The Economics of the International Trade of Waste

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Abstract

International trade in hazardous and nonhazardous waste and scrap products has been growing at an exceptional rate the past two decades. This review presents current data on the magnitude and trends regarding this growth and discusses the recent literature as it pertains to the economic incentives and drivers of international waste trade. Differences in environmental policy, taxes, disposal fees, and transport costs are important determinants across countries. However, the illegal nature of many types of hazardous waste also means that organized crime may play a role in some countries. Gaps in our understanding regarding microeconomic incentives as they relate to upstream and downstream recyclers and to the social welfare implications for wages, environmental quality, and human health are also discussed.

1. INTRODUCTION

Adult male African elephants are the largest land animals on earth, weighing up to 7 tons and measuring 7.5 meters in length. If that fact seems a little obscure for an article on the economics of international waste trade, let me hit you with another bit of trivia. In the 5-year period from 2008 to 2012, the world traded across international borders more than 1 billion tons of waste and scrap products destined for recovery or disposal, which is equivalent in weight to 145 million African elephants. Having difficulty imagining 145 million elephants? Imagine elephants head to tail encircling the earth. . .27 times! Increasing populations and expanded demands for standards of living have led to rising production and consumption globally. The associated waste streams and resource needs of this growth have combined with expanding internationalization of markets to make trade in waste and scrap products a massive global enterprise. These trade flows present a number of interesting questions for environmental quality, environmental policy, economic growth, and the effectiveness of international environmental agreements (IEAs). Despite these large and growing trade flows, the economics literature on international waste trade has been fairly sparse. This review examines some of the current data on international waste trade flows in the context of the theoretical and empirical work on the subject. In this way, the review highlights many of the economic determinants of international trade in waste and scrap products and points to several areas in which the literature remains deficient in explaining waste trade and its effects on societies.

Accurate accounts of hazardous and nonhazardous wastes that are traded globally across international borders can be difficult to achieve. Differences in national accounting standards, environmental regulations and reporting, hazardous classifications and definitions, and adherence to different IEAs among the countries of the world can make exact measurement of data on waste trade flows a challenge. When you add the fact that trade in hazardous waste is often an illegal, yet profitable, enterprise, the possibility of corruption and evasion makes data measurement more complicated. Several datasets are collected and employed to measure transboundary flows of waste and scrap. Among them are the European Pollutant Release and Transfer Register (E-PRTR) (**http://prtr.ec.europa.eu/pgAbout.aspx**), which covers pollutant and waste transfers for the 27 EU member countries; the US Environmental Protection Agency's Toxic Release Inventory (TRI) (**http://www2.epa.gov/toxics-release-inventory-tri-program**), which covers waste transfers of specific pollutants across states and to international destinations; and data on international hazardous waste shipments that are self-reported to the Basel Convention Secretariat (**http://www.basel.int/Countries/NationalReporting/NationalReportingArchives/tabid/2315/Default.aspx**) for countries that are members of the convention. However, few of these datasets give a comprehensive view of waste trade among all countries. To get a sense of the aggregate amount of waste and scrap products traded internationally, data on the total tonnage for a set of 62 six-digit Harmonized System (HS6) codes from the UN Comtrade database were collected for this review. The 62 categories[1] cover everything from clinical and municipal waste to sawdust and ferrous metal scrap. These categories are not inclusive of all waste traded but provide a useful barometer of trade in hazardous and nonhazardous waste and scrap that may be intended for recycling, reuse, and disposal in foreign locations.

Figure 1 makes quite apparent that the global market for trade of waste and scrap experienced a dramatic rate of growth between 1992 and 2012—from 45.6 million tons in 1992 to a peak of

[1]These 62 categories are the same categories used in Kellenberg (2012) and Kellenberg & Levinson (2014) for measuring the physical volume of international waste trade flows across all countries. For the interested reader, descriptions of each category can be found in these publications.

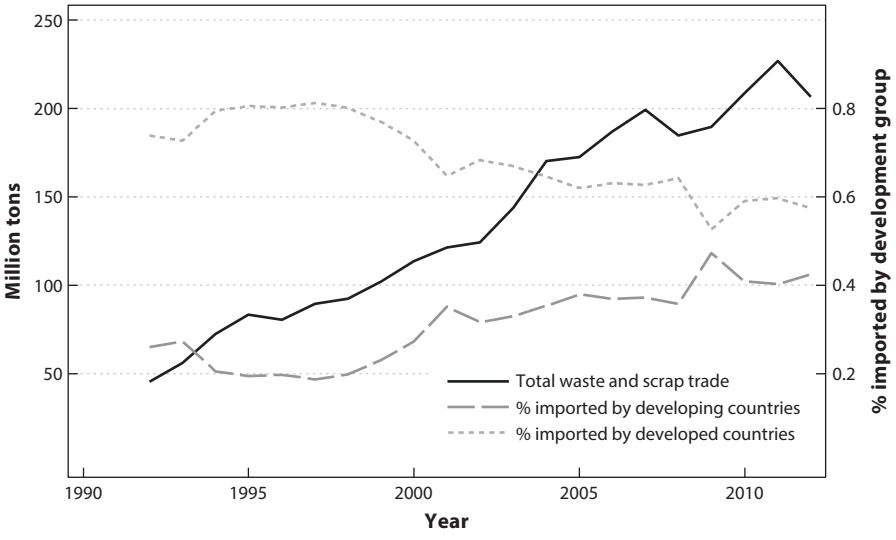

Figure 1

Annual tons of global waste and scrap traded internationally (1992–2012).

222.6 million tons in 2011, a more-than-500% increase in just two decades. What is more striking is the composition of where those waste and scrap products were shipped. The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal defines developed countries as all Organization for Economic Cooperation and Development (OECD) and EU countries.[2] Developing countries are defined as all other countries not in the OECD or EU. On the basis of this categorization, the percentage of total waste imports by development category is also graphed in **Figure 1**. During the early and mid-1990s, when the volumes of international waste trade were still relatively small, a large proportion of the world's waste was imported by developed countries, with developing countries accounting for only 18.7% of the world's waste and scrap imports in 1997. However, beginning in 1998 that trend changed. The proportion of the world's waste and scrap being exported to developing countries began to increase substantially, growing to more than 40% by 2009. **Figure 1** paints a stark picture of the phenomenon of international waste trade over the past two decades, with two notable and prominent characteristics on display: (*a*) World trade in waste and scrap has been growing at exceptional rates, and (*b*) the proportion of this growing waste and scrap trade that is landing in the developing countries has been greatly expanding.

2. DETERMINANTS OF INTERNATIONAL WASTE TRADE

One of the primary aims of this review is to look at some of the important country-level characteristics that are correlated with these patterns of international waste trade and to explore several empirical and theoretical papers that have sought to explain these phenomena. To facilitate the discussion, it is helpful to take a look at the international waste trade data in the context of several

[2]What we describe as developed countries in this paper are those listed in Annex VII of the Basel Convention. All non–Annex VII countries are described as developing.

socioeconomic variables that have been discussed in the literature. To do so, we examine several survey questions on country socioeconomic characteristics from the Global Competitiveness Report (GCR), along with shares of waste trade flows and country income levels.[3] The GCR has been produced annually since the late 1990s and surveys a cross section of executives from a wide variety of industries on a range of characteristics related to doing business in a country. The data and variables produced in the GCR reports have been employed in a substantial trade and foreign direct investment literature for cross-country analyses (see Carr et al. 2001, Kellenberg 2012, and Yeaple 2003 for examples). **Table 1** describes nine of those survey questions that are germane to a discussion of influences on international waste trade. The first five questions provide a measure of the relative strength of environmental regulations (air pollution regulations, water pollution regulations, toxic waste disposal regulations, chemical waste regulations, and consistency of regulation enforcement) across countries. Kellenberg (2012) uses the aggregate of these five environmental variable scores to form an environmental regulation index in each country; larger values imply that a country has more stringent overall environmental regulations. The other socioeconomic variables relate to the degree of organized crime in a country, the nature of competitive advantage, the breadth of a country's companies in the value chain of production, and a country's sophistication in production processes.

Table 2 reports the average scores for each of the survey measures as well as the share of world income, share of world waste exports, share of world waste imports, and GDP per capita for developed and developing countries. The first three rows of the table highlight an important distinction between developed and developing nations with respect to their relative income levels and waste trade. Developed countries produce three-quarters of the world's income, as measured by GDP, and nearly 84% of the world waste exports. By contrast, developing countries have a world waste export share of 16.2%, which is lower than their world income share of 24.2%. This statistic, in and of itself, is not that surprising. Countries with greater ability to produce and consume will also have a greater potential supply of waste and scrap available to export. Indeed, Higashida & Managi (2014) find positive and significant impacts of GDP on bilateral trading pairs for waste and scrap of plastics, copper, and steel. More telling are the shares of world waste imports. Although developed countries import a greater quantity of waste in an absolute sense, their share of world waste imports is far lower than their share of world waste exports. In stark contrast, developing countries have a waste trade import share that is nearly two and a half times greater than their export share. The developing countries of the world import a disproportionately large volume of the world's waste and scrap when viewed in proportion to their income.

What are some factors that explain patterns of international waste trade? Three important determinants that have been found in the literature relate to differences in income, differences in environmental regulations, and the presence of organized crime in a country. Indeed, **Table 2** shows that developed and developing countries have substantial differences in their relative levels of per capita income as well as substantial differences in their indexes of environmental regulation stringency. With regard to the survey question in **Table 1**, the score for organized crime in **Table 2** is based on the absence of organized crime in a country. Thus, the higher score of 5.69 for developed countries indicates that organized crime in these countries imposes less significant costs on businesses than in developing countries, which have a lower score of 4.96 (see **Table 2**). In the next two subsections (Sections 2.1 and 2.2), the significance of income, environmental regulations, and organized crime is discussed in the context of the literature on waste and scrap trade. The last three factors in **Table 2** are returned to below in Section 3, when we look at topics that have not been well

[3]Annual GCR reports and data can be obtained at **http://www.weforum.org/issues/global-competitiveness**.

Table 1 Global Competitiveness Report survey questions (see Kellenberg 2012)

Variable	Survey question
Five survey questions that compose the Environmental Regulation Index	
Air pollution regulations	The air pollution regulations in your country are: (1 = lax when compared with those of most other countries, 7 = among the world's most stringent)
Water pollution regulations	The water pollution regulations in your country are: (1 = lax when compared with those of most other countries, 7 = among the world's most stringent)
Toxic waste disposal regulations	The toxic waste disposal regulations in your country are: (1 = lax when compared with those of most other countries, 7 = among the world's most stringent)
Chemical waste regulations	The regulations concerning chemicals used in manufacturing in your country are: (1 = lax when compared with those of most other countries, 7 = among the world's most stringent)
Consistency of regulation enforcement	Environmental regulation in your country is: (1 = not enforced or enforced erratically, 7 = enforced consistently and fairly)
Other survey questions	
Organized crime	Organized crime (e.g., mafia-oriented racketeering, extortion) in your country (1 = imposes significant costs on businesses, 7 = does not impose significant costs on businesses)
Nature of competitive advantage	What is the competitive advantage of your country's companies in international markets based upon? (1 = low-cost labor or natural resources, 7 = unique products and processes)
Value chain breadth	In your country, do companies have a narrow or broad presence in the value chain? [1 = narrow, primarily involved in individual steps of the value chain (e.g., resource extraction or production); 7 = broad, present across the entire value chain (e.g., including production and marketing, distribution, design, etc.)]
Production process sophistication	In your country, how sophisticated are production processes? (1 = not at all—labor intensive or old technology; 7 = highly technological and knowledge intensive)

researched in the context of international waste and scrap trade markets and that constitute potentially important avenues for future research.

2.1. Income, Environmental Regulations, and Transport Costs

One of the first empirical papers to estimate the effects of a variety of economic factors on international trade in hazardous waste is Baggs (2009). Baggs models the hazardous waste industry as a monopolistically competitive market in which each type of hazardous waste is a differentiated product variety. This specification is based on the more general trade theory developed by Helpman et al. (2008) and is useful, as it plausibly characterizes a differentiated goods waste market (lead waste is a different product than chemical waste or clinical waste), explicitly accounts for countries that do not trade with one another, and reduces to an empirically tractable gravity model of bilateral trade that can be easily estimated. To estimate the model, Baggs uses self-reported hazardous waste trade data reported under the auspices of the Basel Convention by member countries. The Basel Convention is an IEA that was first signed in 1989 by a group of

Table 2 Income shares, waste trade shares, and socioeconomic differences by development group

	Developed countries	Developing countries
Share of world income	75.8%	24.2%
Share of world waste exports	83.8%	16.2%
Share of world waste imports	58.6%	41.4%
GDP per capita	$38,578	$8,848
Environmental Regulation Index[a]	27.7	16.8
Organized crime	5.69	4.96
Nature of competitive advantage	5.05	3.56
Value chain breadth	4.99	3.85
Production process sophistication	5.30	3.83

Data are averaged across country groups for the years 2008–2012. Data on waste imports and exports are from the UN Comtrade database, and data for all other variables are from the World Competitiveness Reports.
[a]The Environmental Regulation Index is the sum of the five environmental survey questions in **Table 1** from Kellenberg (2012); data are from the 2004–2005 World Competitiveness Report.

34 countries. Over time, the number of signatories has grown to more than 170 nations, with nearly all of them going on to either ratify the convention or join by accession.[4] Among the primary measures that the Basel Convention stipulates for its members is that they (*a*) minimize the generation of hazardous and other wastes; (*b*) ensure adequate and environmentally sound disposal facilities; (*c*) minimize the transboundary movement of hazardous and other wastes to protect human and environmental health; (*d*) prohibit the export of hazardous wastes to countries that have legislated a ban on hazardous waste imports, particularly for developing countries; and (*e*) require that exporting countries notify importing countries of any transboundary shipments of hazardous and other wastes and that the importing country accept the shipment.

In addition, member countries are required to self-report data on their shipments of hazardous waste to the Basel Convention Secretariat each year. Baggs (2009) uses this self-reported bilateral trade data from member countries for the years 1994–1997 to estimate the gravity model of trade. In particular, the study explores the role that differences in the size of the economy (measured by GDP), capital/labor ratios, and GDP per capita across countries play in determining bilateral trade in hazardous waste. Not surprisingly, countries with larger economies trade more hazardous waste than do smaller economies. For exporters, the intuition is that larger economies generate more hazardous waste as a by-product of greater production and consumption and therefore have a greater potential supply of hazardous waste products to be exported. For importers, there are two possible explanations. First, larger economies that generate large volumes of waste may also have more developed disposal capacity. To the extent that there are economies of scale in hazardous waste disposal, this possibility may imply a comparative advantage for larger economies in this type of activity. The second possibility is that larger economies have more advanced recycling programs or technologies. This consideration is important, as not all hazardous waste is destined

[4]As of this writing, the United States and Haiti are the only two countries to have signed, but never ratified or acceded to, the Basel Convention and are therefore not members of the Convention (**http://www.ban.org/country-status/country-status-chart/**).

for disposal, and hazardous waste may be usefully recycled into future products. Lead waste, for example, is considered hazardous under the auspices of the Basel Convention, yet lead is a highly recyclable waste product. Thus, larger economies may have greater demand for these recyclable wastes to be reused as inputs in future production.

Capital/labor ratios, which may reflect the technological capabilities of the recycling sectors across countries, are hypothesized to lead to greater imports for countries with more capital per worker. The study of Baggs (2009) finds a positive and significant impact of higher capital/labor ratios on a country's imports of hazardous waste. Given that many developing countries tend to be smaller economies with relatively low capital/labor ratios, these two findings alone would argue against the case that developing countries are pollution havens for developed country hazardous waste. However, Baggs finds that GDP per capita has a negative and significant impact on imports of hazardous waste. An important question for the waste haven effect is whether differences in environmental regulation across countries are a source of comparative advantage for poorly regulated locations. The idea is that, all else equal, waste will flow to countries with the lowest levels of environmental regulation and stringency. Although the study does not have a direct measure of environmental regulation or stringency, GDP per capita has often been used in the literature as a proxy for the strength of environmental policy.[5] The assumption is that, because environmental quality is a normal good, as countries become wealthier, citizens demand higher environmental quality through more stringent environmental regulation. On this point, Baggs finds evidence of a waste haven–type effect, as GDP per capita is negative and statistically significant. All else equal, the higher a country's income and, thus, the presumed level of environmental regulation, the less hazardous waste a country will import. One potential difficulty is that GDP per capita may be picking up wage effects and may not be a pure environmental policy effect. Given that many forms of recycling can be labor intensive, the negative coefficient on GDP per capita may be picking up these differences in wage costs.

Kellenberg (2012) directly tests the waste haven effect by using a more comprehensive dataset of potential waste shipments and an explicit measure of the differences in stringency of environmental regulation between bilateral country pairs. In contrast to using the self-reported hazardous waste trade data for Basel Convention members, which exclude waste exports from some of the world's largest exporters of waste (including the United States), the study uses data from the UN Comtrade database for 62 categories of waste and scrap from the HS6. One of the primary advantages of this dataset is that it provides waste trade data in a large variety of waste categories for both Basel Convention members and nonmembers. A second advancement of the paper is that it uses survey data on environmental regulation stringency from the GCR, shown in **Table 1**, to develop a bilateral-specific measure of the difference in environmental stringency between country pairs. This measure has two primary advantages for isolating and estimating a waste haven effect. First, it allows for a direct estimate of the effect of environmental regulation stringency that is independent of differences in GDP per capita and capital/labor ratios (which are also estimated) and that may be correlated with underlying technological or productivity differences in capital or labor recycling sectors. Second, the environmental policy measure is defined as a gradient for each bilateral pair observation, which means that unobserved multilateral resistance terms that are shown by Anderson & van Wincoop (2003) to be an important source of bias in bilateral gravity models can be controlled for with importer and exporter fixed effects.

The results of Kellenberg (2012) show that differences in environmental regulation across countries have a significant and robust impact on bilateral waste trade flows. All else equal, an

[5]See Antweiler et al. (2001), Cole (2004), and Kellenberg (2008) for examples.

importer whose environmental regulation stringency index falls by 10% vis à vis that of its trading partner can expect a 3.2% increase in waste imports from that bilateral partner. Given that the average developing country has an environmental stringency index that is 39% lower than that of the average developed country, differences in environmental regulation stringency should play a substantial role in explaining the waste haven effect.

Income and environmental regulations are not the only factors that can explain transboundary movements of waste and scrap. Mazzanti & Zoboli (2013) review a number of potential impacts and drivers. One important factor explored is the relationship among the distances between countries and differences in gate fees for waste disposal. Specifically, the hypothesis is that if the foreign gate fee of disposal, plus the transport costs to a foreign location, is less than the domestic gate fee plus the cost of transport to a domestic disposal location, then firms will choose to export to the foreign location. Gate fees for disposal are important, but transport costs can be equally or even more important. Waste products are often high-volume or high-weight goods that are expensive to transport. Given that waste and scrap products typically have zero or low values, even small changes in transport costs can make shipping prohibitive. For example, a waste exporter in Seattle may find that paying a higher disposal fee in Vancouver, British Columbia, is cheaper than shipping the waste domestically to a disposal facility in northern California that may have a lower disposal fee but that is further away. Indeed, in most gravity models of international waste trade, in which distance is a proxy for transportation costs, the coefficients on the effect of distance are significantly larger than for similar gravity specifications for trade in general. This discussion highlights the importance and sensitivity of even small marginal changes in distance for the decision to ship low-value, high-weight goods such as waste and scrap.

The composition and imbalances in trade can also change the dynamics of international shipping and create asymmetric transport costs between countries. Kellenberg (2010) develops a two-country North/South model of trade and demonstrates how shipping market characteristics, the physical characteristics of final goods, and trade deficits can contribute to asymmetric transport costs between countries. When these conditions lead to low transport costs from North to South, waste haven–type effects can occur. The departure from previous literature on international transport costs is that transport is not simply assumed to be a constant function of distance. Rather, the shipping industry is modeled as an imperfectly competitive industry with a fixed number of firms and ship capacity constraints. Firms in the North and South are assumed to specialize in two different kinds of final consumption goods, and waste is a by-product of consumption. Firms in the North specialize in and export goods with high value but take up a low volume of capacity in transport. Examples might be semiconductors, software, surgical equipment, entertainment goods, and pharmaceuticals. South firms specialize in goods with lower ratios of value to physical volume. Goods such as appliances, toys, televisions, and furniture are a few examples. Thus, for a given value of trade, the goods being shipped from South to North take up more space on a ship in transport. If the North and South have balanced trade in the value of their goods, exports going from North to South take up a smaller capacity of ship space than does the same value of goods being exported from South to North. With fixed shipping capacity along the routes, this scenario implies that the demand for shipping capacity is lower for the North-to-South route. As a result, the endogenous shipping price will be lower along that route than along the South-to-North route.

The waste haven effect is driven by the combined disposal and transport costs in the two countries. The South is assumed to have a lower disposal rate than does the North. However, North waste disposers may not be able to take advantage of the lower disposal rate due to prohibitively high transport costs along the North-to-South route. Conversely, if the rate from North to South falls low enough, this decrease can facilitate a waste haven effect by inducing waste

traders in the North to ship their waste to the South, where disposal fees are less expensive. What characteristics decrease shipping costs along the North-to-South route and can contribute to a waste haven effect? First, the greater the difference in the physical volume of consumption goods traded between the North and South, the lower the North-to-South rate will be relative to the South-to-North route. Second, trade deficits, whereby the North is importing more from the South than the South is from the North, lead to lower rates on the North-to-South route and an increased opportunity for North waste traders to ship waste to the South. Third, increases in the number of shipping firms on the route, in the capacity of cargo ships, and in the efficiency of transport (such as fuel efficiency), which lower marginal costs, will decrease the North-to-South rate and make it more advantageous for the North to ship waste to the South. Although the paper offers many testable predictions, the empirical validity of the theory remains untested and is an important area of research for understanding the microeconomic links between shipping dynamics and the transport/disposal cost trade-off of waste industries.

2.2. Organized Crime and Waste Trade

Disparities in regulations, taxes, and disposal costs across countries create substantial opportunities for financial gain by arbitraging cost differences through illicit trafficking of waste. Indeed, several authors detail the role that corrupt politicians and organized crime play in a variety of circumstances related to waste trade and management in different countries.[6] One might expect that organized crime and illegal waste transfers would be detrimental to society, particularly if there are unaccounted-for environmental or health externalities associated with illicit dumping or trading of waste. In many circumstances, this assumption is likely to be correct. However, D'Amato & Zoli (2012) develop a simple model of illegal disposal and enforcement in the presence of a criminal organization and find that under certain situations, mafia presence can actually increase economic activity and improve social welfare, even after accounting for the externalities of illegal disposal. The paper suggests an interesting thought experiment related to the realities that certain governments may face in a second-best policy world. Although perfect enforcement and an optimal Pigouvian tax on waste disposal would provide a first-best policy response, this approach may not always be possible. In such instances, indirect enforcement through extortion by the mafia could, in theory, improve social welfare relative to the status quo when the first-best policies are either not chosen or not feasible.

The social welfare gains in the presence of organized crime in waste trade are certainly open to debate, and the specific instances, if any, when they are socially beneficial are likely just that—specific instances. However, the more general question of whether organized crime plays a substantial role in waste trade beyond specific case studies is also still open in the literature. To our knowledge, no papers examine the role of organized crime in international waste trade in a cross-country framework that could speak more generally to the impacts of organized crime on waste trade flows among countries. Certainly, price differentials in reclaimed materials and disposal costs across countries and the illegal nature of many types of hazardous waste trade make this industry rife for exploitation by corrupt officials and organized crime. Although the literature has not established a strong general link between organized crime and waste trade, Kellenberg (2013) does provide evidence for two particularly toxic categories of waste. In a panel dataset of US bilateral exports of spent lead acid batteries and lead waste, a greater degree of organized crime in the importing country is found to be a statistically significant factor in attracting these waste

[6]See, for example, Clapp (1997), Massari & Monzini (2004), D'Alisa et al. (2010), and Liddick (2010).

categories. Whether this finding holds more generally for a greater number of countries and waste categories should be more carefully explored in future work. The correlation between organized crime and low environmental regulations in many developing countries implies that controlling hazardous international waste flows may require simultaneously addressing both environmental stringency and illicit activity by organized crime to be effective.

2.3. Economic Policies, the Basel Convention, and Waste Trade

In this section, we explore some of the theory and empirics related to particular economic policies, such as trade restrictions, taxes, and IEAs, that address international waste trade issues. One of the seminal theory papers to examine the issue of international trade in waste products is that of Copeland (1991), who explores, front and center, the question of whether trade restrictions should be employed to correct for externalities associated with the transboundary disposal of waste products. The analysis is based on a straightforward small open economy (SOE) trade model with two primary factors, land and labor, that are supplied inelastically for two production activities: a final consumption good and waste disposal services. Waste is assumed to be a by-product of producing the consumption good, and so disposal services must be paid for by final goods production firms. Also assumed is that waste disposal generates externalities. The greater the quantity of waste disposed in one location, the greater are the expected externalities to those living in or near that location. Because these externalities would create a market failure for waste disposal services, a government sector that regulates waste disposal services is modeled. Consumers get utility from the consumption good and disutility from any externalities domestically associated with waste disposal. Profit maximization by the final consumption and waste disposal sectors, combined with utility maximization by a representative agent and full employment conditions for labor and land, yields equilibrium quantities of waste produced by the consumption goods industry as well as the equilibrium quantity of net waste imported. Whether the SOE is a net importer or exporter of waste depends on relative factor intensities with the rest of the world (ROW). For concreteness, it is assumed that the SOE is land abundant and is therefore a net importer of waste from the ROW.

In the absence of government intervention, a free market yields too many domestic and foreign imports of waste, as the domestic price of waste disposal does not account for the externalities associated with disposal. The first-best policy in this case is a tax on waste disposal services that is equal to the marginal damage incurred by consumers. In a perfect world, this solution is optimal. However, Copeland (1991) asks a more pressing and realistic question. If an optimal tax is not feasible, possibly due to political or institutional constraints, might restrictions on imports of waste provide a form of second-best policy to reduce external costs on consumers? The paper considers an import tax on waste, which can also be thought of as an export tax on waste disposal services, in conjunction with a domestic production tax on waste generation. If the domestic production tax is chosen optimally, the optimal import tax is zero. However, if the country faces constraints in administering the optimal production tax, the import tax can be used as a second-best policy instrument to reduce imported waste. Reduced imported waste decreases the probability of negative externalities domestically associated with waste disposal and may increase welfare overall. One undesirable secondary effect, however, is that the import tax lowers the domestic price of disposal services and increases the waste intensity of domestic consumption sector firms. These two effects go in opposite directions, and thus changes in social welfare depend on the net impacts of the price change for waste disposal and subsequent induced factor price changes. As is true in most analyses of second-best policies, the welfare impacts are not definitive.

The Copeland (1991) model is then extended to allow for the possibility of illegal disposal in the domestic sector. Consumption sector firms may pay the domestic tax and cost of disposal, or they may attempt to dispose of their wastes covertly. The unit cost of illegal disposal is lower than the cost of legal disposal, but firms must pay a fine if caught disposing of their waste illegally. Illegal disposal, although less expensive for firms, imposes a much higher social cost due to the negative externalities associated with illegal dumping. Firms maximize profits by choosing an optimal mix of legal and illegal disposal conditional on unit costs, fines, and the probability of illegal disposal detection. Copeland finds that, in the presence of illegal disposal, the first-best policy option of setting an optimal disposal tax may decrease welfare, as increasing the disposal tax will induce firms to dispose of more of their waste illegally. In this setting, the use of a tariff on waste imports may provide a second-best solution that is welfare improving. The intuition is that the tariff reduces the amount of waste in the domestic economy but also reduces the fraction of waste that is disposed of illegally. This last effect occurs because, with a fixed fine rate, the import tariff on waste reduces the domestic price of waste disposal and decreases the return to illegal disposal relative to legal disposal. The end result is that, for a SOE with perfectly competitive markets in waste disposal sectors, the first-best policy is always to set the disposal rate equal to the social marginal cost of the externality. However, if a government faces political or institutional constraints that prevent the first-best disposal tax or the government is faced with the possibility of illegal disposal, then an import tariff on waste can provide a potentially welfare-improving second-best policy option. In other words, small developing countries that face illegal disposal or that do not have the institutional or political capacity to enforce domestic regulations may be able to improve welfare by imposing restrictions on imports of waste.

In a developed country context, Levinson (1999a) considers the inefficiencies of waste disposal taxes in an interjurisdictional model. The basic model considers a multijurisdiction world where each jurisdiction has a fixed level of industrial activity, firms produce composite consumption goods, and hazardous waste is a by-product of production. Citizens in each jurisdiction receive utility from the consumption of the composite good and disutility from a public bad associated with the disposal of hazardous waste. Hazardous waste in each jurisdiction is delineated into two components: waste disposed of domestically in the local jurisdiction and waste that is exported and disposed of out of jurisdiction. The public bad in each jurisdiction is simply the waste produced and disposed of domestically plus any waste that is imported from other jurisdictions. Each jurisdiction takes other jurisdictions' tax rates as exogenous and imposes two tax rates, one on domestic disposal of hazardous waste by domestic firms and another on imported waste from foreign firms. Firms in each jurisdiction face constant, but heterogeneous, jurisdictional marginal costs of disposal and transport costs in addition to the jurisdiction-specific taxes. Firms maximize profits by disposing of hazardous waste in the least-cost location, and governments in each jurisdiction set the tax rates to maximize constituents' utility. Because each jurisdiction can export some of the incidence of a disposal tax to residents of other jurisdictions, the foreign disposal tax will be higher than the domestic disposal tax, which is set equal to the social marginal cost of waste disposal. If jurisdictions export a fraction, rather than all or none, of their waste, then the domestic disposal tax may be lower than the social marginal cost of disposal. In this setting, both the domestic and foreign disposal taxes will be inefficient from a social perspective, with the degree of inefficiency being a function of the foreign and domestic elasticities with respect to the tax rates. The greater the tax elasticities, the greater is the potential degree of inefficiency.

To obtain estimates of these different tax elasticities, Levinson (1999a) uses TRI data from the US Environmental Protection Agency, combined with data on variable disposal tax rates across US states, for the years 1989–1996. After controlling for endogeneity and censoring issues, he estimates the elasticity of waste disposal with respect to waste taxes to be between 0.09 and 0.13.

This range represents a nonnegligible impact of taxation on intrajurisdictional movements of hazardous waste and highlights the importance of even small differences in tax rates to determine the location of waste disposal. In a related paper, Levinson (1999b) estimates a similar model on the effects of differences in hazardous waste taxes across US states by using TRI data as well as data collected by states under the 1984 amendments to the Resource Conservation and Recovery Act (RCRA), with analogous findings.

Waste taxes are also correlated with waste flows in the European Union. Fikru (2012) explores firm-level exports of hazardous waste from EU industrial facilities by using the E-PRTR dataset and finds several correlations between measures of regulatory stringency, taxes, and the propensity for countries to export. The study finds that EU countries with a greater number of hazardous waste regulations and greater tax bases on hazardous waste material have higher propensities to export waste than countries with fewer regulations and tax bases. Furthermore, countries that generate a greater proportion of overall government revenues from environmental taxes have a higher propensity to export hazardous waste. Dubois (2013) also finds that in the past decade, waste shipments within the European Union that are destined for incineration and landfill have been rising dramatically and suggests that these flows may be linked to disparate incineration and landfill taxes across member countries. Although the results of these studies are correlations among environmental policy variables and export intensities, rather than causal confirmations, the story is consistent with a waste haven effect whereby waste disposers in the European Union seek lower-cost, lower-regulation locations for hazardous waste disposal.

Domestic environmental and tax policies are not the only means by which countries have attempted to control the production and transport of waste across state and international boundaries. At the international level, the Basel Convention, discussed above, has been the primary cooperative international effort to control international transport of wastes. The Ban Amendment, introduced in 1995 as part of the Basel Convention, prohibits developed countries from exporting any hazardous wastes to developing countries.[7] Despite the growing number of countries that have ratified the Basel Convention and the Ban Amendment, the convention's effectiveness in reducing international waste trade flows, particularly from developed to developing countries, has been lacking. Using a 21-year panel of bilateral waste trade flows for 117 countries, Kellenberg & Levinson (2014) find little evidence that the Basel Convention or the Ban Amendment has had a causal impact on waste trade flows. The result is consistent with that reported in much of the theoretical literature (Barrett 1994, 1997; Carraro & Siniscalco 1993): Voluntary IEAs have had little impact on environmental improvements beyond noncooperative outcomes. This result is driven largely by the fact that there is a selection problem for those countries joining the agreement. Countries that export a lot of hazardous waste are less likely to join and enforce an agreement than countries that export little hazardous waste. In the case of the Ban Amendment, many of the world's largest exporters of hazardous waste, such as the United States, Canada, and Japan, have not ratified the amendment. Thus, an agreement that is signed and ratified only by countries that have limited waste trade will have little overall impact, as those countries that are large exporters and choose not to participate will continue to export waste.

However, not all waste traded internationally is necessarily hazardous or destined for disposal. Much of the waste and scrap traded internationally is destined for recovery and reuse, and Sugeta & Shinkuma (2012) explore the incentives and environmental impacts of this type of trade. They

[7]The Ban Amendment has been signed, ratified, and implemented into domestic law by many countries but has still not officially become part of the Basel Convention over legal uncertainty regarding the number of ratifying nations needed for adoption of the amendment.

explore a two-country model in which both recycled goods and consumption goods are traded. The recyclable good is assumed to cause environmental harm, but there is a recycling sector in each country that can recover reusable material and mitigate environmental damage. The recycled materials are used as inputs to a downstream recycled consumption goods sector. Unlike the case in Copeland (1991), the waste that is not reusable by the recycling sector is prohibited from being traded and must be disposed of in the country where the recycling takes place. Although a possibly strong assumption, it allows the analysis to be focused on trade in recyclables without confounding the model with a third tradable sector (waste). Consumers maximize a quasi-linear utility function by which they get positive utility from consumption of the recycled consumption good and a numéraire consumption good but disutility from pollution caused by nonrecyclable waste. The recyclable consumption goods sector is a duopoly with one recycling sector firm in each country. Recycled consumption goods are produced with a fixed input technology using labor and virgin/recycled materials as inputs. Virgin and recycled materials are assumed to be perfect substitutes such that recycled materials will be used only when less costly than recycled materials. Each country also has a single upstream recycler that collects recyclable goods and recovers materials for use by the downstream recyclable goods firms. The two countries are assumed to have different recovery rates for recyclable materials, which generates differences in recycling rates in each country. Both upstream recyclers and downstream recycled consumption goods firms in each country are assumed to maximize profits.

The baseline for analysis considers the case in which trade in recycled materials is not permitted, but trade in downstream recycled consumption goods is. In such a situation, there is a two-stage game whereby upstream recyclers set their monopoly prices in each country and then the two downstream recycled consumption goods firms compete in a Cournot fashion. Relative to this baseline, the authors demonstrate a variety of conditions affecting the recycling sector, overall welfare, and changes in pollution associated with opening up trade in both recycled consumption goods and recyclable materials. Unfortunately, the results of the paper do not provide definitive answers to the question of whether trade in recyclable consumption goods or recycled material is good for the environment or overall welfare. Under a variety of different conditions, driven by relative differences in the efficiencies of upstream recyclers and downstream recycled goods firms, a country may be made worse or better off by relaxing trade restrictions. The take-home message is that, in the presence of imperfectly competitive markets, environmental improvements and welfare gains due to relaxing trade in recycled materials can be complicated.

3. DIRECTIONS FOR FUTURE RESEARCH ON INTERNATIONAL WASTE AND SCRAP TRADE

These complications associated with upstream waste products, downstream recyclable goods products, and the internationalization of supply chains bring us back to **Table 2**. Although the literature to this point has given us some insights into how differences in income, environmental regulations, transport costs, Basel Convention participation, and (to a lesser extent) organized crime have impacted international waste flows, there is still much to learn. The particular microeconomic connections between upstream recycling goods markets and the downstream final goods markets that use recycled products as inputs are important for understanding the nature of the demand for waste products in international markets. That is, we need to go beyond aggregate measures of demand such as GDP and income per capita to better understand the dynamics of a growing international trade in recyclable materials. Indeed, **Table 2** shows that there are substantial disparities between developed and developing countries with respect to value chain breadth. Developed countries have survey scores indicating a broader range in the value chain that

include design, production, marketing, and distribution, whereas developing countries have lower scores, indicating that they are more likely to specialize in certain components of the value chain such as production or resource extraction. Furthermore, we need a better understanding of the role that particular types of production technologies play in being able to accommodate recyclable materials in production processes relative to using virgin materials. The results in **Table 2** indicate that there is a substantial disparity in the degree of production process sophistication for developed and developing countries and that developing countries tend to derive their competitiveness in international markets more from low-cost labor and natural resources than from development of unique products and processes. To the extent that these disparities impact recyclable versus virgin input production decisions, they will also drive international demand for waste and scrap resources. This area has not been well researched or documented but is important for understanding more general questions about virgin material use, recycling, and the role that international markets play in these decisions. Indeed, these links are important for any policy discussions regarding the role of open markets for sustainable business practices and resource use.

Another important area of research that is desperately needed is a better empirical understanding of the social welfare impacts of international waste trade. Although the literature to date has focused on understanding and testing many of the drivers of international waste trade, we know far less about the effects of that trade on human health, environmental quality, wages, and economic growth. There is a great deal of anecdotal evidence on the environmental and human health dangers of waste trade to countries ill equipped to handle proper recycling activities or disposal, yet accurate measurements of these impacts across countries are lacking. Likewise, any benefits that may be linked to economic growth, wages, or quality of life associated with waste and scrap trade and proper recycling activities are likewise missing in our knowledge of the subject. Ray (2008) argues that the environmental costs associated with international trade in waste outweigh any potential economic benefit for Asia. This may be true, but without a better understanding of all the social welfare impacts associated with waste trade, it is difficult to make policy recommendations regarding the wide variety of waste and scrap products currently traded in world markets.

4. INTERNATIONAL WASTE TRADE AND RELATED WASTE MANAGEMENT LITERATURE

This article focuses on the economics literature that pertains specifically to international trade in waste and scrap products rather than comprehensively reviewing the economics of waste. There is a large and related literature on the economics of waste management more generally, but this review does not focus on this extensive literature, as it is worthy of a complete review on its own; some of this area is covered in Sigman & Stafford (2011). However, it is worth briefly mentioning some of these important papers for the reader who may be interested in international waste trade issues within the context of waste management more generally. Among them are the paper of Fullerton & Kinnaman (1995), who explore the efficiency of deposit-refund systems when illicit burning or dumping by consumers is a viable alternative to legal disposal or recycling options; the paper of Ichinose & Yamamoto (2011), who investigate a model of illegal dumping by using data from Japan; and the paper of Ino (2011), who examines optimal deposit-refund policies when both consumers and firms have the option of illegal disposal. Palmer & Walls (1997) consider the efficiency of recycled content standards, taxes, and subsidies for solid-waste disposal and find that deposit-refund systems would continue to be a preferred policy in most situations. Two papers that employ plant-level data are the paper of Stafford (2000), who explores the impact of environmental regulations and enforcement on the location of hazardous waste management firms, and

the paper of Sigman (1996), who tests the effects of taxes on the generation and disposal choices of firms with chlorinated solvent waste. Kaffine (2014) considers the impacts of various waste and recycling policies, such as deposit-refund systems, recycling subsidies, and advance disposal fees on scrap prices when policy makers are faced with exogenous world market prices. Acuff & Kaffine (2013) research least-cost policy options for reduction of waste from different materials when accounting for externalities associated with greenhouse gases. Kinnaman et al. (2014) find that recycling rates in Japan, and possibly other developed countries, are higher than the socially optimal level for municipal waste management. Finally, Davis & Kahn (2010) explore an interesting question, although not specifically waste or scrap related, regarding the reuse of products by examining the impacts of used vehicle exports from the United States to Mexico and their impact on lifetime emissions in the two countries.

5. CONCLUSION

International trade of waste and scrap is growing at an exceptional rate and shows no signs of slowing. This review explores several theoretical and empirical papers in the literature on the incentives and motivations for waste trade across borders. Although several important economic drivers like differences in disposal costs, taxes, environmental regulations, transport costs, and illicit behavior have been at the forefront of the economics literature, there is still much to learn about the social welfare impacts of this growing component of the world market. Transport of hazardous waste products to countries that are ill equipped to handle it continues to present problems for human health and the environment. However, trade in recyclable waste and scrap products can have economic benefits through job creation and economic growth and can potentially contribute to more sustainable and efficient resource use across countries. Future research is needed to better understand the microeconomic linkages between resource use decisions and the value chain of production, as well as the competing social welfare effects of waste trade.

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