US) and others negative, Row 5 shows that the composition effect in the mean country changes emissions relative to the US by 176 percent. Row 6 shows that in the mean country, the absolute value of the technique effect increases emissions relative to the US by 47 percent.[11] Comparing Rows 5 and 6 indicates that in absolute values, the composition effect accounts for 79 percent (=176/(176+47)) of the combined composition and technique effect magnitudes.

Figure 6 describes the distribution of the ratio $|Composition|/(|Composition| + |Technique|)$ across countries and pollutants, separately for each reference country. For example, comparing the US to India represents one data point, and India versus France is another, and China versus Russia is another. It shows that composition accounts for slightly more of cross-national differences in pollution than technique does. The distribution is roughly a truncated bell-curve shape. The mean and median composition share are about 0.70. No mechanical reason makes these shares near half. Given prior literature, one might expect technique to account for most of this difference.

Why does Figure 6 find a large role for composition, while prior literature finds a larger role for technique? A proximate reason is that Figure 6 compares across countries and within a time period, while prior literature looks within a country and over time. One deeper potential explanation is that a country's institutions and factor endowments rarely change rapidly. This makes the composition effect less important for explaining change within a country and over time. It is one reason the legal origins, settler mortality, and year 1500 population density instruments predict institutions today. Environmental policy can change more quickly, which makes the technique effect more important for explaining change within a country over time. A second explanation is that technique depends on a country's absolute emissions rate, while composition depends on countries' relative comparative advantage. If environmental policy and institutions strengthen similarly in all countries over time, technique could matter more in the time series but composition could matter more in the cross section. I emphasize that because these are decompositions and not regressions, the aforementioned findings do not reflect differences in regression assumptions about omitted variables bias, or measurement error, or other forces that differ between cross section and panel data regressions, but instead represent some forces (potentially including institution) which

[11] Row 4 shows that the mean technique effect is similar to the US, but Row 6 shows that many countries have a technique effect either higher or lower than the US (i.e., the US and other countries have the same means, but larger differences in absolute value).

make composition more important in the cross section across countries than time series within a country to explain the global distribution of environmental quality.

6 Counterfactual Institutions: Model-Based Estimates

Models

The previous sections use partial equilibrium correlations and regressions to find that institutions provide comparative advantage in clean industries, and that cross-country differences in the composition of production across industries drive cross-country differences in environmental quality. They are not, however, ideally suited to quantifying aggregate impacts of institutions. I now turn to a quantitative model of trade, institutions, and pollution, which can help with this quantification. The model accounts for multiple industries, intermediate goods, input-output links, trade imbalances, tariffs, and pollution emission rates for each country×industry, in all sectors of the economy. Because most model details are typical from the structural gravity literature, I describe them in Appendix D. Here I highlight key features and focus on aspects which differ from a standard trade setting.

Each country has a representative agent who maximizes utility that is a constant elasticity of substitution (CES) aggregate across varieties and Cobb-Douglas across sectors. The representative agent experiences disutility from pollution. This is a multi-country, multi-sector Ricardian trade model of perfect competition (Eaton and Kortum 2002) —buyers source a variety from the lowest-price producer and trade faces iceberg trade costs and tariffs. Production is Cobb-Douglas in labor and intermediate goods, which use inputs from all sectors as dictated by an input-output table. Productivity has a Fréchet distribution with location parameter $T_{i,s}$ and dispersion parameter θ_s. I describe $T_{i,s}$ as each country×industry's technology or productivity level.

I interpret institutions as changing country×industry productivity in potentially every sector, including non-tradable goods. Equation (5) implies that reforming institutions proportionally changes productivity for exporter i and industry s via

$$\hat{T}_{i,s} = exp\left\{\alpha I_s(E_i^{'} - E_i)\right\} \tag{21}$$

To estimate (21), I use estimates of α from the comparative advantage regression equation (8), data on an industry's dependence on institutions I_s and a country's baseline quality of institutions E_i, and then I choose $E_i^{'}$ to define a counterfactual.

Country i's baseline pollution emissions are

$$\mathcal{E}_i = \sum_s \frac{\gamma_{i,s} R_{i,s}}{c_{i,s}}$$

where $\gamma_{i,s}$ measures the baseline units of pollution emitted per real unit of output, $R_{i,s}$ describes country×sector revenue, and $c_{i,s}$ is the unit cost function. The model can accommodate changes in pollution intensity $\gamma_{i,s}$ due to counterfactual changes in institutions. Following the technique effect results discussed in Section 4.5, however, I assume that the pollution intensity $\gamma_{i,s}$ of exporter i in industry s is invariant to counterfactual changes in institutions. If stronger institutions generated cleaner production techniques, this assumption would tend to understate institutions' environmental benefits.

I study a competitive equilibrium. Consumer utility maximization implies the gravity equation (3). Total country×sector expenditure equals the sum of spending on final and intermediate goods, accounting for revenues from fixed trade deficits and tariffs. I study counterfactual policies by expressing variables in changes, i.e., using exact hat algebra (Dekle, Eaton and Kortum 2008). I focus on counterfactuals which change technology in certain country×industry pairs due to changes in institutions. For example, institutions could change an industry's pollution intensity $\gamma_{i,s}$ through changing inputs or technology. The proportional change in pollution due to a counterfactual change in institutions is

$$\hat{\mathcal{E}}_i = \frac{\sum_s (\hat{R}_{i,s}/\hat{c}_{i,s})\mathcal{E}_{i,s}}{\sum_s \mathcal{E}_{i,s}} \tag{22}$$

where $\mathcal{E}_{i,s}$ is the baseline observed pollution for a country×sector. Equation (22) says that the proportional change in a country's pollution is the sum across industrie's of baseline pollution from an industry times the industry's change in real output, all divided by the country's baseline pollution.

Results

I study three counterfactual scenarios. The first counterfactual sets all regions to have the same quality of institutions. This is not a realistic policy change, but instead provides a benchmark to think about the signs and magnitudes of broader changes in institutions. One could think of this as describing the environmental benefit that having above- or below-average institutions provides today. The second counterfactual takes regions with below-median institutional quality and improves their institutions to the level of Northern Europe, the region with the strongest baseline institutions. The third counterfactual takes Latin America, the region with the lowest-quality institutions, and improves its institutions to match those of Northern Europe.

Table 7 shows model-based estimates of the effects of these counterfactuals. Panels A through C analyze each counterfactual. Each row shows estimated effects for one region; the last row of each panel shows the global total. The first column describes raw data on baseline institutional quality. Column (2) shows the change in institutional quality that I choose, to define this counterfactual. Column (3) shows the model-estimated percentage change in emissions due to the counterfactual. Column (4) shows the percentage change in emissions per dollar of output due to the counterfactual. Columns (5) through (7) describe the effect of the counterfactual on the share of output from three groups of industries—the dirtiest, middle, and cleanest third.

Panel A of Table 7 shows that the first counterfactual, which equalizes institutions across regions, also helps equalize pollution across regions. Column (1) shows that Northern Europe, North America, and Pacific countries like Japan and Korea have the strongest baseline institutions. Column (2) shows that in this counterfactual, institutions in these regions worsen the most, by construction. Column (3) shows that these regions experience large increases in pollution. Quantitatively, this counterfactual increases emissions in Northern Europe and decreases emissions in Latin America, both by 8 to 11 percent. Columns (5) through (7) show that these changes come from reallocating production between clean and dirty industries.

Table 7, Panel B, considers the second counterfactual, which improves institutions in regions with below-median institutions to equal the quality of institutions in Northern Europe. Column (2) shows that this counterfactual improves institutions in targeted regions by one to two standard deviations. Column (3) shows that this counterfactual decreases pollution emissions in targeted regions by 3 to 13 percent. In regions where institutions remain unchanged, this counterfactual increases pollution emissions by 3 to 4 percent. The second counterfactual increases pollution in regions where institutions do not change because it works through comparative advantage. As institutions improve in Latin America and Eastern Europe, those regions gain comparative advantage in clean industries. This leads some clean production to move to these targeted regions, and some dirty production to move elsewhere.

Table 7, Panel C, analyzes the third counterfactual, where institutions in Latin America improve to match those of Northern Europe. This counterfactual decreases pollution emissions by 20 percent in Latin America. This counterfactual also makes clean industries move to Latin America and dirty industries move elsewhere. Emissions rise by up to 1 percent in regions outside Latin America, due to comparative advantage-driven reallocation of clean and dirty production.

While these three counterfactuals primarily change pollution by reallocating dirty production between regions, all three counterfactuals decrease total global emissions. The second counterfactual, for example, decreases global emissions by 4 percent. The global decreases occur in part because regions with strong baseline institutions have low baseline emission rates. Thus, reallocating one dollar of dirty production from countries with weak to strong baseline institutions tends to decrease total global production.

While most research on greenhouse gases analyzes global total emissions, I am not aware of prior analysis of the global sum of local air pollution emissions. In part this is because the damages from greenhouse gas emissions create the same climate damages regardless of where they are emitted, while the damages from local pollutants vary by location of emissions since they depend on population density, wind, income, and many other variables.

7 Conclusions

How does international trade change the global distribution of air and water pollution? Does trade help explain why poorer countries have higher pollution levels? Existing research highlights three forces that help answer these questions—weaker environmental regulation in developing countries increases their pollution (the Pollution Havens Hypothesis); greater capital endowments in some countries attract capital-intensive, dirty industries there (Heckscher-Ohlin); and trade openness increases per capita GDP, which has nonlinear effects on the concentration of polluting industries (the Environmental Kuznets Curve).

This paper proposes and evaluates an additional explanation for international patterns of environmental quality. Institutions improve international environmental quality through comparative advantage. Clean industries depend on strong financial, judicial, and labor market institutions to operate efficiently. Clean industries thus disproportionately locate in countries with strong institutions. Quantitatively, institutions have comparable importance as environmental policy in explaining international specialization of dirty industries. Estimates indicate that if countries with the world's weakest institutions instead had some of the world's strongest institutions, their pollution emissions would fall by up to 20 percent. I find an important role for institutions across countries, over two decades of institutional change within countries, and when instrumenting institutions with a country's legal origins.

Trade, macroeconomics, development, and economic history research has scrutinized the role of institutions in driving economic change. Broadly, this paper proposes that institutions may also play an important role for environmental economics in driving global patterns of environmental quality.

This paper's main conclusions do not point to a specific environmental or trade policy that improves environmental quality. Instead, this paper highlights how policy reforms usually thought unrelated to the environment, such as judicial reforms that improve contract enforcement, or financial reforms that improve credit markets, or labor market flexibility reforms, can improve national environmental quality through attracting clean industries.

If environmental policy around the globe was optimal, e.g., if every country had Pigouvian taxes on all air and water pollutants, this finding would not change the national benefits of institutions. To the extent that environmental policy is less stringent than optimal, especially in developing countries, this finding strengthens the case for policies that improve institutions in developing countries, since it shows that such reforms help address environmental externalities. While a Pigouvian tax is first-best, in many settings political economy obstacles impede strong environmental policy. Institutional reforms provide one second-best alternative. Additionally, when international organizations like the International Monetary Fund, World Bank, regional development banks, and bilateral aid organizations advocate for improving institutions, this paper suggests that such reforms can also help improve their environment. I also find that such reforms reallocate dirty production to high income countries, however, which complicates the political economy of such reforms since high-income countries primarily fund the International Monetary Fund and World Bank.

I conclude with one open question for future work. How do choices inside the firm mediate or magnify the effects of institutions on environmental quality? Firms respond to weak institutions in many ways, for example, by changing how transactions are financed (Antras and Foley 2015) or through vertical integration (Boehm and Oberfield 2020). Do firms in dirty and clean industries respond differently to the strength of a country's institutions? And how do such firm responses shape the intensity of pollution and international specialization in clean versus dirty production?

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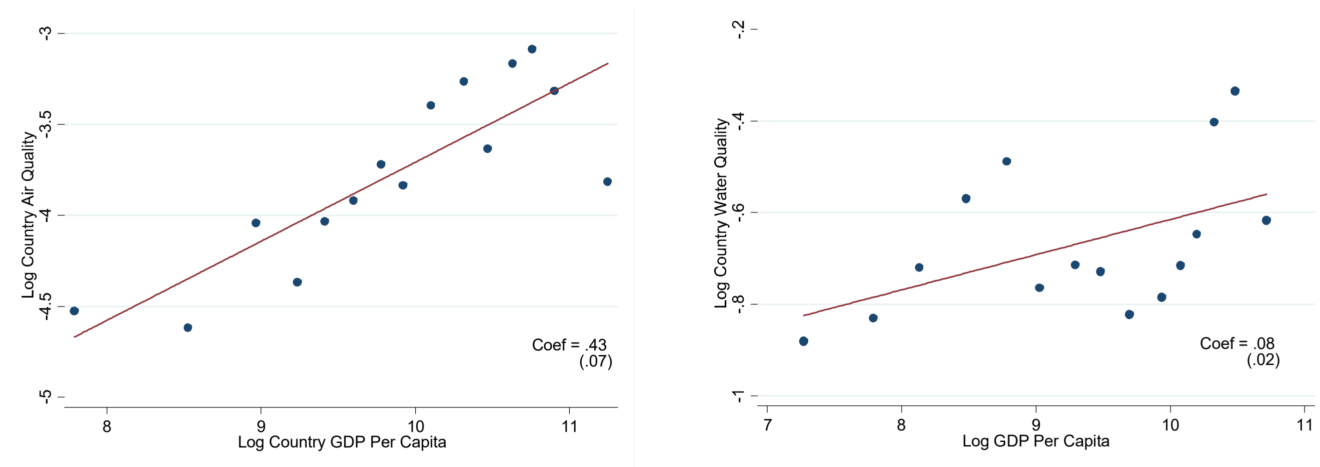
Figure 1. Country Environmental Quality and Country GDP Per Capita

(A) Country air quality & GDP per capita

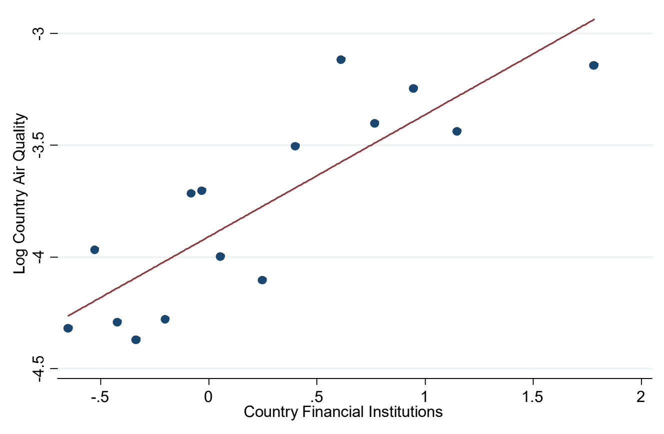
(B) Country water quality & GDP per capita



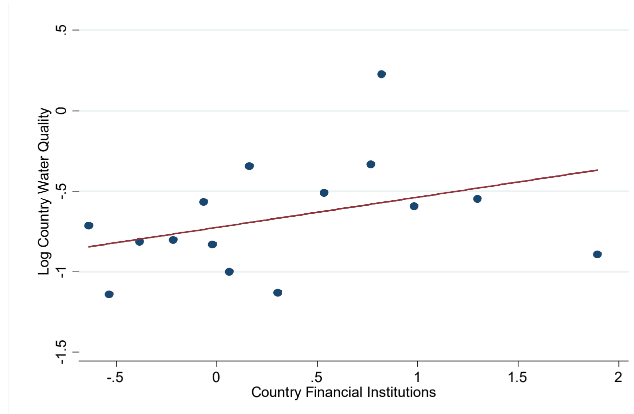
Notes: Each observation is a country. Data are averaged over years 2007-2016. GDP per capita are measured in real 2017$. Y-axis shows negative one times the log of the country's mean PM_{10} in µg/m^3 (Panel A) or times the log of the country's mean biochemical oxygen demand in mg/L (Panel B). Blue circles are means of 15 evenly-sized country bins of GDP per capita. Red line is linear fit. "Coef" shows line slope and its robust standard error.

Figure 2. Country Environmental Quality and Country Institutions

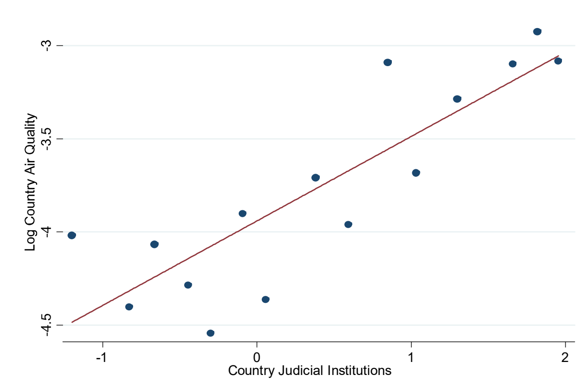
(A) Country air quality & financial institutions



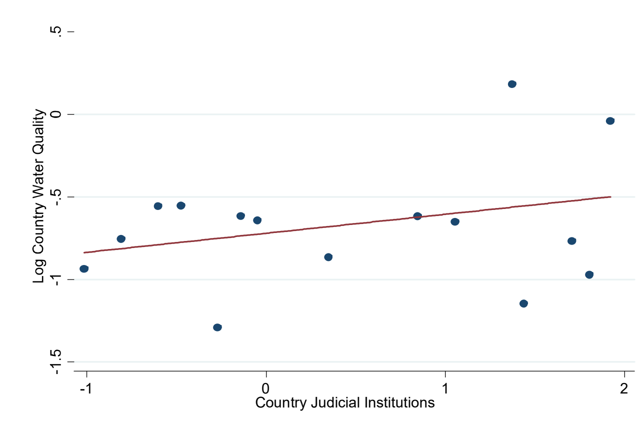
(B) Country water quality & financial institutions



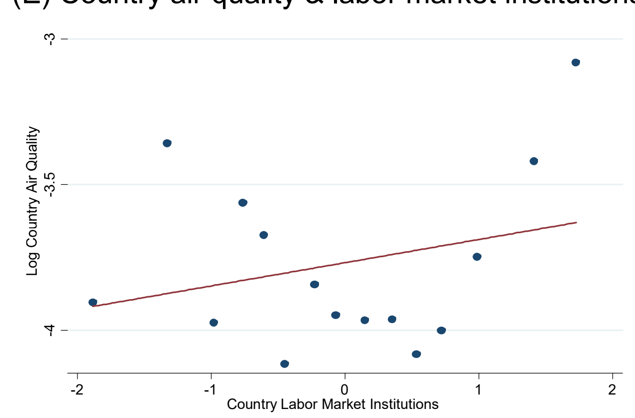
(C) Country air quality & judicial institutions



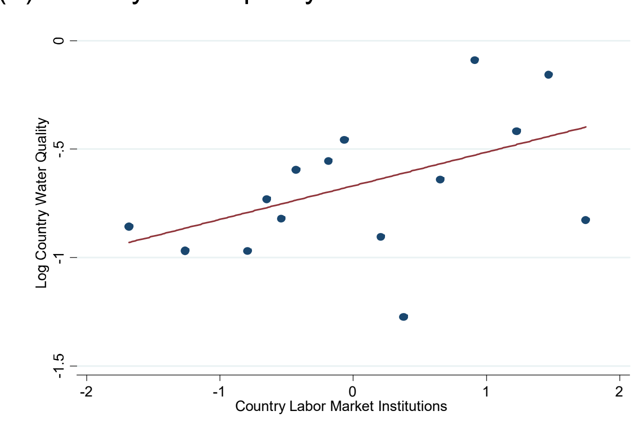
(D) Country water quality & judicial institutions



(E) Country air quality & labor market institutions



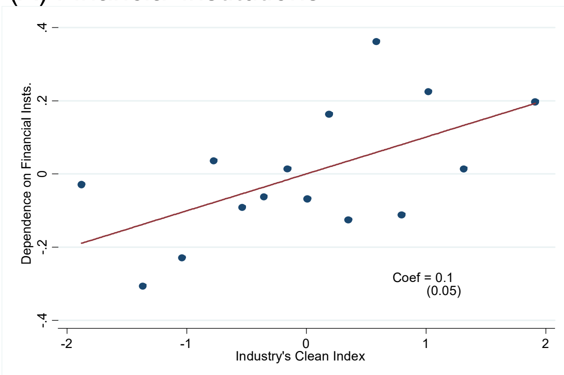
(F) Country water quality & labor market institutions



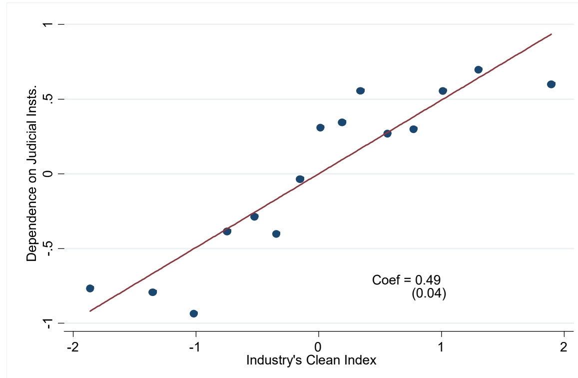
Notes: Each observation is a country. Air pollution data are averaged over years 2007-2016, water pollution data over all available years. GDP per capita are measured in real 2017$. Log of country environmental quality is negative one times the log of the country's mean PM_{10} in μg/m^3 (Panels A, C, and E); or times the log of the country's mean biochemical oxygen demand in mg/L (Panels B, D, and F). Blue circles are means of 15 evenly-sized country bins. Red line is linear fit. "Coef" shows line slope and its robust standard error. Institutions are in z-scores.

Figure 3. Industry Dependence on Institutions and Industry Clean Index

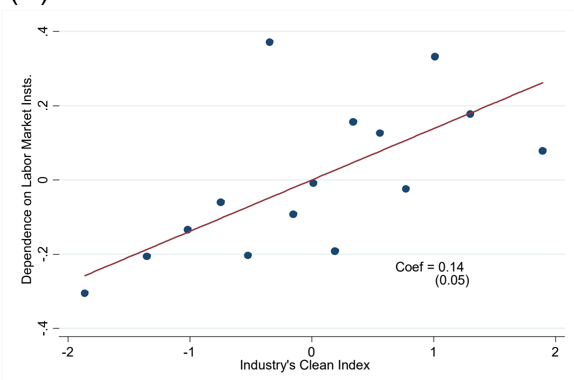
(A) Financial institutions



(B) Judicial institutions



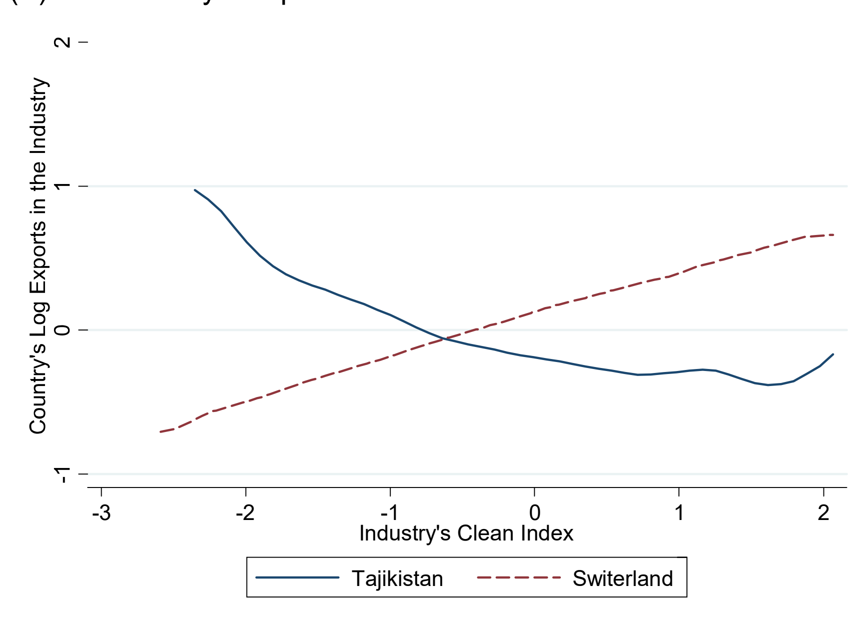
(C) Labor market institutions



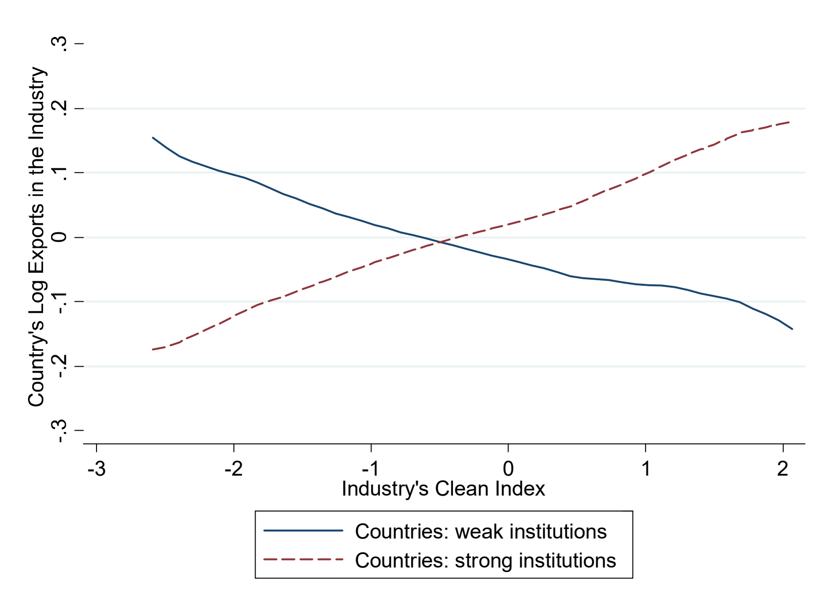
Notes: each observation is a manufacturing industry. Blue circles show means of 15 evenly-sized bins. Red line is linear fit. Dependence on institutions variables are in z-scores.

Figure 4. Industry Clean Index and Exports, by Strength of Country Institutions

(A) Two country comparison

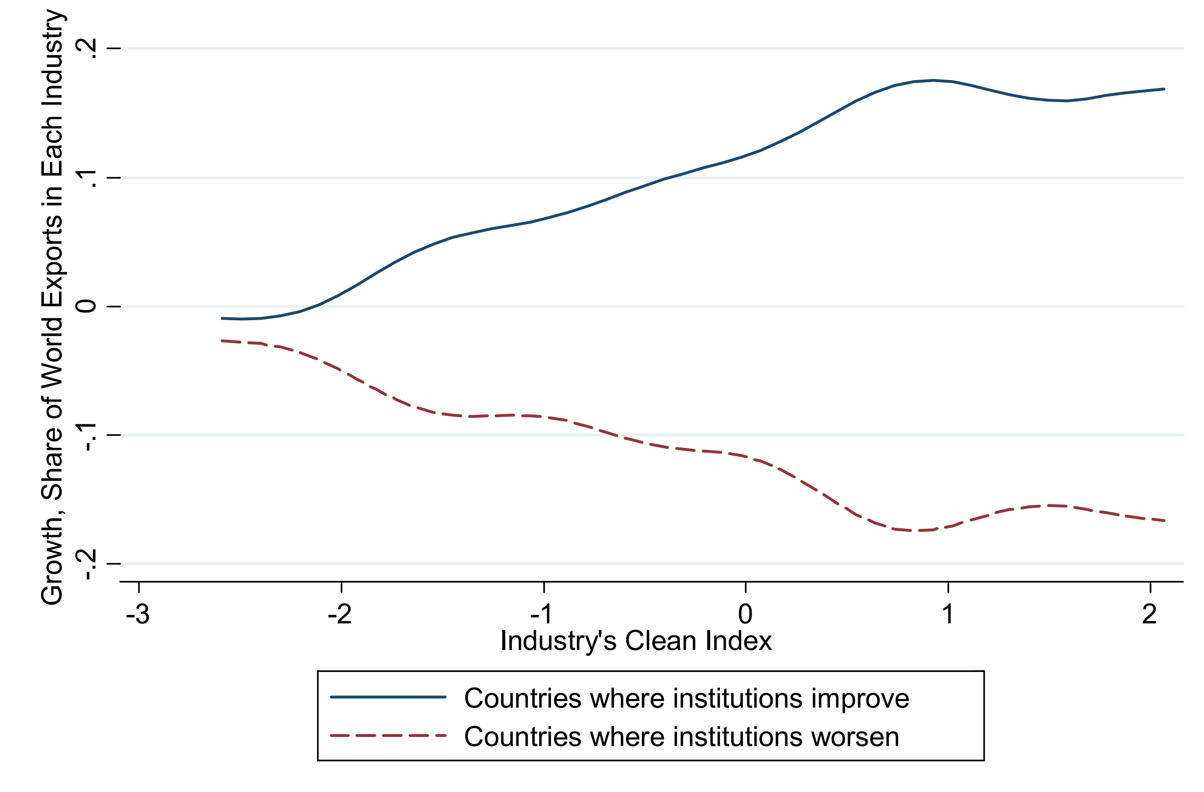


(B) Many country comparison



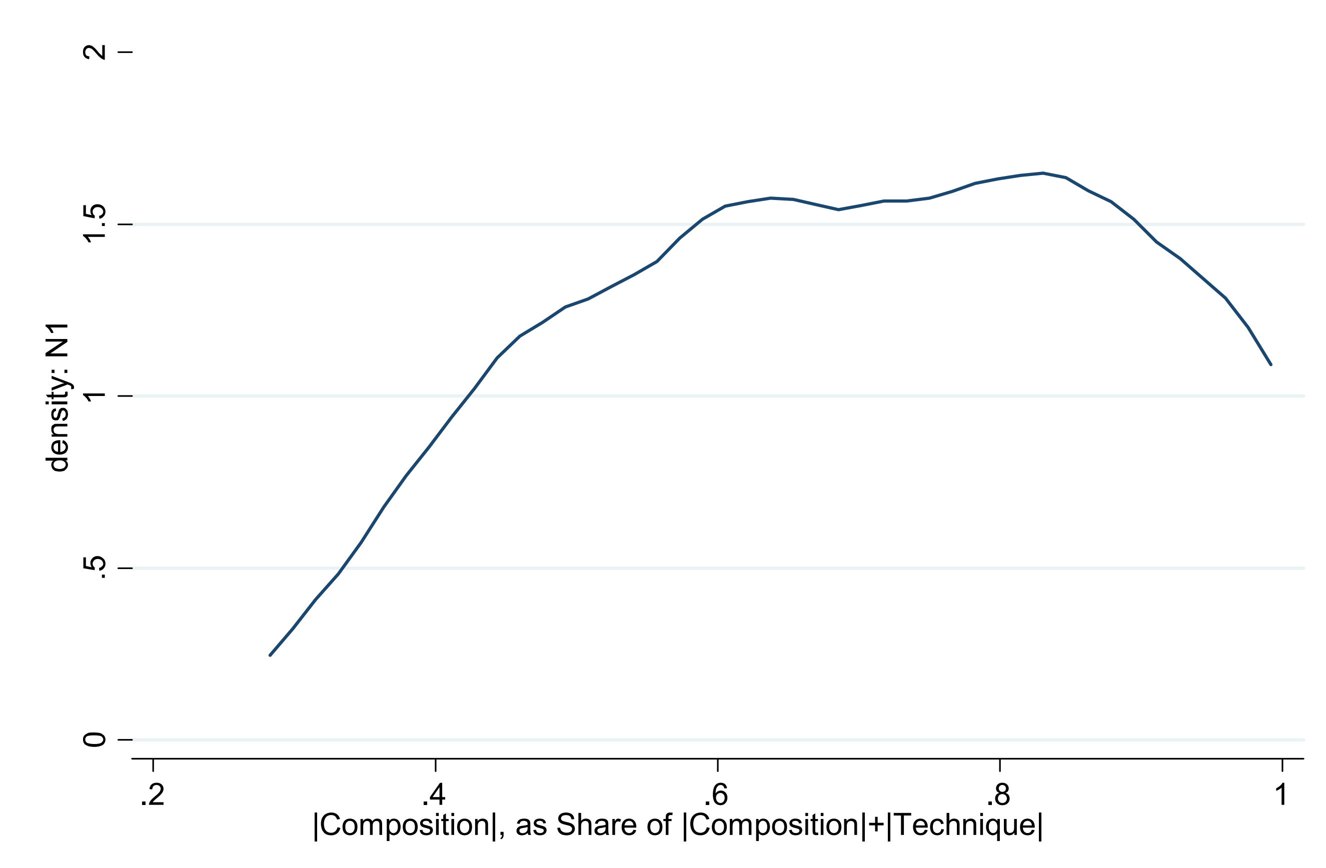
Notes: in Panel A, Tajikistan has weak institutions, while Switerland has strong institutions. In Panel B, "countries: weak institutions" includes all countries with below-median quality institutions, while "Countries: strong institutions" includes all countries with above-median quality institutions. Each graph shows two local linear regressions, with bandwidth of one, for manufacturing industries. For each line, the mean of log exports across industries is normalized to zero.

Figure 5: Changes in Clean Exports and National Institutions, 1996-2015



Notes: Graph divides countries into two groups: countries where national institutions improve between 1996 and 2015, and countries where institutions worsen. Institutions are measured by the principal component index of financial, judicial, and labor market institutions. This analysis calculates the share of world exports in each manufacturing industry that each of these two groups of countries represents in each year (1996 and 2015). Local linear regression is used to calculate nonparametrically smoothed export shares in each year, for each of the two groups of countries. The graph plots the change in that export share for each country group and industry between 1996 and 2015.

Figure 6. Importance of Composition Versus Technique, Distribution Across Countries



Notes: the graph plots the distribution across all possible reference countries and local pollutants. For each reference country *r*, the analysis calculates |*composition*| averaged across all country pairs while using *r* as reference, divided by |*composition*|+|*technique*| averaged across all countries while using *r* as reference. These values average across air pollutants in Exiobase. For example, the data point in this density with the US as reference country corresponds to |*composition*| / (|*composition*|+|*technique*|) from Table 6, column (1), rows 5-6. Calculations cover all industries. Pollution emission rates are winsorized at the 99.9th percentile.

Table 1—Country Environmental Quality and Country Institutions

	(1)	(2)	(3)	(4)	(5)
Panel A. Dependent variable: country air quality					
Country institutions: financial	0.52***	—	—	—	—
	0.00	—	—	—	—
Country institutions: judicial	—	0.63***	—	—	—
	—	(0.07)	—	—	—
Country institutions: labor markets	—	—	0.11	—	—
	—	—	(0.11)	—	—
Country institutions: index	—	—	—	0.54***	—
	—	—	—	(0.08)	—
Country environmental regulation	—	—	—	—	0.65***
	—	—	—	—	(0.08)
N	90	91	86	86	79
Panel B. Dependent variable: country water quality					
Country institutions: financial	0.30**	—	—	—	—
	(0.12)	—	—	—	—
Country institutions: judicial	—	0.29**	—	—	—
	—	(0.13)	—	—	—
Country institutions: labor markets	—	—	0.14	—	—
	—	—	(0.13)	—	—
Country institutions: index	—	—	—	0.31**	—
	—	—	—	(0.13)	—
Country environmental regulation	—	—	—	—	0.27**
	—	—	—	—	(0.12)
N	66	66	66	66	60

Notes: each observation is a country. Log of country air quality is negative one times the log of the country's mean PM_{10} in μg/m^3. Log of country water quality is negative one times the log of the country's mean biochemical oxygen demand in mg/L. Table shows beta coefficients. Asterisks denote p-value * < 0.10, ** < 0.05, *** < 0.01.

Table 2—Industry Clean Index and Industry Dependence on Institutions

	Clean index	Industry dependence on institutions			
		Financial	Judicial	Labor markets	Index
	(1)	(2)	(3)	(4)	(5)
Panel A. Cleanest industries					
Office supply manufacturing	2.64	0.47	0.07	0.12	0.22
Instruments for industrial processes	2.58	1.75	1.18	-0.54	1.21
Fluid power pumps and motors	2.42	1.54	0.66	0.88	1.30
Curtain and linen mills	2.40	-0.23	0.54	1.35	0.90
Precision turned product manufacturing	2.23	-0.61	0.15	0.08	-0.03
Mean for cleanest industries	*2.46*	*0.58*	*0.52*	*0.38*	*0.72*
Panel B. Dirtiest industries					
Aluminum refining and production	-2.17	-0.49	-1.63	-0.53	-1.67
Gypsum product manufacturing	-2.18	-0.59	-1.16	-1.22	-1.60
Pulp mills	-2.22	-0.49	-0.48	-0.18	-0.61
Newsprint mills	-2.30	-0.53	-0.60	-0.81	-0.96
Other petroleum, coal products	-2.43	-0.22	-1.26	0.64	-0.84
Mean for dirtiest industries	*-2.26*	*-0.46*	*-1.03*	*-0.42*	*-1.14*

Notes: table includes manufacturing industries with non-missing values of all listed variables.

Table 3—Sources of Comparative Advantage

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Panel A. Comparative advantage in all industries										
Country endowment × industry intensity:										
Institutions: financ.	0.019***	—	—	—	—	—	—	—	0.011***	—
	(0.001)	—	—	—	—	—	—	—	(0.001)	—
Institutions: judicial	—	0.051***	—	—	—	—	—	—	0.035***	—
	—	(0.002)	—	—	—	—	—	—	(0.002)	—
Institutions: labor	—	—	0.003***	—	—	—	—	—	0.003***	—
	—	—	(0.001)	—	—	—	—	—	(0.001)	—
Institutions: index	—	—	—	0.052***	—	—	—	—	—	0.035***
	—	—	—	(0.002)	—	—	—	—	—	(0.002)
Environmental reg.	—	—	—	—	0.048***	—	—	—	0.026***	0.030***
	—	—	—	—	(0.002)	—	—	—	(0.002)	(0.002)
Factor capital/lab.	—	—	—	—	—	0.002	—	—	0.022***	0.020***
	—	—	—	—	—	(0.002)	—	—	(0.002)	(0.002)
Factor: skills	—	—	—	—	—	—	0.071***	—	0.056***	0.056***
	—	—	—	—	—	—	(0.002)	—	(0.002)	(0.002)
Tariffs	—	—	—	—	—	—	—	-0.049***	-0.049***	-0.049***
	—	—	—	—	—	—	—	(0.005)	(0.005)	(0.005)
N	1,826,444	1,826,444	1,826,444	1,826,444	1,826,444	1,826,444	1,826,444	1,826,444	1,826,444	1,826,444
Panel B: Comparative advantage in clean industries										
Country endowment × clean industry index:										
Institutions: financ.	0.052***	—	—	—	0.035***	—	—	—	—	—
	(0.002)	—	—	—	(0.003)	—	—	—	—	—
Institutions: judicial	—	0.051***	—	—	0.010*	—	—	—	—	—
	—	(0.002)	—	—	(0.005)	—	—	—	—	—
Institutions: labor	—	—	0.019***	—	0.007***	—	—	—	—	—
	—	—	(0.002)	—	(0.002)	—	—	—	—	—
Institutions: index	—	—	—	0.054***	—	0.040***	—	—	—	—
	—	—	—	(0.002)	—	(0.003)	—	—	—	—
Environmental reg.	—	—	—	—	0.009*	0.010***	—	—	—	—
	—	—	—	—	(0.005)	(0.003)	—	—	—	—
Country endowment × industry intensity:										
Factors capital/lab.	—	—	—	—	0.016***	0.016***	—	—	—	—
	—	—	—	—	(0.002)	(0.002)	—	—	—	—
Factors: skills	—	—	—	—	0.060***	0.059***	—	—	—	—
	—	—	—	—	(0.002)	(0.002)	—	—	—	—
Tariffs	—	—	—	—	-0.049***	-0.049***	—	—	—	—
	—	—	—	—	(0.005)	(0.005)	—	—	—	—
N	1,826,444	1,826,444	1,826,444	1,826,444	1,826,444	1,826,444	—	—	—	—
Fitted effect 10→90%	-21.2%	-37.0%	-15.4%	-35.4%	-23.4%	-26.7%	—	—		
Importer×exporter FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Importer×industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: In Panel A, the main explanatory variables are the interaction of an exporter's endowment with the industry's intensity. Each observation is an importer×exporter×manufacturing industry. Dependent variable is log of bilateral trade. Table shows beta coefficients. Fitted effect 10→90% implements equation (10). Standard errors are clustered by importer×exporter pair. Asterisks denote p-value * < 0.10, ** < 0.05, *** < 0.01.

Table 4—Institutions and Comparative Advantage, Alternative Research Designs

	All industries				Clean industries			
Institution:	Financial	Judicial	Labor	Inst. Index	Financial	Judicial	Labor	Inst. Index
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A. Baseline								
Institutions interaction	0.012***	0.036***	0.002***	0.035***	0.038***	0.034***	0.011***	0.040***
	(0.001)	(0.002)	(0.001)	(0.002)	(0.003)	(0.006)	(0.001)	(0.003)
Environmental regulation	0.040***	0.027***	0.040***	0.030***	0.017***	0.011**	0.038***	0.010***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.005)	(0.002)	(0.003)
N	1,826,444	1,826,444	1,826,444	1,826,444	1,826,444	1,826,444	1,826,444	1,826,444
Panel B. Instrument with legal origins								
Institutions interaction	0.029***	0.059***	-0.004***	0.052***	0.034***	0.092***	0.026***	0.048***
	(0.002)	(0.005)	(0.001)	(0.004)	(0.012)	(0.013)	(0.003)	(0.005)
Environmental regulation	0.039***	0.018***	0.040***	0.025***	0.019**	-0.040***	0.036***	0.004
	(0.002)	(0.002)	(0.002)	(0.002)	(0.008)	(0.011)	(0.002)	(0.004)
N	1,826,444	1,826,444	1,826,444	1,826,444	1,826,444	1,826,444	1,826,444	1,826,444
Panel C. Full panel								
Institutions interaction	0.002***	0.018***	0.003***	0.010***	0.005***	0.021***	0.006***	0.013***
	(0.000)	(0.003)	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)
N	29,615,619	31,205,815	29,179,570	27,743,169	30,409,354	31,205,815	29,179,570	28,488,568
Panel D. Long difference								
Institutions interaction	0.002	0.065***	0.034***	0.041***	0.014***	0.073***	0.050***	0.061***
	(0.003)	(0.014)	(0.009)	(0.008)	(0.004)	(0.014)	(0.008)	(0.008)
N	2,977,570	3,129,772	3,125,693	2,973,978	3,057,707	3,129,772	3,125,693	3,054,038
Panel E. Intra-national: India								
Institutions interaction	0.492***	0.096***	0.008	0.117***	0.837***	0.066***	-0.006	0.077***
	(0.104)	(0.020)	(0.017)	(0.010)	(0.091)	(0.017)	(0.015)	(0.009)
N	6,189	7,840	6,686	6,189	6,328	7,840	6,686	6,328
Importer×exporter FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Importer×industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Factor interactions, tariffs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: "Institution interaction: is interaction of county institutions×industry clean index. Environmental regulation is interaction of country environmental regulation and industry clean index. Additional controls in Panel E are state FE, industry FE, and factor interactions. Table entries show standardized beta coefficients, for manufacturing industries. Standard errors are clustered by importer×exporter pair. Asterisks denote p-value * < 0.10, ** < 0.05, *** < 0.01.

Table 5: Roles of Other Industry Characteristics

	Association with clean index	Dependence of clean industries on institutions:			Comparative advantage of clean industries
		Financial	Judicial	Labor	
	(1)	(2)	(3)	(4)	(5)
Baseline	—	0.10**	0.49***	0.14***	0.054***
	—	(0.05)	(0.04)	(0.05)	(0.004)
Energy share	-0.37***	0.11*	0.42***	0.12***	0.053***
	(0.12)	(0.06)	(0.04)	(0.05)	(0.003)
Raw materials share	-0.36***	0.07	0.33***	0.15***	0.043***
	(0.05)	(0.06)	(0.04)	(0.05)	(0.003)
Upstreamness	-0.35***	0.09	0.37***	0.12**	0.059***
	(0.05)	(0.06)	(0.04)	(0.05)	(0.004)
Inverse export supply elasticity	0.27***	0.08	0.50***	0.12*	0.053***
	(0.06)	(0.07)	(0.05)	(0.06)	(0.004)
Mean wage	0.14**	0.08	0.45***	0.09*	0.053***
	(0.06)	(0.06)	(0.05)	(0.05)	(0.004)
Unemployment (%)	0.09*	0.13**	0.47***	0.11**	0.055***
	(0.05)	(0.06)	(0.05)	(0.05)	(0.004)
College educated	0.20***	0.05	0.45***	0.08	0.051***
	(0.06)	(0.06)	(0.05)	(0.05)	(0.004)
Union membership	-0.25***	0.14**	0.47***	0.10*	0.054***
	(0.05)	(0.07)	(0.05)	(0.06)	(0.004)
Intra-industry share	0.12*	0.09	0.56***	0.12**	0.055***
	(0.06)	(0.07)	(0.05)	(0.06)	(0.004)
Geographic dispersion	-0.02	0.12**	0.48***	0.10**	0.054***
	(0.06)	(0.06)	(0.05)	(0.05)	(0.004)
Labor share	0.27***	0.17***	0.43***	0.09	0.051***
	(0.05)	(0.06)	(0.05)	(0.06)	(0.004)
Capital share	-0.20***	0.10*	0.48***	0.10*	0.055***
	(0.07)	(0.06)	(0.05)	(0.05)	(0.004)
Log shipping cost per ton×km	-0.45***	0.00	0.41***	0.03	0.047***
	(0.06)	(0.09)	(0.06)	(0.07)	(0.004)
Mean firm size	-0.10***	0.13**	0.47***	0.10*	0.054***
	(0.04)	(0.06)	(0.05)	(0.05)	(0.004)
Std. dev. Firm size	-0.06	0.13**	0.48***	0.10*	0.054***
	(0.04)	(0.06)	(0.05)	(0.05)	(0.004)
Concentration ratio	-0.11*	0.13**	0.49***	0.10*	0.054***
	(0.06)	(0.06)	(0.05)	(0.05)	(0.004)
Log output	0.02	0.13**	0.47***	0.10*	0.054***
	(0.05)	(0.06)	(0.05)	(0.05)	(0.004)
Output trend 1977-2007	-0.11*	0.13**	0.48***	0.06	0.053***
	(0.06)	(0.06)	(0.05)	(0.05)	(0.004)
All at once	—	-0.08	0.13**	-0.02	0.033***
	—	(0.11)	(0.06)	(0.10)	(0.004)

Notes: Each table entry shows beta coefficients from a separate regression, limited to manufacturing. Column (1) regresses each variable on an indicator for whether the industry's clean index is above median. Columns (2)-(4) regress institutional dependence on the clean industry index and one additional variable shown in a given row; table entries show coefficient on the clean index. Column (5) estimates equation (4), but also controlling for the interaction of institutions with the variable indicated in each row. Parentheses show robust standard errors in columns (1)-(4) and standard errors clustered by country pair in column (5). Asterisks denote p-value * < 0.10, ** < 0.05, *** < 0.01.

Table 6—Decomposition: Scale, Composition, and Technique, US as Reference

	All	CO	NO_x	$PM_{2.5}$	SO_x	VOCs
	(1)	(2)	(3)	(4)	(5)	(6)
1. Scale, composition, and technique	-0.72	-0.75	-0.83	-0.46	-0.68	-0.89
	(0.70)	(0.66)	(0.35)	(1.51)	(0.86)	(0.19)
2. Scale	-0.90	—	—	—	—	—
	(0.19)	—	—	—	—	—
3. Composition	1.75	1.22	2.09	2.79	2.09	0.57
	(1.21)	(1.20)	(1.45)	(1.97)	(2.21)	(0.55)
4. Technique	-0.03	0.09	-0.36	0.24	0.20	-0.32
	(0.59)	(0.75)	(0.43)	(1.07)	(1.18)	(0.31)
5. |Composition|	1.76	1.26	2.09	2.81	2.09	0.60
	(1.19)	(1.16)	(1.44)	(1.94)	(2.21)	(0.52)
6. |Technique|	0.47	0.51	0.49	0.73	0.86	0.38
	(0.36)	(0.56)	(0.28)	(0.81)	(0.82)	(0.22)

Notes: calculations use full Exiobase data. Scale, composition, and technique are all proportional difference relative to US. Row 2 uses production but not pollution data, so it is identical across pollutants. Emission rates are winsorized at 99.9th percentile. Calculations cover all industries.

Table 7—Effects of Counterfactual Institutions on Emissions: Model-Based Analysis

		Counterfactual change in…			Change: share output from…		
	Baseline institutions (z-score)	Institutional quality (z-score)	Emissions (%)	Emissions/ output (%)	Dirty industries	Moderate industries	Clean industries
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A. Counterfactual: remove institutional differences between countries							
Pacific Ocean	1.9	-1.0	3.7%	5.5%	1.2%	0.2%	-1.4%
Western Europe	1.3	-0.4	0.7%	1.5%	0.3%	0.0%	-0.3%
Eastern Europe	0.2	0.6	-2.8%	-2.9%	-0.9%	-0.3%	1.2%
Latin America	-0.6	1.5	-11.0%	-11.5%	-1.3%	-0.8%	2.1%
North America	2.4	-1.6	2.9%	4.9%	0.7%	0.4%	-1.1%
China	0.7	0.2	-1.0%	-1.0%	-0.3%	-0.2%	0.5%
Southern Europe	0.7	0.1	-1.4%	-1.5%	-0.3%	-0.1%	0.4%
Northern Europe	2.2	-1.4	7.8%	9.6%	1.6%	0.7%	-2.3%
Indian Ocean	-0.3	1.2	-5.3%	-4.8%	-0.9%	-0.1%	1.0%
Rest of World	0.2	0.7	-6.1%	-6.0%	-1.0%	-0.6%	1.6%
Global	—	—	*-2.6%*	*-1.8%*	—	—	—
Panel B. Counterfactual: improve institutions in countries with below-median baseline institutions							
Pacific Ocean	1.9	0.0	3.7%	3.6%	0.8%	0.1%	-1.0%
Western Europe	1.3	0.0	3.5%	3.4%	0.7%	0.1%	-0.8%
Eastern Europe	0.2	1.5	-3.6%	-3.6%	-0.9%	-0.3%	1.2%
Latin America	-0.6	2.4	-13.1%	-13.6%	-1.4%	-0.7%	2.1%
North America	2.4	0.0	2.5%	2.3%	0.4%	0.2%	-0.5%
China	0.7	1.1	-2.9%	-2.5%	-0.6%	-0.1%	0.7%
Southern Europe	0.7	0.0	3.0%	2.8%	0.7%	0.1%	-0.8%
Northern Europe	2.2	0.0	3.9%	3.7%	0.6%	0.2%	-0.8%
Indian Ocean	-0.3	2.0	-6.6%	-5.6%	-0.8%	0.2%	0.6%
Rest of World	0.2	1.6	-7.5%	-7.1%	-1.0%	-0.2%	1.2%
Global	—	—	*-3.7%*	*-3.7%*	—	—	—
Panel C. Counterfactual: improve institutions in Latin America							
Pacific Ocean	1.9	0.0	0.4%	0.4%	0.1%	0.0%	-0.1%
Western Europe	1.3	0.0	0.4%	0.4%	0.1%	0.0%	-0.1%
Eastern Europe	0.2	0.0	0.2%	0.2%	0.1%	0.0%	-0.1%
Latin America	-0.6	3.1	-19.6%	-20.4%	-2.2%	-1.1%	3.3%
North America	2.4	0.0	1.1%	1.0%	0.2%	0.1%	-0.2%
China	0.7	0.0	0.3%	0.4%	0.1%	0.0%	-0.1%
Southern Europe	0.7	0.0	0.4%	0.4%	0.1%	0.0%	-0.1%
Northern Europe	2.2	0.0	0.5%	0.5%	0.1%	0.0%	-0.1%
Indian Ocean	-0.3	0.0	0.3%	0.3%	0.1%	0.0%	-0.1%
Rest of World	0.2	0.0	1.0%	0.9%	0.1%	0.1%	-0.2%
Global	—	—	*-1.0%*	*-1.0%*	—	—	—

Notes: institutional quality is principal component for each country. Dirty, moderate, and clean industries are based on dividing global industries into thirds based on global log emissions rate, measured as the first principal component of the log emissions rate across pollutants, and calculated as a weighted average across all countries. Data from Exiobase.

Online Appendix

Institutions, Comparative Advantage, and the Environment:
Why are Developing Countries Polluted?

Joseph S. Shapiro

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A Data Details

A.1 General Data Details

CEPII reports import tariffs in the year 2010 for all but three countries that have data on other required variables (institutions, etc.). For Thailand, I use year 2007 rather than 2010 tariff data. For Iraq and Liberia, I average tariffs within industry code for the adjacent countries (for Iraq, I average Iran, Kuwait, Saudi Arabia, Jordan, Syria, and Turkey; for Liberia, I average Sierra Leone, Guinea, and Code d'Ivoire). One estimate uses measures of bilateral trade frictions (distance, common language, etc.) from CEPII's Gravity database.

I report sensitivity analyses examining 12 alternative measures of institutions. One sensitivity analysis defines financial institutions according to measures of financial institution and market development from the International Monetary Fund (Svirydzenka 2016*a*). Another analysis defines the quality of a country's financial institutions according to the measure of this concept reported in the World Bank's Doing Business Report (World Bank 2007).

For estimates using Exiobase, Shapiro (2021) describes details of cleaning and setting up these data. The air pollution measures in Exiobase use observed information from North America, Europe, and Asia where available, and complete additional pollution measures use information on production technologies by sector and aggregate emissions (Stadler et al. 2018). Exiobase records non-methane volatile organic compounds, which is similar but not identical to the total volataile organic compounds that the National Emissions Inventory reports. Methane is sometimes separated as an organic compound since it is less reactive to form ambient ozone pollution (Jacobsen et al. 2023).

For judicial institutions, sensitivity analyses consider the Fraser Institute (2021)'s index of legal and property rights and the World Bank (2007)'s Doing Business index of contract enforcement.

For labor market institutions, I report sensitivity analyses that use the employment protection index from the International Labor Organization (2015), the employing workers index from the World Bank (2007)'s Doing Business Report, the index of labor market efficiency from the World Economic Forum (2015), and Botero et al. (2004)'s index of employment laws. I multiply the International Labor Organization, World Bank, and Botero et al. indices, which are designed to measure labor market restrictiveness, by negative one so that larger and more positive values of the labor market institutions index represent more flexible labor market institutions.

In the sensitivity analysis using panel data, because labor institutions data are only available for the period 2005-2016, I assume labor institutions are constant over the period 1996-2005. Data on judicial institutions are missing in years 1997, 1999, and 2001, so for the sensitivity analysis using panel data, I linearly interpolate values for these years only within each country.

The National Emissions Inventory is collected every three years, so I use data from the 2011 edition, which is the closest to year 2012. Some firms report pollution with a 6-digit NAICS code, while others report a more aggregate industry code. I measure pollution for each 6-digit NAICS code in the analysis using the most detailed industry code available from the National Emissions Inventory data.

For the industry characteristics data used in Table 5 that help explain why clean industries depend on institutions, many records are adapted from Shapiro (2021) and represent the year 2007.

Large polluting plants must report quarterly concentrations or quantities of many regulated water pollutants to the EPA. The discharge microdata have numerous outflows and measures of concentration per establishment, so I use aggregate emissions data from the EPA's online discharge reporting tool.

To study intra-national production in India, I use production decisions from India's 2015-2016 Annual Survey of Industries. The survey includes all registered factories with over 100 workers, and a sample of smaller establishments.

A.2 Institutions

This subsection provides additional detail on the measures of national institutions. The index of financial institutions measures the depth of bank, finance, and insurance markets, access to bank branches and ATMs, and efficiency in intermediating savings to investment, operational efficiency, and profitability of financial institutions (Svirydzenka 2016*b*). The (World Bank) index of judicial institutions is constructed from international polls, global surveys, and country ratings by many international organizations and risk-rating agencies.

To define each industry's dependence on judicial institutions, I use data on whether each good is sold on an open exchange, reference-priced, or has decentralized exchange; and input shares data from the 2012 Bureau of Economic Analysis Use table, at detail after redefinitions. Rauch reports four measures (liberal and conservative measures of the share of goods that are differentiated or not priced on open markets). My main results use Rauch's liberal definition of the share of goods that are differentiated (i.e., not referenced priced or traded on open markets), since it has the most variability across industries. I discuss sensitivity analyses based on Rauch's other definitions.

A.3 Concordance Files

I use several concordance files to ensure all data have the same country and industry classifications. I obtain raw bilateral trade data from CEPII-BACI, at the 6-digit Harmonized System (HS) code level. I concord this to the US NAICS industry code level using links between these industry codes from the US Census Bureau's Imports and Exports of Merchandise data.

The classification of industries as traded on open markets, reference-priced, or differentiated uses the SITC industry classification (Rauch 1999). I link these to Harmonized System (HS) codes using a concordance file from the United Nations, and then from HS to NAICS using the aforementioned concordance.

I translate various data to U.S. industry codes using other standard concordance files. Some of the industry characteristics are reported in North American Industry Classification System (NAICS) codes from other years like 2002 or 2007, and I use US industry concordances to translate these to the 2012 NAICS codes used in the rest of the paper. For data reported using SIC industry codes, I translate these to NAICS using a concordance file derived from Fort and Klimek (2016). Other industry characteristics are derived from the U.S. input-output table, and I translate input-output industry codes to NAICS industry codes using a concordance file from the Bureau of Economic Analysis.

B Alternative Specifications for Comparative Advantage

Appendix Table 7 shows results from alternative approaches to estimate how institutions affect comparative advantage in clean industries. Appendix A.1 describes data used in several of these estimates. Row 1 re-states the main results from Table 4. Row 2 includes all three institutions simultaneously. Row 3 includes all industries, not only manufacturing. Row 4 replaces the bilateral fixed effects η_{ij}^C from equation (9) with exporter fixed effects η_i^C and controls for bilateral trade frictions from CEPII: bilateral distance, common language, colonizer, religion, legal origin, regional trade agreement, and World Trade Organization membership. Row 5 estimates the regression in levels, including zero trade flow observations, using Poisson pseudo maximum likelihood (Silva and Tenreyro 2006). Row 6 uses Exiobase, at the same level of observation as the quantitative model. Row 7 measures pollution from the Leontief Inverse Matrix of the Input-Output table, which includes emissions embodied in the entire value chain of a good. Row 8 replaces the clean industry index with an indicator for the cleanest roughly 90 percent of industries, which makes this estimate focus on extensive margin differences between especially dirty industries and others, a binary distinction which is commonly analyzed in the Pollution Havens Hypothesis literature. ROw 9 regresses the clean index on industry fixed effects and a country's institutions index, as one way to learn about how institutions relate to cross-country and within industry differences in production techniques.

These sensitivity analyses in Appendix Table 7 obtain results that are qualitatively similar to the main estimates, though magnitudes vary somewhat across samples and specifications. For example, nearly all the alternative estimates are positive, and most are statistically distinguishable from zero. Financial and judicial institutions appear to drive trade more than labor market institutions. Adjusting estimates with methods to account for zero trade flows somewhat decreases the importance of institutions overall but increases their importance for clean industries.

C Details of Scale, Composition, and Technique Decomposition

Many papers report the following decomposition, where x_{rs} represents gross output in industry s and reference (baseline) year r, e_{rs} represents the emission rate from in the reference year, κ_{is} is the share of the economy's gross output from industry s in year i, and X_i is the economy's gross output in year i:

$$\text{Scale} = \frac{X_i}{X_r} \tag{C–1}$$

$$\text{Scale+Composition} = \frac{X_i \sum_s \kappa_{is} e_{rs}}{X_r \sum_s \kappa_{rs} e_{rs}} = \frac{X_i \sum_s \kappa_{is} e_{rs}}{\mathcal{E}_r} \tag{C–2}$$

$$\text{Scale+Composition+Technique} = \frac{X_i \sum_s \kappa_{is} e_{is}}{X_r \sum_s \kappa_{rs} e_{rs}} = \frac{\mathcal{E}_i}{\mathcal{E}_r} \tag{C–3}$$

The second and third lines use the fact that an economy's total emissions in a year are $\mathcal{E}_i = X_i \sum_s \kappa_{is} e_{is}$.

These equations have simple interpretations. The scale effect equals the ratio of gross output in year i relative to the baseline year r. This is identical to the Scale effect from the main text, in equation (18). Scale+Composition allows gross output X and output shares κ to evolve following actual data in year i, but holds emission rates fixed in the baseline year r. Specifically, Scale+Composition evaluates pollution in year i as gross output in that year, multiplied by the sum of output shares in that year, but evaluated at baseline emission rates. The third equation, Scale+Composition+Technique, equals the ratio of national pollution emissions in year i relative to the baseline year r.

How do these equations relate to the Composition and Technique equations from the main text? The composition effect from the main text, in equation (19), equals Scale+Composition in equation (C–2) divided by Scale in equation (C–1):

$$\text{Composition} = \frac{\sum_s \kappa_{is} e_{rs}}{\sum_s \kappa_{rs} e_{rs}} = \frac{\frac{X_i \sum_s \kappa_{is} e_{rs}}{X_r \sum_s \kappa_{rs} e_{rs}}}{\frac{X_i}{X_r}}$$

The technique effect from the main text, in equation (20), equals Scale+Composition+Technique from equation (C–3), divided by Scale+Composition from equation (C–2):

$$\text{Technique} = \frac{\sum_s \kappa_{is} e_{is}}{\sum_s \kappa_{is} e_{rs}} = \frac{\frac{X_i \sum_s \kappa_{is} e_{is}}{X_r \sum_s \kappa_{rs} e_{rs}}}{\frac{X_i \sum_s \kappa_{is} e_{rs}}{X_r \sum_s \kappa_{rs} e_{rs}}}$$

D Quantitative Model of Trade, Institutions, and Pollution

This appendix section describes the quantitative model. The representative agent in country j maximizes utility U_j, which is a CES aggregate across varieties and a Cobb-Douglas aggregate across sectors:

$$U_j = \prod_s \left[\left(\int_\Omega q_{j,s}(\omega)^{\frac{\sigma_s - 1}{\sigma_s}} d\omega \right)^{\frac{\sigma_s}{\sigma_s - 1}} \right]^{\beta_{j,s}} f(\mathcal{E}_j)$$

Here $q_{js}(\omega)$ is the quantity of variety ω shipped from origin i to destination j in sector s, σ is the elasticity of substitution across varieties, and β_{js} is the Cobb-Douglas expenditure share. The representative agent experiences disutility $f(\cdot)$ from pollution Z_j, which I treat as a pure externality that does not directly affect expenditure decisions.

Trade. For each variety, producers in a country draw a productivity from a Fréchet distribution with location parameter $T_{i,s}$ and dispersion parameter θ_s. Buyers source each variety from the seller with the lowest offered price. The associated price index is

$$P_{j,s} = \xi_1 \left[\sum_i T_{i,s} (c_{i,s} \phi_{ij,s})^{-\theta_s} \right]^{-1/\theta_s}$$

where the trade elasticity is $\theta_s = \sigma_s - 1$ and ξ_1 is a constant function of θ_s and σ_s. Goods face iceberg trade costs $\tau_{ij,s} \geq 1$ where τ goods must be shipped for one to arrive, and tariffs $t_{ij,s}$. The full trade cost is $\phi_{ij,s} \equiv \tau_{ij,s}(1 + t_{ijs})$. Although counterfactual policies do not change tariffs, given the differences in trade policy between clean and dirty industries (Shapiro 2021), the model accounts for pre-existing tariff levels.

Production. Production is Cobb-Douglas and uses labor, hired at wage w_i, and intermediate goods, with cost share $\alpha_{ik,s}$ for sector k inputs used to produce sector s outputs. The unit cost function is

$$c_{i,s} = \xi_2 w_i^{1-\alpha_{i,s}} \prod_k P_{i,k}^{\alpha_{i,ks}}$$

where ξ_2 is a constant function of model parameters.

Pollution. The pollution emitted in country i is

$$\mathcal{E}_i = \sum_s \frac{\gamma_{i,s} R_{i,s}}{c_{i,s}}$$

where $\gamma_{i,s}$ measures the baseline units of pollution emitted per real output. This assumes that within a country and industry, pollution is a fixed feature of production that is invariant to counterfactual reforms. Such an assumption would not be appropriate for counterfactual changes like reforming environmental policy. It is a plausible simplification for broad changes in institutions and trade policy and reflects discussion and analysis from the main text of institutions limited impact on production techniques. While reforms for energy and fossil fuels would change prices and supply of these energy goods, air and water pollution are not traded in such global markets, so these concerns are less important for pollution. Finally, institutions could change an industry's pollution intensity $\gamma_{i,s}$ through changing inputs or technology. This analysis provides a conservative role for institutions, by shutting this channel off. Because institutions in this model affect pollution through comparative advantage, if all countries improve institutions proportionally, global pollution does not change.

Equilibrium. I study a competitive equilibrium, in which consumers maximize utility, firms maximize profits, and markets clear. Total country×sector expenditure, $X_{j,s}$, equals the sum of expenditure on final and intermediate goods:

$$X_{j,s} = \beta_{j,s}(Y_j + D_j + G_j) + \sum_k \alpha_{j,sk} R_{j,k}$$

where fixed deficits are given by D_j, government tariff revenues by G_j, and country×sector revenues by $R_{i,s} = \sum_j X_{ij,s}$.

To study effects of counterfactuals, I express variables in changes (Dekle, Eaton and Kortum 2008). For any variable a in the model, let a' denote the value in a counterfactual and let $\hat{a} = a'/a$ denote the proportional change due to a counterfactual. I let global GDP serve as the numeraire. The change in expenditure shares due to a counterfactual is

$$\hat{\lambda}_{ij,s} = \hat{T}_{i,s} \left(\frac{\hat{c}_{i,s}\hat{\phi}_{ij,s}}{\hat{P}_{j,s}} \right)^{-\theta_s} \tag{D–4}$$

where $\lambda_{ij,s} = X_{ij,s}/\sum_i X_{ij,s}$ is the share of (j,s) expenditure on goods from exporting country i. The change in cost shares, country×sector price index, expenditure, and revenues, is

$$\hat{c}_{i,s} = \hat{w}_i^{1-\alpha_{i,s}} \prod_k \hat{P}_{i,k}^{\alpha_{i,ks}} \tag{D–5}$$

$$\hat{P}_{j,s} = \left[\sum_i \lambda_{ij,s} \hat{T}_{i,s} (\hat{c}_{i,s}\hat{\phi}_{ij,s})^{-\theta_s} \right]^{-1/\theta_s}$$

$$\hat{X}_{j,s} X_{j,s} = \frac{\beta_{j,s}}{1 - \sum_{i,s} \frac{t_{ij,s}}{1+t_{ij,s}} \hat{\lambda}_{ij,s}\lambda_{ij,s}\beta_{j,s}} \left(\hat{w}_j Y_j + D_j + \sum_{i,l} \frac{t_{ij,l}}{1+t_{ij,l}} \hat{\lambda}_{ij,l}\lambda_{ij,l} \sum_k \alpha_{j,lk}\hat{R}_{j,k}R_{j,k}\right) + \sum_k \alpha_{j,sk}\hat{R}_{j,k}R_{j,k}$$

$$\hat{R}_{i,s} = \frac{\sum_j X'_{ij,s}}{\sum_j X_{ij,s}} \tag{D–6}$$

Counterfactual revenues equal $\hat{R}_{i,s}R_{i,s} = \hat{w}_i \hat{y}_{i,s} y_{i,s} Y_i/(1-\alpha_{i,s})$. Bilateral sales are given by $X'_{ij,s} = \hat{\lambda}_{ij,s}\lambda_{ij,s}\hat{X}_{j,s}X_{j,s}$, and counterfactual industry shares are given by

$$\sum_s \hat{y}_{i,s} y_{i,s} = 1 \tag{D–7}$$

E Appendix Figures and Tables

Appendix Table 1: Data Sources and Variables

Variable	Measure	Source, Notes
Panel A. Country level variables		
Institutions: financial	Private credit by deposit and money institutions / GDP	World Bank Financial Structure Database
Institutions: judicial	Rule of law index	Kauffman et al. (2011)
Institutions: labor	Labor market freedom index	Heritage Foundation (2021)
Environmental regulation	Sulfur standard for diesel; enviro. regulation enforcement; enviro. regulation stringency; enviro. treaties signed; air quality standards for particulates, sulfur dioxide; lead standard for gasoline; enviro. taxes / GDP.	World Economic Forum (2013); IMF (2022): Joss et al. (2017); Broner et al. (2011); UNEP (2022)
Factor endowments	Log capital stock per worker; human capital index	Penn World Tables (Feenstra et al. 2021)
Ambient pollution	Particulate matter smaller than 10 micrometers (PM_{10}) and biochemical oxygen demand (BOD)	Global Environmental Monitoring System for freshwater (GEMStat)
Panel B. Industry level variables		
Institution intensity: financial	Share of capital expenditures not funded by internal cash flow	Compustat North America. From Rajan and Zingales (1998)
Institution intensity: judicial	Share of industry's inputs not traded on open markets or reference priced	BEA input-output table, Rauch (1999). From Nunn (2007)
Institution intensity: labor	Standard deviation of within-firm sales growth	Compustat North America. From Cunat and Melitz (2012)
Air pollution emissions	Carbon monoxide, nitrogen oxides, particulate matter smaller than 2.5 micrometers, sulfur dioxide, and volatile organic compounds, log pollution per dollar revenue	Year 2011 National Emissions Inventory from US Environmental Protection Agency
Water pollution emissions	Total pounds, log per dollar revenue	US Dicharge Monitoring Reports
Revenues	Industry total value of shipments	US Census of Manufactures
Panel C. Country pair×industry and other data		
Trade, pollution		Exiobase
Trade		CEPII *Base pour Analyse du Commerce International* (BACI)
Tariffs	Applied tariffs	CEPII Market Access Map (Macmap)
Production		India's Annual Survey of Industry

Appendix Table 2—Correlation Between Country Characteristics and Between Industry Characteristics

	Institutions				Factor		Enviro. reg.,
	Financial	Judicial	Labor	Index	Capital	Skills	clean index
	(1)	(2)	(3)	(4)	(5)	(6)	(9)
Panel A. Country characteristics							
Institutions: financial	1.00	—	—	—	—	—	—
Institutions: judicial	0.76	1.00	—	—	—	—	—
Institutions: labor	0.17	0.26	1.00	—	—	—	—
Institutions: index	0.82	0.91	0.58	1.00	—	—	—
Factor intensity: capital	0.65	0.72	0.16	0.68	1.00	—	—
Factor intensity: skills	0.59	0.66	0.14	0.62	0.78	1.00	—
Enviro. regulation	0.74	0.88	0.13	0.79	0.68	0.65	1.00
Panel B. Industry characteristics							
Institutions: financial	1.00	—	—	—	—	—	—
Institutions: judicial	0.16	1.00	—	—	—	—	—
Institutions: labor	0.22	-0.01	1.00	—	—	—	—
Institutions: index	0.49	0.85	0.45	1.00	—	—	—
Factor intensity: capital	-0.02	-0.44	-0.14	-0.42	1.00	—	—
Factor intensity: skills	0.25	0.28	0.07	0.32	0.02	1.00	—
Clean index	0.10	0.50	0.14	0.49	-0.48	0.32	1.00

Notes: table entries show correlation coefficients between the variables. In Panel A, each observation is a country, table uses countries where all these variables are non-missing, N=120. In Panel B, each observation is an industry, N=364.

Appendix Table 3—Clean Index of a Country's Exports and Country Characteristics

	(1)	(2)	(3)	(4)	(5)	(6)	(9)
Country institutions: financial	0.39***	—	—	—	—	—	—
	(0.07)	—	—	—	—	—	—
Country institutions: judicial	—	0.35***	—	—	—	—	—
	—	(0.08)	—	—	—	—	—
Country institutions: labor markets	—	—	0.12	—	—	—	—
	—	—	(0.10)	—	—	—	—
Country institutions: index	—	—	—	0.37***	—	—	—
	—	—	—	(0.07)	—	—	—
Factor endowment: capital	—	—	—	—	0.22**	—	—
	—	—	—	—	(0.09)	—	—
Factor endowment: skills	—	—	—	—	—	0.33***	—
	—	—	—	—	—	(0.08)	—
Environmental regulation	—	—	—	—	—	—	0.39***
	—	—	—	—	—	—	(0.07)
N	111	111	111	111	111	111	111

Notes: each observation is a country. Dependent variable is the clean index of a country's exports, weighted across products by value in dollars. Each table entry shows beta coefficients. Asterisks denote p-value * < 0.10, ** < 0.05, *** < 0.01.

Appendix Table 4—Institutions and Legal Origin Interactions: First-Stage Estimates

	All industries				Clean industries			
Which institutions:	Financial	Judicial	Labor	Inst. Index	Financial	Judicial	Labor	Inst. Index
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Clean index × …								
Legal origins: British	-0.012***	0.005	0.053***	0.084***	-0.123***	0.011	0.652***	0.186***
	(0.004)	(0.006)	(0.003)	(0.013)	(0.040)	(0.014)	(0.046)	(0.027)
Legal origins: French	-0.020***	-0.088***	-0.017***	-0.096***	-0.255***	-0.158***	-0.105*	-0.181***
	(0.005)	(0.008)	(0.004)	(0.014)	(0.049)	(0.015)	(0.057)	(0.029)
Legal origins: German	-0.028***	-0.076***	0.001	-0.070***	-0.200***	-0.130***	0.023	-0.118***
	(0.004)	(0.005)	(0.003)	(0.012)	(0.037)	(0.011)	(0.045)	(0.023)
Legal origins: Socialist	-0.016***	-0.029***	0.004*	-0.029***	-0.133***	-0.051***	0.066**	-0.051**
	(0.003)	(0.003)	(0.002)	(0.010)	(0.026)	(0.006)	(0.033)	(0.020)
N	1,826,444	1,826,444	1,826,444	1,826,444	1,826,444	1,826,444	1,826,444	1,826,444
R-K F Statistic	16.5	97.5	269.4	213.9	10.8	65.8	242.7	164.4
Importer×exporter FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Importer×industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Factor interactions, tariffs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: Panel E uses state and industry FE. Each table entry shows beta coefficients. Standard errors are clustered by importer×exporter pair. Asterisks denote p-value * < 0.10, ** < 0.05, *** < 0.01.

Appendix Table 5—Comparative Advantage: Other Measures of Regulation

Industries:	All (1)	Clean (2)
1. Institutions index	0.029***	0.042***
	(0.003)	(0.004)
Environmental Regulation z score	0.007***	-0.010***
	(0.002)	(0.004)
N	1,277,804	1,277,804
2. Institutions index	0.037***	0.059***
	(0.002)	(0.003)
Environmental enforcement	0.017***	-0.014***
	(0.002)	(0.003)
N	1,826,444	1,826,444
3. Institutions index	0.037***	0.048***
	(0.002)	(0.003)
Environmental stringency	0.023***	-0.001
	(0.002)	(0.003)
N	1,826,444	1,826,444
4. Institutions index	0.042***	0.046***
	(0.002)	(0.002)
Environmental treaties	0.012***	0.008***
	(0.002)	(0.002)
N	1,826,444	1,826,444
5. Institutions index	0.039***	0.045***
	(0.002)	(0.002)
Air quality std. for particulates	0.008***	0.003
	(0.002)	(0.002)
N	1,624,612	1,624,612
6. Institutions index	0.038***	0.043***
	(0.002)	(0.002)
Air quality std. for sulfur dioxide	0.008***	0.003**
	(0.002)	(0.002)
N	1,574,376	1,574,376
7. Institutions index	0.034***	0.032***
	(0.002)	(0.002)
Gasoline standard for lead	0.043***	0.033***
	(0.002)	(0.003)
N	1,560,732	1,560,732
8. Institutions index	0.037***	0.035***
	(0.002)	(0.002)
Diesel standard for sulfur	0.042***	0.032***
	(0.002)	(0.003)
N	1,826,444	1,826,444

9. Institutions index	0.039***	0.041***
	(0.002)	(0.002)
Environmental taxes / GDP	0.005***	0.005***
	(0.002)	(0.002)
N	1,584,110	1,584,110

Notes: Column (1) shows the coefficients on country institution endowment×industry institution intensity and on country environmental regulation×industry clean index. Column (2) shows the coefficient on country institution endowment×industry clean index. Each table entry shows beta coefficients from a separate regression. Row 1 constructs the first principal component of the eight separate measures of regulation. All regressions control for importer×exporter FE, importer×industry FE, factor endowments×factor intensity, environmental regulation×pollution intensity, and tariffs. Standard errors are clustered by importer×exporter pair. Asterisks denote p-value * < 0.10, ** < 0.05, *** < 0.01.

Appendix Table 6—Comparative Advantage: Other Measures of Institutions

Industries:	All (1)	Clean (2)
Country financial institutions interactions		
1. IMF financial development	0.029***	0.066***
	(0.001)	(0.003)
N	1,820,639	1,820,639
2. IMF financial markets	0.024***	0.054***
	(0.001)	(0.003)
N	1,820,639	1,820,639
3. World Bank credit institutions	0.035***	0.061***
	(0.003)	(0.007)
N	1,826,444	1,826,444
Country judicial institutions interactions		
4. Fraser Institute judicial institutions	0.151***	0.097***
	(0.008)	(0.020)
N	1,826,444	1,826,444
5. World Bank number of procedures	0.081***	0.024**
	(0.010)	(0.010)
N	1,826,444	1,826,444
6. World Bank number of days	0.019***	-0.003
	(0.004)	(0.004)
N	1,826,444	1,826,444
7. World Bank percent cost	0.008***	0.005**
	(0.002)	(0.002)
N	1,826,444	1,826,444
Country labor market institutions interactions		
8. ILO labor protection	0.014***	0.007
	(0.003)	(0.006)
N	1,609,287	1,609,287
9. Doing Business Report--rigidity	0.002	0.025***
	(0.001)	(0.003)
N	1,826,444	1,826,444
10. World Economic Forum efficiency	0.022***	0.088***
	(0.005)	(0.013)
N	1,823,957	1,823,957
11. Botero et al. (2004)	0.007***	0.053***
employment laws	(0.003)	(0.004)
N	1,635,297	1,635,297

12. Botero et al. (2004)	0.011***	0.014**
collective relations laws	(0.003)	(0.006)
N	1,635,297	1,635,297
<u>Constraint on executive versus credit market institutions</u>		
13. Constraint on the executive	0.091***	0.031***
	(0.010)	(0.011)
N	1,818,583	1,818,583
14. Constraint on the executive:	0.167***	0.122***
settler mortality IV	(0.032)	(0.035)
N	794,086	794,086
15. Constraint on the executive:	0.589***	1.637
1500 pop. Density IV	(0.108)	(1.008)
N	1,748,835	1,748,835
16. Contracting institutions	0.010***	0.006***
	(0.002)	(0.002)
N	1,719,467	1,719,467
17. Contracting institutions:	0.022***	0.030***
Legal origins IV	(0.003)	(0.003)
N	1,719,467	1,719,467
18. Both:		
Constraint on the executive	0.080***	0.018
	(0.011)	(0.013)
Contracting institutions	0.012***	0.007***
	(0.002)	(0.002)
N	1,712,983	1,712,983
19. Both: settler mortality and legal origins IV		
Constraint on the executive	-0.402***	-0.061
	(0.105)	(0.041)
Contracting institutions	0.122***	0.070***
	(0.020)	(0.007)
N	763,144	763,144
20. Both: 1500 pop. density and legal origins IV		
Constraint on the executive	0.831***	12.245
	(0.190)	(34.622)
Contracting institutions	0.063***	0.429
	(0.011)	(1.020)
N	1,664,812	1,664,812
21. Both: 1500 pop density, settler mortality, and legal origins IV		
Constraint on the executive	0.013	-0.030
	(0.028)	(0.026)
Contracting institutions	0.055***	0.065***

	(0.005)	(0.005)
N	763,144	763,144

Notes: Column (1) shows the coefficient on country institution endowment×industry institution intensity. Column (2) shows the coefficient on country institution endowment×industry clean index. Each table entry shows beta coefficients from a separate regression. All regressions control for importer×exporter FE, importer×industry FE, factor endowments×factor intensity, environmental regulation×pollution intensity, and tariffs. Standard errors are clustered by importer×exporter pair. Asterisks denote p-value * < 0.10, ** < 0.05, *** < 0.01.

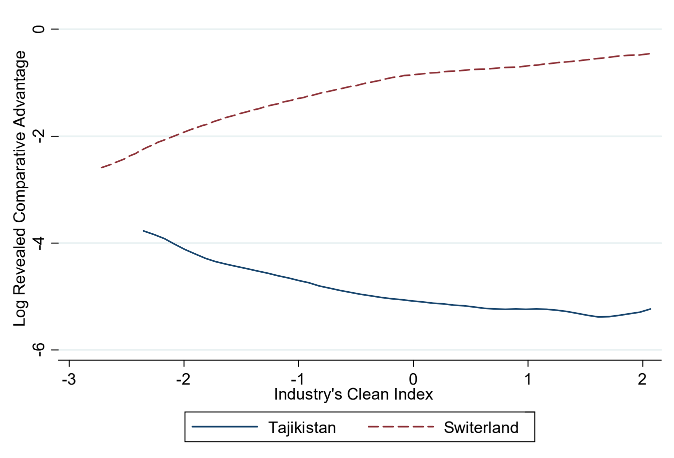
Appendix Table 7—Other Sensitivity Analyses

Industries:	All	Clean
	(1)	(2)
1. Baseline estimates	0.035***	0.040***
	(0.002)	(0.003)
N	1,826,444	1,826,444
2. All institution interactions at once		
Financial institutions	0.011***	0.035***
	(0.001)	(0.003)
Judicial institutions	0.035***	0.010*
	(0.002)	(0.005)
Labor market institutions	0.003***	0.007***
	(0.001)	(0.002)
N	1,826,444	1,826,444
3. All industries, not just manufact.	0.036***	0.044***
	(0.002)	(0.003)
N	1,866,538	1,932,690
4. Trade frictions, not i,j FE	0.035***	0.041***
	(0.002)	(0.003)
N	1,725,382	1,725,382
5. Poisson pseudo maximum likelihood	0.018***	0.052***
	(0.006)	(0.008)
N	87,200	88,843
6. Exiobase	0.123***	0.057***
	(0.007)	(0.007)
N	3,954,353	4,072,672
7. Leontief Inverse matrix	—	0.035***
	—	(0.002)
N	—	1,811,952
8. Indicator for dirtiest industries	—	0.040***
	—	(0.003)
N	—	1,826,444
9. Institutions and technique	-0.018	—
	(0.037)	—
N	6,303	—

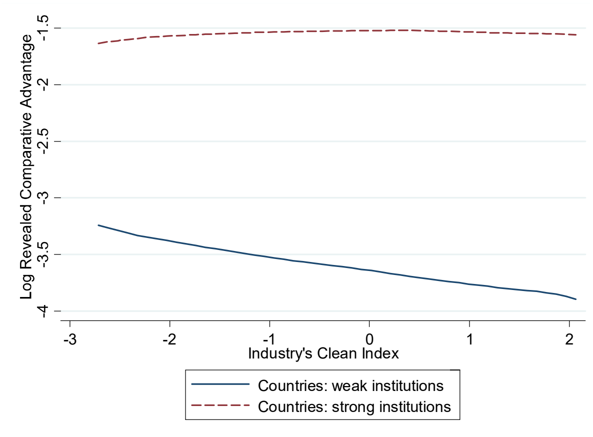
Notes: In rows 1-8, column (1) shows the coefficient on country institution endowment×industry institution intensity. Column (2) shows the coefficient on country institution endowment×industry clean index. Each table entry shows beta coefficients from a separate regression. Regressions control for importer×exporter FE, importer×industry FE, factor endowments×factor intensity, environmental regulation×pollution intensity, and tariffs. Row 3 assumes non-manufacturing industries have mean capital and labor levels. Row 9 regresses country×industry clean index from Exiobase on country institutions, environmental regulation, factor endowments, and industry fixed effects, and reports the coefficient on institutions. Standard errors are clustered by importer×exporter pair (rows 1-9) or by country (row 10). Asterisks denote p-value * < 0.10, ** < 0.05, *** < 0.01.

Appendix Figure 1. Industry Revealed Comparative Advantage and Exports, by Strength of Country Institutions

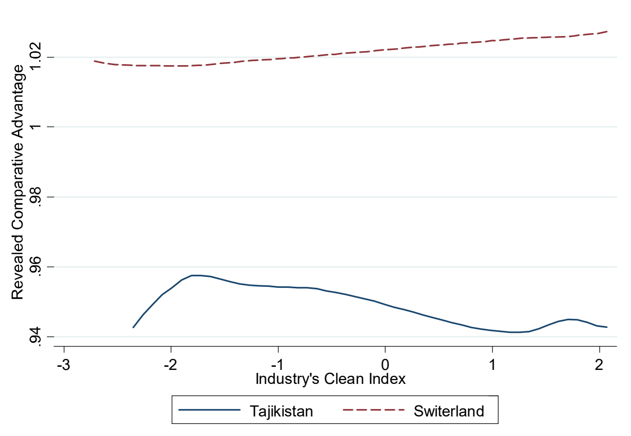
(A) Two country comparison: Balassa (1965)



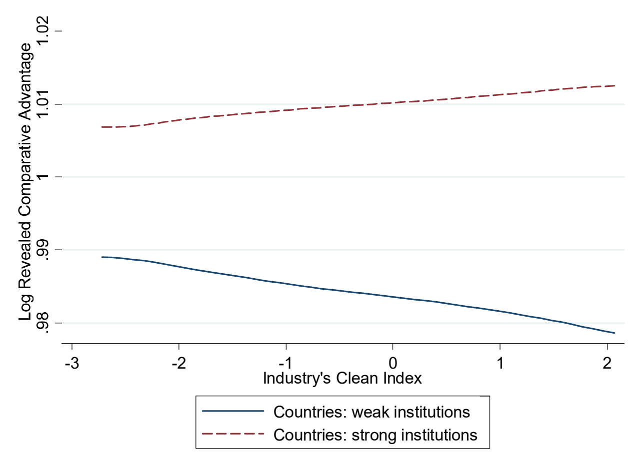
(B) Many country comparison: Balassa (1965)



(C) Two country comparison: Costinot, Donaldson, and Komunjer (2012)



(D) Many country comparison: Costinot, Donaldson, and Komunjer (2012)



Notes: in panel A, Tajikistan has weak institutions while Switerland has strong institutions. In Panel B, "countries: weak Institutions" includes the half of countries with the lowest values of the institutions index, while "Countries: strong institutions" includes the half of countries with the highest values of the institutions index. Each graph shows two local linear regressions, with bandwidth of one. For each line, mean of log exports across industries are normalized to zero. Revealed comparative advantage is defined as a country's share of world exports in a sector divided by the country's share of world exports in all goods.

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