Institute for Economic Studies, Keio University

Keio-IES Discussion Paper Series

日本のリサイクル資源貿易

大久保敏弘、渡部雄太、古山香織

2015 年 12 月 15 日
DP2015-014
http://ies.keio.ac.jp/publications/4828

Institute for Economic Studies, Keio University
2-15-45 Mita, Minato-ku, Tokyo 108-8345, Japan
ies-office@adst.keio.ac.jp
15 December, 2015

日本のリサイクル資源貿易

大久保敏弘、渡部雄太、古山香織

IES Keio DP 2015-014
2015 年 12 月 15 日
JEL Classification: F18; L51; Q56
キーワード: environmental regulations; recyclable waste resources; waste haven;

【要旨】

In this paper, we study the waste haven hypothesis that waste materials are exported to developing countries. Using Japanese trade data on recyclable waste resources (plastic waste, waste paper, iron and steel scrap, and nonferrous metal scraps), we find evidence from our econometric analysis that Asian countries provide a waste haven for Japan. In particular, Japan exports waste materials to Asian countries with low per-capita incomes and large markets. We suggest that environmental regulation should be tightened to reduce traded waste in Asia.

大久保敏弘
慶應義塾大学経済学部
〒108-8345
東京都港区三田2-15-45
okubo@econ.keio.ac.jp

渡部雄太
慶應義塾大学経済学部
〒108-8345
東京都港区三田2-15-45
yutawatabe@gmail.com

古山香織
独立行政法人　国際協力機構
〒162-8433
東京都千代田区二番町5-25　二番町センタービル　1階から6階
kfuruyama.930@gmail.com

Export of Recyclable Materials: Evidence from Japan

Toshihiro Okubo
Keio University
Faculty of Economics
2-15-45 Mita Minato-ku Tokyo, 108-8345, Japan
E-mail: okubo@econ.keio.ac.jp

Yuta Watabe
Keio University
Faculty of Economics
2-15-45 Mita Minato-ku Tokyo, 108-8345, Japan
E-mail: yutawatabe@gmail.com

Kaori Furuyama
Japan International Cooperation Agency (JICA)-
E-mail: kfuruyama.930@gmail.com

Abstract

In this paper, we study the waste haven hypothesis that waste materials are exported to developing countries. Using Japanese trade data on recyclable waste resources (plastic waste, waste paper, iron and steel scrap, and nonferrous metal scraps), we find evidence from our econometric analysis that Asian countries provide a waste haven for Japan. In particular, Japan exports waste materials to Asian countries with low per-capita incomes and large markets. We suggest that environmental regulation should be tightened to reduce traded waste in Asia

JEL: F18, L51, Q56

Keywords: waste haven, recyclable waste resources, environmental regulations.

Acknowledgement

The authors would like to thank Suresh Narayanan, Chia Siow Yue and other participants at the Asian Economic Panel Meeting for helpful and suggestive comments.

1. Introduction

Stringent environmental regulations in industrialised countries can lead to a dramatic rise in the cost of waste disposal. This motivates the export of waste from developed to developing countries. Growing worldwide debate on the surging trade in waste led to the Basel Convention in 1989, which was ratified not only by developed countries, but also by many Asian developing countries. One of its most important aims is to regulate transboundary waste shipments.[1] Nevertheless, Asia has the largest trade in waste flows in the world, which are driven by the demand for and supply of recyclable resources.[2] Asian developing countries have a large demand for waste and recyclable resources because their rapid economic growth has led to a shortage of natural resources. Large low-income countries such as China and India have particularly high demand for natural resources.[3] On the supply side, although high-income countries such as Japan legitimately implement stringent regulations for recycling and waste disposal, this raises the cost of waste disposal. Given these regulations, there is an incentive to export large amounts of recyclable waste materials to reduce the cost of waste disposal. Moreover, economic integration and fragmentation in Asia has increased trade in final products, parts, and components.[4] This further increases trade in waste. In addition, transboundary trade in waste has increased because not all countries recycle and some developing countries lack their own recycling technology.

[1] In 1994, the Basel Convention accepted the Basel Ban, which prohibits exports of hazardous waste by ratifying countries to other countries. As of 2012, 178 countries had signed the Convention. Japan ratified it in 1993. The Convention was ratified by many Asian countries such as China, Korea, the Philippines, Thailand, Indonesia, India, Vietnam, Malaysia, and Singapore. Krueger (2001) discusses the impact of the Basel Convention on international trade in hazardous waste.

[2] Kojima (2005) and Michida (2011) provide an overview of the waste and recycling trade in Asia based on many stylised facts and much evidence.

[3] Yao et al. (2012) show that Chinese economic growth dramatically increases demand for energy and raw materials.

[4] See, e.g., Kimura and Ando (2005), Athukorala (2005, 2009), Ando (2006), Okubo (2007), Baldwin and Okubo (2014), and Okubo et al. (2014) for details.

There are economic gains and losses from trade in recyclable waste resources for waste-importing countries (Kojima, 2005; Kojima, 2011; Higashida and Managi, 2014). Waste-importing countries are developing countries that are cost-competitive in labour-intensive recycling processes and have greater demand for recycled resources. Furthermore, these countries have less-stringent environmental regulations because of government inability to implement regulations. Trade in recyclable waste helps to preserve natural resources and provides recycling and employment opportunities in many low-income countries. However, according to the evidence obtained and case studies conducted by Kojima (2005), these benefits are limited. Indeed, recycling activities can cause serious environmental damage and health problems: much waste includes contaminated and hazardous materials. Because many importing countries do not have their own reliable recycling processes and facilities, hazardous materials are not properly treated, which damages the environment. Hence, it is important to prevent the illegal and illicit transboundary movement of waste.

Waste-exporting countries such as Japan have an incentive to export their waste. In developed countries, recycling policies that increase the collection of recyclables for domestic disposal or export have been implemented. Introducing stringent regulations increases the cost of waste disposal, and the resulting oversupply of waste increases exports to countries with lax regulations. Firms that reduce the costs of disposal through exporting raise their profits. Furthermore, relocating recycling activities to foreign countries can reduce pollution and health damage in developed countries.

Before starting our analysis, it is important to define waste. In general, waste can be categorised. The OECD provides precise definitions of waste, hazardous waste, and disposal.[5] Japan's Law for the Promotion of Utilization of Recycled Resources classifies recyclable resources into three categories: recyclable materials (plastic waste, waste paper, metal scraps, nonferrous metal scraps); second-hand goods (cars and electronics); and goods regulated by the Basel Convention (batteries and coal ash).[6] Whereas Baggs (2009) studies hazardous waste and Kellenberg (2012) chooses 62 six-digit HS categories of waste (not only recyclable waste, but also disposal waste), we focus on waste in the form of four recyclable resource materials: plastic waste, waste paper, iron and steel scrap, and nonferrous metal scrap).[7] Appendix Table 1 lists the recyclable resource materials covered by our data set.

Japan has stringent environmental regulations, whereas China has the most relaxed environmental regulations. These countries border each other and have a close economic relationship. Hence, it is worth examining the waste haven hypothesis (WHH), under which countries with stringent environmental regulations export physical waste materials to countries with lax regulations, by analysing Japanese waste exports.[8]

2. Literature review and this paper

The impact of trade liberalisation on the environment is discussed in the trade and environment literature. A major question addressed in this literature is whether trade liberalisation can reduce

[5] See http://www.oecd.org/env/waste/30654501.pdf for a list of waste products and their definitions.
[6] The law was promulgated in June 2000 as an amendment to the Resource Recycling Promotion Law enacted in 1991.
[7] Our sample covers a wider range of waste products than that of Higashida and Managi (2014), who chose five waste and scrap products (waste, parings, and scrap). Our data includes their five products.
[8] Terazono et al. (2004) demonstrate a recycling loop between Japan and China.

global emissions (Antweiler et al, 2001; Copeland and Taylor, 1999; Dean, 2002; Frankel and Rose, 2005). The literature advances the pollution haven hypothesis (PHH) that stringent environmental regulation leads to a change in trade patterns and location patterns. More precisely, stringent environmental regulation increases 1) imports of pollution-intensive goods and 2) foreign direct investment (FDI) in pollution-intensive sectors. Empirically, the PHH is explored by Eskeland et al. (2003), Ederington et al. (2005), and Cole et al. (2010, 2014). To counter the PHH, Kellenberg (2012) proposes the WHH. This differs from the PHH in that, rather than polluting sectors being relocated or imports of pollution-intensive products increasing, physical waste materials are exported to lax regulation countries.

There is a small, but growing, literature on testing the WHH. As far as we know, all previous studies use the gravity model to identify the determinants of trade in waste. Under the standard specification, $Trade_{ij} = \frac{GDP_i * GDP_j}{Distance}$, trade flows are positively affected by the GDP levels of exporters (*i*) and importers (*j*) and inversely related to geographical distance. Baggs (2009) was the first to study international trade in hazardous waste in 89 countries by using the gravity model of Helpman et al. (2008). This model takes into account firm heterogeneity and incorporates an exporting selection mechanism. By extending Baggs (2009), Kellenberg (2012) estimated a gravity model of bilateral waste trade in 92 countries, using the Poisson pseudo-maximum-likelihood estimator proposed by Santos Silva and Tenreyro (2006).[9] He found that environmental regulation gaps between countries increase trade in waste. Similarly, Higashida and Managi (2014) estimated the standard gravity model at the product level. In all three studies, there are encouraging results for the gravity equation. GDPs and GDP per capita in importing and exporting countries increase trade in waste, whereas distance reduces trade in waste.

[9] They use the augmented gravity model, which includes the GDP per-capita gap and an environmental regulation gap dummy. They use cross-section data for estimation.

However, there are specification problems in estimating gravity models. First, the gravity model is not completely consistent with the WHH. The stylised facts presented by Kellenberg (2012) and Higashida and Managi (2014) show that most trade waste flows from developed countries (with high GDP and GDPs per capita) to developing countries (with low GDP and GDPs per capita) rather than between developed countries.[10] This is problematic for the gravity model because it predicts that the largest trade flows should be between pairs of rich countries (with high GDP and high-GDP per capita), such as OECD countries. The gravity model poorly explains the typical trade-waste patterns from rich to poor countries and between poor countries. Hence, the gravity model is not perfectly suited to testing the WHH.

Furthermore, trade in waste is not consistent with the theoretical underpinnings of the gravity model (Bergstrand, 1985). The gravity model presumes two-way trade (bilateral trade within a sector) based on monopolistic competition with product differentiation. However, waste materials are not compatible with monopolistic competition. Moreover, it is difficult for the gravity model to explain trade in waste when there is firm heterogeneity and selection mechanism of exporting à la Baggs (2009): only high-productivity firms can export waste. There is no apparent selection mechanism in waste exporting. Hence, for these reasons, it is inappropriate to use the gravity model to test the WHH.

[10] According to Kellenberg (2012), the top 10 exporters of waste account for 76% of the total and are all developed countries with high per-capita incomes. China and Turkey are the two largest waste importers in the world and are ranked as having the loosest environmental regulations. Higashida and Managi (2014), who report trade values by destination (developed and developing countries) at the product level, provide more striking stylised facts. Trade between developed and developing countries is largely unbalanced. In most trade in waste products (ferrous waste and scrap, polymers of ethylene, and plastics), exports from developed countries to developing countries predominate, with the second largest trade values being among developed countries. Baggs (2009) uses Basel Convention self-reported data, which differ from the data used in the other two studies as well as ours. These data are available from 1994 to 2004, and between 34 and 61 countries report annual exports and imports of traded waste. Surprisingly, according to his basic statistics, importers' GDP and GDP per capita are larger than those of exporters' on average. Baggs comments that "this is generally contrary to the intuition of the pollution haven."

Our proposal is based on treating waste not as a final good or consumption good, but as being sensitive to the costs of disposal and needing low-skilled labour for recycling. Labour-abundant countries have large pools of cheap unskilled labour. Lax regulations in developing countries reduce the costs of disposal. Moreover, waste is difficult to transport over long distances because of high transport costs. However, there is a quality threshold for recycling: low-quality waste cannot be recycled. Thus, we predict that high-GDP countries with high wage rates will export waste to low-GDP countries with low wage rates that have lax regulations and are not too far away. Trade in waste is expected to be one way.

3. Stylized facts

In this section, we give an overview of Japan's exports of recyclable materials (see Appendix Table 1), from Trade Statistics of Japan (Ministry of Finance of Japan). The first revelation is that trade in waste is typically one-way trade. Figure 1 graphs Japanese exports and imports for four main categories of waste (detailed in Appendix Table 1). Overall, exports are much higher than imports, which suggest trade is one-way. In particular, exports of waste paper and plastics are substantial. One-way trade is not consistent with the standard gravity model.

Second, exports tend to go to specific countries. Figure 2 shows that Asian countries are the main export destinations. In particular, China (and Hong Kong) takes the most exports. This is consistent with the findings of Kellenberg (2012) and Michida (2011) that China is the world's largest importer of waste. Japanese waste exports have increased dramatically over the last ten years.

Third, many traded amounts are zero. Table 1 reports the number of positive and zero trades by product destination at HS-6 digit level from 1998 to 2007, covering 31 foreign countries and 10 years (giving a sample of 310 for each product destination). Although around 10% to 30% of products by destination are positive, many trade flows amount to zero.

Next, an environmental regulation index, used by Kellenberg (2012), is constructed from survey questions from the 2003–2004 Global Competition Report. The report is based on the survey responses of 7,741 CEOs of private companies from all over the world. The CEOs are asked to use a 1–7 scale to rank the environmental stringency of their country's environmental regulations compared with other countries, based on air pollution regulations, water pollution regulations, toxic waste disposal regulations, chemical waste regulations, and the consistency of regulation enforcement. Country regulation indices are calculated from the mean scores (reported in Appendix Table 2). Whereas Japan is stringent, many Asian countries are lax. In general, environmental regulations are lax in developing countries. At 0.7 to 0.9, the correlation between the regulation index and GDP per capita is quite high (see Appendix Table 3). Developing countries with lower GDP per capita tend to have looser environmental regulations. In other words, GDP per capita is a reasonable proxy for environmental regulation.

4. Data and estimation

4.1 Data

We use traded-waste values (in 1,000 yen) and weights (in kgs) from Trade Statistics of Japan (Ministry of Finance of Japan). Our sample includes 31 developed and developing countries, which are Japan's main trading partners (listed in Appendix Table 2). The data cover the period from 1998 to 2007. Data on GDP and GDP per capita (both in US dollars) are taken from World Development Indicators (World Bank). Information on distance (in kms) is taken from the CEPII. Following Kellenberg (2012), the environmental stringency index is based on the 2003–2004 Global Competitiveness Report.

4.2 Estimation strategy

To test our hypothesis, we follow Kellenberg (2012), who first examined the WHH. We use data on gaps in GDP, GDP per capita, and the environmental regulation index between Japan and its export-destination countries. Higher GDP increases waste exports because waste is exported to countries with high waste demand. Countries with regulations that are less stringent than Japan take more waste exports. Gaps in GDP per capita proxy for differences in environmental regulations. This is because low-income developing countries tend to have lax regulations. Correlations between GDP per capita and environmental regulation are high (see Appendix Table 4). We also use the environmental regulation index rather than its proxy, GDP per capita. In addition, the estimated unit price of waste proxies waste quality (in 1,000 yen per kg). There is a quality threshold for recycling: low-quality waste cannot be recycled (Michida et al., 2011).[11] We expect waste quality to affect trade flows positively. We estimate the following equation:

$$Trade_{ipt} = GDP_{it} + GDPCAP_{it} + Dist_i + UnitPrice_{pt} + EnvReg_i + \mu_{ip} + \varepsilon_{ipt}$$

where *Trade* denotes trade flows of waste product *p* from Japan to country *i* in year *t*, and *GDP* (*GDPCAP*) denotes the gap in GDP (GDP per capita) between country *i* and Japan in year *t*; i.e., $GDP_{it} = gdp_{it} - gdp_{JPNt}$ and $GDPCAP_{it} = gdpcap_{it} - gdpcap_{JPNt}$. *Dist* is the geographical distance of country *i* from Japan. *UnitPrice* is the unit price of product *p* in year *t* as a proxy of

[11] In the context of iron and steel scrap, the quality of waste is important for recycling. Michida et al. (2011) investigate econometrically the relationship between waste quality and economic development in importing and exporting countries.

product quality. All variables are in natural logarithms. To control for unobserved product characteristics, we include μ, which is HS-6 digit product and country dummy. *EnvReg* denotes the environmental regulation gap with Japan. The three types of gap variable used (all taken from the Global Competitiveness Report) are based on overall regulation, toxic waste regulation, and air pollution regulation.[12]

Our main concern is the proliferation of zero values (see Table 1). To deal with this problem, we use Tobit panel estimation. We estimate the trade equation based on using both trade values (in yen) and trade quantities (in kg); the latter represents a departure from existing studies.[13]

4.3 Estimation results

Table 2 reports our Tobit estimation results. Column 1 uses GDP per capita as proxy for environmental regulations. The coefficients of GDP and the per-unit price are significantly positive, whereas that of distance is significantly negative. Thus, as expected, the higher is a country's GDP and the closer is that country to Japan, the more likely is it to import waste from Japan. GDP per capita has a negative effect. Countries with lower per-capita incomes are more likely to import Japanese waste. High-quality waste is more likely to be exported because of the difficulty of recycling low-quality waste. The equations reported in columns 2 to 4 include the environmental regulation index rather than its proxy, GDP per capita. The estimates are more favourable than those in column 1. All regulation coefficients are negative and significant. Using regulation indices for

[12] The Global Competitiveness Report includes five specific types of regulation index. All are quite highly positively correlated. Three indices not reported in our paper are water-pollution regulations, chemical-waste regulations, and the consistency of regulation enforcement. Because using these three variables produces similar results to those reported in the paper, they are not reported to save space.

[13] Kellenberg (2012) points out that because trade values are proportional to weights, using weights should not affect estimation. Hence, he uses only trade values.

specific types of regulation increases the robustness of the results. Tightening environmental regulations reduces waste exports. This result supports the WHH.

We estimate additional models to check for robustness. Trade weights (in kg) are used rather than trade values (in yen). The results are reported in Table 3, and are similar to those based on trade values.

5. Policy implications

Several policy implications for Asian economies follow from our results. First, all Asian countries imposing substantial tariff rates uniformly on all types of waste might be effective. Currently, Asia imposes low or no tariffs on waste. Table 4 shows average tariff rates on waste products in each Asian country, taken from Kojima (2005, Ch. 1, page 16). Many Asian countries have no tariffs on waste paper or scrap iron, copper, and aluminium. In particular, Hong Kong sets zero tariff rates on all types of waste. This could be a cause of the waste transit to China.[14] Indeed, the main purpose of imposing tariffs on waste is to prevent illegal movements. Thus, an optimal tariff rate would be one that did not encumber legitimate trade that results in waste going to recycling facilities with environmentally sound technology.

Another worthwhile policy might be to inspect waste in Asian countries before shipment; currently, inspections are enforced only for specific types of waste by some Asian countries. Importing countries suffer from environmental and health problems because waste materials are often contaminated and hazardous. Because many importing countries do not have safe recycling processes

[14] Transit from Hong Kong to China is an important policy issue. See Kojima (2005, Ch. 4) for details.

and adequate facilities, waste is often not properly disposed of or treated, which harms the surrounding environment. Thus, given the limited capacity of developing countries to enforce regulations, waste exports should be inspected to ensure that only clean and nontoxic recyclables are received by exporting countries. Alternatively, exporting countries might put more resources into improving environment and health controls in importing countries. Such policy schemes could reduce trade in waste across Asian countries.[15]

6. Conclusion

In this paper, we studied Japanese trade in waste and tested the WHH. Using trade data and environmental indices, we found evidence that Asia is an important waste haven for Japanese exports. Japan's stringent environmental regulations prompt Japan to export waste to large developing countries with low per-capita incomes and lax environmental regulations. Exports are higher to neighbouring countries and for relatively high-quality waste (with a higher per-unit price). Thus, our results support the WHH.

There remains scope for future research. In the era of globalisation, overseas production networks, well known as Asian fragmentation, affect Asian trade and production patterns. Dispersion of production processes also affects waste flows. Thus, it might be worth investigating the relationship between trade in waste and Asian fragmentation.

[15] Kojima (2005, Ch. 9) identifies problems with Asia's waste and recycling policies and proposes specific policies and suggestions.

Reference

Ando, Mitsuyo. 2006. Fragmentation and vertical intra-industry trade in East Asia. *The North American Journal of Economics and Finance* 17(3):257-281.

Antweiler, Werner., Brian R. Copeland, and M.Scott Taylor. 2001. Is free trade good for environment?, *American Economic Review* 91(4):877-908.

Athukorala, Prema-chandra. 2005. Product Fragmentation and Trade Patterns in East Asia. *Asian Economic Papers* 4(3):1-27.

Athukorala, Prema-chandra. 2009. The Rise of China and East Asian Export Performance: Is the Crowding - Out Fear Warranted?. *The World Economy* 32(2):234-266.

Baggs, Jen. 2009. International trade in hazardous wastes. *Review of International Economics* 17(1):1-16.

Baldwin, Richard, and Toshihiro Okubo. 2014. Networked FDI: Sales and sourcing patterns of Japanese foreign affiliates. *The World Economy* 3(8):1051-1080.

Bergstrand, Jeffrey H. 1985. The Gravity Equation in International Trade: Some Microeconomic Foundations and Empirical Evidence. *Review of Economics and Statistics*, 67 (3):474-481.

Cole, Matthew A., Robert JR Elliott, and Toshihiro Okubo. 2010. Trade, environmental regulations and industrial mobility: An industry-level study of Japan. *Ecological Economics*, 69(10):1995-2002.

Cole, Matthew A., Robert JR Elliott, and Toshihiro Okubo. 2014. International environmental outsourcing. *Review of World Economics* 150(4):639-664.

Copeland, Brian R., and M.Scott Taylor. 1999. Trade, spatial sepration, and environment. *Journal of International Economics* 47(1):137-168.

Dean, Judith M. 2002. Does trade liberalization harms environment? A new test. *Canadian Journal of Economics* 35(4):819-842.

Ederington, Josh, Arik Levinson, and Jenny Minier. 2005. Footloose and Pollution-Free. *The Review of Economics and Statistics* 87(1):92-99.

Eskeland, Gunnar S., and Ann E. Harrison. 2003. Moving to greener pasture? Multinationals and pollution haven hypothesis. *Journal of Development Economics* 70(1): 1-23.

Helpman, Elhanan, Marc Melitz, and Yona Rubinstein. 2008. Estimating trade flows: Trading partners and trading volumes. *Quarterly Journal of Economics* 123(2):441-487.

Higashida, Keisaku, and Shunsuke Managi. 2014. Determinants of trade in recyclable wastes: evidence from commodity-based trade of waste and scrap. *Environment and Development Economics* 19(02):250-270.

Kellenberg, Derek. 2012. Trading wastes. *Journal of Environmental Economics and Management* 64(1):68-87.

Kimura, Fukunari, and Mitsuyo Ando. 2005. Two-dimensional fragmentation in East Asia: Conceptual framework and empirics. *International Review of Economics & Finance* 14(3):317-348.

Kojima, Michikazu. 2005. Ajia ni Okeru Junkan Shigen Boueki (*International trade of recyclable resources in Asia).* Chiba: Institute of Developing Economics Japan External Trade Organization. (written in Japanese).

Kojima, Michikazu. 2011. Issues Relating to the International Trade of Secondhand Goods, Recyclable Waste and Hazardous Waste, in Ch1. In Economic Integration and Recycling in Asia edited by Michikazu Kojima and Etsuyo Michida, pp.1-8. Chiba, Japan: Institute of Developing Economics.

Krueger, Jonathan. 2001. The Basel Convention and the International Trade in Hazardous Wastes, in *Yearbook of International Co-operation on Environment and Development 2001/2002* edited by Olav Schram Stokke and Øystein B. Thommessen pp.43–51, London: Earthscan Publications.

Michida, Etsuyo. 2011. International Trade of Recyclables in Asia: Is cross-border recycling sustainable? in Ch2.In Economic Integration and Recycling in Asia, edited by Michikazu Kojima and Etsuyo Michida, pp.9-27, Chiba, Japan: Institute of Developing Economics.

Michida, Etsuyo, Atici, C and Kojima Michikazu. 2011. Does quality matter in the iron and scrap trade? IDE Discussion paper, No.28., Chiba, Japan: Institute of Developing Economics.

Okubo, Toshihiro 2007. Intra-industry Trade, Reconsidered: The Role of Technology Transfer and Foreign Direct Investment. *The World Economy*, *30*(12): 1855-1876.

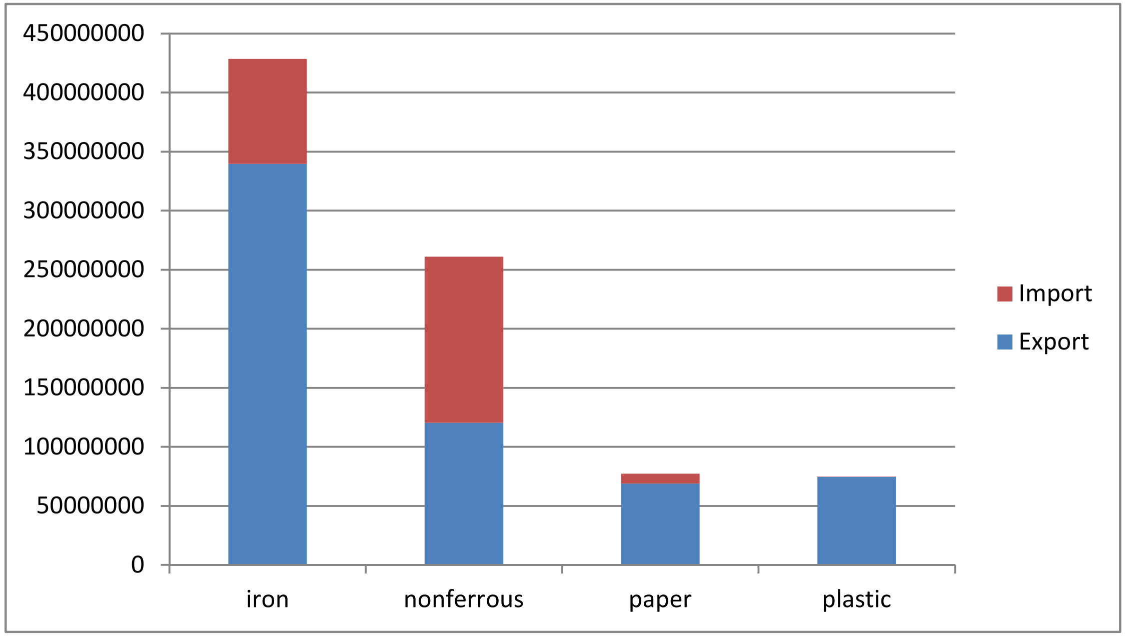
Okubo, Toshihiro, Fukunari Kimura, and Nozomu Teshima. 2014. Asian fragmentation in the global financial crisis. *International Review of Economics & Finance* 31:114-127.

Silva, JMC Santos, and Silvana Tenreyro. 2006. The log of gravity. *Review of Economics and Statistics* 88(4): 641-658.

Terazono, Atsushi, AyaYoshida, Jianxin Yang, Yuichi Moriguchi, and Shin-ichi Sakai. 2004. Material cycles in Asia: especially the recycling loop between Japan and China. *Journal of Material Cycles Waste Management* 6(2): 82-96.

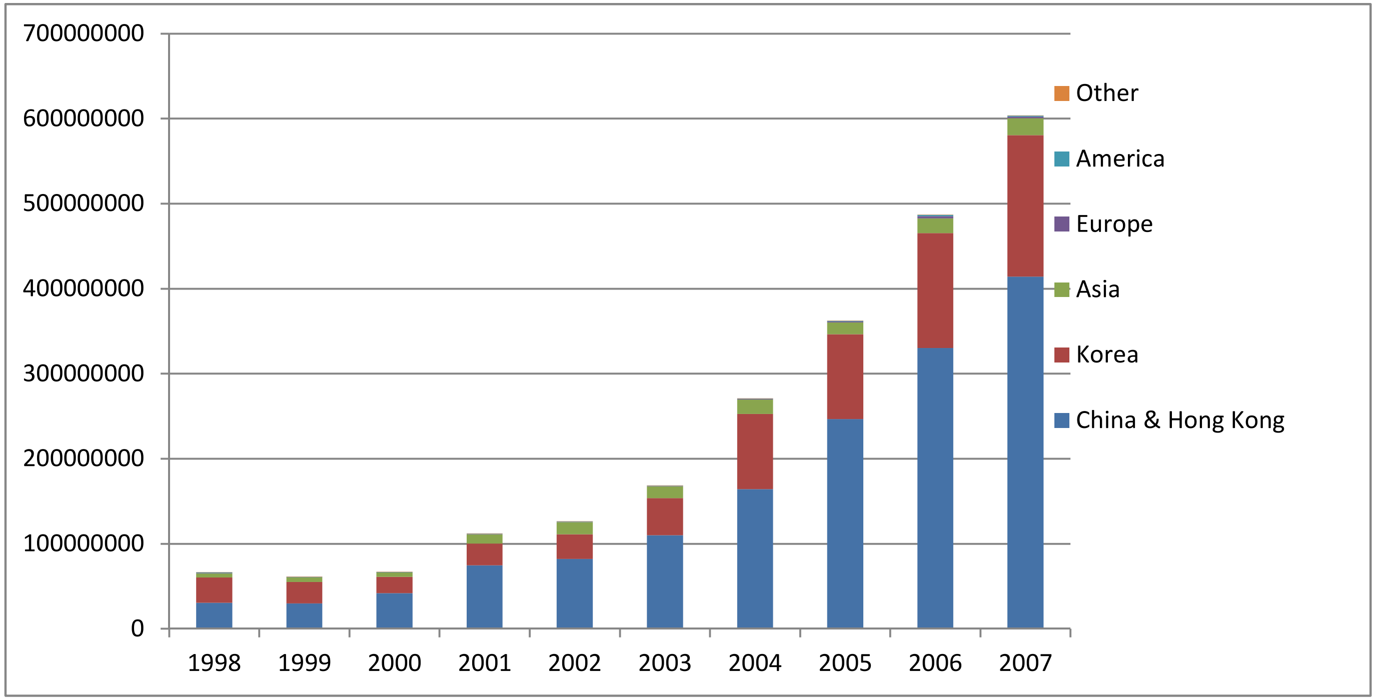
Yao, Shuji, Dan Luo, and Tyler Rooker. 2012. Energy efficiency and economic development in China. *Asian Economic Papers 11*(2): 99-117.

Figure 1: Waste Exports and Imports in Japan（2007）



Unit: 1,000 yen

Figure 2: Destinations of Japanese Waste Exports



Unit: 1,000 yen

Note: Asia excludes China, Hong Kong and Korea.

Table 1: Zero and positive value of exports (1998 to 2007)

HS code	Total	Positive	Zero	Share of Positive
391510	310	98	212	0.316
391520	310	75	235	0.242
391530	310	78	232	0.252
391590	310	172	138	0.555
470610	310	28	282	0.090
470620	310	40	270	0.129
470691	310	38	272	0.123
470692	310	38	272	0.123
470710	310	65	245	0.210
470720	310	56	254	0.181
470730	310	79	231	0.255
470790	310	81	229	0.261
720410	310	37	273	0.119
720421	310	73	237	0.235
720429	310	90	220	0.290
720430	310	9	301	0.029
720441	310	42	268	0.135
720449	310	109	201	0.352
720450	310	52	258	0.168
740400	310	91	219	0.294
750300	310	67	243	0.216
760200	310	72	238	0.232
780200	310	29	281	0.094
790200	310	25	285	0.081
800200	310	31	279	0.100

Table 2: Basic Estimation Results

	1	2	3	4
GDP	5.572	5.142	5.662	5.729
	[8.75]***	[9.46]***	[10.00]***	[10.16]***
GDPCAP	−0.683			
	[−1.13]			
Dist	−13.958	−13.976	−13.635	−13.325
	[−19.58]***	[−20.25]***	[−18.12]***	[−17.69]***
Unit Price	0.00054	0.00054	0.00053	0.00053
	[7.57]***	[7.57]***	[7.52]***	[7.53]***
Env_reg		−0.211		
		[−1.61]*		
Toxic			−0.653	
			[−1.98]***	
Air				−1.007
				[−2.76]***
Log likelihood	−7697.2776	−7696.6062	−7526.716	−7524.9286
Wald Chi−2	514.85	519.92	515.47	520.2
Observations	7750	7500	7500	7500

z statistics in parentheses. * p<0.1, ** p<0.05, *** p<0.01

Table 3: Basic Estimation Results (volume)

	1	2	3	4
GDP	6.339	5.627	6.273	6.359
	[7.66]***	[8.02]***	[8.61]***	[8.76]***
GDPCAP	−1.147			
	[−1.45]			
Dist	−17.592	−17.686	−17.358	−16.977
	[−18.93]***	[−19.64]***	[−17.61]***	[−17.19]***
Unit Price	0.00051	0.00051	0.00050	0.00049
	[5.55]***	[5.55]***	[5.49]***	[5.49]***
Env_reg		−0.299		
		[−1.77]*		
Toxic			−0.741	
			[−1.71]*	
Air				−1.174
				[−2.46]***
Log likelihood	−7953.1331	−7952.5987	−7772.0922	−7770.6187
Wald Chi−2	456.81	460.17	456.57	461.02
Observations	7750	7500	7500	7500

z statistics in parentheses. * $p<0.1$, ** $p<0.05$, *** $p<0.01$

Table 4: Average Tariff Rates in Asia (Kojima, 2005, page 16)

	Plastic Waste	Paper Waste	Steel and Iron Waste	Copper Waste	Aluminum Waste
China	10.7	0	0–2	1.5	1.5
Hong Kong	0	0	0	0	0
India	20	16	10	15	15
Indonesia	5	0–15	0	0	0
Japan	4–4.8	0	0–4.7	0	0
Korea	6.5	0	1	0	1
Malaysia	0–30	0	0–5	0	0
Philippines	1—5	1	0–3	3	1
Taiwan	6.5	0	0–3.8	0	0
Thailand	30	1	1	1	1
Vietnam	10	3	0	0	0

Unit: Percent
As of August 2004.
See Kojima (2005) for the derivation of average tariff rates.

Appendix Table 1: Waste List (HS-6)

Category	HS code	Commodity description
Plastic Waste	391510	Waste, parings & scrap, or polymers of ethylene
	391520	Waste, parings & scrap, or polymers of styrene
	391530	Waste, parings & scrap, or polymers of vinyl chloride
	391590	Waste, parings & scrap, or polymers of n.e.s in 39.15
Paper Waste	470610	Cotton linters pulp-Air
	470620	Pulps of fibres derived from recovered (waste and scrap) paper or paperboard
	470691	Mechanical-Air
	470692	Chemical-Air
	470710	Recovered (waste & scrap) unbleaced kraft paper/paperboard
	470720	Recovered (waste & scrap) papar/paperboard mainly of bleached chem.
	470730	Recovered (waste & scrap) paper/paperboard made mainly of mech. Pulp
	470790	Recovered (waste & scrap) paper/paperboard (excl. of 4707.10-4707.30)
Iron and Steel Waste	720410	Waste & scrap of cast iron
	720421	Waste & scrap of stainless steel
	720429	Waste & scrap of alloy steel other than stainless steel
	720430	Waste & scrap of tinned iron/steel
Non-ferrous waste	720441	Ferrous turnings, shavings, clips, milling waste, sawdust, filings
	720449	Ferrous waste & scrap (excl. of 7204.10-72044.41)
	720450	Remelting scrap ingots of iron or steel
	740400	Copper waste & scrap
	750300	Nickel waste & scrap
	760200	Aluminum waste & scrap
	780200	Lead waste & scrap
	790200	Zinc waste & scrap
	800200	Tin waste & scrap

Appendix Table 2: Country List and Regulationl Index

Country	Toxic waste disposal	Air pollution
Australia	6.3	5.7
Austria	6.4	6.1
Belgium	6.3	5.9
Brazil	4.3	4.2
Canada	5.9	5.7
China	3.4	3.5
Czech	4.7	5
Denmark	6.6	6.5
England	5.8	5.7
France	5.9	5.7
Germany	6.8	6.7
HongKong	4.6	4
India	3.3	3.8
Indonesia	3.7	3.5
Israel	4.4	4.1
Italy	5.1	5
Japan	5.7	5.9
Korea	4.6	4.4
Malaysia	4.6	4.4
Mexico	3.9	4.1
Netherland	6.5	6.2
NewZealand	6.1	5.6
Pakistan	2.8	2.7
Philippines	2.8	2.9
Russia	3.1	3
Singapore	6.2	5.8
Singapore	6.2	5.8
Switzerland	6.6	6.5
Thailand	3.9	4
UnitedStates	5.9	5
UAE	-	-
Vietnam	2.9	2.7

Appendix Table 3: Basic Statistic

Variable	Obs	Mean	Std. Dev.	Min	Max
Export value	7750	299918	3786329	0	136000000
GDPgap	7750	0.4059208	0.2702769	0.112026	1.660314
GDPCAPgap	7750	0.6847275	0.3260108	0.139369	1.275096
Dist	7750	7855.836	3400.008	1156.67	18549.61
Unit Price	7750	74.09726	976.5203	0	59500
Env_reg	7750	−0.6415161	1.21602	−3.4	2.6
Toxic	7571	−0.7739532	1.301657	−4.3	1.1
Air	7571	−1.150192	1.195493	−4.6	0.8

Appendix Table 4: Correlation Matrix

	Exp	GDP	GDP capita	Dist	Envreg	Toxic
GDP	0.0102					
GDP capita	−0.2248	0.3927				
Dist	−0.581	0.2563	0.4122			
Env_reg	−0.2495	0.2581	0.6991	0.4092		
Toxic	−0.2578	0.3033	0.8867	0.4533	0.7992	
Air	−0.2801	0.3	0.8448	0.4687	0.7964	0.9793