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Ecologically Unequal Exchange of Plastic Waste?

A Longitudinal Analysis of International Trade in Plastic Waste

Yikang Bai
Washington State University
yikang.bai@wsu.edu

Jennifer E. Givens
Utah State University
jennifer.givens@usu.edu

Abstract

Plastic production has been increasing since mass production of plastics started in the 1950s. As plastic production has continued to rise, so has plastic waste. Meanwhile, international trade in plastic waste has increased as well. The narrative about global trade in plastic waste oftentimes is that the Global North transfers waste to the Global South. However, little is known quantitatively about the extent to which the Global North shifts environmental harms of plastic waste to the Global South. We examine the extent to which global trade in plastic waste provides evidence for ecologically unequal exchange relationships from 2003 to 2013. We then explore whether plastic waste can be a resource for some countries. Specifically, we investigate how trade in plastic waste is associated with level of economic development in high-income countries and non-high-income countries. The findings provide nuanced evidence of ecologically unequal exchange relationships between high-income countries and non-high-income countries in plastic waste trade. The results also indicate that higher plastic waste import is associated with greater economic development in non-high-income countries. This research advances our understanding of the theory of ecologically unequal exchange in the context of international trade in plastic waste.

Keywords: Ecologically Unequal Exchange, Plastic Waste, Trade, Environment, Development

Plastics are widely used in many sectors throughout the world and many plastic products are used by people in their everyday lives. Plastics are produced almost entirely from chemicals from fossil fuels. Over the past fifty years, global plastic production has steadily increased. In 2012, 288 million tons of plastics were produced globally, which represented a 620% increase since 1975 (Jambeck et al. 2015). Global plastic production reached 359 million tons in 2018 (Plastics Europe 2019), a 25% increase from 2012. World plastic production will double at the current rate of increase in the next 20 years (Lebreton and Andrady 2019).

The steady increase in global plastic production and consumption in the past half century suggests that a growing amount of plastic waste is generated. The amount of plastic waste is expected to be as comparably enormous as the amount of the plastics being produced. The difference between the amount of production and that of waste results from the time lag because plastics are durable, and they may not be disposed of immediately after they are used (Jambeck et al. 2015). Despite the time lag, it is estimated that 275 million tons of plastic waste were generated in world coastal countries alone in 2010 (Jambeck et al. 2015), which indicates that the amount of global plastic waste is even higher if both landlocked and coastal countries are considered.

The majority of plastics eventually are buried in landfills or left in the natural environment. It was estimated that since the 1950s when large-scale plastic production has started, around 4900 million tons, about 60% of all plastics ever produced, were disposed of in this way (Geyer, Jambeck, and Law 2017). When plastic waste is not buried in landfills, incinerated for energy, or left in the natural environment immediately after it is used, plastic waste can be recycled and processed. Some countries, especially high-income countries, may have considerable amounts of plastic waste. It is costly to recycle and process plastic waste in high-income countries so these countries would rather sell plastic waste to other countries. Conversely, some countries, especially non-high-income countries, may need enormous amounts of plastic waste to put into plastic production. The cost of plastic waste is lower than the cost of virgin plastics. These non-high-income countries may consider plastic waste a resource they are willing to purchase from other countries.

Two Perspectives on Waste Flow

The Theory of Ecologically Unequal Exchange

Building on the concept of unequal exchange from world-systems theory and other relevant literature (Bunker 1984; 1985; Rudel 1989; Hornborg 1998a; 1998b; Roberts, Grimes and Manale 2003; Jorgenson and Rice 2005; Jorgenson 2006; Gellert, Frey, and Dahms 2017), environmental social scientists have introduced and developed the theory of ecologically unequal exchange (Røpke 2001; Roberts and Parks 2007; Hornborg 2009; Jorgenson, Austin, and Dick 2009; Jorgenson and Clark 2009a; 2009b; Austin 2010; Foster and Holleman 2014; Jorgenson 2016; Noble 2017; Givens 2018; Givens, Huang, and Jorgenson 2019; Theis 2021). The theory of ecologically unequal exchange has roots in Ricardo's classical economic concept of unequal

exchange and Marx's political economy and concept of the metabolic rift.[1] Ecologically unequal exchange focuses on how the economic structure of the world-system contributes to environmental inequality between countries. As eco-Marxists note, capitalism exploits land and labor; within the capitalist world-system, unequal relationships between more and less developed countries result in trade that favors the more powerful, more developed countries (Foster and Holleman 2014). This is a historical relationship tied to the current economic system and it is a mechanism by which wealth, *both economic and ecological*, is accumulated in wealthier countries at the expense of the less wealthy. The monetary values tied to trade obscure that equal exchange is an illusion; there is always inequality in the exchange; for example, the "exchange of more ecological use value (or nature's product) for less" (Foster and Holleman 2014: 205).

Empirical research in this tradition demonstrates that less-developed countries often face negative environmental impacts of global integration (Burns, Kick and Davis 2003; Jorgenson 2003; Shandra and Shor 2008; Jorgenson, Austin, and Dick 2009; Shandra, Shircliff, and London 2011; Jorgenson 2012). This line of research supports the claim that developed countries in the core, which have higher levels of resource consumption, shift the consumption-based environmental costs to the less-developed nations in the periphery. Less-developed countries in the periphery often depend on agricultural, extractive, and export-oriented production when they have trade with countries in the core. In other words, less-developed countries perform energy-intensive production processes for developed countries. These production processes often consume enormous natural resources and cause substantial environmental harms, thus less-developed countries are often faced with increased levels of environmental degradation. (Jorgenson and Rice 2005; Jorgenson 2006). While countries in the periphery often have to face great environmental impacts thereafter, developed countries in the core enjoy the benefits from the trade and consumption without suffering from the environmental harms. Developed countries invest heavily in energy-intensive industries in less-developed countries. By doing so, they externalize the environmental costs to less-developed countries, which suggests that the hierarchy in the world system is related to environmental inequality between countries.

A growing body of literature, which tests the perspective of ecologically unequal exchange in empirical analyses, focuses on how the economic structure of the world-system is associated with environmental degradation in less-developed countries, and researchers maintain that the status of nations in the world system is related to differential environmental impacts (Burns, Kick, and Davis 2003; Jorgenson 2003). Non-core countries, which depend on export-oriented production, consume enormous domestic natural resources and, as a result, produce environmental harms, especially in recent years. The semi-peripheral position in the world-system is associated with intense deforestation and higher carbon dioxide and methane emissions (Burns et al. 1994; Kick et al. 1996; Burns, Davis, and Kick 1997; Roberts, Grimes, and Manale 2003). Prior studies have applied the perspective of ecologically unequal exchange to examining e-waste flow (Frey 2012b), and they posit that developed countries shift energy-intensive production processes to less-

[1] For a detailed historical background, see Foster and Holleman 2014; see also Hornborg 2014; 2015.

developed countries. Developed countries also externalize the cost of waste management by transferring the wastes to less-developed countries (Frey 2012a; 2012b), and thus less-developed countries are a tap for resources and a sink for wastes. However, much less is known about whether the structure of the world economy is likely to contribute to the disposal of other forms of environmental harms in less-developed countries. This article fills the gap by examining the flow of plastic waste, another increasingly important type of waste flow.

Another Perspective: Waste is A Resource

The Institute of Scrap Recycling Industries, a U.S.-based non-profit trade association, has pointed out that waste is bought rather than sold because there is a legitimate market for waste (McVeigh 2018). Taking non-high-income countries' considerations when they import plastic waste into account improves studies of international trade in plastic waste, which tend to focus on high-income countries' shifting potential environmental hazards to non-high-income countries and thus cannot capture the whole picture. In other words, studies on international plastic waste trade from the perspective of ecologically unequal exchange should not only explore the flow of plastic waste between countries, especially the flow from high-income countries to non-high-income countries, but also examine the background and motives for trading plastic waste. Non-high-income countries' motives for buying plastic waste should be of great interest to researchers. The rationale for non-high-income countries to import plastic waste from other countries, especially from high-income countries, which previously has received little attention in studies of ecologically unequal exchange, should be brought into the discussion.

Some electronic waste scholars contend that a thorough understanding of "the character, distribution, and scale of harms and benefits arising from global flows of e-waste" (Lepawsky 2018: 13) requires us to change the simplified narrative that the Global North dumps waste on the Global South. E-waste is of practical usefulness in less affluent countries and the disposal of e-waste does not happen immediately after it is imported from affluent countries. Rather, when the disposal of e-waste does happen in less affluent countries, it is after several rounds of repair, reuse and materials recovery (Lepawsky 2018). What is considered e-waste in high-income countries could be an important resource for many non-high-income countries where new electronic devices are often not affordable for many people. Many electronic devices, such as cellphones, laptops, computers, printers and copy machines, which have been imported as e-waste from affluent countries, are still fully functional. Other electronic devices, which have been imported as e-waste, can become functional after repair and refurbishment and thus are useful. In other words, non-high-income countries often consider e-waste a resource when they import it. In less affluent countries, it is often after making use of some components of these imported used electronic devices that e-waste is discarded, albeit often in ways that are highly detrimental to environmental and human well-being. This study conducts similar analyses of trade in plastic waste.

Data and Methods

Data

National level data for the analyses come from the United Nations Comtrade Database (UN Comtrade 2019) and the World Bank's World Development Indicators (World Bank 2019). We selected the time periods from 2003 to 2013 because we could obtain the largest number of countries with both plastic waste import data and plastic waste export data over these eleven years. This balanced panel dataset includes 85 countries/regions, listed in Table 1.

Plastic waste import and plastic waste export data are from the UN Comtrade Database. The UN Comtrade Database utilizes Harmonized Commodity Description and Coding Systems (HS) to classify traded goods. Using the codes from the Harmonized System (HS), countries can report trade data corresponding to each type of the traded goods. We used the 4-digit code 3915 to extract plastic waste data from the UN website. The plastic waste in this category includes waste, parings and scrap of ethylene polymers, styrene polymers, vinyl chloride polymers, and other types of plastics. In other words, the UN Comtrade provides the data of waste of polyethylene (PE), polystyrene (PS), polyvinyl chloride (PVC), and other plastics.

Table 1. Countries/Regions Included in the Analyses

High-Income Countries/Regions (45)		Non-High-Income Countries (40)	
Australia	Norway	Albania	Paraguay
Austria	Oman	Bangladesh	Peru
Bahrain	Poland	Belarus	Philippines
Barbados	Portugal	Bolivia	Romania
Belgium	Russian Federation	Bosnia Herzegovina	South Africa
Canada	Saudi Arabia	Botswana	Sri Lanka
Chile	Singapore	Brazil	Tanzania
Hong Kong SAR, China	Slovakia	Bulgaria	Thailand
Croatia	Slovenia	China	Tunisia
Czech	Spain	Colombia	Turkey
Denmark	Sweden	Costa Rica	Ukraine
Estonia	Switzerland	Dominican Republic	Viet Nam
Finland	Trinidad and Tobago	Ecuador	
France	U.S.	El Salvador	
Germany	United Arab Emirates	Guatemala	
Greece	United Kingdom	Hungary	
Iceland	Uruguay	India	
Ireland		Indonesia	
Israel		Jamaica	
Italy		Kazakhstan	
Japan		Lebanon	
Korea, Rep		Malaysia	
Latvia		Mexico	
Lithuania		Morocco	
Luxembourg		Namibia	
Malta		Nicaragua	
Netherlands		Pakistan	
New Zealand		Panama	

Dependent Variable for the First Set of Analyses

The dependent variables for the first set of analyses are plastic waste import trade value in U.S. dollars and plastic waste export trade value in U.S. dollars. These data, obtained from the United Nations Comtrade Database (UN Comtrade 2019), indicate the trade value of imported and exported plastic waste. These data measure the magnitude of plastic waste import and plastic waste export for each country.

Independent Variables for the First Set of Analyses

The key independent variable of interest in this study is the percentage of exports to high-income countries. These data, obtained from the World Bank's World Development Indicators (World Bank 2019), represent the share of merchandise export to high-income countries of total merchandise exports. This independent variable is a measure of the vertical flow of exports, which has been commonly employed in previous studies that test hypotheses derived from the theory of ecologically unequal exchange (Rice 2007; Shandra, Leckband, and London 2009; Shandra et al. 2009; Jorgensen 2012; Givens 2018).

We also include percentage of exports to low and middle-income countries outside the region and percentage of exports to low and middle-income countries within the region. The key independent variable of interest in this study and in previous studies is the percentage of exports to high-income countries, which is used to indicate the level of ecologically unequal exchange relationships. However, prior studies have not given enough attention to trade relationships with non-high-income countries. As demand for recycled plastics in non-high-income countries has increased, trade between those countries has flourished. Nowadays, not only do high-income countries export plastic waste to non-high-income countries, but non-high-income countries also have more frequent trade with other non-high-income countries. In the following analyses of the panel data of non-high-income countries, we include percentage of exports to low and middle-income countries outside the region and percentage of exports to low and middle-income countries within the region. Within the region where most high-income countries are located, there are few non-high-income countries. Therefore, there is not much data with regard to percentage of high-income countries' export to low and middle-income countries within the region since this situation does not apply to most high-income countries. Therefore, in the analyses of the panel data of high-income countries, we only include percentage of exports to low and middle-income countries outside the region.

We include GDP per capita in constant 2010 dollars, which is a measure of a country's level of economic development. Higher GDP per capita in the country indicates higher levels of economic development. GDP per capita is widely used in cross-national studies which test hypotheses derived from the theory of ecologically unequal exchange.

Also included in the panel regression analyses are export as percentage of GDP, manufacturing as percentage of GDP, and industry as percentage of GDP. Export as percentage of GDP measures the level of a country's integration in the world economy. Manufacturing as percentage of GDP and industry as percentage of GDP measure the share of the secondary sector

and industry in the country's economy. All variables in the analyses are logged. Table 2 and Table 3 provide the descriptive statistics of the variables included in the analyses of non-high-income countries and high-income countries respectively.

Table 2. Descriptive Statistics for 40 Non-High-Income Countries

Descriptive Statistics	Obs.	Mean	Std. dev.	Min	Max
Plastic Waste Import Trade Value in $ (ln)	440	6.075	1.054	1.431	9.806
Plastic Waste Export Trade Value in $ (ln)	440	6.415	.929	2.090	8.472
% of export to high-income countries (ln)	440	1.813	.107	1.468	1.981
% of export to low and middle-income countries outside region (ln)	439	.859	.458	-1.262	1.533
% of export to low and middle-income countries inside region (ln)	418	1.204	.371	.222	1.800
GDP per capita (ln)	440	3.592	.324	2.754	4.142
Export as % of GDP (ln)	440	1.526	.208	1.035	2.062
Manufacturing as % of GDP (ln)	439	1.166	.179	.615	1.511
Industry as % of GDP (ln)	440	1.457	.107	1.148	1.686

Table 3. Descriptive Statistics for 45 High-Income Countries/Regions

Descriptive Statistics	Obs.	Mean	Std. dev.	Min	Max
Plastic Waste Import Trade Value in $ (ln)	495	6.756	1.056	2.276	9.269
Plastic Waste Export Trade Value in $ (ln)	495	7.079	1.069	.845	9.087
% of export to high-income countries (ln)	495	1.865	.098	1.450	1.984
% of export to low and middle-income countries outside region (ln)	495	1.271	.287	.565	1.818
GDP per capita (ln)	495	4.463	.263	3.890	5.049
Export as % of GDP (ln)	484	1.672	.269	.956	2.360
Manufacturing as % of GDP (ln)	483	1.127	.221	.149	2.117
Industry as % of GDP (ln)	492	1.410	.171	.827	1.855

Dependent Variable for the Second Set of Analyses

The dependent variable for the second set of analyses is GDP per capita in constant 2010 U.S. dollars, which is a measure of countries' level of economic development.

Independent Variables for the Second Set of Analyses

The key independent variables of interest are trade value of plastic waste import and trade value of plastic waste export in U.S. dollars.

In order to assess how the relationship between plastic waste trade and GDP per capita change over time, we include a set of interactions between plastic waste import and dummy variables for each year where 2003 is the reference category. We also include a set of interactions between plastic waste export and dummy variables for each year where 2003 is the reference category.

Percentage of exports to high-income countries is also included in the second set of analyses. As with the first set of analyses, in the analyses of the panel data of non-high-income countries, we include percentage of exports to low and middle-income countries outside the region, and percentage of exports to low and middle-income countries within the region. In the analyses of the panel data of high-income countries, we include percentage of exports to low and middle-income countries outside the region.

Analytic Strategy

We use Prais-Winsten regression with panel corrected standard errors (PCSE) and an AR(1) correction. The general model is: $y_{it} = Bx_{it} + u_i + w_t + e_{it}$. The subscript i represents each unit of analysis (i.e., country), and the subscript t represents the time period (i.e., year). The term on the left side of the equation, y_{it}, indicates the dependent variable for each country at each time period. Bx_{it} represents the vector of coefficients for predictor variables that vary over time, u_i is the unit-specific (i.e., country-specific) disturbance term, w_t is the period-specific disturbance term that is constant across all countries, and e_{it} is the disturbance term unique to each country at each point in time. We use dummy variables to control for country-specific and period-specific disturbance terms. Country-specific dummy variables control for potential unobserved heterogeneity that is temporally invariant within countries (unit-specific intercepts). Period-specific dummy variables control for potential unobserved heterogeneity that is cross-sectionally invariant within periods (period-specific intercepts). Employing both country-specific dummy variables and period-specific dummy variables makes the model function as a two-way fixed effects model. As all variables are logged, the estimated coefficients are elasticity coefficients. A one percent change in the independent variable is associated with an estimated percent change in the dependent variable.

To better understand whether trade in plastic waste has a different relationship with economic development based on a country's level of economic development, we classify countries into two groups: high-income countries and non-high-income countries. We use World Bank 2013 classification (World Bank 2013) to group the countries. Countries that met the 2013 World Bank criterion of high-income countries are grouped together, while countries that did not meet the 2013 World Bank criterion of high-income countries are put together in the group of non-high-income countries. High income countries are identified as those countries that their GNI per capita exceeds $12,745 and non-high-income countries are countries that their GNI per capita is below $12,745 in 2013. Using this criterion, 45 high-income countries and 40 non-high-income countries are included in the analyses. In the following analyses, we examine the two groups separately.

In the first set of analyses, we also included plastic waste import weight in kilograms and plastic waste export weight in kilograms as the dependent variable respectively. We did not find substantive differences in the results compared to the analyses with plastic waste trade value as the dependent variable. The second set of analyses also included plastic waste import weight and plastic waste export weight as the independent variable respectively. The results were substantively the same as those from the analyses with plastic waste trade value as the independent variable. The results of the analyses with plastic waste import weight and plastic waste export weight are available on request from the first author.

Results And Discussion

Table 4 and Table 5 present the findings for the analyses of 40 non-high-income countries. We report unstandardized coefficients and standard errors of all the predictors. The tables also present r-squared values, number of observations, number of countries, and rho for each estimated model. All six models in the tables include unreported country-specific and year-specific intercepts.

Model 1, which includes percentage of exports to high-income countries and GDP per capita, is the baseline model. Model 2 adds two other variables: percentage of exports to low and middle-income countries outside the region, and percentage of exports to low and middle-income countries within the region. Building on Model 1, Model 3 adds export as percentage of GDP. Model 4 introduces percentage of exports to low and middle-income countries outside the region, and percentage of exports to low and middle-income countries within the region to Model 3. Model 5 adds manufacturing as percentage of GDP and industry as percentage of GDP to Model 3. Model 6 combines Model 5 with two other variables: percentage of exports to low and middle-income countries outside the region, and percentage of exports to low and middle-income countries within the region.

Most countries have observations of all the variables in each year of the eleven-year period. However, some countries may not have observations of certain variables in certain years. Due to missing data, the estimated models that include percentage of exports to low and middle-income countries outside the region, percentage of exports to low and middle-income countries within the region, or manufacturing as percentage of GDP use an unbalanced panel dataset.

We first discuss the results from the estimated models with plastic waste import trade value as the dependent variable. Results in Table 4 indicate that GDP per capita, export as percentage of GDP, and manufacturing as percentage of GDP are positively associated with the trade value of plastic waste import. When levels of economic development in non-high-income countries rise, domestic demand for products made from plastics increases. Meanwhile, when the economy of non-high-income countries flourishes, infrastructure investment often increases and manufacturing industries grow as well, which suggests that the demand for plastics greatly increases.

Table 4. Regression of Plastic Waste Import Trade Value, 2003-2013, Two-Way Fixed Effects PW Regression Model Estimates for 40 Non-High-Income Countries.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
% of export to high-income countries	-1.632**	-1.297*	-1.775**	-1.368*	-1.845**	-1.620*
	(.627)	(.590)	(.652)	(.600)	(.634)	(.626)
% of export to low and middle-income countries outside the region		-.357**		-.373**		-.414***
		(.112)		(.109)		(.111)
% of export to low and middle-income countries inside the region		.356*		.409**		.294†
		(.168)		(.156)		(.150)
GDP per capita	1.674**	2.036**	1.858***	2.202***	2.021***	2.366***
	(.557)	(.651)	(.517)	(.618)	(.546)	(.671)
Export as % of GDP			1.076**	1.199**	1.069**	1.216**
			(.355)	(.361)	(.371)	(.378)
Manufacturing as % of GDP					1.282†	1.462*
					(.670)	(.695)
Industry as % of GDP					-.659	-.969
					(1.009)	(.991)
R-squared	.833	.841	.837	.847	.838	.848
N	440	417	440	417	439	416
Number of countries	40	38	40	38	40	38
Rho	.376	.392	.357	.362	.364	.357

***p<.001. **p<.01. *p<.05. † p < .10; standard errors in parentheses; all models include unreported country-specific and year-specific intercepts.

In order to meet this demand, non-high-income countries may need to import recycled plastics. This could explain why GDP per capita and manufacturing as percentage of GDP are positively associated with the trade value of plastic waste import. The positive association between export as percentage of GDP and plastic waste import trade value may indicate that when the share of export is large in non-high-income countries' GDP, these countries may export greater amounts of products made from plastics. Imported plastic waste could be an important source of obtaining plastic materials for these production processes in the non-high-income countries.

Table 5. Regression of Plastic Waste Export Trade Value, 2003-2013, Two-Way Fixed Effects PW Regression Model Estimates for 40 Non-High-Income Countries.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
% of export to high-income countries	-.170	1.201*	-.209	1.182*	-.329	1.070†
	(.603)	(.575)	(.606)	(.580)	(.532)	(.580)
% of export to low and middle-income countries outside the region		.122		.117		.108
		(.100)		(.100)		(.101)
% of export to low and middle-income countries inside the region		1.036***		1.058***		1.023***
		(.158)		(.156)		(.181)
GDP per capita	.258	.585	.300	.647	.761	.885
	(.516)	(.542)	(.511)	(.550)	(.609)	(.614)
Export as % of GDP			.297	.511†	.353	.482†
			(.341)	(.283)	(.261)	(.287)
Manufacturing as % of GDP					1.561**	.446
					(.575)	(.658)
Industry as % of GDP					-1.063†	.079
					(.546)	(.656)
R-squared	.824	.835	.824	.836	.827	.838
N	440	417	440	417	439	416
Number of countries	40	38	40	38	40	38
Rho	.395	.357	.387	.354	.369	.349

***p<.001. **p<.01. *p<.05. †p<.10; standard errors in parentheses; all models include unreported country-specific and year-specific intercepts

Percentage of exports to low and middle-income countries outside the region is negatively associated with the trade value of plastic waste import. This indicates that, for non-high-income countries, export to other non-high-income countries outside the region is not associated with greater amount of plastic waste import. However, percentage of exports to low and middle-income countries within the region is positively associated with the trade value of plastic waste import. This suggests that, for non-high-income countries, thriving trade with other non-high-income countries in the same region is associated with higher trade value of plastic waste import.

Percentage of exports to high-income countries is negatively associated with plastic waste import trade value. Taken together with the positive association with percentage of exports to low and middle-income countries within the region, the results suggest that non-high-income countries may be more likely to import recycled plastics from other non-high-income countries in the same region.

We next examine the results from the estimated models with plastic waste export trade value as the dependent variable. Results in Table 5 show that export as percentage of GDP is marginally significant. It is positively associated with the trade value of plastic waste export.

Percentage of exports to low and middle-income countries within the region is positively associated with the trade value of plastic waste export. This indicates that, for non-high-income countries, fast-growing trade with other non-high-income countries in the same region is associated with higher trade value of plastic waste export.

For non-high-income countries, the results in Table 4 and Table 5 together suggest that the vertical flow of exports to high-income countries is not positively associated with the import of plastic waste. Rather, the vertical flow of exports to other non-high-income countries in the same region is positively associated with plastic waste import and plastic waste export. In other words, the results suggest that non-high-income countries may be more likely to trade recycled plastics with other non-high-income countries in the same region.

Tables 6 and 7 present the findings for the analyses of 45 high-income countries. Unstandardized coefficients and standard errors of all the predictors are reported. R-squared values, number of observations, number of countries, and rho for each estimated model are also presented. All the six models in the tables include unreported country-specific and year-specific intercepts.

Model 1, which includes percentage of exports to high-income countries and GDP per capita, is the baseline model. Building on Model 1, Model 2 adds another variable: percentage of exports to low and middle-income countries outside the region. Model 3 adds exports as percentage of GDP to Model 1. Model 4 introduces percentage of exports to low and middle-income countries outside the region to Model 3. Model 5 adds manufacturing as percentage of GDP and industry as percentage of GDP to Model 3. Model 6 combines Model 5 with another variable: percentage of exports to low and middle-income countries outside the region.

The estimated models that include exports as percentage of GDP, manufacturing as percentage of GDP, or industry as percentage of GDP use an unbalanced panel dataset because of missing data.

Table 6. Regression of Plastic Waste Import Trade Value, 2003-2013, Two-Way Fixed Effects PW Regression Model Estimates for 45 High-Income Countries.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
% of export to high-income countries	.878	1.041	1.100†	1.174†	1.429**	1.623**
	(.563)	(.646)	(.566)	(.638)	(.499)	(.552)
% of export to low and middle-income countries outside the region		.188		.106		.252
		(.273)		(.265)		(.261)
GDP per capita	1.294**	1.321**	1.516**	1.523**	1.727***	1.748***
	(.457)	(.460)	(.450)	(.453)	(.434)	(.438)
Export as % of GDP			.435	.421	.724	.695
			(.558)	(.548)	(.457)	(.445)
Manufacturing as % of GDP					-1.157**	-1.187**
					(.396)	(.395)
Industry as % of GDP					.923	.985†
					(.581)	(.598)
R-squared	.922	.922	.920	.920	.924	.924
N	495	495	484	484	481	481
Number of countries	45	45	44	44	44	44
Rho	.410	.405	.395	.392	.419	.418

***p<.001. **p<.01. *p<.05. †p < .10; standard errors in parentheses; all models include unreported country-specific and year-specific intercepts.

We first discuss the results from the estimated models with plastic waste import trade value as the dependent variable. Results in Table 6 show that GDP per capita and industry as percentage of GDP are positively associated with the trade value of plastic waste import. Manufacturing as percentage of GDP is negatively associated with the trade value of plastic waste import. When levels of economic development in high-income countries rise, these countries are more likely to increase plastic waste import. The negative association between manufacturing as percentage of GDP and plastic waste import implies that in high-income countries, manufacturing industries may not need to import recycled plastics for their production. Since virgin plastics are readily available in high-income countries and the price of virgin plastics is relatively low, manufacturing industries are more likely to use new plastics.

Table 7. Regression of Plastic Waste Export Trade Value, 2003-2013, Two-Way Fixed Effects PW Model Estimates for 45 High-Income Countries.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
% of export to high-income countries	2.260*	2.388*	2.109†	2.256*	2.809**	3.032**
	(1.032)	(.921)	(1.076)	(.956)	(1.070)	(.925)
% of export to low and middle-income countries outside the region		.144		.194		.270
		(.327)		(.360)		(.360)
GDP per capita	.425	.443	.549	.560	.877*	.900*
	(.441)	(.455)	(.502)	(.503)	(.435)	(.439)
Export as % of GDP			.348	.328	.937†	.920†
			(.578)	(.560)	(.531)	(.513)
Manufacturing as % of GDP					-1.921**	-1.961**
					(.675)	(.677)
Industry as % of GDP					.664	.750
					(.897)	(.893)
R-squared	.894	.894	.892	.892	.895	.895
N	495	495	484	484	481	481
Number of countries	45	45	44	44	44	44
Rho	.459	.453	.452	.448	.468	.460

***p<.001. **p<.01. *p<.05. † p < .10; standard errors in parentheses; all models include unreported country-specific and year-specific intercepts.

Percentage of exports to high-income countries is positively associated with the trade value of plastic waste import. This positive association suggests that when the share of exports to high-income countries increases, high-income countries may increase plastic waste import.

We then investigate the results from the estimated models with plastic waste export trade value as the dependent variable. Results in Table 7 show that GDP per capita is positively associated with the trade value of plastic waste export. Percentage of exports to high-income countries is positively associated with the trade value of plastic waste export. This positive association suggests that when the share of exports to high-income countries increases, high-income countries may increase plastic waste export.

For high-income countries, the results in Table 6 and 7 together indicate that when levels of economic development rise, plastic waste trade in these countries are more likely to increase. When the share of exports to high-income countries increases, plastic waste trade in high-income countries tends to expand.

The results from the previous set of analyses do not offer strong evidence of ecologically unequal exchange relationships in plastic waste trade between high-income countries and non-high-income countries. These findings suggest that although non-high-income countries are often

depicted as the destination of waste from rich countries, the generalization that the Global North transfers plastic waste to the Global South cannot capture the nuances in the flow of plastic waste from high-income countries to non-high-income countries. In other words, plastic waste trade between high-income countries and non-high-income countries should not be simply understood as the transfer of plastic waste from the Global North to the Global South.

It is undeniable that when high-income countries export plastic waste to non-high-income countries, they certainly shift potential environmental harms to those less affluent countries. However, the discussion of global trade in plastic waste is severely limited in scope if the focus is only on the Global North dumping waste on the Global South. A deeper and more thorough understanding of global trade in plastic waste from the perspective of ecologically unequal exchange requires us to examine the background and motives for importing and exporting plastic waste, especially non-high-income countries' motives for importing plastic waste. If plastic waste has no use for non-high-income countries, it is unlikely that those countries would want to import immense amount of plastic waste. The following analyses empirically test whether plastic waste trade has a different relationship with the level of economic development for high-income countries versus non-high-income countries.

Table 8 reports the findings for plastic waste import trade value. In the estimated models for non-high-income countries, the main effect of plastic waste import trade value on GDP per capita is negative. However, the association between plastic waste import trade value and GDP per capita became positive in 2005 and continued to be positive till 2013 for non-high-income countries. This result shows that plastic waste import is positively associated with economic growth in non-high-income countries. Turning to high-income countries in Table 8, although the main effect of plastic waste import trade value on GDP per capita was positive in 2003, it has become less positive since 2007. Taken together, the findings do not present a prevailing trend in the relationship between plastic waste import and GDP per capita for high-income countries.

Table 9 presents the findings for plastic waste export trade value. In the estimated models for non-high-income countries, the effect of plastic waste export trade value on GDP per capita was positive in 2012 and 2013. The results do not show a prevailing trend in the relationship between plastic waste export trade value and GDP per capita. Turning to high-income countries in Table 9, the relationship between plastic waste export trade value and GDP per capita was negative from 2006 to 2009 and it was also negative from 2012 to 2013. The overall trend is that plastic waste export is negatively associated with GDP per capita in high-income countries.

Table 8 Regression of GDP per capita, 2003-2013, on Plastic Waste Import Trade Value and Other Selected Independent Variables: Two-Way Fixed Effects PW Model Estimates for 40 Non-High-Income Countries and 45 High-Income Countries

	Non-high-income countries	High-income countries
Plastic Waste Import Trade Value	-.005†	.008*
	(.003)	(.004)
Plastic Waste Import Trade Value x 2004	.003	.002
	(.002)	(.002)
Plastic Waste Import Trade Value x 2005	.005*	-.0004
	(.002)	(.001)
Plastic Waste Import Trade Value x 2006	.006*	-.003
	(.002)	(.002)
Plastic Waste Import Trade Value x 2007	.007*	-.004†
	(.002)	(.002)
Plastic Waste Import Trade Value x 2008	.007*	-.006***
	(.002)	(.002)
Plastic Waste Import Trade Value x 2009	.013***	-.006**
	(.003)	(.002)
Plastic Waste Import Trade Value x 2010	.013***	-.003*
	(.003)	(.002)
Plastic Waste Import Trade Value x 2011	.018***	-.001
	(.003)	(.002)
Plastic Waste Import Trade Value x 2012	.022***	-.003†
	(.003)	(.002)
Plastic Waste Import Trade Value x 2013	.022***	-.005***
	(.003)	(.001)
Plastic Waste Export Trade Value	.002	.001
	(.002)	(.003)
% of export to high-income countries	.076**	-.100
	(.028)	(.064)
% of export to low and middle-income countries outside the region	.002	-.017
	(.005)	(.018)
% of export to low and middle-income countries inside the region	.008	
	(.010)	
R-squared	.999	.999
N	417	495
Number of countries	38	45
Min./mean/max. obs. Per country	10/11/11	11/11/11
Rho	.668	.666

***p<.001. **p<.01. *p<.05. † p < .10; standard errors in parentheses; all models include unreported country-specific and year-specific intercepts.

Table 9 Regression of GDP per capita, 2003-2013, on Plastic Waste Export Trade Value and Other Selected Independent Variables: Two-Way Fixed Effects PW Model Estimates for 40 Non-High-Income Countries and 45 High-Income Countries

	Non-high-income countries	High-income countries
Plastic Waste Export Trade Value	.002	.006
	(.002)	(.004)
Plastic Waste Export Trade Value x 2004	.0006	-.00009
	(.001)	(.001)
Plastic Waste Export Trade Value x 2005	.0005	-.002
	(.002)	(.001)
Plastic Waste Export Trade Value x 2006	-.0005	-.005**
	(.002)	(.002)
Plastic Waste Export Trade Value x 2007	-.0003	-.007**
	(.002)	(.002)
Plastic Waste Export Trade Value x 2008	-.003	-.008***
	(.002)	(.002)
Plastic Waste Export Trade Value x 2009	.00009	-.007**
	(.002)	(.003)
Plastic Waste Export Trade Value x 2010	.0009	-.004
	(.002)	(.002)
Plastic Waste Export Trade Value x 2011	.001	-.002
	(.002)	(.002)
Plastic Waste Export Trade Value x 2012	.005**	-.005**
	(.002)	(.002)
Plastic Waste Export Trade Value x 2013	.005*	-.006***
	(.002)	(.002)
Plastic Waste Import Trade Value	.004*	.004
	(.002)	(.004)
% of export to high-income countries	.066*	-.096
	(.027)	(.065)
% of export to low and middle-income countries outside the region	.003 (.004)	-.015 (.017)
% of export to low and middle-income countries inside the region	.012 (.010)	
R-squared	.999	.999
N	417	495
Number of countries	38	45
Min./mean/max. obs. Per country	10/11/11	11/11/11
Rho	.677	.692

***p<.001. **p<.01. *p<.05. † p < .10; standard errors in parentheses; all models include unreported country-specific and year-specific intercepts.

Conclusion

The theory of ecologically unequal exchange contends that the unbalanced trade structure between developed countries and less-developed countries contributes to the externalization of environmental harms from developed countries to less-developed countries. Developed countries benefit environmentally from the trade with less-developed countries, while less-developed countries often have to carry the burden of environmental degradation.

The results from the previous analyses provide some evidence of ecologically unequal exchange relationships between high-income countries and non-high-income countries when it comes to global trade in plastic waste. Clearly, when countries are importing plastic waste, whether it is reused or dumped, they are importing environmental harms. However, findings from the second set of analyses show that trade in plastic waste has a different relationship with the level of economic development for high-income countries and non-high-income countries. Plastic waste export is negatively associated with GDP per capita for high-income countries. This result indicates that trade in plastic waste does not facilitate economic growth in high-income countries. However, plastic waste import in non-high-income countries tells a different story. Plastic waste import trade value is positively associated with GDP per capita from mid 2000s to 2013 for non-high-income countries. This result indicates that plastic waste import is positively associated with economic development, which suggests that plastic waste, while clearly an environmental harm, is also a valuable resource for non-high-income countries. This article highlights the necessity to broaden our perspective when studying global trade in plastic waste. Our results show there is a legitimate market for plastic waste, especially in non-high-income countries.

This article enriches our understanding of the theory of ecologically unequal exchange in the context of global trade in plastic waste. Although plastic waste import is positively associated with economic development and therefore plastic waste could first and foremost be considered a resource for non-high-income countries, environmental pollution and degradation associated with plastic waste processing is very likely to occur in those non-high-income countries. Severe air and water pollution was documented in the Chinese city which was once the heart of plastic waste processing industry in China (Minter 2013). Additionally, when disposed of improperly, non-recyclable plastic waste and other trash, which is often mingled in imported plastic waste, is harmful to the environment as well as human well-being in non-high-income countries, which supports the negative well-being impacts in non-high income countries identified by the theory of ecologically unequal exchange (Rice 2008; Global Alliance for Incinerator Alternatives 2019). This indicates that ultimately ecologically unequal exchange relationships still exist between high-income countries and non-high-income countries. This is in line with Foster and Holleman, who cite Marx (paraphrasing John Stuart Mill) and make the point that despite the gains of the poorer countries, they are still being exploited by the wealthier countries in these trade relationships (Foster and Holleman 2014). Policy implications include regulations on plastic waste trade, including regulating the inclusion of contaminants that cannot be reused and the disposal of such materials.

One limitation is that the data on plastic waste in this study may be far from accurate and exhaustive, although the data is currently the most comprehensive one that is available. There could be errors when a country reports plastic waste trade data to the UN. Also, since hazardous waste, such as e-waste, can be falsely labeled as non-hazardous product when it is exported to the recipient countries (Pellow 2007), these data could underestimate the actual volume of waste trade because official statistics on plastic waste trade may not cover these clandestine practices.

Future research should extend this examination of ecologically unequal exchange and the global trade in plastic waste. Previous studies on ecologically unequal exchange focus on examining trade relationships between high-income countries and non-high-income countries. Results in this study suggest that trade between non-high-income countries in the same region and trade between high-income countries could also be important trade relationships warranting further examination in future studies. Recent studies on e-waste trade contend that in general less-developed countries are major importers of e-waste from developed countries (Frey 2012a; 2012b). However, global e-waste trade in recent years is increasingly conducted intra-regionally in developed countries and inter-regionally in developing countries (Lepawsky and McNabb 2010; Lepawsky 2015a; 2015b). The findings from this study and e-waste studies suggest that future studies could examine plastic waste trade between non-high-income countries as well as plastic waste trade between high-income countries, and attend to changes as patterns in global plastic waste trade change over time.

About the Authors: Yikang Bai's research interests include environmental sociology and global and comparative sociology. His current research examines the relationship between the structure of international trade and the transfer of environmental hazards across nations. **Jennifer E. Givens** is an Assistant Professor of Sociology at Utah State University. As an environmental and comparative international sociologist, she studies relationships between the environment, human well-being, global inequality, and development. She also studie s environmental and climate change concern, actions, and policy support, both within and across nations. Her research appears in journals such as *Environmental Sociology*, *Sociology of Development*, *Sociology Compass*, *Society and Natural Resources*, and *Energy Research and Social Science*.

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