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Are Developed Countries Outsourcing Pollution?

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Since the beginning of serious national environmental regulatory policy in the early 1970s, public debate has assumed that, absent constraints, polluting industries would shift production to countries with less strict standards. Developed countries would outsource pollution by importing goods they once produced at home. Domestic industries in developed countries have argued against the strongest environmental standards, for fear of losing jobs and market share to countries with weaker standards. Environmental advocacy groups have worried that outsourcing will worsen pollution in developing countries; the environmental policy jargon for that is "pollution havens." At the same, proponents of both protecting the environment and allowing unrestricted international trade suspect that fears of outsourcing are being used to justify both weaker pollution standards and protectionist trade barriers.

At the 1972 Stockholm Conference on the Human Environment, developed countries asked the United Nations to set uniform environmental rules to help them avoid losing their polluting industries to pollution havens. Since then, we have seen periodic proposals to take unilateral action to prevent outsourcing pollution from US firms to overseas suppliers. Walter Cronkite (1980), the iconic long-time anchor of the CBS Evening News, advocated banning imports from countries with less strict environmental rules to "protect both American industry and the environment."

In 1991, Oklahoma Senator David Boren proposed the International Pollution Deterrence Act. That bill would have imposed a tax, or tariff, on imports of goods

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manufactured in countries without strict standards. Similar worries arose among US states. The 1977 amendments to the Clean Air Act were in part an attempt to prevent outsourcing by states with strict environmental regulations to states with less strict standards (Pashigian 1985).

By 1993, when Canada, the United States, and Mexico were negotiating details of the North American Free Trade Agreement (NAFTA), opposition by prominent environmental groups obliged the parties to include an environmental side agreement, the North American Agreement on Environmental Cooperation. A goal of that 1993 pact was to prevent industries from avoiding their own countries' environmental rules by outsourcing. Since then, international trade negotiations typically feature debates about the environmental consequences of lowering tariffs. Today the World Trade Organization has a standing committee with a broad mandate to address links between trade and the environment.

For pollutants that damage local environments, like hazardous waste or airborne particulates, outsourcing by developed countries would involve tradeoffs. Environmental quality would improve in the developed world and decline in the pollution havens. When the focus of concern turns to climate change, outsourcing raises a different issue. Carbon dioxide and other greenhouse gases cause the same environmental damage no matter where in the world they are emitted. Thus, if national policies to reduce carbon emissions only lead the sources of those emissions to relocate to other countries, with no effect on total global carbon pollution, that outsourcing would undermine the environmental benefits of those national policies (Campbell, McDarris, and Pizer 2021). The climate-policy jargon for that is "leakage."

In July 2021, with the goal of combating leakage, US legislators introduced a bill to impose a tax, or tariff, on imports.[1] The tariff rate would be based on the domestic cost that US climate regulations impose on US production—although, ironically, at the time the United States had no comprehensive federal climate policies, at least not ones that imposed easily calculable costs. Today, the Inflation Reduction Act of 2022 mostly grants subsidies to US firms for reducing greenhouse gases. Subsidies raise no concerns about leakage, because companies have no incentive to relocate overseas to avoid them. Despite that fact, some US environmental organizations like the Sierra Club (2022) support versions of the idea—taxing foreign goods based on their carbon content without regard to US domestic carbon policy.

Europe does have rules that impose costs on carbon pollution through its Emissions Trading System. As of March 2023, permits were selling for more than €100 per ton of carbon emitted. To address concerns about leakage from that system, in April 2023 the European Parliament approved key features of a new "carbon border adjustment mechanism." It will levy tariffs, starting at low rates in 2026, that will eventually equal the cost of permits businesses would have needed to purchase had they

[1] For an overview of the FAIR Transition and Competition Act of 2021, see https://www.coons.senate.gov/imo/media/doc/one_pager__fair_transition_and_competition_act_-_117.pdf (accessed May 31, 2022).

manufactured the imported goods in Europe. The goal is to eventually eliminate the ability of European businesses to avoid Europe's climate policy by outsourcing.

To date, however, no rules against outsourcing pollution have taken effect; indeed, laws that impose tariffs to offset less strict environmental standards in other countries may be illegal under existing international trade rules (Böhringer et al. 2022). But notice that all such efforts presume that deterrence is necessary to prevent polluting industries from evading developed countries' strict environmental standards—whether aimed at local or global concerns—by relocating production to places were pollution is regulated less strictly and exporting products back to the developed countries. In this essay, I demonstrate that evidence for that presumption is sparse.

The next two sections set the stage for more detailed empirical discussion. I first point out some general patterns: real GDP in high income countries nearly doubled in the last three decades, but local and global pollutants from those countries have not risen. Can this be explained by the rapid rise in trade between high-income countries and the rest of the world? I then explore the theoretical question that hovers in the background: from an economic perspective, what's wrong with outsourcing pollution? As we will see, the answer depends in part on the nature of the pollutant.

The following sections then address the title question by splitting it into three separate parts. First, have high-income countries improved their own environments by importing goods produced in polluting factories? Second, has pollution worsened in countries manufacturing those goods for export to high-income countries? Third, have the environmental regulations enacted by rich developed countries had a cause-and-effect relationship on either of the first two changes?

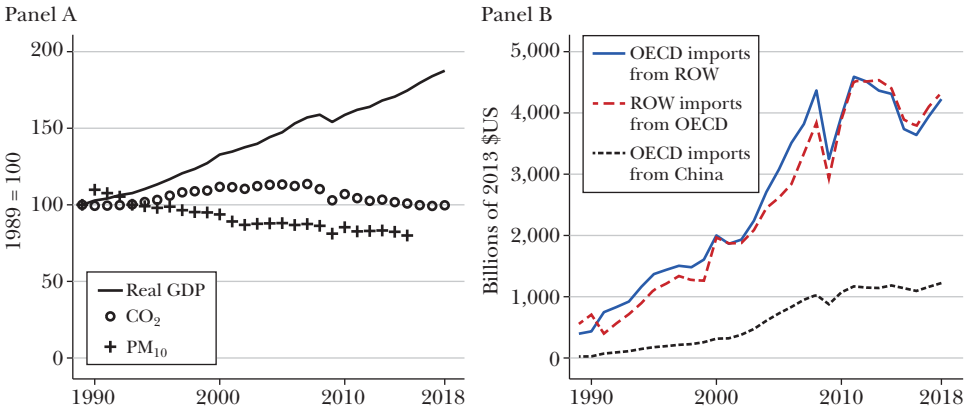
Trends in Growth, Pollution, and Trade

In recent decades, high-income countries as a group have managed to grow their economies without emitting more pollution. In theory, outsourcing could explain that achievement. In practice, basic patterns of trade and pollution cast doubt on that explanation.

As a starting point, consider the group of 24 high-income countries that belonged to the Organisation for Economic Co-operation and Development (OECD) as of 1993 (before the organization expanded to 38 members, including some middle-income countries).[2] Figure 1a plots the real gross domestic product (GDP) of those 24 countries, indexed so that 1989 equals 100. Their collective

[2]The 24 members of the OECD as of 1993 were Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, Türkiye, United Kingdom, and the United States. The 14 countries that have joined since then are Chile, Colombia, Costa Rica, Czech Republic, Estonia, Hungary, Israel, Korea, Latvia, Lithuania, Mexico, Poland, Slovak Republic, and Slovenia. List is available at https://www.oecd.org/about/document/ratification-oecd-convention.htm.

Figure 1
OECD Cleanup and Trade



Source: In panel A GDP in $US from the Organisation for Economic Co-operation and Development (OECD) (data.oecd.org) is adjusted using the US GDP deflator from the Federal Reserve (fred.stlouisfed.org). Pollution of particles smaller than 10 microns (PM_{10}) and carbon dioxide (CO_2) are taken from the Emissions Database for Global Atmospheric Research (edgar.jrc.ec.europa.eu). Panel B depicts trade volumes from the United Nations (comtrade.un.org), as reported by the importing countries.
Note: Real GDP doubled while pollution remained flat or declined (panel A). Trade between OECD countries and the rest of the world increased more than seven-fold (panel B).

economic output nearly doubled in the past three decades, which you can see by following the top solid line from its starting point at 100 in 1989 to nearly 200 by 2018. For comparison, Figure 1a also includes two measures of air pollution. Particulate matter smaller than 10 microns (PM_{10}) can be viewed as representing local air pollution, and is represented by small crosses in Figure 1a. Carbon dioxide (CO_2) dioxide is a global pollutant, shown as small circles. Both PM_{10} and CO_2 remained nearly flat or even declined in those 24 countries, even as their collective GDP doubled.

Could imports to the 24 OECD countries from the rest of the world help to explain the pattern of growth without additional pollution? Figure 1b plots the value of goods imported and exported by those 24 countries. The solid line plots total imports for these 24 high-income countries from the rest of the world (ROW), measured in real US dollars. Those imports grew from around $400 billion in 1989 to more than $4 trillion by 2018. The dashed line plots trade in the reverse direction, from the rest of the world (ROW) to these 24 countries.

As Figure 1b shows, trade between those 24 OECD countries and the rest of the world is eight to ten times larger today than it was 30 years ago—a growth rate much faster than the doubling of overall economic activity. In addition, notice that goods trade between the 24 countries and the rest of the world was approximately balanced. The solid line depicting OECD imports from the rest of the world closely follows the dashed line depicting the reverse. (Remember, the group of 24 high-income

counties includes both economies that have often had large trade deficits, like the United States, but also countries that have had large trade surpluses, like Japan and Germany.) Thus, if outsourcing explains pollution reductions in developed countries, it must be that the types of goods the OECD imports from the rest of the world differ from the types of goods other countries import from the OECD.

Finally, Figure 1b illustrates some nuance in the definition of "developed" because of the way economies and trade patterns have changed in the last few decades. For example, China, which accounts for a large and growing fraction of imports by the 24 high-income countries, rapidly transitioned from "low-income" to "upper middle-income" over this period, according to the World Bank. It seems plausible that countries like China may be changing the types of goods they export and import as they develop.

How have the 24 high-income OECD countries managed to increase the scale of their real output without increasing local or global pollution, as shown in Figure 1a? There are two possibilities here: technology and composition. Technology—sometimes dubbed "technique"—would involve the countries producing largely the same mix of goods, but using production processes that pollute less: cleaner fuels, more energy-efficient equipment, or better end-of-pipe controls. Composition would involve the high-income countries producing a different mix of goods and services, shifting towards products requiring less pollution to manufacture. In turn, that composition change itself could be traced to two causes. Either citizens of high-income countries consume a cleaner mix of products, or they purchase the ones that create the most pollution from importers rather than from domestic manufacturers—that is, they outsource pollution.

To put these explanations in more specific terms, if a country manufactures more steel and cars in factories that pollute less, that is technique. If a country's economy shifts from producing steel and cars to producing fewer polluting goods or services—electronics or insurance—that is composition. A shift in composition could result from the country's residents demanding less steel and fewer cars and more electronics and insurance. Or, that composition shift could result from the country importing the steel and cars it once produced domestically. Only the last explanation for the pattern in Figure 1a, importing polluting goods formerly produced domestically, involves outsourcing.

The next section will consider the economic argument for what can be wrong with outsourcing pollution. We then explore an accounting exercise to investigate how the much of the pattern in Figure 1a might be explained by outsourcing.

What's Wrong with Outsourcing Pollution?

Before describing the problem with outsourcing pollution, it's worth being clear about what is meant by each word: "outsourcing" and "pollution." Economists sometimes describe outsourcing as occurring at the firm level, when a particular company contracts with a third party to purchase goods or services—either a final

output or intermediate inputs—that were previously produced or could have been produced by the company's own employees. A university that hires a landscaping company rather than employing groundskeepers has outsourced those jobs. In this essay, I use "outsourcing" in the more general national sense, to describe what happens when a country imports goods rather than producing them domestically. Those could be final products such as automobiles, or intermediate inputs to those products such as car parts, or inputs to those intermediate inputs such as steel and rubber.

As for pollution, in the popular conception it is an output, because it comes "out" of smokestacks or wastewater pipes. In economic terms, however, pollution is an input. Manufacturing a product for sale often requires pollution, just as it requires capital and labor. If it helps, think of pollution as a waste disposal service. Goods can be manufactured using more pollution and less capital and labor, or less pollution and more of those other inputs. Manufacturers can outsource pollution to countries with different production methods or lower standards just as they can outsource labor to countries with lower wages, by importing the goods created using that pollution and labor.

The problem with outsourcing pollution depends on the nature of the pollutant. If the pollution is local, like the emissions of particulates depicted by PM_{10} in Figure 1a, outsourcing improves the environment in one country and degrades it in another. If the pollution is global, like CO_2, shifting production from one country to another has no effect on the environment unless the countries' production methods involve different amounts of pollution. Before the world's attention turned to CO_2 emissions and climate change, most environmental policies targeted local pollutants: urban smog or airborne particulates, toxic waste dumps, and water pollution.

Outsourcing local pollution from one location to another may be undesirable, but it is not *necessarily* so. Just as some countries have comparative advantages from natural resource abundance or skilled labor, others may have comparative advantages in production of goods that cause pollution. Imagine an island country where pollution blows out to sea and rapidly disperses, doing little or no harm to its residents or anybody else. Trade between other countries and the island could expand production possibilities in both places.

Of course, most countries are not windswept islands, and most local pollution does at least some local damage. Even so, some outsourcing of local pollution might still be efficient, at least in the cold calculus of economics. If clean air is a normal good, meaning higher-income people want more of it, then citizens of rich democracies will vote for more stringent pollution policies than citizens of poor democracies. As a result, poor countries will have a comparative advantage in production that pollutes—and could become pollution havens. The World Bank's chief economist once made that efficiency argument in defense of pollution havens, to foreseeable controversy (a story told in Hausman and McPherson 2006, p. 12).

However, a long catalog of assumptions must be met before this efficiency result holds in full. Oates and Schwab (1996) formalized the theoretical case for

outsourcing to pollution havens, in an academic setting that attracted less public scrutiny. They described countries competing to attract businesses that cause local pollution but raise local wages. The workers who suffer from the pollution must also be receiving the higher wages. Local governments must be welfare-maximizing, and their residents homogenous. Any industry profits need to be earned by those homogenous worker-residents, not paid to multinationals in other countries. If any of those conditions are not met, local regulatory authorities will set economically inefficient pollution standards. Those could be insufficiently strict, race-to-the-bottom, pollution-haven standards. Or they could be overly stringent, race-to-the-top, not-in-my-backyard (NIMBY) standards (Levinson 2003).

If some countries do not have sufficiently capable regulatory infrastructures necessary to manage their local environments, the odds that outsourcing pollution could lead to efficiency gains look even slimmer. If regulators fail to internalize externalities appropriately, through incompetence, corruption, or everyday politics, then importing goods from those places least capable of enacting and enforcing reasonable pollution regulations seems more likely to exacerbate market failures than to be Pareto-improving.

If we add concerns about equity and democratic representation, problems with outsourcing local pollution compound. Not everyone can vote at a ballot box or vote with their feet by emigrating if they find their preferences unrepresented, their wages insufficient, or the nearby pollution excessive.

With these concerns about local environments in mind—efficiency, regulatory capability, and equity—116 countries met in Switzerland in 1989 to adopt the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes.[3] By shipping waste to developing countries, especially in Africa, developed countries had been outsourcing one pollution-intensive part of their manufacturing, the final disposal of dangerous byproducts. The Basel Convention recognized the problems with the "limited capabilities of the developing countries to manage hazardous waste." It explicitly prohibited the export of such waste from OECD to non-OECD countries.

Hazardous waste is a local pollutant for which the outsourcing process is particularly obvious and identifiable, because the pollution travels by ship between countries. For most pollutants, firms in high-income countries can simply invest in production processes that pollute in other countries or purchase their products directly. Local environmental quality would improve in high-income countries and degrade elsewhere. It would be good to know how much, if any, outsourcing of local pollution is happening as a result of those less obvious processes.

For global pollution like CO_2 that causes climate change, it does not matter whether the factory sits on a windswept island or in the center of a densely populated valley. If an industry that emits CO_2 relocates from a developed country to a developing one, without changing its production processes, environmental quality

[3]For background on the Basel Convention, see www.basel.int (accessed March 25, 2022).

does not improve or worsen anywhere. Regulations designed to combat climate change, but that merely shift pollution among countries, impose costs with no benefits. So understanding the degree to which developed countries outsource CO_2 is central to understanding the degree to which their domestic climate policies have had any success.

For local pollutants, outsourcing to pollution havens raises concerns about efficiency, regulatory capability, and equity. For global pollutants, in addition to those issues, outsourcing takes the form of leakage that would undermine the efficacy of domestic policies.

Are Developing Countries Cleaning Up by Outsourcing Pollution?

Assessing the extent to which high-income countries reduce domestic pollution by importing goods whose production generates foreign pollution is essentially an accounting exercise. Calculate how much total pollution is used to manufacture each product in developed countries. Divide that total pollution produced by the total dollar value of each product manufactured to get each product's pollution intensity, measured in tons of pollution per dollar of product sold. Multiply those pollution intensity values by the total value of imports for each good to get the pollution displaced by those imports. That tells us how much pollution each of those imported goods would have caused in the developed country had they been produced domestically instead of imported. Sum those multiples across all imported goods to get the total amount of pollution embodied in imports. That is the amount of pollution "outsourced."

For our purposes, we want to compare the amount of pollution outsourced by high-income countries to those with lower incomes with the amount of pollution outsourced (by this same definition) from lower-income to high-income countries. This exercise requires no identification of cause and effect. It is just a descriptive, multi-step accounting of trade flows.

Emission Intensities for Each Industry

The first step in that accounting requires a measure of how much pollution each industry emits. For example, the National Emissions Inventory (NEI) from the US Environmental Protection Agency reports US emissions of many dozens of air pollutants, including local pollutants like PM_{10} and global pollutants like CO_2, across nearly 300 different manufacturing industries.[4]

That level of detail is important to studying outsourcing of pollution. Consider the paper subsector, defined by the North American Industrial Classification System

[4]For a description, see Yang et al. (2017). For details, see www.epa.gov/air-emissions-inventories/national-emissions-inventory-nei (accessed 4/8/2022).

(NAICS) with the three-digit code 322.[5] That includes pulp mills that convert raw wood into paper, NAICS six-digit industry code 322110, which is one of the more polluting processes in all of manufacturing. But it also includes factories that purchase paper and use it to manufacture envelopes and other stationery, NAICS 322230, a process that involves relatively little pollution. Knowing only that a developed country imports paper, without knowing if the shipment contains envelopes or the raw paper from pulp mills, is not sufficient to assess the pollution content or the degree of outsourcing.

Most studies of pollution outsourcing focus on the manufacturing sector. The other sectors are either not as polluting—finance, retail trade, warehousing—or they cannot easily be outsourced—construction, transport, electric utilities. In 2017, the North American Industrial Classification System listed 21 three-digit manufacturing subsectors comprising 360 six-digit manufacturing industries. Table 1 describes some sample industries from the National Emissions Inventory, ordered by their PM_{10} emissions intensities in column 1. Manufacturing stationery involves relatively little pollution. The pulp mills that make the paper involve a lot more.

Some countries aside from the United States do publish emissions inventories; however, they are typically less detailed than the US National Emissions Inventory. For example, the European Union reports emissions of some of those same air pollutants, including PM_{10} and CO_2, for about 75 industrial sectors, including manufacturing, mining, agriculture, and utilities.[6] Canada publishes a detailed emissions inventory for CO_2, for 142 industrial sectors, 87 of which are in manufacturing. But the US National Emissions Inventory covers the most pollutants and with the most narrowly detailed definitions of manufacturing industries.

Direct and Total Emissions Intensities

Next, for each good imported into a developed country, in order to know the amount of outsourced pollution we need to know the pollution that would have been emitted domestically while manufacturing that imported product, as well as the pollution that would have been emitted manufacturing inputs to that product, plus the pollution emitted manufacturing inputs to those inputs, and so on. Suppose that a developed country switches from producing envelopes domestically using domestically manufactured paper and begins importing envelopes that use paper manufactured elsewhere. If we use only the *direct* emissions intensities in column 1 of Table 1 to calculate outsourced pollution, and include only the pollution used to manufacture the envelopes themselves, that calculation would miss pollution that would have been

[5] For an overview of NAICS, see www.census.gov/naics/ (accessed 4/12/2002). NAICS codes are six digits long. The first two digits describe broad sectors, such as agriculture or manufacturing. The first three digits define subsectors, like textiles or transportation equipment within manufacturing. The four-digit codes are industry groups, like shipbuilding or motor vehicles within transportation. The full six-digit codes describe specific industries, such as those manufacturing truck trailers or brake systems.

[6] For discussion of the EU reporting, see www.eea.europa.eu/data-and-maps/data/industrial-reporting-under-the-industrial-4 (accessed 4/12/2022).

Table 1
Sample Emissions Intensities

		1,000 kg per 2013 $US of production				*Percent of US manufacturing output 2021*
		PM_{10}		CO_2		
NAICS	*Industry*	*Direct*	*Total*	*Direct*	*Total*	
334516	Analytical Laboratory Instrument Manufacturing	0.000006	0.08	3.4	198	0.41
334112	Computer Storage Device Manufacturing	0.000044	0.05	2.2	147	0.10
339910	Jewelry and Silverware Manufacturing	0.000078	0.37	6.2	340	0.14
336112	Light Truck and Utility Vehicle Manufacturing	0.000086	0.16	9.4	342	1.95
322230	Stationery	0.000210	0.21	13.3	507	0.06
333415	Air-Conditioning, Heating, and Refrigeration Equipment	0.000346	0.17	9.4	303	0.70
326160	Plastics Bottle Manufacturing	0.000637	0.29	13.1	682	0.22
335911	Storage Battery Manufacturing	0.001127	0.42	41.3	565	0.14
336414	Guided Missile and Space Vehicle Manufacturing	0.001631	0.04	2.1	97	0.28
311513	Cheese Manufacturing	0.003952	2.24	26.9	516	0.58
337127	Institutional Furniture Manufacturing	0.009099	0.20	18.4	369	0.09
311111	Dog and Cat Food Manufacturing	0.009550	2.22	42.1	493	0.43
325510	Paint and Coating Manufacturing	0.003914	0.39	98.0	592	0.53
331420	Copper Rolling, Drawing, Extruding, and Alloying	0.006126	0.73	36.0	505	0.39
322110	Pulp Mills	0.262743	0.68	328.9	827	0.13
327310	Cement Manufacturing	1.473377	1.82	7,199.0	8,077	0.20

Source: Emissions intensities from the EPA Environmentally-Extended IO Tables, www.epa.gov/land-research/us-environmentally-extended-input-output-useeio-technical-content (Yang et al. 2017). Percentages of US manufacturing output from the 2021 Annual Survey of Manufactures https://www2.census.gov/programs-surveys/asm/data/2021/ (file AM1831BASICC01).
Note: Just a few of the 200+ manufacturing industries in the EPA Environmentally-Extended IO Tables. Units are industrial emissions in 1,000 kilograms per 2013 US dollars. Direct numbers include only emissions from manufacturing final products. Totals include all upstream emissions from manufacturing inputs.

emitted by domestic pulp mills to manufacture the paper used as inputs to those envelopes, pollution emitted by the inputs to the pulp mills, and so on.

That sounds like a daunting problem. But in the 1970s, long before any of this data was even available, Leontief (1970) explained how to do the calculation. It requires an input-output table of the economy—that is, a table in which each row represents an output and each column represents an input. Each cell of the table

reports how many dollars' worth of the corresponding input industry is used to manufacture one dollar's worth of the output industry. To cover all 360 six-digit manufacturing NAICS codes, an input-output table needs $360 \times 360 = 129{,}600$ entries. Leontief provided an example that also includes pollution as one of the inputs. He used only a few broadly defined sectors, all that was empirically possible at the time, but demonstrated the linear algebra techniques needed for a solution.

These days, the US Commerce Department publishes input-output tables for hundreds of industries that can be matched with six-digit NAICS codes. Combining those with the emissions intensities from the National Emissions Inventory, using Leontief's (1970) computational approach, yields a set of *total* industry-specific emissions intensities, which report the pollution needed to create a dollar's worth of each good, including all of the inputs, inputs to inputs, and so on. I walk through the details in Levinson (2009). Thankfully, the National Emissions Inventory now does that calculation for us and reports both direct and total emissions intensities.

Table 1 lists, for that same subset of six-digit NAICS industries, the total pollution from making the final product and all its inputs. For the stationery industry, the total PM_{10} intensity is 1,000 times larger than the direct intensity. For pulp mills that make the paper, total pollution is only 2.5 times the direct pollution. That pattern makes sense, because the highly polluting pulp mills are an important input into stationery, but not vice versa.

Linking Emissions Intensities to Exports and Imports by Industry

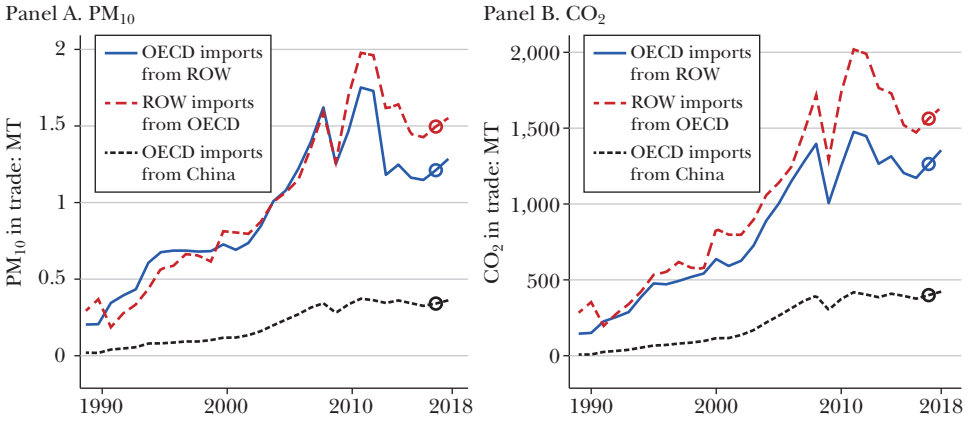
To estimate pollution outsourcing, the next requirement is data on each industry's imports from and exports to each country. The UN Comtrade data reports annual trade between every pair of countries, valued in US dollars, for thousands of commodities.[7] Those dollar values formed the basis for Figure 1b. I match those Comtrade commodity codes to the NAICS industries used by the emissions inventory using a concordance constructed by Pierce and Schott (2012). I then adjust those to 2013 dollars to match the emissions intensities reported in the National Emissions Inventory, using the US GDP deflator.

From there, the last step multiplies the total emissions intensity for each industry by the total dollar value of imports. That product provides the total amount of pollution outsourced when that particular industry's goods are imported. Summing those products across all imported industries yields the total amount of outsourced pollution embodied in those imports.

Figure 2 depicts pollution outsourcing as calculated by this method for two air pollutants: PM_{10} and CO_2. The solid blue lines estimate the pollution that would have been caused in the 24 high-income OECD countries to manufacture the goods that these countries actually imported from the rest of the world (abbreviated ROW).

[7]For details on the UN Comtrade data, see comtrade.un.org (accessed 12/17/2021).

Figure 2
Total Pollution in Trade



Source: Trade data from comtrade.un.org for 24 high-income countries that were in the OECD as of 1973 and the rest of the world (ROW). Pollution calculated using total emissions coefficients for the year 2017 (circled) from www.epa.gov/land-research/us-environmentally-extended-input-output-useeio-technical-content, using the method described in the text.
Note: MT=million tons.

Importantly, recognize that changes over time depicted in Figure 2 do not involve changes to production or pollution control technologies, because the data points for all years are calculated using the 2017 pollution intensities reported by the US EPA. The figure only shows changes in the total volume of imports and exports—the scale of trade—and shifts in which industries make up that total—its composition. The actual pollution that would have been caused in the OECD would differ if those pollution intensities—techniques—changed over time or differed in other countries.

The scale and composition estimates of pollution embodied in OECD imports, depicted in Figure 2, grew steeply over the past 30 years, from 0.2 to 1.29 million tons of PM_{10}, and from 145 to 1,354 million tons of CO_2. Wealthy countries now import goods responsible for six to nine times as much pollution as 30 years ago.

Evaluating the Outsourcing Claim: Absolute versus Percentages, Net versus Gross

On the surface, that result seems like straightforward evidence of outsourcing. But the rest of the world also imports goods from the high-income countries, and those imports have increased as well. The dashed red lines estimate the pollution actually emitted in OECD countries to manufacture the goods shipped in the reverse direction, exported from the OECD to the rest of the world. Using the same estimation approach, the dashed red lines in Figure 2 show that pollution caused by manufacturing goods in the OECD for export to the rest of the world has increased

Table 2
Pollution in Trade: 1989–2018

	OECD imports from ROW	ROW imports from OECD	OECD imports from China
Imports (2013 US $billion)			
1989	396	556	24
2018	4,225	4,331	1,223
Percent change	+966%	+678%	+4,961%
PM_{10} (Million tons)			
1989	0.20	0.29	0.02
2018	1.29	1.55	0.36
Percent change	+531%	+429%	+1,721%
CO_2 (Million tons)			
1989	145	284	8
2018	1,354	1,637	423
Percent change	+830%	+477%	+5,117%

Note: This table reports the starting and ending values, for 1989 and 2018, of the lines in Figure 2.

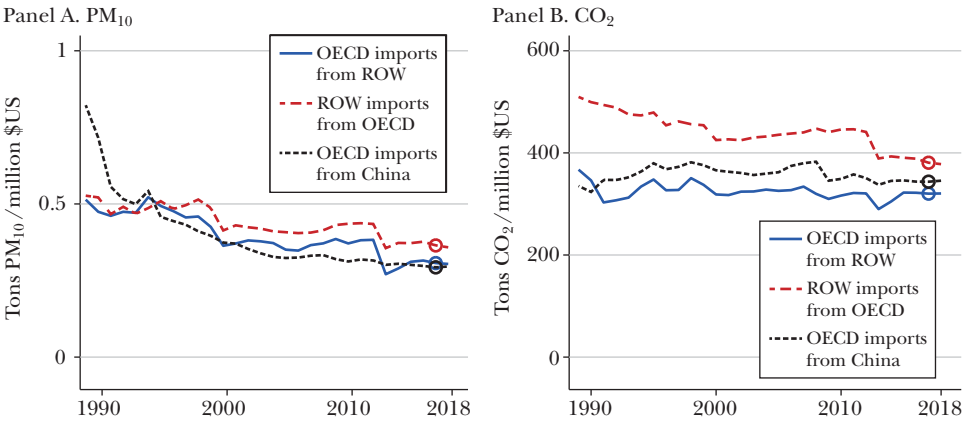
from 0.29 to 1.55 million tons of PM_{10}, and from 284 to 1,637 million tons of CO_2. Wealthy countries now *export* goods responsible for five to six times as much pollution as 30 years ago. Seen that way, the rest of the world has been outsourcing pollution to the 24 high-income OECD nations.

So, have developed countries outsourced pollution by importing pollution-intensive products from the rest of the world? The answer depends in part on whether we think in absolute amounts of pollution or percentage changes. It also depends on whether we subtract the pollution embodied in exports from imports to calculate net pollution outsourced.

Table 2 presents both the absolute and percentage changes in trade and estimated pollution, calculated by comparing the starting and ending points of the lines in Figures 1 and 2. Pollution embodied in imports of the 24 high-income OECD countries from the rest of the world did grow, by 531 percent for PM_{10} and 830 percent for CO_2. Also, both grew faster than pollution embodied in exports from the high-income countries to the rest of the world, 429 percent and 477 percent. That looks like outsourcing pollution.

However, pollution embodied in trade also grew less steeply than overall trade. The dollar value of imports to the 24 high-income OECD countries grew 966 percent, while pollution embodied in those imports grew by less. Similarly, the dollar value of exports from the OECD grew by 678 percent, and pollution embodied in those exports grew less. The reason is that the mix of goods being imported *and* exported by the 24 high-income OECD countries shifted towards cleaner goods. That does not look like evidence of outsourcing pollution.

Figure 3
Pollution Intensity of Trade



Source: Author's calculations.
Note: Values calculated as the total predicted pollution in trade, from Figure 2, divided by the total volume of goods trade, from Figure 1 panel B.

Pollution Intensity Relative to Trade

Figure 3 depicts the pollution intensity of trade—estimated pollution content in Figure 2 divided by the dollar value of trade in Figure 1a. Or equivalently, it is a weighted average of industry-specific emissions intensities, where the weights are the dollar values of imports and exports. In each case, the values are based on the emissions intensities in the 2017 US National Emissions Inventory, so again, any change over time reflects only changes in the composition of goods being imported and exported, and nothing else. For both PM_{10} and CO_2 in Figure 3, the mix of manufactured goods imported by the 24 high-income countries is *less* polluting than the mix exported by those countries to the rest of the world. The solid lines lie below the dashed lines.

That finding may surprise readers who expect less developed countries to be producing the most polluting goods. What's the explanation? High-income countries have a comparative advantage in capital-intensive, high-skill industries that also happen to be relatively polluting. Thus, if polluting goods are traded, they are more likely to be exported by high-income countries, not imported. Moreover, a number of the most polluting industries—like petroleum refining, paper manufacturing, and cement—tend to be the most costly to transport long distances from local factor or product markets (Ederington, Levinson, and Minier 2005). That limits trade in those polluting goods, in either direction.

In addition to showing that the sample of high-income OECD nations imports a less polluting mix of goods than it exports, Figure 3 shows that the pollution intensity of neither imports nor exports is rising. For neither PM_{10} nor CO_2 have

the OECD nations imported an increasingly polluting mix of goods. That does not sound like outsourcing.

For China's economy, which has developed rapidly and accounts for a large and growing fraction of trade with the OECD, pollution outsourcing also appears to be unimportant. For PM_{10} in Figure 3a, the mix of goods China sends to the 24 high-income countries was more polluting in 1989 than the mix that those countries imported or exported to the rest of the world. But by 2018, China was sending a less polluting mix of goods to the 24 OECD countries. For CO_2, China's mix of goods lies somewhere between that of the imports and exports of the 24 high-income countries.

Although the illustrative analysis in Figures 2 and 3 suggests little outsourcing of pollution, that conclusion comes with caveats. Trade flows are measured in US dollars, which has the effect of applying the same inflation adjustment to all industries. For example, energy price spikes will make it appear as though the pollution embodied in trade increases because the dollar value of energy-intensive shipments will increase—even if the physical volume does not. In addition, the analysis in Figures 2 and 3 classifies one particular set of 24 countries as developed, when in fact some of those 24 have grown more rapidly than others. Some of the countries outside the group of 24, like China, have themselves become more developed in the intervening years. Finally, the analysis uses the total emissions intensities reported by the US Environmental Protection Agency, which assume that all of the inputs to the products were also produced in the United States. The outsourcing depicted, therefore, describes the amount of pollution that would have been emitted in the 24 OECD countries if all imports and exports were produced domestically, *along with all inputs* to those imports and exports, using 2017 US technologies.

Congruence with Existing Research

Though this analysis is based on strong assumptions, the conclusions here corroborate earlier studies, which find that the composition of imports to rich countries has been shifting toward less polluting goods, not more polluting goods (Cole 2004; Brunel 2017; Levinson 2010). A nearly universal conclusion is that composition of production, including outsourcing and changing domestic consumption, plays a relatively small role, if any, in the ability of high-income economies to expand in recent decades without generating more pollution. Copeland, Shapiro, and Taylor (2022) summarize this research and add their own analysis, drawing the same conclusion: "Overall, this comparison across countries largely echoes the findings of previous country-specific studies—technology, rather than composition or scale effects, accounts for the largest share of the change in emissions."

That answers one important question: whether outsourcing accounts for environmental improvements in developed countries. Largely, it does not. But what about developing countries? The next section explores whether expanded trade has resulted in more pollution there.

Is Pollution Relocating to Developing Countries?

This question is complicated by the fact that countries have different production technologies. Some are more pollution-intensive than others, meaning they cause more pollution for the same output. If a country imports a product rather than producing it domestically, then total global pollution could increase or decrease, depending on which country employs the more pollution-intensive production technologies. Measuring the *net* pollution change due to trade requires knowing pollution intensities in both locations.

Asking whether just one single country outsources pollution in that way—increasing it by more abroad than it decreases at home—requires a slight modification to the input-output tables used in Leontief's (1970) calculation. Manufacturing an envelope using domestically produced paper involves more domestic pollution than manufacturing that same envelope using imported paper. Thus, to calculate pollution caused in the exporting country, we need to know the fraction of the paper used as an input that was itself also manufactured in that exporting country. In general, therefore, in addition to knowing pollution intensities in both countries, we need to know the share of each of the 360 NAICS industries that is produced domestically in both countries. That requires a lot of fine-grained data not universally available, but conceptually it is straightforward.

Asking whether a collection of relatively high-income countries like the OECD outsources pollution to another collection of countries makes that problem of imported intermediate inputs far trickier. In that case we do not care if the United States imports paper or envelopes from Canada, another country in the high-income group, but we do care if it imports them from a developing country. That means we must know not only the dollar value of each input required to manufacture a dollar of each output, but the dollar value of each input *from each other country*.

That information is called a multi-region input-output table. If the original country-specific input-output table covers 360 industries, then examining outsourcing by 24 OECD countries to 100 rest-of-the-world countries would require an input-output table with $(360 \times 124) \times (360 \times 124)$ entries. That is nearly two billion data points. The next step would require each of the 124 countries to report emissions intensities for each of those 360 industries. So far, only a few countries report emissions in anywhere close to that detail. Those that do tend to use different definitions of industries and pollution intensities.

Several organizations have assembled versions of multi-region input-output tables.[8] Most aggregate manufacturing industries into only a few dozen sectors. None has industry detail comparable to the US National Emissions Inventory used to draw Figures 2 and 3. As a consequence, those multi-region input-output tables cannot distinguish between imports of paper, which outsource pollution, and

[8] See, for example, the World Input-Output Database (Timmer et al. 2015), Exiobase (Stadler et al. 2018), and Eora26 (Lenzen et al. 2013). The website http://environmentalfootprints.org describes those and others (accessed 4/14/2022).

imports of envelopes, which may or may not, depending on where the paper for those envelopes is produced.

Copeland, Shapiro, and Taylor (2022) use one of those multi-region input-output tables, the World Input Output Dataset, to answer this outsourcing question. They use an accounting exercise similar to that behind Figure 2 here, but different in one key way. In their version (see their Figure 5), the solid line corresponding to pollution caused by imports to high-income countries is measured using pollution intensities for the countries doing the exporting. It approximates how much pollution was caused in developing countries as a consequence of their exports. Recall that in Figure 2, the solid line corresponding to pollution embodied in OECD imports is measured using the US National Emissions inventory. That approximates the pollution that would have occurred in the OECD had those goods been produced domestically rather than imported. It is an important distinction. If the same goods were being traded back and forth, in the same amounts, Copeland, Shapiro, and Taylor (2022) would show net outsourcing of pollution, while Figure 2 would not.

In the Copeland, Shapiro, and Taylor (2022) figure, pollution embodied in rich-country imports is larger than pollution embodied in rich-country exports (equivalent to the sold line being above the dashed one in Figure 2). That is consistent with richer countries having stricter pollution standards and using cleaner production technologies, even for the same goods. The gap between the two lines also grows over time, although it is not clear whether that represents changes to the mix of goods imported and exported, changes to the emissions intensities in rich and poor countries, or as the authors note, simply "changes in the scale of net trade flows."

Copeland, Shapiro, and Taylor (2022) conclude, based on their version of Figure 2, that "rich countries are increasingly outsourcing pollution." Although that sounds contradictory to most of the prior results and to the illustration in the previous section, they are asking a different question. They ask how much larger pollution is in developing countries as a consequence of exports. Figure 2 asks how much more pollution there would have been in developed countries without those imports. It should not be surprising that the answers are different.

Another important distinction between the analyses involves industry aggregation. Copeland, Shapiro, and Taylor (2022) and others (like Peters et al. 2011) that reach similar conclusions use multi-region input-output tables with only a few dozen categories of manufacturing industries. The 2013 World Input Output Dataset had only 24 different categories of imports, 14 of which are manufactured goods. In these kinds of datasets, paper mills and envelope manufacturers are combined with printers and publishers into one industry, with one pollution intensity. It is possible that this aggregation, though necessary to compare trade among multiple countries with incomplete or incompatible data, either exaggerates or understates the pollution embodied in trade.

Finally, because these studies estimate poor-country emissions intensities to be larger than rich-country intensities, when the scale of trade grows they show

net pollution imports to be increasing. If nothing changes except that imports and exports both double, their measure of the pollution embodied in net imports would also double. Whether to call that "outsourcing pollution" seems debatable, and more about semantics than economics.

That leaves our third question. Have the environmental regulations enacted by developed countries caused them to increase imports of polluting goods?

Do Environmental Regulations in High-Income Countries Cause Outsourcing of Pollution?

In hindsight, a sensible research agenda might have started with the answer to our title question: Is there outsourcing of pollution? And then, if the answer was "yes," the next step would be to examine the causes of this outsourcing, one of which might include more stringent environmental regulations in developed countries. But chronologically, that is not how this research has progressed. Economists' study of pollution outsourcing began with the harder question: whether strict environmental standards lead to outsourcing of pollution.

One of the very first studies of whether regulations cause outsourcing illustrates the difficulties in determining that cause-and-effect relationship. Weighing into the debate about the environmental consequences of the North American Free Trade Agreement (NAFTA) enacted in 1994, Grossman and Krueger (1993) asked whether industries facing higher pollution abatement costs in the United States were more likely to be outsourced to Mexico. They regressed US imports from Mexico in each of 136 industries on those industries US pollution abatement costs and other characteristics. The pollution cost coefficients are small and statistically insignificant, indicating that industries facing higher pollution costs in the United States were not more likely to be imported from Mexico. The researchers concluded that US "environmental regulations and enforcement . . . play at most a minor role" in outsourcing.

However, in some specifications, Grossman and Krueger (1993) found that goods with higher pollution costs when manufactured in the United States were statistically significantly *less* likely to be imported from Mexico. Nobody concludes from that result that the United States is a pollution haven for certain Mexican industries. More likely, this cross-section empirical work, with a mere 136 observations, has trouble accounting for omitted variables and the endogeneity of the regulations. Places that find themselves with worse pollution, all else equal, will want to set stricter standards. Indeed, the Clean Air Act in the United States requires places with the worst air quality to have the strictest pollution regulations. If the poor air quality arises as a result of some local comparative advantage for polluting industries, like abundant natural resources or access to transport, the places with strictest standards will also be the places where polluting industries locate and consequently where the pollution is worst. In the US-Mexico context, it will appear as though Mexico is outsourcing pollution to the United States.

Properly answering whether pollution regulations cause outsourcing of pollution requires two kinds of data and a methodology that can be interpreted in cause-and-effect terms. The first data requirement is a measure of the stringency of pollution regulations, which is not easy to come by. Grossman and Krueger (1993) and many subsequent researchers used a survey of US manufacturers called the Pollution Abatement Costs and Expenditures Survey. But that survey only covered the United States, and it was last conducted in 2005. Other researchers have used surveys of business managers, such as the WEF Executive Opinion Survey (Kellenberg 2009; Wagner and Timmins 2009). But that survey solicits perceptions, and executives from polluting industries are more likely to perceive strict regulations (Kalamova and Johnstone 2012). Still others rely on counts of the number of regulations or on econometric estimates of the inefficiencies caused by regulations. In the future, if more places enact regulations to put a price on carbon, perhaps researchers may be able to use that price as a measure of regulatory stringency going forward. But in the meantime, measuring the strictness of environmental regulations across varying pollutants remains logistically and conceptually difficult (Brunel and Levinson 2016).

The second data requirement is a measure of how regulatory stringency across industries changes over time. Grossman and Krueger (1993) showed that industries facing high pollution regulation costs in the United States are not more likely to be imported from Mexico. However, it is possible that industries facing larger *increases* in costs may be more likely to increase their imports, consistent with an outsourcing story. Why the difference? Comparing changes in stringency to changes in imports holds location-specific differences constant, effectively controlling for omitted characteristics of countries and industries that are fixed over time, like natural resources or good transport. This second requirement magnifies the difficulty associated with the first. We need data on changes over time in a difficult-to-measure concept.

The methodological challenge to answering whether regulations cause outsourcing involves the fact that changes in regulations are endogenous. Locations that find themselves experiencing increasing pollution, due to a locally expanding polluting industry, are more likely to tighten their standards. That tightening could create a positive correlation between the presence of polluting industries and strict antipollution regulations, spuriously making it seem as though strict regulations attract polluting businesses. A typical solution would be to seek an instrumental variable, something correlated with changes in pollution regulations but uncorrelated with outsourcing except through the effect of those regulations. That compounds the difficulty of properly answering the question. We need an instrumental variable to proxy for changes over time in a difficult-to-measure concept. That sounds daunting, and it is.

One new paper that comes close to overcoming these data and methodological hurdles is Cherniwchan and Najjar (2022). They study Canada's rule that required every major city and town to achieve at least a minimum level air quality. Affected manufacturers located in places failing to meet the standard became subject to new, more strict pollution rules. The measure of stringency is easily quantifiable, if blunt:

some places meet the standard, others do not. It is a measure that changes over time as cities move into or out of compliance. It is plausibly exogenous, given that the standard was set nationally. Cherniwchan and Najjar (2022) find that targeted factories decreased exports by more than 20 percent. That does not, however, mean that polluting production was outsourced to developing countries. Production could have moved to other Canadian provinces or to the United States, or been matched by a decline in use of those products.

In general, recent surveys of research into this third question have a consensus. Dechezleprêtre and Sato (2017), Cole, Elliott, and Zhang (2017), Jakob (2021), and Caron (2022) all find that pollution regulations impose costs that are relatively small shares of total costs for most industries and just one of many such costs that affect import decisions. In 2005, when the United States last surveyed manufactures about this, pollution abatement costs amounted to less than one-half of a percent of the value of manufacturing shipments, ranging from less than 0.1 percent for textiles to a max of 1.1 percent for primary metals (Bureau of the Census 2008). Research that appropriately controls for omitted variables and endogenous regulations can sometimes find statistically significant effects of regulations on trade, but when it does, the estimated magnitudes are small.

The review articles also note that for some industries that are particularly pollution-intensive, and easily imported or exported, regulations may meaningfully cause outsourcing of pollution. As an example, Tanaka, Teshima, and Verhoogen (2022) study one industry, battery recycling, and one regulation, the US standard for airborne lead. They show convincingly that when the regulation tightened in 2009, air quality improved in neighborhoods near US battery recyclers and degraded near Mexican battery recyclers, and that US exports of used batteries to Mexico increased. That seems like a clear case study providing rare empirical evidence of regulation-induced outsourcing of pollution, but it does not appear to represent a general pattern.

In sum, answering this third question—whether environmental regulations cause pollution outsourcing—is profoundly difficult. In the absence of regulations that price pollution explicitly, measuring regulatory stringency poses a conceptual challenge. Few researchers who try to answer the question have panel data allowing them to examine the effect of changes in stringency over time on changes in trade flows. Even fewer have managed to deploy a convincing instrumental variable to control for the fact that places with growing pollution problems enact the strictest rules. Summarizing the research in this area, the World Bank's annual flagship publication, the *World Development Report*, concludes that "strict environmental regulation of polluting industries has not led to large relocations to countries with less strict standards" (World Bank 2020, p. 125).

Conclusion

For those who are concerned about the potential risks of outsourcing pollution from high-income countries to the rest of the world, an obvious workaround is

border taxes, or tariffs, based on the pollution embodied in imports. Such a policy would have two objectives.

First, border pollution taxes would seek to prevent outsourcing pollution. However, if the main thrust of the research described here is correct, even without border taxes there has been limited meaningful outsourcing. In that case, border taxes would be protecting domestic industries from an imagined threat. In political terms, perhaps those border taxes are a necessary chip in bargaining over domestic environmental policy rules (Jakob et al. 2022). In fact, there is some evidence that tariffs are already higher on goods facing more costly domestic environmental standards (Ederington and Minier 2003), although Shapiro (2021) shows that tariffs are on average lower for more polluting imports. In this issue, border taxes are discussed in greater depth in the paper by Clausing and Wolfram.

Second, border pollution taxes would be a way for higher-income countries to encourage exporting countries in the rest of the world to set more stringent environmental standards of their own. For local pollutants like PM_{10}, the justification for high-income countries to exert this kind of pressure on exporters in the rest of the world may arise from concerns about environmental quality in those countries. For global pollutants like CO_2, the justification would be preventing leakage.

If the question is whether developed countries cleaned their own environments by importing polluting goods, then the answer seems to be "no." Imports and exports to and from developed countries have grown rapidly. But the mix of goods imported has not tilted disproportionately towards relatively more polluting industries. In fact, over the past three decades that mix has shifted towards cleaner industries, not dirtier.

If the question is whether developed country imports have resulted in more pollution elsewhere, the answer seems to be "it depends." Detailed industry-specific emissions intensities are not available for most countries. As a result, existing multi-region input-output tables use broad classifications that blur important distinctions between polluting and clean industries in the same sector. Attempts to use those do find that emissions intensities for those broad classifications are higher in poor countries than in rich ones, which means that even balanced trade between poor and rich countries will show more pollution caused by developed country imports than exports, even for the same goods. And proportional growth in imports and exports will show that gap to be increasing. Whether we should label that "outsourcing pollution" is unclear.

Finally, if the question is whether regulations in developed countries cause polluting industries to relocate to pollution havens, the answer is that identifying that cause-and-effect relationship is tricky. For specific, geographically mobile, and pollution-intensive industries, examples can be demonstrated. But in general, the balance of the evidence to date does not find statistically or economically significant evidence of regulations causing outsourcing. For all the talk of outsourcing pollution in the media and politics, there is surprisingly little empirical evidence that high-income regions increasingly and disproportionally import products of the most polluting sectors.

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