Waste of Effort? International Environmental Agreements

Derek Kellenberg, Arik Levinson

Abstract: Most evidence suggests that the 1,000 or so different International Environmental Agreements (IEAs) operating today are ineffectual, merely ratifying business-as-usual outcomes. But much of that empirical analysis faces two obstacles: (1) limited data from before the IEAs were enacted and thus an inability to make before-and-after comparisons and (2) difficulty estimating the counterfactual outcomes—what would have happened absent the agreements. We study one particular IEA—the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal. In this special case we do have data prior to the agreement, enabling us to identify the treaty's effects using annual bilateral waste shipments among countries before and after one of the trading partners ratifies the agreement. Despite the strengths of this approach, we find almost no evidence that the Convention has resulted in less waste being shipped among countries.

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MANY OF THE WORLD'S pressing environmental problems are international, from endangered species, to the hole in the ozone layer, to greenhouse gas emissions and climate change. Addressing these problems requires international cooperation—in some cases on an unprecedented scale. Worryingly, however, economic research has so far yielded little hope that international environmental agreements (IEAs) can meet these

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global challenges. Economic theories demonstrate that due to free ridership problems IEAs can achieve little more than what individual countries would volunteer without the agreements and far less than would be optimal. Most empirical work supports the theories, finding that IEAs result in no improvements beyond what would have occurred in their absence.

Are IEAs effective? The empirical work to date has faced two obstacles to answering that question. First, IEAs typically require member countries, as a first step toward compliance, to begin reporting data on their contributions to the relevant environmental problem. The Montreal Protocol required countries to report their production and consumption of ozone-depleting substances, but only treaty members report and only after they join the treaty. It is hard to know what countries were doing before they joined or to compare participants with nonparticipants.[1] More importantly and more generally, researchers have a hard time differentiating countries' actions after joining IEAs from what they would have done absent the IEAs. If an environmental problem worsens after member countries enact an IEA, but worsens less than if the countries had not acted, the agreement might be falsely deemed a failure despite its success in slowing pollution growth. Conversely, if countries expecting emissions reductions are more likely to join an IEA, the agreement might be falsely deemed successful despite merely ratifying business-as-usual practices.

In this study we examine one particular IEA that enables us to address both problems: the Basel Convention on the Control of Transboundary Movements of Hazardous Waste and Their Disposal. The Convention was adopted in the context of growing international shipments of hazardous waste—so-called toxic trade—from industrialized countries to parts of the world where disposal is less expensive and presumably less safe. The Convention's central goal is "restriction of transboundary movements of hazardous waste except where it is perceived to be in accordance with the principles of environmentally sound management."[2] Starting in the early 1990s, the Convention required member countries to publicly report details about their exports and imports of hazardous and other waste. Then in 1995, the Convention's Ban Amendment prohibited all exports of hazardous waste from countries listed in Annex VII (all Organization for Economic Cooperation and Development [OECD] and European Union countries plus Liechtenstein) to all other countries not listed in Annex VII (henceforth A7 and non-A7 countries).

At the simplest level, international hazardous waste trade would not appear to fit the standard characteristics of an environmental problem requiring international

1. See Cole, Rayner, and Bates (1997), Murdock and Sandler (1997a, 1997b), and Auffhammer, Morzuch, and Stranlund (2005).

2. http://www.basel.int/TheConvention/Overview/tabid/1271/Default.aspx, accessed July 17, 2013.

cooperation. If waste is improperly handled, that creates local pollution, not cross-border externalities or open-access "tragedy of the commons" problems. If every country regulates hazardous waste disposal appropriately within its borders, international waste trade should be efficient and welfare improving just like trade in any good or service. All the usual comparative advantage arguments for free trade apply. But as has long been recognized, if some countries cannot appropriately regulate natural resources or pollution emissions within their borders, trade restrictions may be a second-best policy.[3] Throughout this paper we assume that to be the fundamental motivation for the Basel Convention and Ban—the concern that some countries' institutions are incapable of providing their citizens with their desired level of "environmentally sound management" of hazardous waste, and that those countries are better off limiting their imports through international treaties.

To assess whether the Basel Convention or the Ban succeeds in achieving that second-best policy and alters waste shipments beyond what would have occurred anyway, we use a variant of the gravity model of international trade, 60 six-digit Harmonized System (HS) tariff codes describing bilateral shipments of various types of waste among 117 countries over 21 years, and data on if and when those countries ratified the Basel Convention or its Ban Amendment. We pose two basic questions.

First, we ask whether the Basel Convention, independent of the Ban Amendment, did anything to reduce waste flows among ratifying countries. Descriptive statistics suggest that countries ratifying the Convention were those countries with slower-than-average growth in hazardous waste trade and that the Convention did nothing to alter that pattern. Controlling for other country characteristics, those that ratified the Convention did export less hazardous waste, but our inference is that they would have done so anyway.

Second, we ask whether the subsequent Ban Amendment had any effect. This is where our unique identification strategy has power, because the Ban Amendment restricts one particular type of waste trade—shipments from A7 to non-A7 countries. While controlling for other country characteristics, we interact controls for Ban ratification with controls for A7-to-non-A7 shipments. We find that although A7 countries ratifying the Ban do appear to export less waste to non-A7 countries, that effect disappears once we include country-year fixed effects or country-pair fixed effects, suggesting that the Ban, like the Convention itself, left unaltered existing trends in waste exports by A7 ratifying countries. One possible explanation for the treaty's lack of apparent effect on A7 exports is trade diversion. Countries banned from shipping waste to non-A7 importers may transship that waste via nonparticipants. We explore this possibility but find no aggregate evidence that trade diversion has circumvented the treaty's objectives.

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3. See Copeland (1991), Chichilnisky (1994), and Brander and Taylor (1997).

Although we had expected that the empirical advantages of our approach might help us to overcome the obstacles faced by earlier research and yield results consistent with IEA-improving environmental outcomes, we find no evidence that A7 countries that ratified the Ban slowed their exports to non-A7 countries as the agreement requires. We do find limited evidence that non-A7 countries that ratified the Ban have slowed their imports of the most toxic waste from A7 countries, a result consistent with Copeland's (1991) finding that trade restrictions may be welfare improving for small countries that are unable to enforce domestic environmental regulations. After controlling for a number of empirical issues, including endogeneity and unobserved country characteristics, this is the only effect we find in terms of the Ban reducing waste trade. Before describing our model and data in detail, we begin with some background on IEAs in general, and the details of international hazardous waste trade and the Basel Convention.

1. BACKGROUND

IEAs have been proliferating. From 1951 to 1980, 216 new multilateral IEAs or protocols were enacted worldwide; in the following 30 years through 2010, 398 new multilateral IEAs and protocols were enacted (Mitchell 2002–11). Today, more than 1,000 multilateral IEAs are in operation.[4]

The Economics of IEAs

According to most theoretical economic models, all these new IEAs will have been largely ineffective. Typical theoretical results show that IEAs can do little to improve the environment beyond noncooperative outcomes (Carraro and Siniscalco 1993; Barrett 1994, 1997). Due to the obvious free-rider problem, models demonstrate that equilibrium participation in IEAs will be small or that larger coalitions can only be supported if the abatement targets are far less than the social optimum (Finus and Maus 2008). Of course, game theoretic models do not necessarily predict behavior, and IEAs might be effective despite theories to the contrary.

Unfortunately, the few empirical examinations of this issue have also failed to find significant effects of IEA participation on pollution. These have included studies of sulfur emissions and the Helsinki Protocol, ozone-depleting substances and the Montreal Protocol, and sulfur emissions again under the Oslo Protocol.[5] The lone paper finding statistically significant consequences of an IEA is Bratberg, Tjøtta, and Øines (2005), who find that countries ratifying the Sofia Protocol reduced their nitrogen oxide emissions relative to nonratifying countries. But even this result is con-

4. International Environmental Agreements Database Project website (iea.uoregon.edu/page.php?file=home.htm).

5. See Murdoch and Sandler (1997a, 1997b), Finus and Tjøtta (2003), and Ringquist and Kostadinova (2005).

sistent with Finus and Maus's (2008) theoretical finding that any IEA gains will be small and far from the social optimum.

Given the lack of theoretical and empirical evidence that voluntary IEAs can solve international environmental issues, their growing prevalence remains a puzzle. Rose and Spiegel (2009) provide evidence for one plausible explanation: that participation in noneconomic international partnerships such as IEAs facilitates spillovers to other potentially more meaningful economic sectors, such as international lending. In other words, countries join IEAs and comply with their stipulations in order to gain the benefits of other international cooperation.

Whatever the reason for their prevalence, IEAs are the primary mechanism for efforts to solve global environmental problems. It is therefore critical that we try to understand whether IEAs can succeed. For that we turn to one particular IEA, the Basel Convention, with two distinct advantages. It governs international waste trade, about which we have data for countries before and after they join the agreement; and countries trade with multiple partners, providing numerous sources of identification that can potentially solve the problems associated with countries' endogenous decisions to join.

The Basel Convention and Ban Amendment

International hazardous waste trade has been growing exponentially. Between 1992 and 2008, the total physical volume of waste traded internationally grew 500%, from 45 to 221 million tons. For context, the total weight of all passenger automobiles shipped internationally in 2008 was 48 million tons—one-fifth the weight of the waste traded that year. To the extent that waste is exported to countries with safe and environmentally responsible recycling or disposal capacity, waste trade may be seen as economically efficient in the same sense as goods trade. But if waste is exported to less developed countries with lax safety or environmental regulations, then waste trade may be creating substantial environmental problems in the importing countries. Indeed, Puckett and Smith (2002), Puckett (2005), and Pellow (2007) have all documented drastic environmental degradation occurring in Asia and North Africa where hazardous waste—especially used electronics—is being imported from developed countries. In that case, an IEA might help by enlisting the cooperation of exporters limiting their shipments to countries struggling to limit their imports.

The Basel Convention came into force in 1992 and aims to "protect human health and the environment against the adverse effects resulting from the generation, management, transboundary movements and disposal of hazardous and other wastes."[6] It is the most comprehensive IEA governing hazardous and other wastes, and it had 175 participants by 2011. While the Convention has a number of goals, its

6. http://www.basel.int/Portals/4/Basel%20Convention/docs/text/BaselConventionText-e.pdf, accessed May 19, 2014.

primary policy tool is a ban on shipping waste across country borders. Article 4 of the convention stipulates, among other things, that (i) countries may ban hazardous waste imports, (ii) waste-exporting countries must honor bans by waste importers, (iii) importers must be alerted to shipments and must approve the shipments in writing, and (iv) ratified countries may not ship waste to or from countries that have not ratified the Convention.[7]

All else equal, points i and ii above should lead to a reduction in international waste trade if importing countries announce a ban and exporting countries enforce the prohibition on exports to those countries. However, the effects of points iii and iv are less clear. Although they were likely intended to increase transparency and to create an incentive for countries to join the convention, critics argued that these components of the Convention did more to legitimize international waste trade than to reduce it. A nonratified country that was previously unable to trade with a ratified member (point iv) could simply ratify their membership in the convention and then choose to accept properly announced waste shipments (point iii). In this case, once both countries have ratified the Convention we could see an increase, rather than a decrease, in waste trade between them.

To be clear, this may be more of a concern about empirical strategies than real effects. Taking the Convention as given, if one member of a pair of trading countries ratifies, waste shipments to and from the nonparticipating member should drop. If the second country then ratifies, waste shipments can increase relative to when only one member had ratified. In our analysis, we must be careful to distinguish two effects: the effect of the Convention and Ban on participating countries relative to nonparticipants and the overall effect of the Convention and Ban relative to a world without those IEAs.

In response to concerns about the Convention legitimizing toxic trade, in 1995 the Ban Amendment prohibited A7 countries from exporting hazardous waste to non-A7 countries, whether or not the importers are Basel members. The Ban first went into force for ratified countries in 1998.[8] If the Ban has been effective then we should expect a reduction of waste exports from ratifying A7 countries to non-A7 countries.

The Basel Convention and Ban Amendment are in some ways ideal circumstances in which to assess empirically the effect of IEAs. The stated environmental goals of the Convention (restricting the movements of waste products to countries ill equipped to safely handle them) are directly linked to patterns of international

7. See Article 4 of the Convention, Sections 1(a), 1(b), 1(c), and 2(f); and Article 5.

8. The Ban Amendment is not yet officially part of the Basel Convention as there is still legal uncertainty about how many countries must ratify the Ban for it to take effect. However, most countries that have ratified the Ban did so as part of their domestic laws regarding waste exports.

trade, for which there are abundant data. Moreover, those trade flows are measureable across time and countries. And finally, most countries trade waste with numerous other countries, providing multiple sources of identification. We can assess the effect of the Convention and Ban across countries in a given year, over time for a given country, across trading partners for a given country in a single year, and even within pairs of countries over time before and after they ratify the IEAs.

We combine information about countries' ratifications of the Convention and Ban with detailed bilateral international waste trade data based on the Harmonized Commodity Description and Coding System (HS), yielding a comprehensive panel data set covering 117 countries over 21 years. Using variants of the standard gravity model of trade, we explicitly test the effectiveness of the Basel Convention and the Ban Amendment, while controlling for endogenous selection into the agreements by comparing the effects within pairs of countries over time.

2. INTERNATIONAL WASTE TRADE DATA AND TRENDS

The Basel Convention requires members to report their hazardous waste imports and exports, but those data cannot be used to compare members to nonmembers or to study members before and after ratifying the Convention. As a consequence, we use a close proxy for the waste trade governed by Basel: the United Nations Comtrade database and 60 six-digit Harmonized System (HS6) tariff codes for which the product description lists "waste," "scrap," "slag," "residue," or "ash" as the primary descriptor of the product.[9] Appendix table A1 lists each of the 60 waste categories, along with their HS6 codes. Data were collected for 117 countries that had at least some positive quantity of trade from 1988 to 2008.[10] Our main unit of observation is the aggregate annual tonnage of waste traded between countries, summed across the 60 waste classifications in table A1. Each country pair potentially appears twice per year: once for each direction of waste flows. In total, there are 285,012 possible observations.[11] After omitting country pairs with zero waste trade, or for which GDP data were unavailable, we are left with 46,149 observations.

The Convention's definition of "hazardous" relies on the waste's characteristics (eco-toxic, corrosive, flammable, poisonous, infectious, oxidizing, toxic, etc.), while

9. The UN Comtrade database can be found at http://comtrade.un.org/.

10. The Harmonized System Codes for commodity classification began with the 1992 HS codes. However, several countries retrospectively reported trade data from prior years using the 1992 HS codes. In our data set, we include 37 countries that reported imports from 85 different exporters from 1988–91, for a total of 2,553 annual observations during those years. Later, in table 6, we demonstrate the robustness of our results when those retrospective observations are excluded.

11. 117 exporters × 116 importers × 21 years.

the HS6 data we used to assemble table A1 are based on product descriptions.[12] Each of the 60 categories in table A1 can have both hazardous and nonhazardous components. As an example, consider HS6 code 720449 for ferrous waste or scrap metal, one of the largest components of waste trade by weight. A crushed car would be in this HS code, and so we classify it as waste trade, but whether the Convention would classify that car as hazardous depends on whether its oil, transmission fluid, and antifreeze had been removed before it was crushed. Even product categories whose descriptions may appear safe can be hazardous under the convention. Scrap glass (HS6 711210) is hazardous if it is from computer monitors containing lead; sawdust (400400) is hazardous if it has been used to absorb industrial solvents. As a consequence, our Comtrade waste data do not perfectly match the Convention's definition of hazardous waste, but they do allow us to compare Convention and Ban participants to nonparticipants before and after the agreements were in force.

As a check on this proxy, we also create a second definition of hazardous trade using 20 of our original 60 waste categories where the description in the Basel Conventions' Annex VIII list of hazardous waste products match closely to the product descriptions in the HS code. These are listed in appendix table A2. Each of these 20 product categories are certain to contain products that are completely, or nearly completely, composed of wastes considered hazardous under the Basel Convention.[13]

Finally, we can compare our Comtrade proxy to the actual voluntarily reported hazardous waste trade data collected under the auspices of the Basel Convention, for those countries that have ratified the Convention and for the years following their ratification. Under the Convention, both exporters and importers report waste shipments, and so there are two separate measures. Table 1 presents all these correlations, including official Basel data for 1994–2003. The two types of waste shipments listed in tables A1 and A2 are positively correlated but not completely collinear (ρ = 0.403). And both Comtrade proxies are correlated with the official Basel Convention data.

Our use of the Comtrade data as a proxy for Basel-defined waste trade raises two possible concerns. First, treaty ratification might alter the composition of waste trade rather than its aggregate volume. For example, shippers might comply with the treaties by exporting or importing more recyclable or recycled materials in lieu of the raw hazardous waste. Even so, the treaty imposes a restriction that presumably raises the cost of shipping those materials and will in theory reduce the quantity

12. Annex II and Annex VIII of the Basel Convention describe waste streams and categories of products that are considered hazardous, while Annex IV describes wastes considered nonhazardous.

13. These are not official concordances but are concordances made by us based on the commodity descriptions in both the HS6 code and the codes in Annex VIII of the Basel Convention.

Table 1. Correlations among Categories of Waste

	Highly Hazardous	Basel Importer Data	Basel Exporter Data
All Comtrade waste (table A1)	.403	.508	.390
	n = 14,194	n = 1,723	n = 1,685
Highly hazardous Comtrade (table A2)	. . .	.465	.378
		n = 1,216	n = 1,132
Basel importer data	. . .	. . .	.452
			n = 906

Note.—From authors' calculations from United Nations Comtrade data 1988–2008 and Basel Convention data 1994–2003.

shipped. Second, the Comtrade data may simply be a noisy measure of the Basel-defined waste, inflating the standard errors on the treaty coefficients. We address that by discussing not just the sign and statistical significance of those coefficients but also their magnitudes. In the empirical analyses that follow we focus on the broadest definition of waste trade, the 60 Comtrade categories. But in robustness checks we demonstrate similar results with the narrower list of 20 highly hazardous Comtrade codes and the much more limited set of countries and years for which we have official Basel data.

The complex annual data on waste volumes shipped in each direction between each pair of countries, differentiated by A7 status, provide a number of different ways to identify the treaty's effects. There are four types of exporters (A7 and non-A7 participants and nonparticipants) and four types of importers, yielding 16 different types of annual waste shipments. The Convention's objective is to restrict international shipments in general, though it was motivated by the growth in shipments to developing (non-A7) countries. Accordingly, if the Convention is successful, we should see a decline in exports by participants, especially to non-A7 countries. This could be identified from a number of differences in the data: smaller exports from participants than from nonparticipants, smaller exports to non-A7 countries from A7 signatories than from A7 nonsignatories, or smaller shipments among participants than among nonparticipants. Each of these differences can be examined across countries or within countries or country pairs over time when one country ratifies the Convention or the Ban.

Table 2 begins to describe these data. From 1988 to 2008, 2.2 billion tons of waste were shipped among countries. More than half of this waste was shipped among A7 countries (A7 to A7). Shipments from A7 to non-A7 countries make up the second largest component of waste trade. These developed-to-developing country shipments are the primary target of the Basel Convention and Ban. By weight, shipments from non-A7 countries, in columns 4 and 5, make up only a small part of in-

Table 2. Hazardous Waste Shipped among Countries: 1988–2008

	All (1)	A7 to A7 (2)	A7 to Non-A7 (3)	Non-A7 to A7 (4)	Non-A7 to Non-A7 (5)
Total (million tons)	2,163	1,295	456	202	211
Annual country pairs	46,149	13,531	10,083	11,864	10,671
Average annual (tons)	46,865	95,670	45,178	17,001	19,775
SD	(304,563)	(420,143)	(363,328)	(121,229)	(177,567)

Note.—From authors' calculations from United Nations Comtrade data. "A7" refers to countries defined in Annex VII of the Basel Convention (all OECD and European Union countries plus Liechtenstein). Excludes 1,241 observations where an importer or exporter only traded with one other country in a given year or where a pair of countries only traded in one year.

ternational waste trade. Column 1 also shows that the average annual shipment among countries in our data was 47,000 tons and that the average annual shipment between pairs of A7 countries (96,000 tons) was more than twice as large as the average annual shipment from A7 to non-A7 countries.

In fact, waste volumes among all countries have been growing so much that these cross-section differences in table 2 may be obscured by overall growth. Figure 1 shows that between 1988 and 2008, waste trade has grown by many multiples and that waste shipments from A7 to non-A7 countries—the ones prohibited by the Ban—account for more than a quarter of the overall growth in waste trade. To get a better idea of the importance of shipments from A7 to non-A7 countries, in figure 2 we plot average waste flows conditional on Basel ratification status. The result is striking. When the A7 and non-A7 countries have both ratified the Convention, average annual waste shipments remain fairly constant over the 21-year period. However, when one or both are not ratified members of the Convention, the average volume of bilateral waste flows between countries increases by a factor of five. This makes it seem as though the Convention succeeded in reducing international waste shipments to non-A7 countries.

Although figure 2 looks as though Basel has succeeded, that could be an artifact of the composition of countries ratifying the Convention. The growing difference between the waste shipments among Basel participants and nonparticipants depicted in figure 2 combines two possible changes: (i) a real effect of the Convention on participants, reducing waste shipped among participants relative to waste shipped among nonparticipants, and (ii) a change in the composition of participants over time. This second effect is a form of selection bias. If countries trading the most waste ratify Basel first, and if over time the countries joining the Convention are those trading relatively less, then the average annual waste shipped among participants might be declining, even if countries maintain the same patterns of trade regardless of their

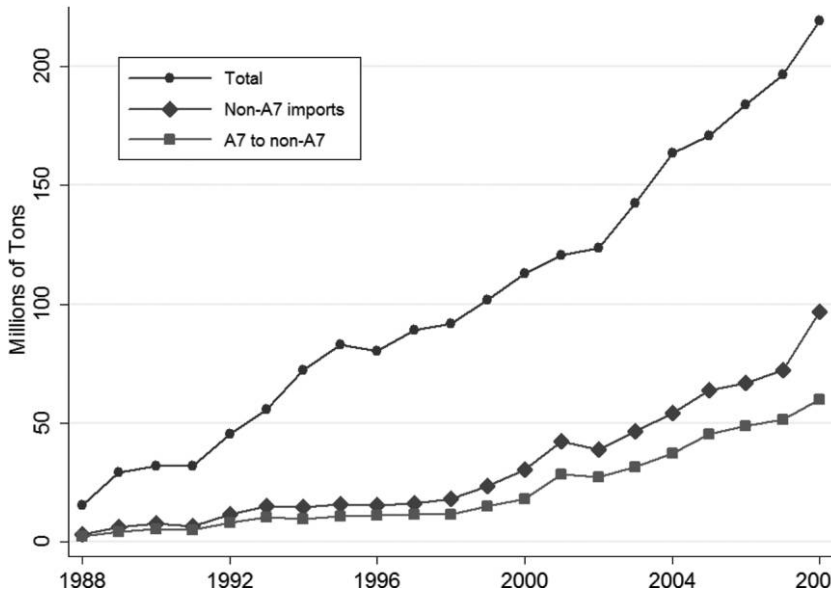

Figure 1. Total annual waste shipments. A color version of this figure is available online

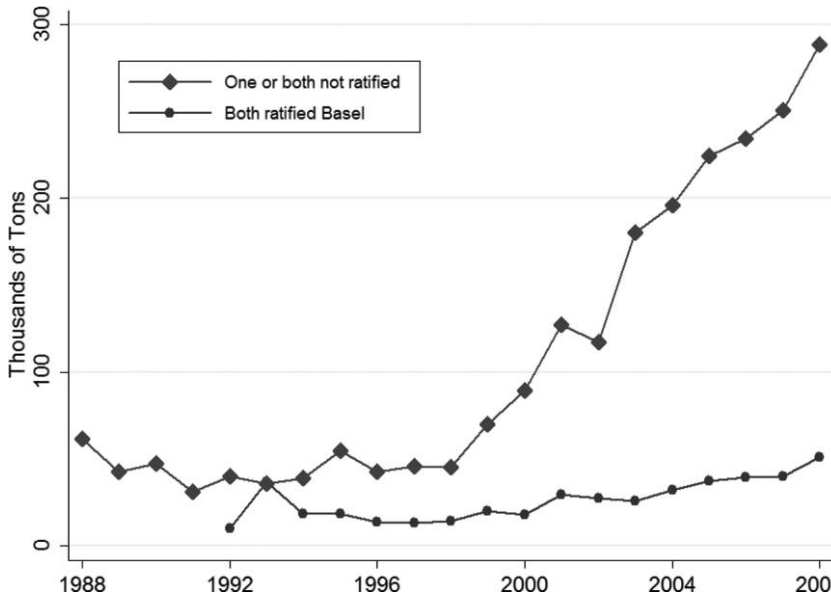

Figure 2. Average annual shipments from A7 to non-A7 countries. A color version of this figure is available online.

participation. In other words, the growing difference between participants and nonparticipants may be explained by the uneven sample of countries ratifying the Convention, rather than the effect of the convention on participants.

Figure 3 demonstrates this selection bias. It reports the average annual waste exports and imports over the entire 21-year period, plotted against the year in which the countries ratified the Convention. Countries that joined Basel in 1992 exported an average of 1.5 million tons per year between 1988 and 2008. But countries that ratified in 2000 exported an average of only 390,000 tons. The average waste exports of Basel members are shrinking in part because the countries that joined the Convention later export less waste. The same is true for imports—average waste imported by members declines because later signatories are lower-volume importers. A figure drawn for countries ratifying the Ban (not shown) looks similar: those ratifying the Ban most recently export and import the least. If we are not careful, we could mistake this selection of countries into the Convention and Ban for the causal effect of those agreements.

To address this selection problem, table 3 presents averages for country pairs where at some point between 1988 and 2008 one of the countries ratified the Convention. For example, the first row presents average annual waste shipments between countries where the exporter ratified the Convention. After exporters ratified it, exports to both A7 and non-A7 countries rose. The same is true for country pairs

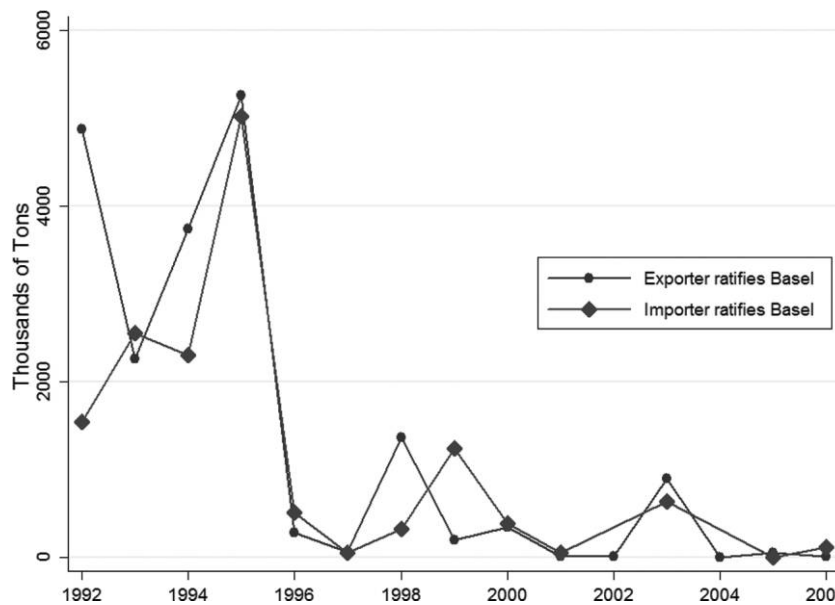

Figure 3. Average annual total waste shipments by year of treaty ratification. A color version of this figure is available online.

Table 3. Tons of Hazardous Waste Shipped: Before and After Change in Basel Status, 1988–2008

	A7 to A7		A7 to Non-A7	
	Before (1)	After (2)	Before (3)	After (4)
By Basel status:				
1. Exporter ratifies Basel	61,502	105,826*	25,924	63,640*
	(273,188)	(402,563)	(69,509)	(332,765)
	n = 1,356	n = 5,741	n = 665	n = 3,110
2. Importer ratifies Basel	88,779	118,690*	24,361	35,702*
	(387,287)	(482,552)	(94,547)	(129,617)
	n = 1,451	n = 5,714	n = 1,233	n = 3,765
3. Both ratify Basel	61,579	90,837*	16,740	50,286*
	(264,983)	(344,226)	(55,484)	(303,406)
	n = 1,583	n = 6,026	n = 1,253	n = 3,754
By Ban status:				
4. Exporter ratifies Ban	88,053	105,104*	16,831	34,121*
	(335,767)	(378,181)	(58,036)	(178,634)
	n = 4,546	n = 4,474	n = 2,522	n = 2,869
5. Importer ratifies Ban	82,920	102,527*	42,009	135,781*
	(327,320)	(384,231)	(205,640)	(826,537)
	n = 4,288	n = 4,431	n = 1,813	n = 1,706
6. Both ratify Ban	103,313	137,006*	23,061	65,162*
	(362,361)	(445,873)	(81,988)	(282,270)
	n = 3,589	n = 2,674	n = 1,269	n = 975

Note.—Each row contains only those bilateral pairs for which the row description is relevant. For example, row 1 ("Exporter ratifies Basel") contains only bilateral pairs for which at some point during the 17 years, the exporter ratified Basel. Similarly, row 3 contains only bilateral pairs for which at some point the second of the two trading partners ratified Basel. Standard deviations in parentheses.

* Means in cols. 2 and 4 statistically significantly different from cols. 1 and 3, respectively, at 5%.

where the importer ratified the Convention, and also in row 3 where at some point during the 21-year period the second of the two countries ratified the convention.

Comparing figure 2 and table 3 reveals a stark fact. Figure 2 shows that from 1988 to 2008 waste shipments from A7 to non-A7 were smaller and grew less quickly when both of the countries were Basel members, seemingly in accordance with the agreement's intent. But table 3 shows that this difference is driven in large part by the timing and selection of countries ratifying the Convention. Whether or not the importer, the exporter, or both ratified the Convention, waste shipments were larger after ratification than before, seemingly in violation of the agreement's intent.

Recall, however, that very few countries trading waste during this period were not Basel members and that international waste trade in general increased steeply.

Because of that, we also examine the Ban amendment. Rows 4–6 of table 3 provide similar evidence suggesting the Ban has been ineffective. After A7 exporters ratified the Ban, average waste exports to non-A7 countries doubled (to 34,000 tons); after non-A7 waste importers ratified the Ban, average waste imports more than tripled (to 136,000 tons).

What's going on here? The most plausible explanation is that the overall growth in worldwide waste trade depicted in figure 1 swamps any effect of the agreements. To identify the effect of the Basel Convention or Ban, we need to know whether the growth in A7 to non-A7 waste shipments was lower among members than it would have been absent their participation, not whether it was lower in absolute terms. That is a much more difficult question to answer, but one that our rich panel of waste-trade data can help address.

As a final piece of descriptive evidence, examine figure 4, which plots average annual waste shipments from A7 to non-A7 countries. Instead of calendar years on the bottom axis, however, we have plotted the years relative to the year the Ban was ratified—by the importer for the top line and the exporter for the bottom line. The top line shows that during the four years before non-A7 importers ratified the ban, average waste imports from A7 countries grew steadily; and during the four years after non-A7 importers ratified the Ban, waste shipments from non-A7 countries continued to grow steadily at approximately the same rate. The bottom line

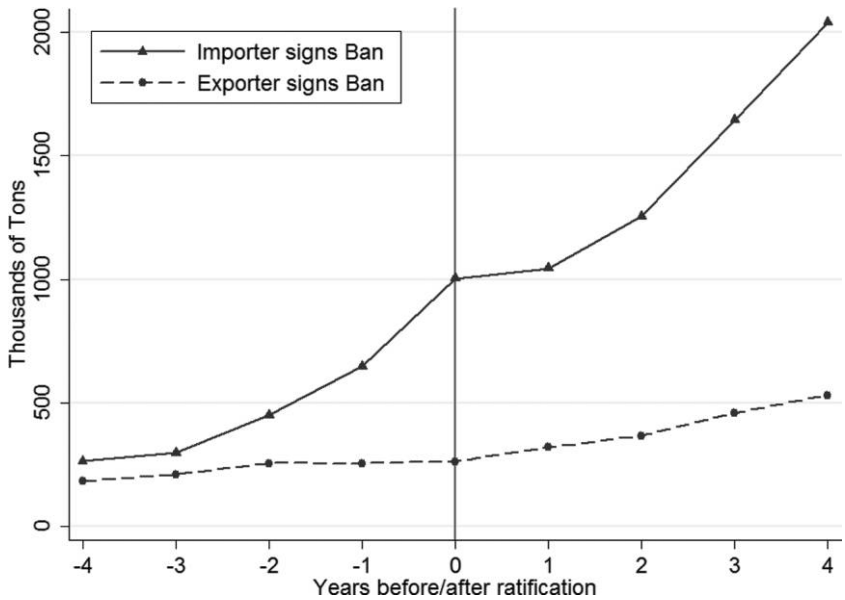

Figure 4. Average annual A7 to non-A7 shipments before and after ratification. A color version of this figure is available online.

shows that waste exports from A7 to non-A7 countries grew steadily both before and after the A7 exporters ratified the Ban.

All of this descriptive material might be taken as evidence that the Basel Convention and Ban did not reduce waste shipments from developed to developing countries. This would be consistent with most of the theoretical and existing empirical research on IEAs. Any such conclusions, however, must be tempered by two caveats. First the descriptive evidence controls for nothing about countries aside from whether or not they join the Convention or the Ban. We know from the large empirical trade literature that countries' characteristics such as their distance from one another and the size of their populations and economies are highly correlated with international trade. Second, and perhaps more importantly, participation in these IEAs seems likely to be endogenous. If countries receiving or expecting to receive growing quantities of waste respond by joining Basel or the Ban, that may mask the effect of those IEAs on what waste trade would have been absent their participation. Alternatively, countries for which waste trade constitutes an important industry may be less likely to join Basel or the Ban, making the treaties appear spuriously effective. As a consequence, our next step is to estimate the effect of the Basel Convention and Ban on waste trade holding those other country characteristics constant, and attempting to control for the potential endogeneity of countries' participation in the treaty.

3. GRAVITY-MODEL TESTS OF THE BASEL CONVENTION AND BAN AMENDMENT

To examine the effects of the Basel Convention and Ban on international waste shipments, we estimate a version of the standard "gravity" model of international trade, where instead of goods trade we substitute our measure of waste shipments in tons. The underlying theory that generates the gravity equation can be derived from the industry-level monopolistic competition model developed by Helpman, Melitz, and Rubenstein (2008) that has subsequently been employed to explain trade in hazardous waste in a gravity equation by Baggs (2009) and Kellenberg (2012). Since many waste products are recycled as intermediate inputs for other production processes (e.g., lead, ash containing copper, ferrous waste, among many others), they have positive economic value and can easily be interpreted in a Helpman et al. framework as an intermediate goods industry with firms selling and exporting differentiated waste products.[14] Our baseline gravity model is

14. Note that some waste products may not have a recyclable component and will be exported strictly for disposal. In these cases, the Helpman et al. framework can be thought of in terms of firms competing in differentiated waste disposal services, rather than products. That is, if country j imports a positive physical quantity of waste strictly for disposal from country i, this corresponds to a physical import for country i from j, but an export of waste

$$\begin{aligned}\ln X_{ijt} = {} & \boldsymbol{\beta}_t + \beta_1(\ln\text{GDP}_{it}) + \beta_2(\ln\text{GDP}_{jt}) + \beta_3(\ln\text{Distance}_{ij}) + \beta_4(\text{Border}_{ij}) \\ & + \beta_5(\text{Language}_{ij}) + \beta_6(\text{Colony}_{ij}) + \beta_7(\text{Basel}_{it}) + \beta_8(\text{Basel}_{jt}) + \beta_9(\text{Basel}_{ijt}) \\ & + \beta_{10}(\text{FTA}_{ijt}) + \beta_{11}(\text{WTO}_{ijt}) + \beta_{12}(\text{nonA7toA7}_{ij}) + \beta_{13}(\text{A7toA7}_{ij}) \\ & + \beta_{14}(\text{A7to nonA7}_{ij}) + \beta_{15}(\text{Ban}_{it}) + \beta_{16}(\text{Ban}_{jt}) + \beta_{17}(\text{Ban}_{ijt}) \\ & + \beta_{18}(\text{A7to nonA7}_{ij} \times \text{Ban}_{jt}) + \beta_{19}(\text{A7to nonA7}_{ij} \times \text{Ban}_{it}) \\ & + \beta_{20}(\text{A7to nonA7}_{ij} \times \text{Ban}_{ijt}) + \varepsilon_{ijt}.\end{aligned} \tag{1}$$

The dependent variable is the log of waste shipments, in tons, from country i to country j in year t (X_{ijt}). This is regressed on year fixed effects ($\boldsymbol{\beta}_t$); the log of the real GDP of countries i and j in year t, the log of the distance between countries i and j, and whether countries i and j share a border, a common official language, or have ever had colonial ties; dummy variables indicating if countries i and j were ratified members of the Basel Convention or the Ban Amendment in year t (Basel_{it}, Basel_{jt}, Ban_{it}, Ban_{jt}),[15] as well as the interactions (Basel_{ijt}, Ban_{ijt}), indicating that both countries were ratified members; and dummy variables indicating whether countries i and j are members of the WTO or some other Free Trade Area or Customs Union in year t (WTO_{ijt}, FTA_{ijt}). Table 4 presents descriptive statistics for the right-hand-side variables in equation (1).

To account for differences in general bilateral trade flows among and between A7 and non-A7 countries, we also include three additional dummy variables: A7toA7_{ij}, A7to nonA7_{ij}, and nonA7toA7_{ij}. Shipments among non-A7 countries are the omitted category. We capture the effect of ratification of the Ban Amendment on A7 to non-A7 waste flows by interacting the A7to nonA7_{ij} dummy with the Ban_{it} dummy to get A7Bto nonA7_{ijt}. Notice that this dummy variable is time varying and country-pair specific. The coefficient β_{20} tells us whether there is any difference in bilateral waste trade from A7 countries to non-A7 countries when the A7 exporting country has ratified the Ban Amendment relative to when the A7 country has not ratified the Ban Amendment, controlling for other country characteristics.

The error term $\boldsymbol{\varepsilon}_{ijt}$ in equation (1) may include unobserved time-varying exporter ($\boldsymbol{\omega}_{it}$) and importer ($\boldsymbol{\omega}_{jt}$) characteristics that influence bilateral trade from country i to country j as well as unobserved bilateral characteristics that are time invariant ($\boldsymbol{\omega}_{ij}$):

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disposal services for country i. In this case, the physical flow of waste from country j to country i can be thought to have a negative price, but it is really a positive price on the export of disposal services from i to j. These country-specific prices on waste goods and waste disposal services are captured in the country-specific price indexes for our aggregate waste industry, which are unobserved in equation (1) below but are captured by our importer-year and exporter-year fixed effects later in equations (2) and (3).

15. Countries were coded 1 if they had either ratified or acceded to the Convention. Countries that had signed the convention but not ratified or acceded were coded 0. We use the term "ratify" from here on out to mean ratification or accession.

Table 4. Descriptive Statistics

	A7 to A7 (1)	A7 to Non-A7 (2)	Non-A7 to A7 (3)	Non-A7 to Non-A7 (4)
Average annual tons waste	95,670	45,178	17,001	19,775
	(420,142)	(363,328)	(121,229)	(177,567)
Average tons high hazard waste	4,768	2,509	639	1,394
	(20,371)	(21,210)	(1,887)	(6,597)
Importer GDP (billion 2000 $)	996	225	1,471	265
	(2,050)	(403)	(2,414)	(449)
Exporter GDP (billion 2000 $)	947	1,455	187	210
	(2,057)	(2,628)	(379)	(428)
Distance (km)	4,140	6,687	6,273	5,596
	(4,498)	(3,971)	(4,028)	(4,788)
Shared border	.092	.035	.035	.165
Shared language	.086	.142	.129	.315
Colonial ties	.056	.067	.074	.017
Importer ratified Basel	.851	.826	.838	.830
Exporter ratified Basel	.856	.858	.784	.856
Importer ratified Ban	.348	.197	.322	.207
Exporter ratified Ban	.351	.376	.175	.212
Importer WTO member	.987	.788	.995	.850
Exporter WTO member	.975	.995	.728	.794
Number of annual country pairs	13,531	10,083	11,864	10,671
Country pairs with highly hazardous waste	5,971	2,650	2,892	2,681

Note.—Standard deviations in parentheses.

$$\varepsilon_{ijt} = \omega_{it} + \omega_{jt} + \omega_{ij} + e_{ijt}.$$

The terms $\boldsymbol{\omega}_{it}$ and $\boldsymbol{\omega}_{jt}$ would include any unobserved characteristics that are country specific and change over time, but are not specific to a bilateral trading pair *ij*. Examples might include time-varying importer- and exporter-specific price indexes and multilateral price terms (Anderson and van Wincoop 2003), environmental regulations and recycling costs (Kellenberg 2012), capital-labor ratios (Baggs 2009), political environments (Grossman and Helpman 1994), or firm-level heterogeneity due to the fixed costs of exporting (Helpman et al.). These are all potentially correlated with both waste trade flows among country pairs and the probability that countries ratify the Convention or Ban and therefore represent a possible source of omitted variable bias.

Additionally, the log-linear specification generated by our Helpman et al. framework incorporates only positive bilateral trade values. Any unobserved bilateral characteristics ω_{ij} beyond our observed characteristics, such as distance or common border, may influence whether two countries have historically been trading partners in waste products. If these unobserved bilateral characteristics are important in determining the occurrence of a zero or positive value of trade, the exclusion of bilateral pairs with zero trade can create a selection problem and bias our estimates. Several papers have estimated cross-sectional gravity models addressing this omitted zeros problem in a variety of ways, including two-stage Heckman-type procedures (Helpman et al.), Tobit models (Eaton and Kortum 2002), and Poisson specifications (Santos Silva and Tenreyro 2006). However, the rich panel data in our paper allow us to address biases from omitted variables, selection, and simultaneity in a more straightforward fashion by incorporating both country-year and bilateral fixed effects as demonstrated by Baier and Bergstrand (2007), which we specify below.

One concern raised by the elimination of country pairs in years when zero waste was traded, which would not be addressed by time-invariant bilateral fixed effects, is that the objective of the Ban was to completely eliminate waste trade. If the Ban succeeded in completely eliminating waste trade between some bilateral pairs and we discard those observations with no trade, we may create a bias against measuring the Ban's effect. That concern is ameliorated in part by our use of the Comtrade proxy. Because the 60 waste codes we use include some nonhazardous waste, the result of the Ban should be to reduce the volume of waste traded, not necessarily eliminate it entirely.

Second, the proportion of country pairs in our data with waste being shipped one way or both was rising steadily during this period, not falling. Figure 5 reproduces the first figure from Helpman et al., dividing all possible country pairs into those with no trade, trade in only one direction, and trade in both directions. In the Helpman et al. figure, the shares are relatively constant for 30 years, lending support to the claim that most of the changes in trading patterns involve the volume of trade between countries, not the addition or subtraction of countries. In our case, fewer countries trade—there are more zeros—and the share with positive trade grows from 1988 to 2008. But the growth in countries trading is dwarfed by the growth in the volume of waste traded depicted in figure 1. And during this time period the number of countries ratifying the Ban amendment grew steadily from 12 in 1998 to 53 in 2008. So rather than reducing the share of country pairs shipping waste, the growth in Ban participation is contemporaneous with growth in the share of countries shipping waste.

Finally, on this point, figure 6 plots the proportion of country pairs with positive waste trade before and after one of the countries ratifies the Ban. In other words, for each pair of countries where one member ratified the Ban at some point, we plot the fraction with nonzero waste shipments before and after that date of

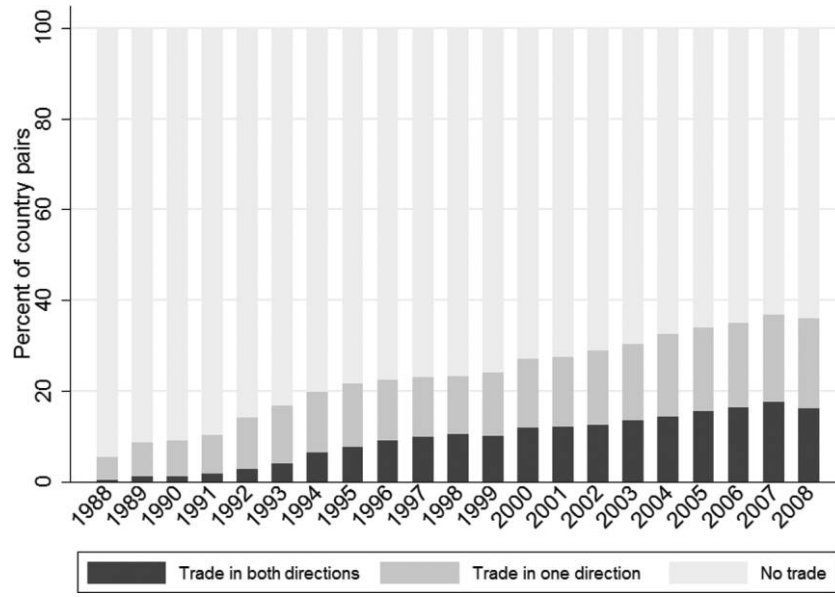

Figure 5. Distribution of country pairs based on direction of trade. A color version of this figure is available online.

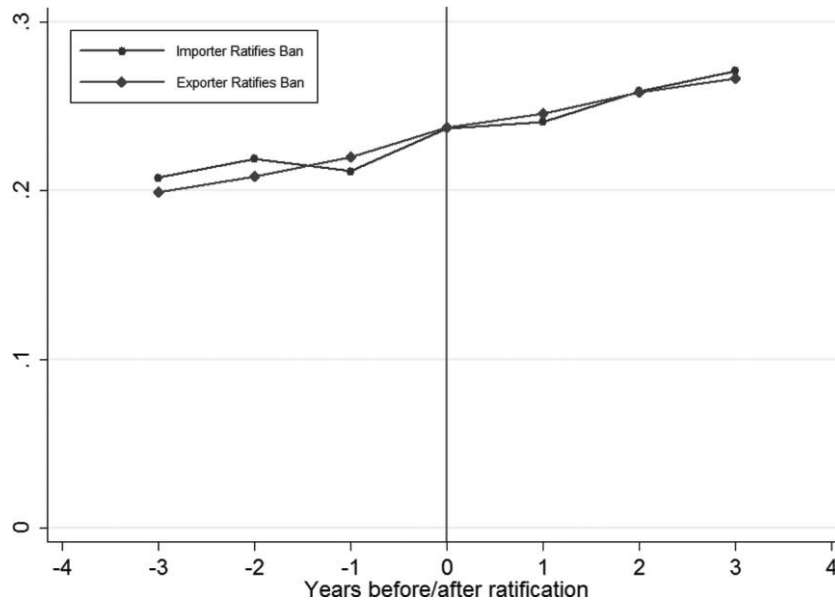

Figure 6. Proportion of country pairs with waste trade. A color version of this figure is available online.

ratification. Notably, countries are more likely to have nonzero waste after one of the trading partners signs the Ban than before, further suggesting that the result of the Ban has not been to eliminate waste entirely.

For now, we focus on versions of equation (1) that use only the sample of countries with nonzero trade. In robustness checks later we return to this issue and employ the whole sample of countries. Table 5 begins with versions of equation (1) that include only the time fixed effects—no country-specific fixed effects. The results in columns 1 and 2 confirm that in this new context of waste shipments, the gravity model has explanatory power typical of empirical models of trade in goods. More waste is shipped among countries that have higher GDP, are closer together, share a common border or colonial history, and are members of the WTO or other trade agreements.

Columns 1 and 2 also contain indicator variables for annual country pairs where the exporter, the importer, or both countries have ratified the Basel Convention or the Ban. The Basel indicators are all negative and statistically significant in the cases where the exporter is a member. Interpreted literally, the point estimates (−0.403 and −0.421) mean that trade flows are 33% lower when the exporting country has joined the Basel Convention.[16] Similarly, the coefficient in column 1 on the indicator for the exporting country having ratified the Ban Amendment (−0.494) suggests that in those cases, waste exports are 39% lower. Column 2 differs from column 1 in that it includes an interaction between the Ban indicator variables and cases where the observation involves a shipment from an A7 exporter to a non-A7 importer. That coefficient (−0.401) is also large and statistically significant, implying that the Ban is associated with a 33% drop in waste trade in that prohibited situation.

These results in columns 1 and 2 cannot be interpreted as a causal effect of the Convention or the Ban on international waste shipments, because we know that waste trade grew voluminously during this period, that large exporters and importers were among the first to ratify the Convention and the Ban, and that countries' decisions to ratify either treaty were likely endogenous with respect to their waste shipments. In fact, there are signs of this endogeneity in columns 1 and 2. The coefficient on "Ban both"—a dummy equal to one if both the exporter and importer have ratified the Ban—is positive and statistically significant and suggests that when both countries have joined, waste shipments are one-third larger, exactly the opposite of the treaty's intent. It could be that waste exporters are more likely to join the Ban if they know their waste exports are declining anyway, or that waste importers are more likely to join if they experience large increases. For those reasons, in columns 3–6 of table 5 we attempt to address those sources of bias with country-year and country-pair fixed effects.

16. This interpretation of dummy coefficients in semilog equations is from Kennedy (1981). The percentage change can be approximated as $100[\exp(c - \frac{1}{2}v) - 1]$, where c is the estimated coefficient on the dummy variable and v is that estimate's variance.

Exporter- and Importer-Year Fixed Effects

To account for time-varying, country-specific omitted variables (ω_{it} and ω_{jt}), columns 3 and 4 of table 5 add importer-year and exporter-year fixed effects:

$$\ln X_{ijt} = \boldsymbol{\beta}_{\mathbf{it}}^{\theta} + \boldsymbol{\beta}_{\mathbf{jt}}^{\theta} + \ldots, \quad (2)$$

where all time-varying exporter- and importer-specific characteristics in year t are now captured by the coefficients $\boldsymbol{\beta}_{\mathbf{it}}^{\theta}$ and $\boldsymbol{\beta}_{\mathbf{jt}}^{\theta}$. Any country-year-specific variables drop out, including GDP and membership in the Basel and Ban agreements, because they are collinear with the fixed effects $\boldsymbol{\beta}_{\mathbf{it}}^{\theta}$ and $\boldsymbol{\beta}_{\mathbf{jt}}^{\theta}$. What remains are characteristics that are bilateral specific, such as distance, common language, and whether both countries are members of the Convention and Ban.[17]

In column 3 of table 5, the "Basel both" coefficient is small and statistically insignificant, and the "Ban both" coefficient (0.218) retains its counterintuitive positive sign, suggesting that when both countries ratify the Ban waste shipments are 25% larger. Column 4 adds the interaction term with the indicator for A7-to-non-A7 shipments. Here we include the interacted term with indicators for whether the exporter or importer has ratified the Ban. The fixed effects do not absorb that variation, because exporters ship to both A7 and non-A7 countries in any given year, and so the interaction term varies within country-years. The key coefficient for when the exporter ratifies the Ban (−0.409) remains large and statistically significant, suggesting a waste decline of 33%. Meanwhile the counterintuitive coefficient on both countries ratifying the Ban (0.140) has declined significantly, implying a 15% waste increase, and that coefficient is tiny and insignificant for the A7-to-non-A7 shipments.[18]

Despite the addition of country-year fixed effects, the negative interaction coefficient of the Ban exporter indicator could still be spurious if countries are more likely to ratify the Ban if they have shrinking relative waste shipments to non-A7 countries. The reason countries join the Convention or ratify the Ban may involve their historical relationships with particular trading partners, rather than their own country characteristics. In that case unobserved bilateral relationships in the error term are correlated with waste shipments and IEA membership and may bias our estimates. In other words, columns 3 and 4 of table 5 are still open to concerns about omitted variable bias, in which case they would still not answer our central question—

17. For example, France's ratification of the Convention is perfectly collinear with France's importer-year and exporter-year dummies, but in any given year France may ship waste to and from countries that may or may not also be members of the Convention, so the dummy "Basel both" remains identified.

18. One possible explanation for these counterintuitive coefficients involves waste being rerouted from A7 Ban participants to non-A7 countries via third parties—other A7 countries that have not ratified the Ban. We explore evidence for that in the penultimate section of the paper.

Table 5. Basic Waste Regressions

Dependent Variable: ln(annual waste)	Year Fixed Effects		Country-Year Fixed Effects		Bilateral Fixed Effects	
	(1)	(2)	(3)	(4)	(5)	(6)
ln(GDP exporter)	.372*	.369*				
	(.008)	(.008)				
ln(GDP importer)	.784*	.785*				
	(.009)	(.009)				
Non-A7 to A7	−1.318*	−1.326*	9.89*	9.90*		
	(.040)	(.040)	(1.20)	(1.20)		
A7 to A7	−.683*	−.701*	15.70*	15.60*		
	(.046)	(.046)	(.97)	(.97)		
A7 to non-A7	−.199*	−.004	5.86*	5.87*		
	(.043)	(.053)	(.81)	(.81)		
ln(distance)	−1.001*	−1.000*	−1.799*	−1.793*		
	(.017)	(.017)	(.020)	(.020)		
Common border	1.348*	1.350*	1.201*	1.210*		
	(.0535)	(.0535)	(.0485)	(.0486)		
Common language	−.170*	−.178*	.150*	.151*		
	(.037)	(.037)	(.037)	(.037)		
Colony	.722*	.747*	.939*	.946*		
	(.057)	(.057)	(.050)	(.050)		
FTA	.153*	.139*	.073	.058	.018	.017
	(.036)	(.036)	(.042)	(.042)	(.053)	(.053)
WTO	.236*	.229*	.201	.200	.0911	.0852
	(.036)	(.036)	(.118)	(.118)	(.130)	(.130)
Basel importer	−.119	−.119				
	(.093)	(.093)				
Basel exporter	−.403*	−.421*				
	(.092)	(.091)				
Basel both	−.195	−.174	.044	.049	.111	.113
	(.101)	(.100)	(.109)	(.109)	(.095)	(.095)
Ban importer	−.050	−.015				
	(.043)	(.044)				
(Ban importer) × (A7 to non-A7)		−.135		.123		.130
		(.122)		(.108)		(.117)
Ban exporter	−.494*	−.375*				
	(.041)	(.046)				
(Ban exporter) × (A7 to non-A7)		−.401*		−.409*		.022
		(.080)		(.079)		(.081)
Ban both	.286*	.310*	.218*	.140*	.059	.086
	(.062)	(.068)	(.056)	(.063)	(.056)	(.062)

Table 5 (*Continued*)

Dependent Variable: ln(annual waste)	Year Fixed Effects		Country-Year Fixed Effects		Bilateral Fixed Effects	
	(1)	(2)	(3)	(4)	(5)	(6)
(Ban both) × (A7 to non-A7)		−.300		.021		−.167
		(.171)		(.137)		(.139)
Constant	9.15*	9.15*	11.71*	11.62*	7.40*	7.69*
	(.21)	(.21)	(.91)	(.91)	(1.00)	(1.24)
Year fixed effects	Yes	Yes	No	No	No	No
Importer and exporter year fixed effects	No	No	Yes	Yes	Yes	Yes
Bilateral fixed effects	No	No	No	No	Yes	Yes
Observations	46,149	46,149	46,149	46,149	46,149	46,149
R^2	.265	.267	.576	.576	.814	.814

Note.—From UN Comtrade Data, classified according to appendix table A1. Robust standard errors in parentheses.

* $p < .05$.

whether countries that ratify the Convention or the Ban experience declines in waste trade relative to what they otherwise would have experienced. To answer that question, we need an empirical strategy that identifies the relevant coefficients before and after one of the parties ratifies the Convention or Ban.

Columns 5 and 6 of table 5 address this last concern by including country-pair fixed effects in equation (2),

$$\ln X_{ijt} = \boldsymbol{\beta}_{\mathbf{it}}^{\theta} + \boldsymbol{\beta}_{\mathbf{jt}}^{\theta} + \boldsymbol{\beta}_{\mathbf{ij}}^{\theta} + \beta_9(\text{Basel}_{ijt}) + \beta_{12}(\text{WTO}_{ijt}) + \beta_{13}(\text{FTA}_{ijt}) + \beta_{19}(\text{Ban}_{ijt}) + \beta_{20}(A7B\text{to non}A7_{ijt}) + \varepsilon_{ijt}. \quad (3)$$

This is the approach taken by Baier and Bergstrand (2007), and in this context it controls for all characteristics that could possibly be correlated with annual waste shipments among countries, other than those that are both time varying and country-pair specific.

The general idea behind these country-pair fixed effects is illustrated by the bottom half of table 3, discussed earlier. The first cell in row 4 contains the average bilateral waste shipments (X_{ijt}) from A7 to other A7 countries where the exporter has not yet ratified the Ban (88,000 tons). Column 3 contains those pre-ratification shipments to non-A7 countries. The difference is 71,222 (not shown in the table), which is large and statistically significant. Columns 2 and 4 contain those same figures after the exporting A7 country has ratified the Ban. That difference (70,983) is also large and significant but only insignificantly smaller. That difference-in-differences is not only statistically insignificant, but goes in the wrong direction. The Ban should

have increased the difference between shipments to A7 and non-A7 countries, not decreased it. Looked at differently, row 4 shows that after exporters ratified the Ban, shipments to A7 countries grew by 17,051 tons, while shipments to non-A7 countries grew by 17,290 tons. In fact, in percentage terms the shipments to non-A7 countries grew by much more than shipments to A7 countries. Again, if the Ban were effective, we would expect shipments to non-A7 countries to have gone down relative to A7 countries, not up. It may be that table 3 simply does not account for other covariates also correlated with waste trade and Ban participation. To estimate that difference-in-differences conditional on covariates, we run various versions of equation (3) in the last two columns of table 5.

In columns 5 and 6 of table 5, we estimate equation (3). Here any variables that either vary over time for a single country (GDP, treaty ratification) or are fixed over time for a single country pair (distance, A7 or non-A7 status) are absorbed by the combination of country-year and country-pair fixed effects. None of the policy variables are statistically significant. The coefficient on both countries ratifying the Ban (0.059) implies that the average waste shipped among countries that both ratify is 6% higher relative to that same country pair before both had ratified, consistent with the difference-in-difference calculations from table 3. Column 6 adds the interaction with A7-to-non-A7 shipments (β_{20}). That coefficient (−0.167) is negative, as expected, but it is small and statistically insignificant.

Before we can be certain that neither the Basel Convention nor the Ban Amendment affected international waste shipments, we must be certain that our proxy for waste trade—the UN Comtrade data—does not contain too many categories of waste not deemed hazardous by the treaty, that the selective retrospective waste trade data between 1988 and 1991 are not compromising the results, and that the treatment of zeros in the data do not explain the lack of evidence for the treaties' efficacy.

Alternative Measures of Waste Shipments

One potential explanation for why the Basel Convention and the Ban Amendment do not entirely eliminate waste shipments is the discrepancy between wastes categorized as "hazardous" by the Basel Convention and trade listed as "waste" by the tariff system. As an alternative, we use the narrower definition of hazardous trade in table A2, 20 product categories that are more likely than our original 60 categories in table A1 to be completely composed of wastes considered hazardous under the Basel Convention.

In the first column of table 6 we reproduce the very last column of table 5—with importer-year, exporter-year, and bilateral fixed effects—but with the narrower category of Comtrade waste data as the left-hand-side variable.[19] The coefficient on

19. All the specifications are available separately from the authors and the working paper version of this study.

Table 6. Robustness Checks

		Basel Waste Data		Starting in 1992		Linear Probability [p(Waste > 0)]	
	Highly Hazardous Waste (1)	Importer Data (2)	Exporter Data (3)	All Waste (4)	Highly Hazardous (5)	All Waste (6)	Highly Hazardous (7)
FTA	−.284*	−1.43	1.49	−.005	−.323*	.0740*	.0588*
	(.087)	(1.62)	(1.14)	(.054)	(.091)	(.0043)	(.0036)
WTO	−.770	−2.99*	1.75	.124	−.774	−.0036	−.0135*
	(.449)	(1.30)	(1.92)	(.131)	(.458)	(.0049)	(.0031)
Basel both	.375*	4.08*	−7.21*	.114	.415*	−.0124*	−.0097*
	(.162)	(1.25)	(1.43)	(.097)	(.166)	(.0037)	(.0024)
(Ban importer) × (A7 to non-A7)	−.618*			.052	−.600*	.0057	−.0145*
	(.249)			(.062)	(.254)	(.0043)	(.0051)
(Ban exporter) × (A7 to non-A7)	−.123			.053	−.104	−.0029	−.0548*
	(.142)			(.119)	(.147)	(.0067)	(.0061)
Ban both	−.128	−.021	.536	−.001	−.146	.0126	.0038
	(.092)	(.332)	(.307)	(.083)	(.092)	(.0069)	(.0033)
(Ban both) × (A7 to non-A7)	.452			−.150	.459	−.0075	.0125
	(.288)			(.140)	(.293)	(.0092)	(.0069)
Constant	8.92*	7.18*	5.94*	3.71*	8.21*	.1930*	.0664*
	(.82)	(2.19)	(1.87)	(1.00)	(.68)	(.0045)	(.0030)
Importer-year, exporter-year, and bilateral fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	12,802	1,331	1,188	43,564	12,027	217,152	217,152
R^2	.923	.885	.887	.820	.925	.716	.584

Note.—The dependent variable in cols. 1–4 is the log of waste trade; in cols. 5 and 6 it is a one if waste traded between the two countries and zero otherwise. Each regression has importer-year and exporter-year fixed effects, and bilateral fixed effects, as in cols. 5 and 6 of table 5. Robust standard errors in parentheses.

* $p < .05$.

both countries participating in the Convention (0.375) is positive and significant, implying that waste shipments are 48% higher when both countries have joined. One possible explanation for this outcome is that the Convention restricts participants from trading with nonparticipants. So within country pairs, when only one member is a Basel member, waste trade is restricted. When the second member joins, and the "Basel both" indicator switches from zero to one, waste trade is unrestricted. In that sense, the outcome may be the intentional consequence of the treaty—increasing waste trade among participants where it is monitored and regulated while decreasing trade among nonparticipants where it is not.

The interaction of the Ban Amendment with the indicator for A7-to-non-A7 shipments offers one small piece of evidence supporting the efficacy of this treaty. The coefficient on importers ratifying the Ban (−0.618) implies that waste shipments to non-A7 countries are 44% lower when the non-A7 importer has ratified the Ban. This finding however, is not necessarily evidence of cooperative behavior among countries participating in an IEA. If it were, we should have found the strongest declines in bilateral waste trade occurring when both countries were ratifiers of the Ban. However, we found no evidence that ratification by A7 countries, who are the largest waste exporters, had any effect on waste flows to developing countries. Rather, this result merely reflects noncooperative behavior, where non-A7 countries make decisions regarding what is best for their own local environmental quality. When a non-A7 country ratifies the Ban, highly toxic waste imports from A7 countries decline to that country. This result is consistent with Copeland (1991), who demonstrated that a small country that is unable or unwilling to enforce its own first best domestic environmental regulations may make themselves better off by imposing an import ban on waste as a second best policy. It is not obvious, however, why an IEA such as the Ban would be necessary for that to happen.

Columns 2 and 3 of table 6 estimate equation (3) using the data collected by the Basel Convention. This must be treated with caution, because data from nonratifiers are only available when they are collected by ratifying countries that trade with those nonratifiers. In column 2, the Basel coefficient is identified by exporting nonratifiers that export to ratifiers. In column 3, the Basel coefficient is identified by importing nonratifiers that import from ratifiers. These are clearly selected samples, and there are not enough observations to separately identify the effect of the Ban on A7-to-non-A7 shipments.

Columns 4 and 5 of table 6 estimate equation (3) for 1992–2008, eliminating those observations from 1988–91 that were based on data from retrospective surveys from a few select countries. The results are not meaningfully different from the full sample.

Finally, columns 6 and 7 of table 6 estimate linear probability versions of equation (3) using the entire sample of countries and years, and where the dependent variable is a one if any waste was shipped between the two countries in that year

and a zero otherwise. The coefficients on "Basel both" are negative and statistically significant in both columns, for all Comtrade waste categories and for the 20 highly hazardous HS codes. But the coefficients are small, suggesting that if two countries have both ratified the Convention, there is only about a 1% smaller likelihood of waste being shipped between them. In column 7, the coefficients on the interactions between ratifying the Ban and shipments from A7 to non-A7 countries are also negative, statistically significant, and small. If an A7 country ratifies the Ban, there appears to be a 5.48% lower chance that it ships highly hazardous waste to a non-A7 country. Given the evidence in figure 5 that the number of countries trading waste has grown steadily, and in figure 6 that the proportion of countries trading waste grows after they ratify the Ban, we do not believe that the Convention or the Ban have worked to any significant degree on the extensive margin by eliminating waste trade among participating countries. Moreover, as documented in figure 4 and table 6, the growing volume of waste traded among countries that do trade—the intensive margin—seems to have been unaffected by the Convention or the Ban.

4. TRADE DIVERSION: WASTE TRANSSHIPPED TO NON-A7 COUNTRIES

One explanation for the lack of a decline in waste shipments in aggregate, or the decline in A7-to-non-A7 shipments in some cases, might be trade diversion. The Ban Amendment prohibits A7 members from shipping hazardous waste to any country outside of the A7 countries. Ban participants can, however, ship waste to other A7 countries, whether or not the recipient has ratified the Ban. If those shipments are in turn re-exported to non-A7 countries, that diversion would circumvent the intent of the Ban. The data we have enable us to examine whether hazardous waste is leaking from developed to developing countries through this loophole in the Ban.

Two trade patterns would betray evidence of waste being re-exported to circumvent the Ban. First, consider the originators of the waste. Figure 7 plots the share of waste shipped from A7 countries to A7 countries that have not ratified the Ban and are therefore possible intermediaries for shipments to non-A7 countries. The top line plots that share from A7 countries that ratified the Ban at some point during the 21-year period; the bottom line represents countries that had not ratified the Ban by 2008.[20] The figure clearly shows that countries ratifying the Ban shipped a higher fraction of their waste to A7 countries that never ratified the Ban,

20. Note that we distinguish countries by whether they "ever" or "never" ratified the Ban. If instead we distinguished countries by their current status, the percentage waste would change over time for two reasons: the effect of the Ban and the composition of countries. Also, since the Ban did not exist before 1998, the top line would be 1.0 and the bottom line 0.0 for every year before then.

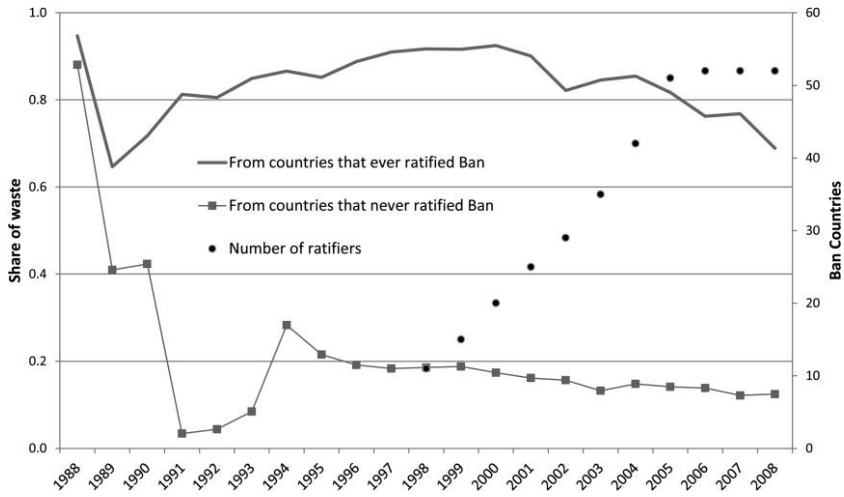

Figure 7. Share of waste shipped from Annex VIII to Ban nonratifiers. A color version of this figure is available online.

but that they did so always, from before the Ban existed to after they ratified. Moreover, for both groups—the ever-ratified and the never-ratified—the fraction shipped to nonratifiers declines over time. There seems to be no evidence in figure 7 that ratifiers are circumventing the Ban by shipping more waste to the nonratifying A7 countries.

A second piece of evidence for trade diversion would involve countries transshipping the waste through intermediary countries. If there is diversion, A7 countries that do not ratify the Ban and that serve as intermediaries would ship more waste to non-A7 countries the higher their imports of waste from A7 countries that did ratify the Ban. Figure 8 contains two scatter plots. The left-hand graph plots the percentage of waste shipped to non-A7 countries against the percentage of imports from ratifying A7 countries, for A7 countries that have not ratified the Ban. If nonratifying A7 countries serve as a loophole in the Ban, re-exporting waste from A7 ratifiers to non-A7 countries, we should see the percentage of waste shipped to non-A7 countries increase with the percentage of imports from ratifying A7 countries. Figure 8 shows that is not happening. If anything, the higher the share of imports from ratifying A7 countries, the lower the share of exports to non-A7 countries.

To double-check, on the right-hand side of figure 8 we have drawn that same plot for A7 countries that have ratified the Ban. To be clear, exports by A7 ratifiers should be zero, but recall that our measure of trade merely proxies for hazardous waste as defined by Basel. So there are many positive observations, but there is also a mass of observations around (1, 0); when most imports come from A7 ratifiers, little or no waste is exported to non-A7 countries.

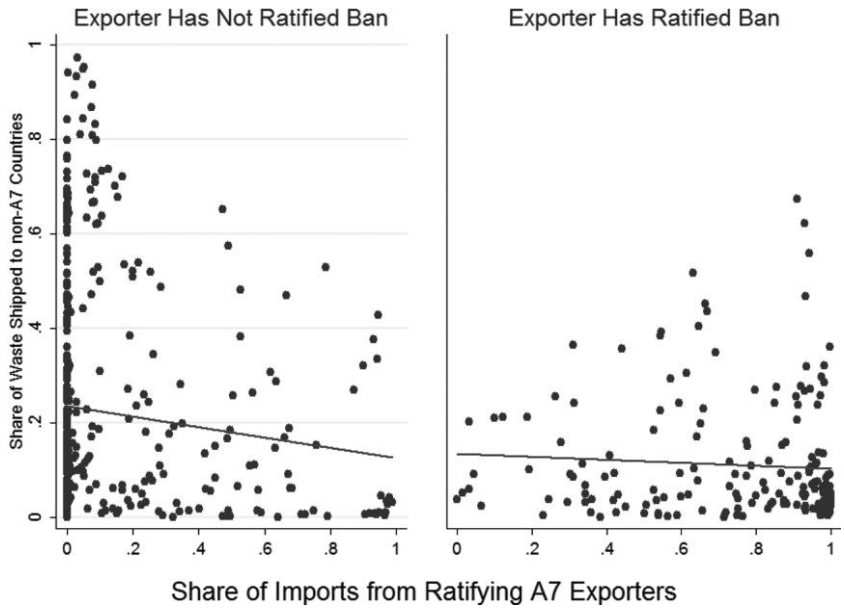

Figure 8. Rerouted waste to non-A7 countries via Ban nonratifiers. A color version of this figure is available online.

In sum, the evidence based on patterns of imports by Ban members, and their exports to non-A7 countries, suggests that there has been no significant circumvention of the Ban by nonratifiers re-exporting waste to non-A7 countries. The treaty's apparent lack of effect is not the result of countries circumventing the treaty's intent by transshipping waste; it is the result of the treaty having had little effect on A7 exporters.

5. CONCLUSIONS AND IMPLICATIONS

The theoretical and empirical economics literature to date is almost entirely skeptical about the efficacy of the IEAs that have proliferated worldwide over the past 30 years. Our results do not controvert that skepticism: IEAs appear to do little more than ratify what countries would have done absent the agreements. Before embarking on this study, we believed that empirical drawbacks in the existing evidence offered hope that IEAs might be effective. Data on international environmental problems are scarce for countries that do not participate in treaties, making before-and-after comparisons difficult, and existing work has a difficult time ascertaining what countries that ratify IEAs would have done absent the agreements. We address those problems by examining the Basel Convention using Comtrade data on international waste trade as a close approximation of the types of hazardous waste governed by Basel, and comparing waste exports before and after each country ratifies the Ban,

holding constant existing trends and country characteristics with country-year and country-pair fixed effects. But despite the empirical advantages of our approach, we find almost no evidence to contradict that conventional skepticism. The Basel Convention and Ban seem to have had no effect on the growth of international hazardous waste and almost no effect on shipments from developed to developing countries.

What can be done? To strengthen the efficacy of IEAs, some have proposed linking them to international trade. For example, the climate change bill that passed the US House of Representatives in 2009 would have imposed a border tax on imports to the United States from countries deemed insufficiently aggressive in abating their own greenhouse gas emissions. The border tax would both induce other countries to participate in international climate agreements and protect US industries from imports made less expensive by nonparticipation. Some economic theory has demonstrated that threats of trade sanctions, like the border tax, can ameliorate free-rider problems and persuade countries to participate meaningfully in IEAs. In practice, however, relatively few IEAs have been linked to trade sanctions, and that theory has not been tested empirically.

Might our results have broader implications for other international problems? For the sake of the global climate, we hope not. Global environmental issues such as climate change pose starkly different problems than hazardous waste trade. Climate change involves a global pollutant emitted at the location where goods are produced, whereas hazardous wastes are local pollutants that can be separated from the point of consumption or production and shipped globally. That difference means that the world's hazardous waste problems are potentially solvable without international agreements, while the same is not true for climate change or other transboundary global pollutants. If all countries had efficient local environmental and waste disposal regulations, there would be no need for treaties like the Basel Convention and Ban. International waste trade would be efficient like trade in any other good or service. But transboundary pollution such as greenhouse gas emissions imposes a global externality, and so local regulations are insufficient and governments will always face incentives to free-ride on other countries' abatement efforts. In that respect, the fact that voluntary IEAs appear ineffective is disheartening and suggests that alternative policy mechanisms and strategies that go beyond voluntary IEAs may need to be developed to solve large global problems such as climate change.

APPENDIX

Table A1. HS6 Code Classifications and Waste Commodity Descriptions

HS6 Code	Commodity Description	HS6 Code	Commodity Description
230800	Vegetable materials/waste/residues/by-products, whether or not in pellets	520210	Cotton yarn waste (including thread waste)
262011	Ash or residues containing hard zinc spelter	700100	Glass cullet, waste or scrap, glass in the mass
262019	Ash and residues, containing zinc other than hard zinc spelter	711210	Waste or scrap containing gold as sole precious metal
262020	Ash or residues containing mainly lead	711220	Waste/scrap containing platinum as sole precious metal
262030	Ash or residues containing mainly copper	711290	Waste/scrap, precious metals except pure gold/platinum
262040	Ash or residues containing mainly aluminium	720410	Waste and scrap of cast iron
262050	Ash or residues containing mainly vanadium	720421	Waste or scrap, of stainless steel
262100	Slag and ash nes, including seaweed ash (kelp)	720429	Waste and scrap of alloy steel other than stainless steel
262110	Ash and residues from the incineration of municipal waste	720430	Waste or scrap, of tinned iron or steel
262190	Slag and ash, other than from the incineration of municipal waste	720441	Waste from the mechanical working of iron or steel nes
382510	Municipal waste	720449	Ferrous waste or scrap, nes
382520	Sewage sludge	740400	Copper/copper alloy waste or scrap
382530	Clinical waste	750300	Nickel waste or scrap
382541	Halogenated waste organic solvents	760200	Aluminium waste and scrap
382549	Waste organic solvents other than halogenated waste organic solvents	780200	Lead waste and scrap
382550	Wastes of metal pickling liquors, hydraulic fluids, brake fluids and antifreeze fluids	790200	Zinc waste and scrap
382561	Wastes from chemical/allied industries, mainly containing organic constituents, nes	800200	Tin waste and scrap
382569	Wastes from chemical/allied industries, nes	810197	Tungsten (wolfram) waste and scrap

Table A1 (*Continued*)

HS6 Code	Commodity Description	HS6 Code	Commodity Description
382590	Residual products of the chemical/allied industries, nes	810297	Molybdenum waste and scrap
391510	Polyethylene waste or scrap	810330	Tantalum waste and scrap
391520	Polystyrene waste or scrap	810420	Magnesium waste and scrap
391530	Polyvinyl chloride waste or scrap	810530	Cobalt waste and scrap
391590	Plastics waste or scrap nes	810730	Cadmium waste and scrap
400400	Rubber waste, parings, and scrap (except hard rubber)	810830	Titanium waste and scrap
440130	Sawdust, wood waste, or scrap	810930	Zirconium waste and scrap
470620	Pulps of fibers derived from recovered (waste and scrap) paper/paperboard	811020	Antimony waste and scrap
470710	Waste or scrap of unbleached kraft or paperboard	811213	Beryllium waste and scrap
470720	Waste, scrap of paper, board of bleached chemical pulp	811222	Chromium waste and scrap
470730	Waste or scrap of paper or board of mechanical pulp	811252	Thallium waste and scrap
470790	Waste, scrap of paper, board, nes (including unsorted)	854810	Waste and scrap of primary cells, primary batteries and electric accumulators

Note.—nes = not elsewhere specified.

Table A2. Concordances between HS6 Codes and Basel Annex VIII Codes for Waste with a High Probability of Being Hazardous

HS6 Code	Commodity Description	Basel Code	HS6 Code	Commodity Description	Basel Code
262011	Ash or residues containing hard zinc spelter	A1070, A1080	382550	Wastes of metal pickling liquors, hydraulic fluids, brake fluids, and antifreeze fluids	A1060
262019	Ash or residues, containing zinc other than hard zinc spelter	A1070, A1080	382561	Wastes from chemical/allied industries, mainly containing organic constituents, nes	A3130, A3140
262030	Ash or residues containing mainly copper	A1090	382569	Wastes from chemical/allied industries, nes	A4140, A4150
262020	Ash or residues containing mainly lead	A1080	382590	Residual products of the chemical/allied industries, nes	A4140, A4150
262110	Ash and residues from the incineration of municipal waste	Y47*	810730	Cadmium waste and scrap	A1010
382510	Municipal waste	Y46*	811020	Antimony waste and scrap	A1010
382520	Sewage sludge	Y3, Y23, Y41†	811213	Beryllium waste and scrap	A1010
382530	Clinical waste	A4020	780200	Lead waste and scrap	A1010
382541	Halogenated waste organic solvents	A3150	811252	Thallium waste and scrap	A1010
382549	Waste organic solvents other than halogenated waste organic solvents	A3130, A3140	854810	Waste and scrap of primary cells, primary batteries, and electric accumulators	A1160, A1170, A1180

Note.—nes = not elsewhere specified.

* Municipal waste and its residues from incineration are not listed specifically in Annex VIII of the Basel Convention. However, Annex II of the Convention does list Basel Codes Y46 and Y47 as household waste and its incineration as requiring special consideration as hazardous waste.

† Sewage sludge is also not listed specifically in Annex VIII of the Basel Convention. However, Annex I of the Convention does list categories of hazardous waste streams to be controlled that include waste from pharmaceuticals (Y3), zinc waste (Y23), and halogenated organic solvents (Y41), among many others that have been demonstrated (Stokstad 2009) to be present in biosolids from sewage sludge.

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