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Essays on Trade, Environment, and Regulation

This study is based on the doctoral dissertation titled "Essays on Trade, Environment, and Regulation" selected as the citation-winning entry for the India Exim Bank International Economic Research Annual Citation 2024. This dissertation was written by Dr. Prakrati Thakur, who received her Ph.D. degree in Economics from the University of Illinois, Urbana Champaign, USA, in 2022. The dissertation was written under the supervision of Prof. George Deltas (Chair); Prof. Dan Bernhardt; Prof. Tatyana Deryugina and Prof. Greg Howard.

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Executive Summary

International trade in waste is a growing component of international trade and imposes negative externalities on the health of the workers employed in the recycling sector and the environment in the importing countries. Despite these market failures, international trade in waste remains a largely understudied issue in the economics literature. The first two chapters explore the determinants and the welfare consequences of international trade in waste. To study the effects of international trade in waste, the effects of a set of waste trade regulations on economic benefits, environmental costs, and manufacturing production are quantified. In contrast to these works which focus on the impact of regulation on economic outcomes, the final chapter investigates how the structure of international trade creates economic incentives for countries to adopt health and environmental regulations.

The first chapter examines the determinants of international trade in waste by employing data on international waste flows and a reduced-form structural gravity model. The estimates reveal that waste flows are positively associated with exporters' and importers' income levels and negatively associated with trade barriers, i.e., they follow the standard gravity predictions. Additionally, low-value waste is more sensitive to trade barriers than high-value waste, while richer countries import a greater share of high-value waste than low-value waste. Although the reduced-form analysis in this chapter yields key empirical facts pertaining to the waste trade data, it does not allow quantification of the welfare consequence of global waste trade.

The welfare effects of international trade in waste are quantified in the second chapter. Based on the empirical findings in the preceding chapter, a structural gravity model is built in which the generation of waste, including that of recyclables, is expressed as a byproduct of manufacturing. The quantitative framework combined with waste trade data reveals that existing patterns of waste trade make countries of all income levels better off. However, trade in low-value waste, which creates large negative externalities relative to its private value, makes middle-income countries worse off. Further, China's 2018 ban on low-value waste imports made China and several lower-income countries better off. Depending on the type of waste trade banned, manufacturing production in countries is also differentially affected. While a high-value waste trade ban reduces manufacturing output for rich countries, a low-value waste trade ban reduces the output for lower-income countries.

The third chapter, explores network effects in the diffusion of regulatory standards through international trade. The results show that countries are more likely to domestically adopt regulations that they comply with while exporting. Further, such diffusion occurs primarily in regulations concerning attributes of the final product rather than production processes. Consistent with a network effect, the findings reveal that countries more open to international trade are the drivers of regulatory diffusion. The study finds that among various labelling regulation features; those aimed at ensuring safe usage are the most widely adopted across countries. Overall, these results support the argument that economic integration can facilitate the strengthening of regulatory standards.

1 Determinants of International Trade in Waste

International trade in waste began with the growing demand for cheap recycled materials by developing countries in the late 1980s. Waste trade, a growing component of international trade, adversely affects the health of the waste-operators and the environment in importing countries (Kirby, 1994). However, despite its market failures, international trade in waste remains a largely understudied issue in the economics literature. The determinants of international trade in waste are investigated in this chapter and then, its welfare implications are quantified in the second chapter.

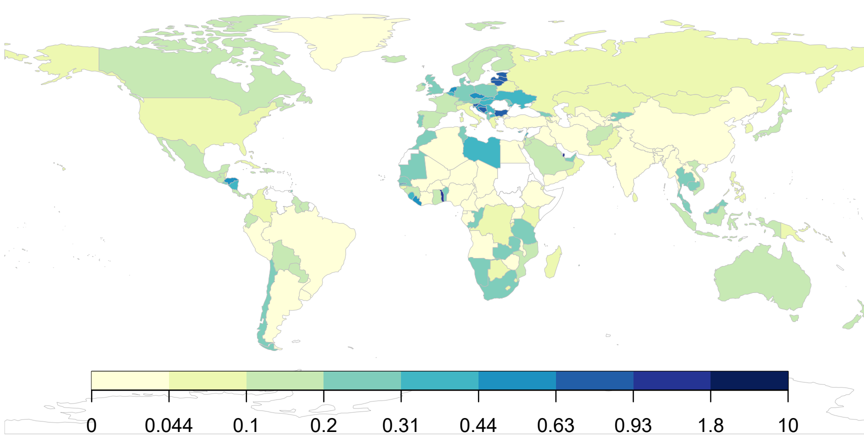
To gather the empirical facts, cross-sectional data on international trade in waste from the UN Comtrade Database is combined with information on country characteristics, including environmental preferences and bilateral trade barriers, in a reduced-form stochastic gravity setup. To study how different types of waste differ in their trade flows, waste is decomposed into low-value waste and high-value waste. Findings reveal that waste flows, including those of low-value waste and high-value waste, follow the gravity predictions, i.e., waste flows are positively associated with the income levels of exporting and importing countries and negatively associated with trade barriers.

Among the two types of waste, low-value waste is more sensitive to trade barriers than high-value waste while richer countries spend a larger share on importing high-value waste than low-value waste. These findings suggest greater economic benefits to trading in high-value waste than low-value waste. Further, controlling for other factors, countries with higher level of environmental regulation export more and import less waste. This finding suggests that countries with stronger preferences for a cleaner environment seek external avenues for dealing with their domestic waste.

This study builds on the studies of factors determining international trade in waste (Copeland, 1991; Baggs, 2009; Kellenberg, 2012) by examining heterogeneity in international trade flows by type of waste. High- and low-value waste not only differ in their trade flows but also in the ease of recycling. In chapter two, this decomposition allows separate quantification of both the economic benefits and environmental costs to trade in the two types of waste by employing a structural gravity framework that captures the key empirical facts obtained in this chapter.

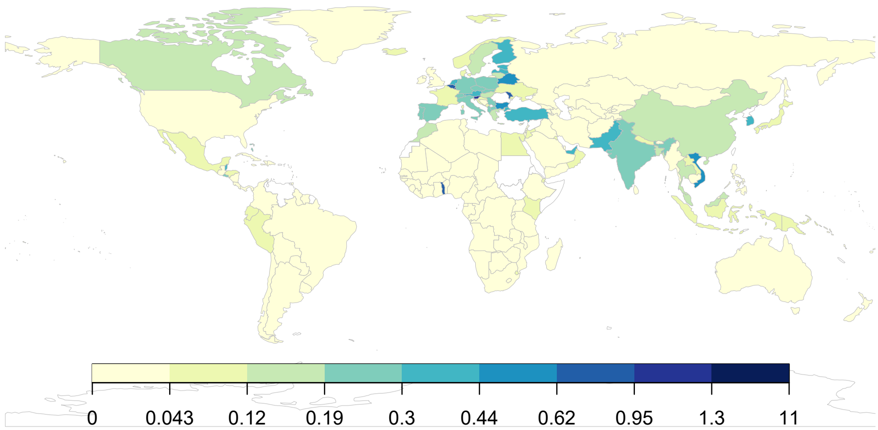
To begin, patterns in total waste exports and imports across the world are examined. **Figure 1.1** displays the value of total waste exports as a share of GDP, while **Figure 1.2** displays the value of total waste imports as a share of GDP across countries. As a share of GDP, high-income countries, mainly in the European and North American regions, are the largest exporters of waste. In contrast, as a share of GDP, the largest importers of waste comprise not only low-income countries such as Pakistan, Türkiye, and Vietnam but also high-income countries such as Belgium, Finland, and South Korea. Thus, the pattern of aggregate waste flows reveals that waste exports primarily come from rich countries, while countries of all income levels-, rich to poor, are among the major importers of waste.

Figure 1.1: Aggregate Waste Exports (as % of GDP)



Note : This map is for representation purpose only and not to scale.

Figure 1.2: Aggregate Waste Imports (as % of GDP)



Note : This map is for representation purpose only and not to scale.

Next, waste flows are disaggregated into two types of waste---high-value and low-value---based on value-to-weight ratios of the 62 categories of waste. To construct the value-to-weight ratios, the average dollar-value and average weight of trade in each category are computed. Then, the 62 categories are divided into two types of waste: high-value, which corresponds to the top tercile, and low-value, which corresponds to the bottom two terciles of value-to-weight ratios (See **Figure 1.3**).

Figure 1.3: Value-to-Weight Ratios for Waste Categories

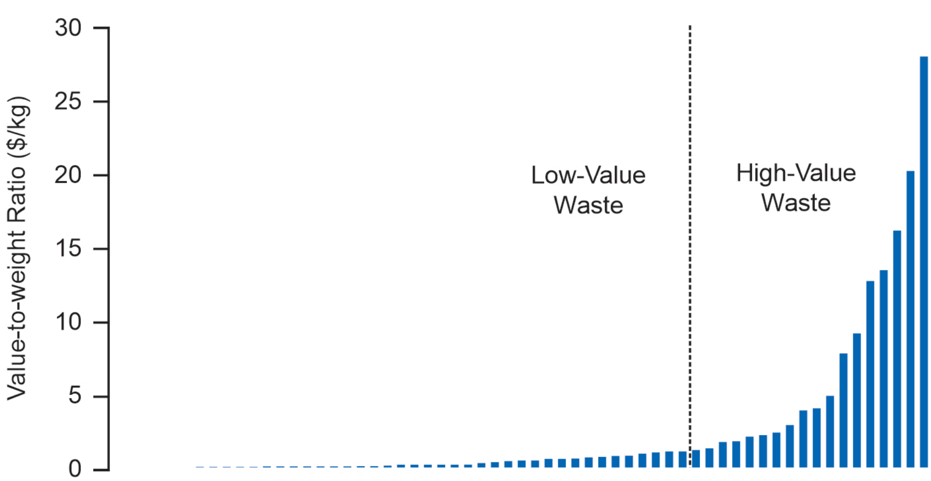


Figure 1.4 shows that while 75% of the materials in high-value waste are metallic in nature, low-value waste is a mix of different materials, including plastics and paper.

Figure 1.4: Composition of High-Value Waste and Low-Value Waste

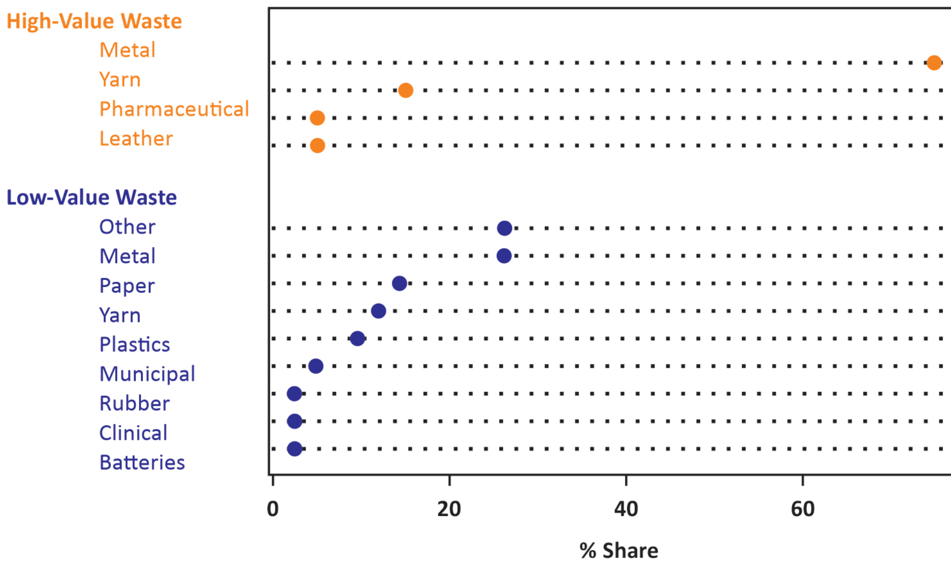


Table 1.1 presents summary statistics on the two types of waste. **Panel A** shows that, on average, countries exporting high-value waste have similar levels of GDP per capita, GDP, and Environmental Performance Index (EPI), as countries exporting low-value waste. In contrast, countries importing high-value waste, on average, have higher GDP per capita, GDP, and EPI than countries importing low-value waste. Thus, the statistics reveal that importers of low-value waste, on average, have lower incomes, lower incomes per capita, and lower levels of environmental regulation than importers of high-value waste. **Figures 1.5** and **1.6** depict a pattern that is consistent with these findings.

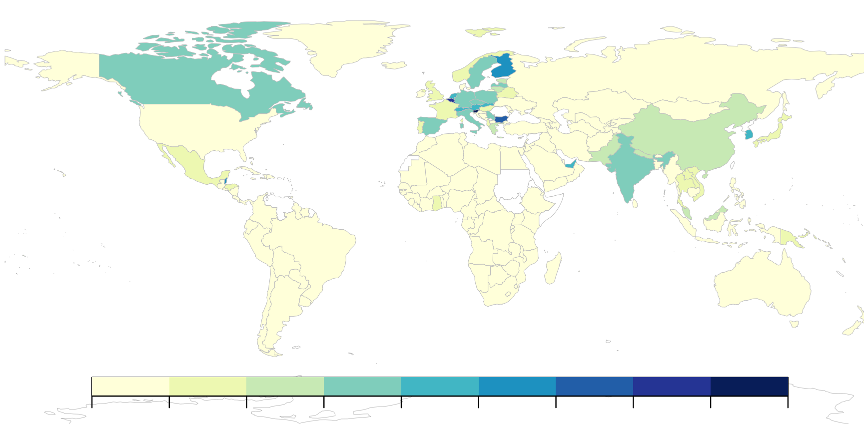
Table 1.1: Summary Statistics by Type of Waste

This table reports the summary statistics for the two types of waste. Panel A reports the summary statistics for the exporter- and importer-specific variables. Panel B reports the summary statistics for the bilateral variables.

Panel A:	***Exporter:***		***Importer:***	
	High-Value Waste	Low-Value Waste	High-Value Waste	Low-Value Waste
GDP per capita	US$ 22,790	US$ 22,575	US$ 24,932	US$ 20,380
GDP (in US$ billion)	US$ 1,367	US$ 1,365	US$ 1,630	US$ 1,159
GDP/Land (1000 US$/sq. km)	US$ 13,388	US$ 12,950	US$ 19,501	US$ 16,624
EPI	75.39	75.19	75.93	72.63
Panel B:	***High-Value Waste***		***Low-Value Waste***	
Weight (1000 kgs)	4,091		30,503	
Value (in '000 US$)	10,766		8,079	
Distance	5,878		6,113	

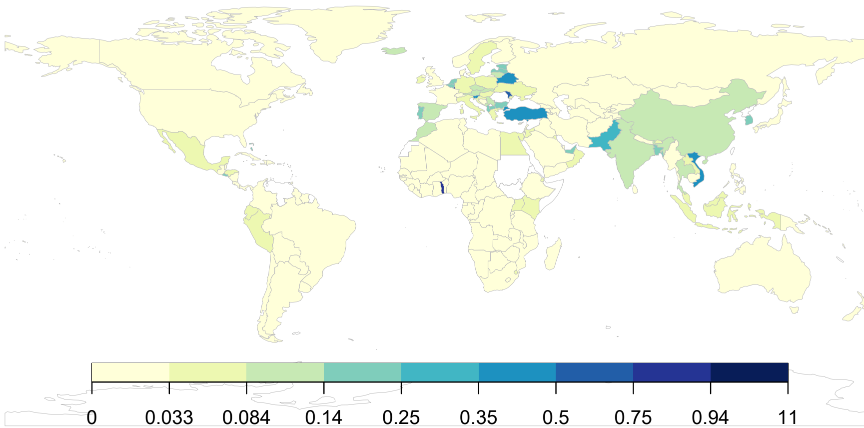
As a share of GDP, high-income countries in the European and North American regions are the major importers of high-value waste. However, as a share of GDP, the major importers of low-value waste are primarily lower-income countries, such as Pakistan, Türkiye, and Vietnam. Finally, the table shows that on average, a tonne of high-value waste is valued at US$ 2,631.4, while a tonne of low-value waste is valued at US$ 264.8.

Figure 1.5: High-Value Waste Imports (as % of GDP)



Note : This map is for representation purpose only and not to scale.

Figure 1.6: Low-Value Waste Imports (as % of GDP)



Note : This map is for representation purpose only and not to scale.

Fact 1: Bilateral waste flows across countries are positively associated with exporters' and importers' income levels.

Table 1.2 reports the elasticity of aggregate bilateral waste flows with respect to exporter's and importer's incomes. The elasticity of the aggregate value of bilateral waste trade with respect to exporters' GDP is 0.552 and with respect to importers' GDP is 1.199, both significant at the 1% level. These results indicate that higher-income countries have larger overall production and consumption activity than lower-income countries. Therefore, they generate and export larger quantities of waste. Furthermore, higher-income countries likely have a greater capacity to recycle waste and a greater demand for secondary inputs in their manufacturing sector and, consequently, engage in more waste imports. Findings show that waste trade is more sensitive to importer's income than to exporter's income. In contrast, for manufactured goods, trade is almost equally sensitive to both exporter's and importer's income levels, with elasticities in the 0.84-0.89 range. In addition, waste trade is more sensitive to importer's income level and less sensitive to exporter's income level than trade in manufactured goods.

Table 1.2: Gravity Equation Estimations for Waste Flows

*This table reports the results from estimation of the gravity equation. Columns 1 and 2 report the results with aggregate bilateral waste flows, Columns 3 and 4 with bilateral high-value waste flows, and Columns 5 and 6 with bilateral low-value waste flows as the dependent variables. Standard errors clustered by exporter-importer pairs are in parentheses. Significance codes: *** p<0.01, ** p<0.05, * p<0.1.*

	Aggregate Waste		High-Value Waste		Low-Value Waste	
log(Exporter's GDP)	0.552***		0.477***		0.551***	
	(0.0781)		(0.107)		(0.0912)	
log(Importer's GDP)	1.199***		1.331***		1.092***	
	(0.0703)		(0.106)		(0.0706)	
log(Exporter's EPI)	2.785***		2.668***		2.685***	
	(0.743)		(0.805)		(0.749)	
log(Importer's EPI)	-3.910***		-2.798***		-4.447***	
	(0.459)		(0.674)		(0.438)	
log(Exporter's GDP/Land)	0.102**		0.0394		0.143***	
	(0.0409)		(0.0391)		(0.0554)	
log(Importer's GDP/Land)	0.249***		0.329***		0.198***	
	(0.0437)		(0.0722)		(0.0480)	
log(Distance)	-0.681***	-0.911***	-0.535***	-0.728***	-0.781***	-1.055***
	(0.0814)	(0.0722)	(0.0757)	(0.0937)	(0.105)	(0.0801)
Contiguity	0.920***	1.020***	0.999***	1.019***	0.798***	1.082***
	(0.241)	(0.204)	(0.236)	(0.254)	(0.261)	(0.211)
Common Language	0.0909	0.0751	0.195	-0.0988	0.0510	0.370**
	(0.150)	(0.178)	(0.161)	(0.212)	(0.172)	(0.172)
Constant	-26.46***	25.72***	-34.48***	23.74***	-20.26***	26.21***
	(4.351)	(0.613)	(4.537)	(0.798)	(4.196)	(0.666)
Exporter FE		Y		Y		Y
Importer FE		Y		Y		Y
R-squared	0.515		0.458		0.423	
Observations	28,056	42,435	28,390	38,802	28,390	42,851

Fact 2: Bilateral waste flows across countries are inversely related to trade barriers.

Table 1.2 shows that waste trade and distance have an inverse relationship. Specifically, the magnitude of the negative elasticity of waste trade with respect to distance is 0.681-0.911 and significant at the 1% level. In contrast, the negative elasticity of manufactured goods trade is 0.457-0.653, suggesting that waste trade is more sensitive to geographic barriers than manufactured goods trade. Moreover, the coefficient on the geographic barrier variable, contiguity, is positive and significant at the 1% level. If two countries are contiguous, they trade 151-177% more in waste than noncontiguous country pairs, as opposed to manufactured goods, where they trade 68-92% more. Since lesser benefits accrue from importing waste than manufactured goods for a country, waste trade is more sensitive to trade barriers. Lastly, Table 1.2 shows a positive, albeit not statistically significant, correlation between waste flows and the common language dummy.

Turning to the effects of environmental regulations, findings reveal a positive elasticity of waste trade with respect to exporter's EPI, with magnitude 2.398, and a negative elasticity with respect to importer's EPI, with magnitude 3.880, both significant at the 1% level. Arguably, a country with greater environmental regulation finds it harder to dispose or recycle negative externality-generating waste and thus exports more and imports less of it. This finding suggests that countries with stricter environmental regulations that care more about the negative externality due to waste seek external avenues for waste management by exporting it to other countries with lax environmental regulations (Kellenberg, 2012).

Fact 3: Low-value waste is more sensitive to trade barriers than high-value waste.

Table 1.2 also shows that the negative elasticity of low-value waste is larger in magnitude than the elasticity of high-value waste with respect to distance. Specifically, in columns 3 and 5, the elasticity of high-value waste with respect to distance is -0.535 as opposed to -0.781 for low-value waste, and the elasticity of low-value waste statistically significantly exceeds that for high-value waste at the 5% level. Similarly, in models with exporter- and importer-specific effects, in columns 4 and 6, the magnitude of the negative elasticity with respect to distance for high-value waste, 0.728, is statistically significantly smaller than that for low-value waste, 1.055, at the 1% level. This finding indicates greater benefits to importing high-value waste than low-value waste, so trade in this type of waste is not as sensitive to trade costs as low-value waste trade. The observed trade patterns appear to arise from differences in waste-processing technology available in different countries. Processing high-value waste likely requires technology that is available in only a select set of high-income countries. As a result, technological availability swamps trade costs in determining flows of high-value waste. Conversely, trade costs swamp technological considerations while determining the direction of low-value waste trade.

Fact 4: As income increases, a greater share of a country's waste imports is high-value waste.

To further understand the choice between importing the two types of waste by a country, a specification where the ratio of high-value to total waste is the dependent variable is estimated. **Table 1.3** reveals that importer's income per capita is positively associated with the fraction of spending on high-value waste in total waste imports. Specifically, the elasticity of fraction spent on high-value waste imports with respect to an importer's GDP per capita is 0.107 and significant at the 1% level. Thus, richer countries allocate a greater share of their expenditure to importing high-value waste than to importing low-value waste.

Table 1.3: Choice between High- and Low-Value Waste by Income of a Country

*This table reports the results from estimation of the gravity equation with the dependent variable replaced by "Ratio". The dependent variable, Ratio, is the ratio of dollar-values of bilateral high-value waste flows to total waste flows. Standard errors clustered by exporter-importer pairs are in parentheses. Significance codes: *** p<0.01, ** p<0.05, * p<0.1.*

	Ratio	
log(Exporter's GDP/capita)	-0.0256	
	(0.0261)	
log(Importer's GDP/capita)	0.107***	
	(0.0268)	
log(Exporter's EPI)	-0.0624	
	(0.145)	
log(Importer's EPI)	1.181***	
	(0.176)	
log(Exporter's GDP/Land)	-0.0126	
	(0.0145)	
log(Importer's GDP/Land)	0.0692***	
	(0.0135)	
log(Distance)	0.0285	-0.0211
	(0.0188)	(0.0245)
Contiguity	-0.0305	-0.175**
	(0.0865)	(0.0819)
Common Language	-0.109**	0.105**
	(0.0470)	(0.0470)
Constant	-7.775***	-0.699***
	(0.861)	(0.208)
Exporter FE		Y
Importer FE		Y
R-squared	0.111	
Observations	6,117	6,740

2 Welfare Effects of International Trade in Waste

International trade in waste, including that of recyclables, has experienced considerable growth over the past three decades, with a five-fold increase in trading volume from 33.9 million tons in 1988 to 156.7 million tons in 2015. However, international trade in waste is contentious among countries because its economic and environmental ramifications on all trading partners are unclear. Although trade in waste has benefits similar to trade in other commodities such as lower prices of recycled materials, increased employment opportunities, and additional income, it also creates local negative externalities in importing countries via the health and environmental hazards posed by waste (Kirby, 1994). Over the years, health and environmental considerations have led countries to put a range of controls on waste trade, from multilateral agreements, such as the Basel Convention implemented in 1992, to the unilateral ban on imports of select waste types by China in 2018. However, little evidence quantifies the effects of such waste trade controls on welfare, waste generation, and the primary source of waste generation, manufacturing production.

This chapter quantifies the welfare effects of international trade in waste. Specifically, gross gains ---benefits due to changes in real income---from waste trade are estimated and compared against the environmental costs of waste trade across countries. To this end, the Ricardian model of trade in manufactured goods by Eaton and Kortum (2002) is extended by adding the generation of waste as a byproduct of manufacturing. To assess heterogeneity in welfare by type of waste, the waste flows are decomposed into high- and low-value waste. Empirically, richer countries import a higher fraction of high-value waste than low-value waste. This finding is interpreted as non-homothetic production in a country's recycling sector that uses the two types of waste to produce a recycled good. Apart from the nature of their trade flows, the two types of waste also differ in ease of recycling. High-value waste, which mainly comprises precious metals and yarn, is easier to recycle than low-value waste, which comprises mixed waste, including plastics. Thus, decomposing waste flows aids in quantifying the heterogeneity by waste type not only in the gains but also in the externality costs due to disposal from waste trade.

The size of gains to trade crucially hinges on the elasticity of the trade value of manufactured goods, high-value waste, and low-value waste with respect to trade barriers. These trade elasticities are estimated using geographic barrier, distance, as an instrument for a measure of trade barriers constructed using price data. **Table 2.1** reports the trade elasticity estimates in the three sectors: manufactured goods, high-value waste, and low-value waste. The OLS estimates with origin- and destination-level effects have the expected negative sign and increase in magnitude when moving from manufacturing to low-value waste sector, consistent with the pattern in Table 1.2. However, the measurement error in the trade barrier variable can lead to attenuation bias in the OLS estimates. In support of this interpretation, the negative 2SLS estimates are larger in magnitude, in the range of 7.260 to 9.831. As before, the size of the estimates increases from manufactured goods to low-value waste. This finding implies that a 1% decrease in trade costs causes a 7.26% increase in manufacturing, a 7.29% increase in high-value waste, and a 9.83% increase in low-value waste flows. Since most countries accrue lesser benefits from importing low-value waste than from importing high-value waste or manufactured goods, the low-value waste flows are the most sensitive to trade costs.

Table 2.1: Estimating Trade Elasticities

*This table reports the results from estimation of the gravity equation. Columns 1, 2 and 3 report the results with bilateral manufactured good flows, Columns 4, 5, and 6 with bilateral high-value waste flows, and Columns 7, 8, and 9 with bilateral low-value waste flows as the dependent variables. For each sector, the first column reports the OLS estimates, the second column reports the first-stage estimates, and the last one reports 2SLS estimates. In all three sectors, the test for weak instruments yields robust F-statistics ranging from 294-510, above the cutoff of 104. Standard errors clustered by exporter-importer pairs are in parentheses. Significance codes: *** p<0.01, ** p<0.05, * p<0.1.*

	Manufactured Goods			High-Value Waste			Low-Value Waste		
	OLS	FS	2SLS	OLS	FS	2SLS	OLS	FS	2SLS
Trade Barrier	-1.170***		-7.260***	-1.361***		-7.290***	-1.501***		-9.831***
	(0.0794)		(0.338)	(0.140)		(0.428)	(0.123)		(0.527)
log(Distance)		0.252***			0.250***			0.231***	
		(0.011)			(0.015)			(0.012)	

	Manufactured Goods			High-Value Waste			Low-Value Waste		
	OLS	FS	2SLS	OLS	FS	2SLS	OLS	FS	2SLS
Exporter FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
Importer FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
R-squared	0.947	0.986		0.924	0.987		0.919	0.987	
Observations	6,932	6,932	6,932	2,470	2,470	2,470	3,411	3,411	3,411

To quantify the externality of waste in monetary terms, existing estimates of the social marginal cost of waste disposal (Bond et al., 2020; McKinsey, 2016) are used and extrapolated to the countries within the sample. To estimate the other key parameters of the model, the world economy is simulated using cross-sectional trade data for 91 countries, representing over 90% of world trade in the three sectors in 2015.

In the autarky counterfactual, trade in all commodities---manufactured goods, high-value waste, and low-value waste---is shut down. Prohibiting all trade is an extreme measure to tackle the issue of international trade in waste. However, since the counterfactuals related to waste trade policies are novel exercises, it is imperative to measure gains to waste trade relative to gains to overall trade. The autarky counterfactual provides welfare implications from not only shutting down all trade but also from changes in overall volumes of production in every sector that ensue from this policy change. Thus, trade in manufactured goods, which account for considerable generation of waste, has the potential to adversely affect local environments in countries via changes in the scale of production.

Panel A in **Table 2.2** presents the gross benefits and environmental costs of shutting down all trade. The rich countries have the largest gains to trade of 3.25% of GDP. Countries, such as Belgium and Singapore, that are relatively open to trade have among the highest benefits, while countries that are relatively closed to trade, such as the United States, have among the lowest benefits to trade. A host of modeling assumptions on the supply-side---market structure, firm-level heterogeneity, one sector, multiple sectors, intermediate goods, and multiple factors of production---and the demand side---CES utility---play a role in explaining the modest size of these benefits (Costinot and Rodríguez-Clare, 2014). Being an extension of the work-horse Eaton and Kortum (2002) framework, the size of the gains to trade from my model is consistent with their estimates.

Table 2.2: Counterfactual Results

Each panel in this table reports the results from a counterfactual exercise. The income groups, in Column 1, are based on 2015 GDP per capita. The poor comprise 13 countries with GDP per capita <US$2400. The middle and the rich each comprise 39 countries with GDP per capita ≥US$2400 and <US$14000 and GDP per capita ≥US$14000, respectively. The Δ Gross Benefits are calculated in terms of proportional changes in real income, and Δ Environmental Costs are simply the differences between gross and net benefits, i.e., equivalent variation. Baseline GDP is 2015 GDP.

	Δ Gross Benefits		**Δ Environmental Costs**	
Income Group	(% of GDP)	(billions US$)	(% of GDP)	(billions US$)
Panel A: Autarky				
Global	-3.05	-2168	-0.39	-274
Rich	-3.25	-1480	-0.35	-159
Middle	-2.63	-589	-0.49	-109
Poor	-3.21	-99	-0.19	-6
Panel B: Waste-Autarky				
Global	-0.013	-9	0.018	13
Rich	-0.014	-6	0.019	8
Middle	-0.009	-2	0.016	4
Poor	-0.021	-0.6	0.024	0.8
Panel C: High-Value Waste-Autarky				
Global	-0.01	-7	0.030	21
Rich	-0.012	-6	0.037	17
Middle	-0.007	-2	0.019	4
Poor	-0.001	-0.04	0.004	0.1
Panel D: Low-Value Waste-Autarky				
Global	-0.004	-3	-0.005	-4
Rich	-0.006	-3	-0.003	-1
Middle	0.001	0.2	-0.012	-3
Poor	-0.004	-0.1	0.002	0.06

	Δ Gross Benefits		Δ Environmental Costs	
Income Group	(% of GDP)	(billions US$)	(% of GDP)	(billions US$)
Panel E: China Ban				
Global	-0.002	-1	0.003	2
Rich	-0.002	-1	0.006	3
Middle	-0.0001	-0.03	-0.003	-0.6
Poor	0.002	0.06	-0.006	-0.2
Panel F: Ban Amendment				
Global	-0.003	-2	0.004	3
Rich	-0.003	-2	0.003	1
Middle	-0.002	-0.4	0.007	2
Poor	-0.010	-0.3	0.013	0.4

On the environmental costs side, middle-income countries disproportionately bear externality costs due to trade of 0.49% of GDP. This finding reflects that the middle-income countries spend a higher fraction of their GDP on disposal-intensive low-value waste. Although poor countries also allocate greater fractions of their GDP to low-value waste, middle-income countries have higher social marginal costs of waste disposal than those countries. At the country level, findings show that although most countries incur larger environmental costs from opening to trade, some smaller-sized countries, such as the Seychelles and Moldova, incur smaller costs too. Such smaller economies have limited domestic capacity to recycle and thus rely primarily on exports to deal with waste. Since waste trade accounts for only 0.07% of overall international trade in commodities, the small environmental costs due to waste, approximately 0.13% of gross benefits, are unsurprising.

In the waste-autarky counterfactual, trade in both high-value and low-value waste is shut down. On the one hand, in the autarky counterfactual, access to technology from the rest of the world declines, leading to a fall in labor efficiency and wages. On the other hand, in the waste-autarky counterfactual, wages rise due to substitution away from waste inputs and towards labor in the manufacturing sector. This counterfactual provides the effect of shutting down trade in waste and the changes in production volumes in all sectors that result from this policy change.

Panel B in **Table 2.2** reports the gross benefits and environmental costs of prohibiting trade in waste. The second column shows that the global gains to trade in waste are 0.013% of GDP, which is 0.43% of the global gains to overall trade. Differentiating by income group, the study finds that poor countries disproportionately benefit from trade in waste, at 0.021% of GDP. In addition, the volume of high-value waste rises by 12.25%, while the volume of low-value waste declines by 0.73%. The changes in the prices of the two inputs to recycling, i.e., high- and low-value waste, relative to the price of recycled output are sufficient to explain the changes in overall volumes of waste generation. Thus, a rise in the price of low-value waste and a fall in the price of high-value waste relative to the price of recycling output explain the volume changes. Since low-income countries specialize in low-value waste, the relative price increase for this input benefits them the most.

The columns number 4 and 5 show that allowing waste trade decreases the environmental costs for all country groups, with poor countries experiencing the largest decrease. Poor countries allocate a larger share of their income to disposal-intensive low-value waste, whose overall generation volume is declining. Thus, all country groups are better off with waste trade even after accounting for its environmental costs. High-value waste trade creates welfare effects that are qualitatively similar to the overall waste trade. However, rich countries, which specialize in high-value waste exports and disproportionately use it as an input in their recycling, gain the most---0.012% of GDP---and incur the largest decline in environmental costs---0.037% of GDP---due to high-value waste trade (**Panel C** in **Table 2.2**). In contrast, with low-value waste trade, the direction of changes in the volume of generation of the two types of waste flips; high-value waste generation decreases while low-value waste generation increases. Thus, even though trade in low-value waste makes the middle-income group worse off, it still makes the rich and low-income countries better off (**Panel D** in **Table 2.2**).

On the benefits side, countries more open to trade in waste, such as Belgium and Vietnam, experience the largest gains to waste trade, while countries relatively closed to waste trade, such as the United States and Brazil, experience the lowest benefits. Some countries, such as the Seychelles and Zambia, experience negative gains and positive externality costs to waste trade. Such countries that are reliant on exports to deal with waste increase the volume of generation of both waste types as more options become available with allowing waste trade. In addition, the price of recycled good increases relative to wages, leading to a decrease in their real incomes.

Lastly, shutting down trade in waste reorganizes manufacturing production across countries. Rich countries see a fall in production volumes by 0.002% while middle and poor countries see a rise of 0.003% and 0.0003%, respectively. Rich countries are major producers and exporters of high-value waste input to manufacturing. Thus, as the overall volumes of this major input fall, manufacturing production by rich countries is also adversely affected.

In 2018, China imposed an import ban on 24 categories of waste that included types of plastics, paper, and yarn. Over the next two years, it expanded the banned categories to include scrap metal, old ships, slag, stainless steel, and timber (You, 2018). Since the banned categories have substantial overlap with low-value waste in my sample, imports of low-value waste by China, which is a major importer of this type of waste to study the effects of the ban, are shut-down. The policy helps China on both fronts, with an increase in gross benefits and a decrease in environmental costs, while also helping other low-income countries, such as India and the Philippines, in the same manner.

Panel E in **Table 2.2** presents the impacts on gross benefits and environmental costs aggregated by income level. Column 2 shows that rich countries lose 0.002% of GDP, while poor countries gain 0.002% of GDP because of the ban. Since poor countries are major buyers of low-value waste, they experience positive benefits from this policy change, explained by the decrease in price of low-value waste relative to wages. The overall volume of high-value waste increases by 0.46%, while that of low-value waste decreases by 0.11%, qualitatively similar to low-value waste autarky. Since middle-income and poor countries allocate a greater fraction of their income to low-value waste than to high-value waste, their environmental costs also decrease. In contrast, the rich allocate a greater share to high-value waste, so their environmental costs increase. Thus, in terms of net benefits, the rich are worse off, while the middle- and poor-income countries are better off.

Finally, the Chinese ban also reorganizes the production of manufactured goods globally in accordance with the generation volume changes in the two types of waste. While rich and the poor countries see a decrease of 0.001% in manufacturing production, middle income countries see a rise of 0.002%.

The Ban amendment to the Basel Convention, which came into force in 2019, is an agreement among parties to the Convention to prohibit exports of all hazardous waste from the Organization of Economic Cooperation and Development (OECD), the EU, and Liechtenstein to other countries that primarily include developing countries (Basel Action Network and International Pollutants Elimination Network, 2019). According to the amendment, Annex VII countries that have ratified the amendment are prohibited from exporting hazardous waste to any Non-Annex VII country, regardless of whether they ratified the amendment or not. Similarly, the Non-Annex VII countries that have ratified the amendment are prohibited from accepting imports of hazardous waste from any Annex VII country. The amendment also bans trade in non-hazardous waste that is contaminated with hazardous substances and defers to country definitions of hazardous waste in several cases. Since all waste can, arguably, have some degree of hazardous content (Kellenberg and Levinson, 2014), the Ban amendment is imposed by shutting all waste exports from Annex VII countries that ratified the amendment to all Non-Annex VII countries and all waste imports of Non-Annex VII countries that ratified the amendment from all Annex VII countries.

Panel F in **Table 2.2** reports the gross benefits and environmental costs of the Ban amendment. The results are qualitatively similar to the waste-autarky counterfactual, albeit the magnitudes are lower. The welfare effects of imposing the Ban amendment are 22-23% of the effects of imposing an overall waste trade ban. Surprisingly, estimates in this analysis reveal that this policy that is meant to favor the developing countries that ratified the amendment is most harmful to them, like an overall waste trade ban, which is also most harmful to poor and developing countries.

3 Trade Networks and Diffusion of Regulatory Standards

The impact of regulation on economic outcomes is of central interest in policymaking. On the one hand, adoption of regulations by countries can hinder competition by adversely affecting trade (Disdier et al., 2008), technology diffusion (Conway et al., 2004), and production (Greenstone, 2002; Maskus et al., 2005). On the other hand, regulation is not only necessary to meet social goals such as protection of human health and the environment but can also achieve efficiency gains (Shapiro and Walker, 2020). A country's incentives for unilateral adoption of regulations that impose constraints on domestic producers are limited when competing against non-regulated foreign producers. However, when a country is pressured to comply with these regulations while exporting, the gains to domestic adoption can outweigh the costs imposed by such constraints. Thus, countries that adopt stricter standards can indirectly encourage further implementation in exporting countries, possibly enabling widespread adoption of these policies. The phenomenon of diffusion of regulations through market mechanisms, conceived as the "California effect" in Vogel (2000), demonstrates that economic incentives can align with the social goals of countries by stimulating regulatory coordination among them. Although limited empirical literature documents diffusion in standards, little is known about the factors that facilitate regulatory propagation.

In this chapter, the extent of diffusion in the domestic adoption of regulations due to compliance requirements by regulation-imposing importing countries is uncovered. Further, factors, such as regulation types and economic openness of countries, that aid the propagation of regulatory standards through trade networks are examined. To quantify the diffusion process, spatial econometric techniques are combined with a sample of regulations---Technical Barriers to Trade (TBT)---that offer information on various regulation types imposed by countries on imports of a broad class of organic chemicals. The class of organic chemicals, which comprises commodities ranging from the relatively safe (e.g. food additives) to the hazardous (e.g. pyrotechnics and pesticides), is the ninth most traded commodity globally. In addition, it is also the most regulated class of commodities in our TBT data set. Regulation data are combined with trade data on organic chemicals to construct a detailed panel comprising information on the adoption of eight regulations by each country's importers, allowing assessment of heterogeneity in diffusion across regulations.

1 written jointly with Sergio Rocha (Monash University)

Results show that countries tend to domestically adopt regulations that they comply with when exporting internationally, suggesting that pressure from importers is a meaningful diffusion channel. Controlling for other diffusion mechanisms (i.e., pressure from export competitors, knowledge spillover from other commodities, coercion, and cultural proximity) and economic indicators, findings show that one standard deviation (s.d.), i.e., roughly 30 percentage point (p.p.), increase in the share of exports that comply with a regulation is associated with a 1.06-1.92 p.p. increase in the probability of domestic adoption of that regulation. The size of these estimates is commensurate with 6.85-12.37% of average adoption. Results also show extensive variation in the diffusion by type of standard and countries' openness to international trade.

Diffusion is stronger for product standards---regarding physical attributes of the final product---as opposed to process standards, which pertain to the manufacturing process. Product regulations, such as labelling and packaging requirements, are likely more cost-effective than regulations that involve adjustments to the production process. Further, regulatory bodies can test for conformity with product standards, so they can discriminate against non-complying products, which confers a competitive advantage to complying exporters (Vogel, 2000; Greenhill, 2009). However, since compliance with process standards, such as labor rights or amount of pesticides used during production, is harder to verify in the final product, domestic adoption of such standards by exporting countries would confer little competitive advantage over other producers in the global market.

Importantly, results show that countries that are relatively open to international trade are the drivers of regulatory diffusion. In addition, our estimated network effect is monotonically increasing in a country's level of openness to trade. These findings are consistent with Vogel's argument that economic openness and international competition are the drivers of policy diffusion because relatively closed countries face modest incentives to match trade partners' policy decisions. These results corroborate that the empirical approach captures a network effect rather than secular trends in regulation adoption.

The regulation adoption variable uses information on TBTs imposed by countries on their trading partners over the years. The data provide information on the type of regulation, its imposing country, exporting countries regulation is imposed on, the regulated commodities, and the year of implementation.

Several features of the TBT data set make it suitable for analysis: As per the agreement on the Technical Barriers to Trade, World Trade Organization member countries can use TBT to achieve policy objectives, such as protection of human health or environment, or prevention of deceptive practices. However, they must not employ TBT as unnecessary barriers to trade. Therefore, even though TBT can potentially have economic effects by influencing traded quantities and prices, they are not supposed to be implemented with the objective of protectionism or restricting foreign competition. Moreover, the TBT should be non-discriminatory between like products regardless of their country of origin.

The data set contains only regulatory standards adopted by countries at the national level and used as admissibility requirements on imports. Countries adopt these regulations at will and are at liberty to choose the level of stringency to impose. Further, the data, compiled by classifying legal documents into pre-defined Non-Tariff Measure (NTM) codes, consists of regulations coded in a standardized way into types. Thus, information on their stringency is limited.

The NTM codes classify the TBTs based on compliance requirements with product characteristics or production processes. The study adopts data on the following NTMs: B210-Tolerance limits for residues or contamination by certain substances, B220-Restricted use of certain substances, B310-Labelling requirements, B320-Marking requirements, B330-Packaging requirements, B410-TBT regulations on production processes, B420-TBT regulations on transport and storage, and B700-Product quality, safety or performance requirements. **Table 3.1** provides examples on regulations under each NTM code.

Table 3.1: Example TBT Regulations

This table provides an example of a regulation under each NTM code, obtained from the manual on International Classification on Non-Tariff Measures.

B210: Tolerance Limits
- ***Example:*** *The salt level in cement or sulphur level in gasoline must be below the specified amount.*

B220:Restricted Use
- ***Example:*** *This measure refers to the restricted use of solvents in paints and the maximum level of lead allowed in consumer paint.*

B310: Labelling
- ***Example:*** *Refrigerators must carry a label indicating size, weight and level of electricity consumption.*

B320: Marking
- ***Example:*** *Handling or storage conditions according to the type of product must be specified; typically, indications such as "Fragile" or "This side up" must be marked on the transport container.*

B330: Packaging
- ***Example:*** *Palletized containers or special packages should be used for the protection of sensitive or fragile products.*

B410: Production Processes
- ***Example:*** *Animal slaughtering requirements according to Islamic law must to be followed.*

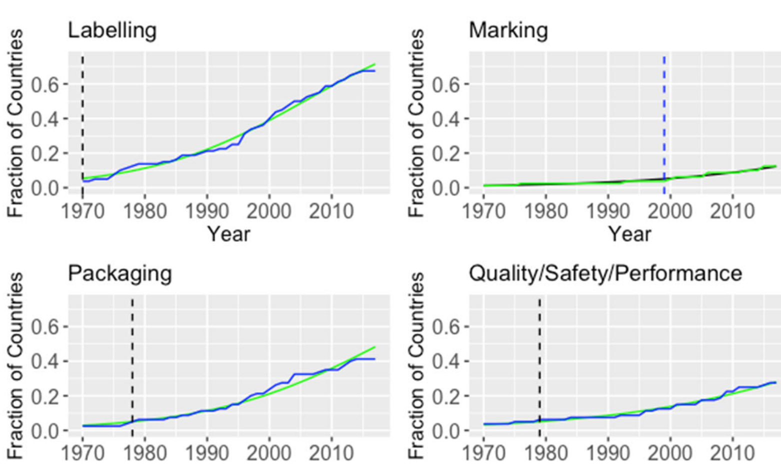
B420: Transport and Storage
- ***Example:*** *Medicines should be stored below a certain temperature.*

B700: Quality, Safety , or Performance Requirements
- ***Examples:*** *Doors must resist a certain minimum high temperature. Toys for children under three years of age shall not contain articles smaller than a certain size. There are minimum conditions for the performance of pedal bicycles in relation to handlebars, seats and brakes.*

Since focus is on heterogeneity across regulations, the sample is restricted to 2-digit HS category 29: Organic Chemicals, the most heavily regulated commodity in the TBT data. Being in principle non-discriminatory, a TBT imposes the standard on domestic production and all imports simultaneously. However, for about 2% of cases, the requirements were imposed on exports from only a subset of countries. For simplicity, these observations are dropped. As a result of the above cleaning, data span adoption of regulations by 80 countries across the 8 NTMs in the years 1970-2017.

Figure 3.1 shows that the actual fraction of countries that adopted closely follow the S-shaped pattern of fitted logistic curve. In general, product regulations diffuse faster than process regulations. The exceptions are Marking requirements, a product regulation with relatively slow adoption, and Transport requirements, a process regulation with relatively fast adoption. Labelling requirements is the first regulation to reach the conventional 5% adoption threshold. In fact, it reaches the threshold even before the sample period began in 1970. After labelling, regulations that reach the 5% threshold are Packaging, Quality-Safety-Performance, and Transport regulations, in that order, in late the 1970s or 1980s. The rest of the regulations reach the 5% threshold in the late 1990s, or the 2000s. The speed of adoption varies substantially across all eight regulations. For example, at the beginning of the sample period, the adoption of labelling regulations doubled roughly every ten years, going from 5% in 1970 to 10% in 1979 to 20% in 1989. In contrast, process regulations diffused much slower, including some that don't even cross the 10% threshold by the end of the sample period.

Figure 3.1: Fraction of Countries that Adopted



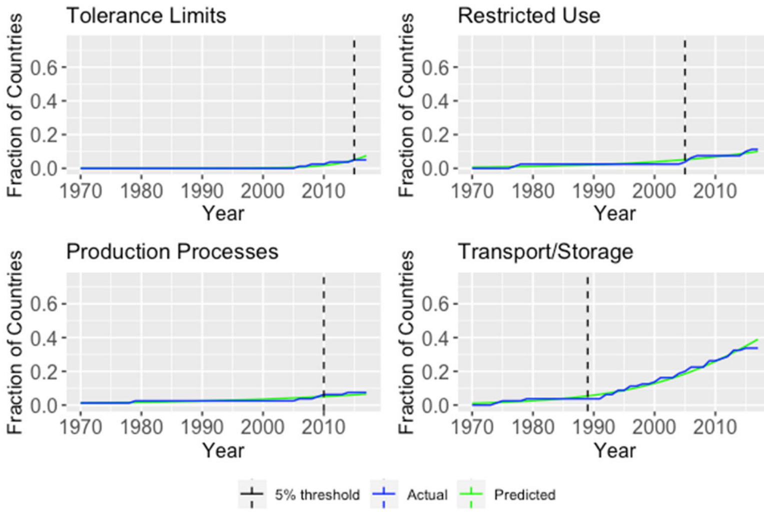


Table 3.2 reveals a positive relationship between adoption probability and the fraction of exports affected by a regulation. The coefficient on main variable of interest, Affected Exports (AE), is in the range 0.036-0.065. It is statistically significant at the 5% level across specifications, except in column (3), where the model is saturated with country-year and NTM level fixed effects. The observed estimates imply that a 10 p.p. increase in affected exports of a country is associated with a 0.36-0.65 p.p. increase in the adoption probability of any regulation by that country. These findings provide evidence that countries are more likely to adopt a regulation when their exports already comply with it, suggesting that importer pressure is an important factor driving the propagation of regulations across countries. The positive link between adoption of regulation and importers' influence in a trade network supports the findings in the context of automobile emission standards (Saikawa, 2013) and labour rights (Greenhill et al., 2009).

Table 3.2: Diffusion Mechanisms

*This table reports output from the estimation of the baseline specification, but not allowing the coefficient of AE to vary. The dependent variable is a regulation-country-year adoption indicator that equals one when a country has a regulation in place in a given year. The first column describes the diffusion mechanism associated with the corresponding independent variable given in the second column. Significance levels are indicated by *, **, and *** at the 10%, 5%, and 1% level, respectively. Standard errors are two-way clustered at NTM-Country and NTM-Year level.*

		Adopted		
		(1)	(2)	(3)
Mechanism:	**Explanatory Variable:**			
Importer Pressure	AE	0.036**	0.065**	0.044
		(0.016)	(0.031)	(0.030)
Knowledge Spillover, from Other Chemicals	$KS^{other\ chem.}$	-0.065*	0.117**	0.128***
		(0.036)	(0.047)	(0.045)
Knowledge Spillover, from Machinery	$KS^{machinery}$	0.025	0.046	0.072*
		(0.031)	(0.043)	(0.043)
Competitor Pressure	HHI	-0.008**		
		(0.004)		
Competitor Pressure	CP		0.156***	0.061
			(0.058)	(0.052)
Adoption by Colonial Partners	CA	-0.145**	0.030	0.042
		(0.062)	(0.030)	(0.027)
Adoption by Language Partners	LA	-0.105	0.096	-0.006
		(0.090)	(0.080)	(0.080)
Adoption by Religion Partners	RA	0.104	0.449***	0.288***
		(0.121)	(0.095)	(0.110)
Coercion	ODA	0.001		
		(0.001)		
	Political Regime	-0.002		
		(0.002)		
	GDP/capita	0.00001***		
		(0.00000)		
	FDI	-0.001*		
		(0.0004)		
	NTM-Country FE	Y	N	N

		Adopted		
		(1)	(2)	(3)
	NTM-Year FE	Y	N	N
	Country-Year FE	N	Y	Y
	NTM FE	N	N	Y
	Observations	15,744	18,560	18,560
	R^2	0.770	0.454	0.462
	Adjusted R^2	0.758	0.375	0.385

Next, the study considers knowledge-spillovers from importing other commodities that are regulated. **Table 3.2** shows that the signs on the coefficients to the variable $KS^{other\ chemicals}$ depend on the set of fixed effects at use. Similarly, the only specification where the coefficient for knowledge-spillovers from Machinery, $KS^{machinery}$, is both positive and significant is model (3). Thus, evidence for knowledge-spillovers from importing regulation-complying Other Chemicals and Machinery on a country's domestic adoption of regulations for Organic Chemicals is inconclusive.

Turning to pressure due to exports competition, as in model (1), the variable capturing competitor pressure, HHI, is negatively associated with adoption probability at the 5% significance level. A country with high HHI holds a substantial market share in exports of Organic Chemicals, and thus, faces less pressure to match the standards of export competitors. The estimated coefficient on HHI implies that a one s.d. increase in HHI is associated with a 1.32 p.p. decrease in adoption probability. Further, in models (2) and (3), where country-year fixed effects are included, our alternative measure of competitor pressure, CP, has a positive coefficient, albeit significant only in model (2) at the 1% significance level. Since CP measures the prevalence of a regulation across a country's major exports competitors, countries with higher CP experience more competitive pressure to adopt the regulation. Consistent with this reasoning, a 10 p.p. increase in adoption by a country's major competitors is associated with a 0.61-1.56 p.p. increase in the probability of adoption by that country. Regardless of the variable used, findings suggest that competitor pressure is an important driver of policy diffusion, consistent with Simmons and Elkins (2004) and Saikawa (2013).

Finally, among the variables capturing adoption by cultural partners, only the coefficient on adoption by dominant religion partners is significant across specifications. The coefficient on RA is positive and significant, at 1% level, in models (2) and (3). Here, the coefficient ranges between 0.288-0.449, implying that a 10 p.p. increase in dominant religion partners that adopted is associated with a 2.88-4.49 p.p. increase in adoption probability. However, the results present weak evidence, if any at all, in support of adoption due to the influence of colonial and language partners.

Table 3.3 shows that the coefficient on AE interacted with the indicator of product regulation is positive and significant, at least at the 10% level, across all models (1)-(3). The estimates vary from 0.045-0.099, implying that a 10 p.p. increase in exports affected by product regulations is associated with a 0.45-0.99 p.p. increase in adoption probability. Notably, the magnitude of the point estimates for the diffusion of product standards is 25-66% higher than the 0.036-0.065 obtained in Table 3.2. In contrast, there's no evidence of diffusion in process regulations via the importer pressure channel. Since compliance with product regulations can be directly observed, manufacturers gain a competitive advantage by differentiating their products by meeting product standards (Greenhill et al., 2009). However, process regulations are harder to monitor, so adoption by a country's importers provides a weak incentive for the country's internal adoption.

Table 3.3: Heterogeneity in Diffusion by Regulation

*This table reports output from the estimation allowing coefficient of AE to vary by type of regulation. The dependent variable is a regulation-country-year adoption indicator that equals one when a country has a regulation in place in a given year. In columns (1), (2), and (3), where the main independent variable of interest is interacted, AE, with indicators of product and process regulations. In columns (4), (5) and (6), the effect into regulation level is further broken down by allowing the diffusion coefficient of AE to vary by NTM code. Significance levels are indicated by *, **, and *** at the 10%, 5%, and 1% level, respectively. Standard errors are two-way clustered at NTM-Country and NTM-Year level.*

	Adopted					
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
AE × Product Reg.	0.045**	0.099**	0.073*			
	(0.022)	(0.041)	(0.039)			
AE × Process Reg.	0.021	0.011	0.001			
	(0.020)	(0.038)	(0.036)			
AE × Tolerance				-0.040	-0.214*	-0.247**

	Adopted					
	(1)	(2)	(3)	(4)	(5)	(6)
				(0.047)	(0.125)	(0.113)
AE × Restricted				0.003	-0.059	-0.052
				(0.018)	(0.053)	(0.052)
AE × Labelling				0.087**	0.168***	0.101*
				(0.035)	(0.059)	(0.058)
AE × Marking				0.041	-0.014	0.011
				(0.041)	(0.059)	(0.055)
AE × Packaging				0.002	0.153**	0.153***
				(0.036)	(0.061)	(0.050)
AE × Production				-0.019	-0.041	0.002
				(0.038)	(0.066)	(0.060)
AE × Transport				0.065	0.092	0.078
				(0.041)	(0.061)	(0.057)
AE × Quality, Safety & Performance				0.040	-0.122	-0.128
				(0.065)	(0.106)	(0.101)
NTM-Country FE	Y	N	N	Y	N	N
NTM-Year FE	Y	N	N	Y	N	N
Country-Year FE	N	Y	Y	N	Y	Y
NTM FE	N	N	Y	N	N	Y
Observations	15,744	18,560	18,560	15,744	18,560	18,560
R^2	0.770	0.455	0.462	0.770	0.460	0.466
Adjusted R^2	0.758	0.377	0.385	0.758	0.382	0.389

The results in **Table 3.3** further reveal that labelling regulations, and to a certain degree, packaging regulations, are driving the positive association between the adoption of product regulations and importer pressure. The coefficient on interaction of AE with the labelling regulation indicator is in the range 0.087-0.168 and significant at least at 10% level across models. Comparison between these point estimates and those reported in models (1)-(3) of **Table 3.3** suggest that labelling standards diffuse 38-93% faster than overall product regulations.

Adoption of regulations through importer pressure can also depend on the openness of a country to international trade. Arguably, a country with minor international trade flows will have little incentives to match the policies of its trade partners. **Table 3.4** shows that the coefficient on the fraction of affected exports, AE is positive and significant at least at 10% level across thresholds, indicating that importer pressure is a relevant channel of diffusion in relatively open countries. Also, moving from models (1) to (3)---as the average level of openness of the relatively open countries increases---so does the magnitude of the point estimates. The estimates range from 0.061-0.103, higher than the estimates of 0.036-0.065 in Table 3.2.

Table 3.4: Heterogeneity in Diffusion by Level of Openness of Countries

*This table reports output from the estimation for different definitions of "Closed" countries. The dependent variable is a regulation-country-year adoption indicator that equals one when a country has a regulation in place in a given year. Columns (1), (2), and (3), classify a country as "Closed" if it lies in the bottom 0.2, 0.33, and 0.5 quantile of the distribution of openness, respectively. Significance levels are indicated by *, **, and *** at the 10%, 5%, and 1% level, respectively. Standard errors are two-way clustered at NTM-Country and NTM-Year level.*

	Adopted		
	(1)	**(2)**	**(3)**
AE	0.061*	0.080**	0.103**
	(0.032)	(0.035)	(0.040)
AE × Closed	-0.114	-0.136**	-0.140**
	(0.085)	(0.066)	(0.064)
Total	-0.052	-0.056	-0.037
	(0.078)	(0.056)	(0.048)
Country-Year FE	Y	Y	Y
NTM FE	Y	Y	Y
Observations	18,528	18,528	18,528
R^2	0.463	0.463	0.464
Adjusted R^2	0.385	0.386	0.389

In contrast, the coefficient on the fraction of affected exports interacted with ``Closed” dummy is consistently negative and significant at 5% level in models (2) and (3). The slope on the fraction of affected exports for closed countries is lower by 0.114-0.140 units than the slope for relatively open countries. These coefficients show that relatively closed countries experience less diffusion due to importer pressure. Further, row 3 in **Table 3.4** shows no perceptible diffusion due to importer pressure for these countries. Consistent with a network effect, our findings suggest that countries that are open to international trade are the main drivers of the observed international regulatory diffusion.

4 Conclusion

A crucial first step to quantifying the welfare effects of trade in waste is to gather empirical facts, which will be used to formulate a structural model of international waste flows. To gather the empirical facts, cross-sectional data on international trade in waste is combined with information on country characteristics and bilateral trade barriers in a reduced-form stochastic gravity setup. To study how different types of waste differ in their trade flows, waste is decomposed into low- and high-value waste.

Waste flows, including for low- and high-value waste, follow the gravity predictions, i.e., waste flows are positively associated with the income levels of exporting and importing countries and negatively associated with trade barriers. Among the two types of waste, low-value waste is more sensitive to trade barriers than high-value waste while richer countries spend a larger share on importing high-value waste than low-value waste. These findings suggest greater benefits to trading in high-value waste than low-value waste.

Further, the environmental preferences of a country combined with the recycling rates and changes in volumes of disposal due to a trade policy is a crucial input to quantifying the environmental costs to trade in low- and high-value waste. Although the reduced-form analysis in the first chapter yields key empirical findings, it does not allow explicit quantification of the effects of waste trade policies on economic benefits or environmental costs. To do so, structure on the waste flows, based on the empirical facts obtained in this chapter, is needed. In the second chapter, such a structural model is described, along with the estimation strategy, and the counterfactual results.

In Chapter 2, a structural gravity model with the generation of waste micro-founded as a by-product of manufacturing is built. To assess heterogeneity in welfare by type of waste, the study decomposes waste flows into low- and high-value waste and estimate separate trade elasticities for both types along with for manufactured goods. This setup also allows the externality costs, which depend on the ease of recycling different materials, to vary by type of waste. The key finding through counterfactual simulations is that existing patterns of waste trade make all countries better off. However, the low-value waste trade makes middle-income countries worse off.

Overall, results show that the existing patterns of waste trade make countries of all income levels better off even after accounting for negative externalities of waste disposal. The global gains to waste trade comprise 0.43% of gains to all trade even though waste trade accounts for only 0.07% of overall trade by value. Thus, per unit of trade value, waste trade generates more than five times the welfare gains of regular trade. Differentiating the gains to waste trade by income level, findings reveal that poor countries have the largest gains, at 0.021% of GDP. Further, allowing waste trade decreases the environmental costs for all income levels, but for the poor, it does so by the largest amount of 0.024% of GDP. The decline in environmental costs reflects the scale and compositional changes in the generation of the two types of waste. As countries gain access to import opportunities from opening to trade in waste, their recycling sector shifts its expenditure toward high-value waste and away from low-value waste. Thus, the scale of generating low-value waste, which has higher disposal intensity and creates high externality costs, counterintuitively decreases even as more options for dealing with waste become available through the waste trade.

Further, high-value waste trade creates gains and environmental costs qualitatively similar to the overall waste trade. Thus, countries of all income levels are better off due to trade in high-value waste. However, rich countries, which both specialize in and disproportionately import high-value waste, realize the largest net benefits of 0.049% of GDP. In contrast, low-value waste trade harms the primary importers of this type, i.e., middle-income countries. Even though poor countries are also primary importers of low-value waste, middle-income countries place a higher social marginal cost on waste disposal than low-income countries.

The welfare implications of recent policies regulating waste trade are also quantified, beginning with China's 2018 ban on select waste imports. China's ban on low-value waste imports has qualitatively similar welfare effects to a ban on all low-value waste trade, albeit with smaller magnitudes. This policy helps China on both fronts---by increasing gross benefits and decreasing environmental costs---while also benefiting other lower-income countries such as India and the Philippines. Like an overall low-value waste trade ban, the scale of low-value waste generation declines, making lower-income countries better off. Regulations on waste trade differentially affect manufacturing production in countries depending on the type of waste trade that is banned. Banning trade in all or only high-value waste reduces manufacturing output by high-income countries, while increasing output by middle-income and poor countries. In contrast, only banning trade in low-value waste decreases the manufacturing output of both poor and rich countries. Although the effects of waste trade bans on manufacturing production across income levels are small, they indicate that trade bans on the type of waste a country specializes in have the potential to adversely affect its manufacturing sector.

Although imposing regulations on domestic producers adversely affects economic outcomes, regulations are necessary to meet the health and environmental protection goals of a country. Potentially, when a country is pressured to comply with a regulation imposed by its importing country, the gains to domestic adoption can outweigh the costs, encouraging further adoption in the exporting country. Thus, economic integration and international competition can strengthen the adoption of regulations by facilitating diffusion from importing to exporting countries in an international trade network.

The extent of diffusion in domestic adoption of Technical Barriers to Trade, required for admissibility of imported organic chemicals, is quantified. Controlling for other diffusion mechanisms and economic indicators, there's a positive association between domestic adoption by a country and the extent to which the country complies with a standard while exporting. In addition, the heterogeneity analysis sheds light on types of regulations and country characteristics associated with stronger diffusion. Consistent with network effect, results suggest that regulatory diffusion is primarily driven by the adoption of standards with observable compliance and by countries that are relatively open to international trade.

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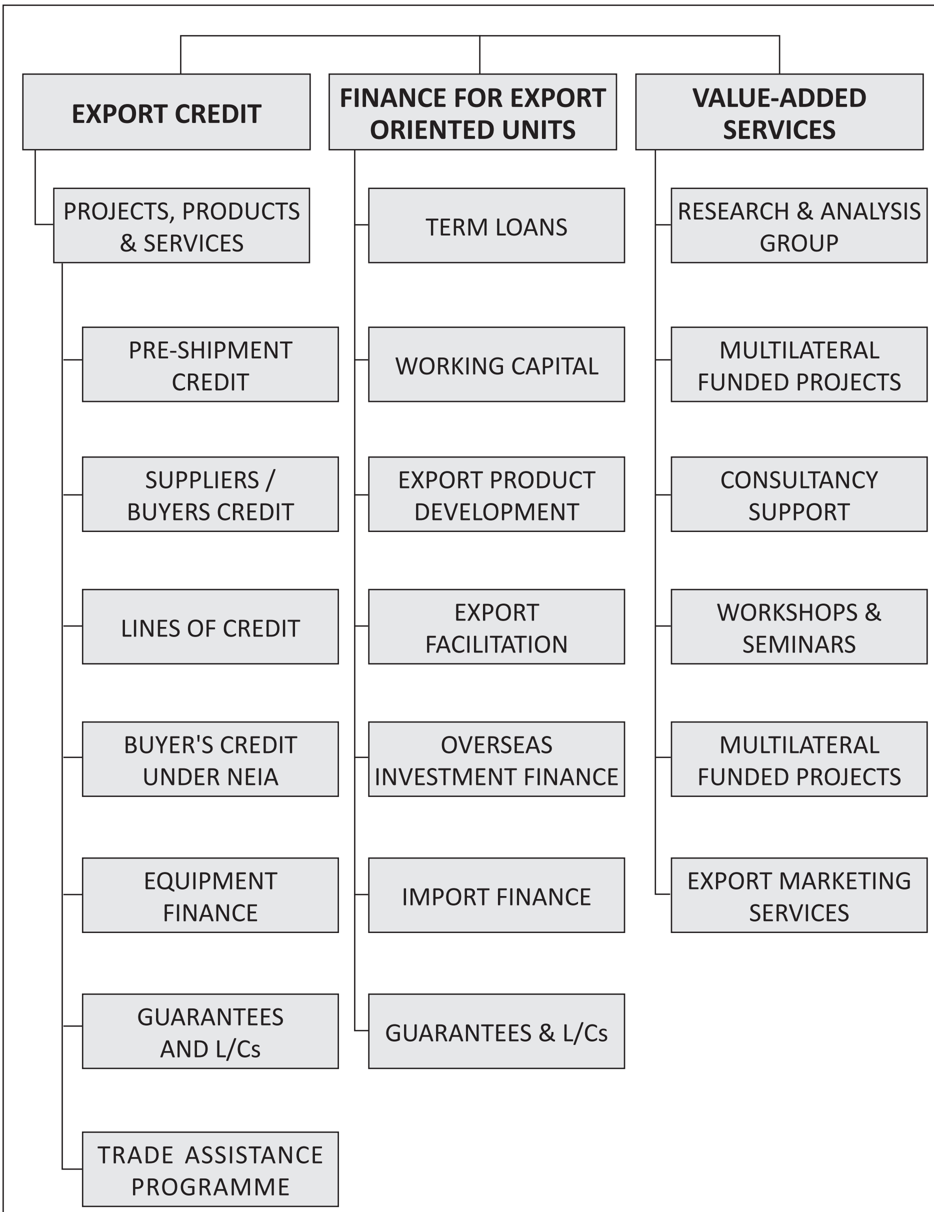

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