The impact of China's import ban: An economic surplus analysis of markets for recyclable plastics

Kumamaru, Hirotaka
Takeuchi, Kenji

(Citation)
Waste Management,126:360-366

(Issue Date)
2021-05-01

(Resource Type)
journal article

(Version)
Accepted Manuscript

The impact of China's import ban:
An economic surplus analysis of markets for recyclable plastics

Hirotaka Kumamaru [a] · Kenji Takeuchi [b]

[a] Graduate School of Economics, Kobe University, Kobe 6578501 Japan. Email: kumamaru12@stu.kobe-u.ac.jp
[b] Graduate School of Economics, Kobe University, Kobe 6578501 Japan. Email: takeuchi@econ.kobe-ac.jp

Abstract

Over the years, China has imported a significant quantity of plastic waste from the rest of the world. In December 2017, however, it implemented a ban on the import of plastic waste, used paper, and miscellaneous scrap goods. This study aims to provide new insight on the waste trade, with specific focus on the market for recyclable plastics. By employing an economic surplus analysis, we investigate the impact of China's import ban on the market for recyclable plastics in China and Japan. Obtained results suggest a significant change in economic surpluses; Japan and China's surpluses reduced by 58 billion yen and 1,304 billion yen at the maximum, respectively.

Keywords: Import ban; Plastic waste; Waste trade; Economic surplus analysis

1. Introduction

The generation of plastic waste worldwide has increased in the past few decades. According to Geyer et al. (2017), it is estimated that 6300 Mt of plastic waste has been generated between 1950 to 2015. Of this, approximately 800 Mt (12%) have been incinerated and 600 Mt (9%) have been recycled. Of the latter, only 10% has been recycled more than once. Approximately 4900 Mt—60% of all plastic ever produced—was disposed of in landfills or the natural environment. If current trends of waste generation continue to 2050, 9000 Mt of plastic waste will be recycled, 12,000 Mt incinerated, and 12,000 Mt discarded in landfills or the natural environment. As the generation of plastic waste worldwide increases, the import and export of plastic waste will also increase. Globally, the import and export of plastic waste began to increase in the early 1990s, growing by 723% and 817% between 1993 and 2016, respectively (Brooks et al., 2018; Hoornweg, D., & Bhada-Tata, 2012).

China has imported a vast amount of plastic waste from all over the world. It is estimated that China accounted for a 45.1% share of global cumulative imports of plastic waste (Brooks et al., 2018). The primary reason for the large volume of imports is the high demand for resources to sustain China's economic growth. In December 2017, however, China implemented a ban on the import of plastic waste, used paper, and miscellaneous scrap goods. There are two reasons for this ban. The first reason is to reduce environmental pollution in China (Kellenberg, 2012; Qu et al., 2019). The volume of mismanaged plastic waste in China in 2010 was 8.82 million tons, which was 27.7% of the total volume of plastics produced globally. It is estimated that 1.32-3.53 million tons of plastic waste flow out to the ocean as plastic marine debris each year. The resulting microplastic and marine pollution have attracted much attention (Jambeck et al., 2015; Plastic Waste Management Institute, 2019). The second reason is to promote domestic recycling in China. Chinese firms and consumers generate a large volume of plastic waste; the domestic supply of recyclable materials is, therefore, sufficient to meet the capacity of Chinese recycling facilities and industry requirements for recycled virgin materials. A study by (Liang et al., 2021) showed that this implication of trade policy adjustment has prevented 1.4 million tons of waste plastic from flowing into Asia.

This study provides new insights into the study of the waste trade by focusing on the market for recyclable plastics. Specifically, we investigate the impact of China's import ban of recyclable plastics on the economic surpluses of China and Japan. Since China imports 50% of its plastic waste requirement from Japan, the policy may significantly impact the markets of both countries.

Several researchers have investigated the factors affecting the international trade of waste

(Higashida and Managi, 2008; Ichinose et al., 2013). However, little attention has been paid to the economic consequences of the Chinese ban on the import of waste. The objective of this study is twofold. First, we seek to investigate the impact of China's import ban on economic welfare. For this purpose, we employ an economic surplus analysis to explore the welfare implications of the ban on the waste trade. While previous research has focused on the determinants of the waste trade, discussion on the benefits and costs of restricting the waste trade has been limited. By using economic surplus analysis, we can assess the economic consequences of the import ban in the recycling market and explore its impact on recycling industries. In that respect, it is of great significance to investigate waste import ban using economic surplus analysis. Second, we also aim to quantitatively assess Japan's response to the Chinese ban on plastic waste imports. As China's import ban affects the flow of Japan's domestic waste, the Japanese government is expected to act in response to the ban. This study, therefore, discusses the implications of Japan's policy response, including increased domestic recycling and the reduction of plastic waste generation.

The remainder of this paper is organized as follows. Section 2 presents the literature review. Section 3 describes the theoretical model of international trade in waste. Section 4 presents the empirical results of the economic surplus analysis. Section 5 discusses

Japan’s potential responses and their economic implications. Section 6 concludes the paper.

2. Literature review

Some studies have empirically examined the impact of trade liberalization on the environment. Pioneering research on the international trade of waste by Grace et al. investigated the relationships between the amount of recycling for secondary materials and the volume traded internationally(Grace et al., 1978). Since then, many empirical studies have addressed recycling in open economies (Berglund and Söderholm, 2003; van Beukering, 2002; Van Beukering and Bouman, 2001). This is because most trade of waste flows from developed to developing countries. Recycled materials can be a substitute for many virgin materials used in the production of various commodities. Developing countries with scarce resources tend to import recycled material as cheaper resources.

Previous research has reviewed the impact of the waste trade by estimating the export demand functions for several types of waste and scrap. Ichinose et al., (2013) examined the substitutability of waste and scrap, such as ferrous and plastics exported from different countries to China. They showed that the substitutability of waste and scrap was weak among exporting countries. Higashida and Managi, (2014) also highlighted the possibility that trade restrictions impair production efficiency by making it harder for more advanced, developing countries to procure materials at low prices. Krutilla (1991) suggested that environmental regulation by a large country affects the world price of commodities. He found that the terms-of-trade affect the optimality of environmental policy. Furthermore, Ino (2011) theoretically analyzed the optimal environmental policy for waste disposal and recycling, from the perspective of non-compliant firms.

Despite the above, there has been limited analysis of the economic impact of waste policy on international waste trade. Although several studies have evaluated the global impact of the ban on plastic wastes (Brooks et al., 2018; Huang et al., 2020; Qu et al., 2019), they did not explore the impact on economic welfare. We fill this gap by estimating the demand and supply curve for plastic waste in Japan and China. We then employ an economic surplus analysis as a method for policy evaluation to analyze the impact of China's import ban on both countries. By examining the impact of economic welfare, we can understand the consequences of trade restrictions from an economic point of view in the partial equilibrium analysis. Focusing on the bilateral trade between Japan and China allows a simpler investigation of the change in economic surplus. As a result of the import ban, waste exporters might divert their waste away from China to other countries with less stringent waste import policies. However, Balkevicius et al., (2020) pointed out that there is no statistically significant evidence that China's import restrictions of waste in 2013 increased waste exports from developed countries to developing countries excluding China. They also pointed out that there is no statistically significant evidence that the restrictions in 2013 increased the diversion of waste to developing countries with the weakest environmental regulation. Because import ban is stricter than import restrictions, we expect that the economic consequences of the policy are more substantial. Ishimura (2019) analyzed the trade surplus in Japan and China after China's import ban on plastic waste by using the bilateral model. The difference between Ishimura's study and ours is the data used in the analysis. While Ishimura used only the data of trade in plastic waste, we additionally use data of domestic supply and expand the scope of the analysis.

3. The theory of international trade

Various government actions can affect trade flows. These actions include taxes on some international transactions, subsidies for others, and legal limits on the value or volume of particular imports. In this section, we analyze the economic surplus of importing and exporting countries through a variety of non-tariff barriers, such as import quotas (quantitative restrictions on imports).

To analyze the impact of China's import ban, this study assumes a large importing economy in a competitive market. Because this import ban changes the international waste flow, it will have a significant impact not only on Japan but also on other countries (Sasaki, 2020). If a small country assumption was to be employed, it would mean that a policy change would not affect the world market(Krugman, 2018). In this study, we assume that the policy of China does affect the world market, but the policy of Japan does not.

Fig 1 illustrates international trade theory under the large country assumption. D_J and D_C are the domestic demand for plastic waste in Japan and China, respectively. Note that D_J and D_C represent the demand by firms that use plastic waste. S_J and S_C represent the domestic supply of plastic waste; and P_J and P_C show the domestic recycling price in Japan and China, respectively. The subscripts J means Japan, and the subscripts C means China. D is international demand, and S is the international supply for plastic waste. P_w is the international price and is determined in the international market. It is assumed that P_w equals both P_J and P_C.

< **Fig 1**>

Fig 2 graphically illustrates the impact of China's import ban under the large country

assumption. Japan is an exporter of plastic waste and China is an importer. Japan exports $S_{J1} - D_{J1}$ at $P_1 = P_J = P_W$ and China imports $D_{C1} - S_{C1}$ at P_1. After the ban, China decreases its imports to zero $(D_{C1} - S_{C1} = 0)$, and China's domestic equilibrium price and quantity increase to P_C. The dramatic decrease in import volume leads to a decrease in the international market demand, so the demand curve shifts to the left (from D_1 to D_2). Under the large country assumption, China's policies affect the international market. The equilibrium point of the international market shifts to the lower left and the equilibrium price goes down. Due to the reduction in price from P_1 to P_2, demand increases from D_{J1} to D_{J2}, and supply decreases from S_{J1} to S_{J2}. Subsequently, Japan's export volume decreases from $S_{J1} - D_{J1}$ to $S_{J2} - D_{J2}$.

<**Fig 2**>

In summary, China's import ban induces a drop in the domestic price of recyclable goods in Japan. Furthermore, the consumer surplus in the Japanese market increases, while the producer surplus decreases; therefore, the total surplus decreases. The change in economic surplus is apparent from **Fig 2**. In the Japanese market, the consumer surplus increases from ACP_1 to AEP_2, and producer surplus decreases from BFP_1 to BGP_2.

For the exporter, the consumer surplus increases because of the price decrease, and the demand increases due to the import quota. The producer surplus decreases because of the decrease in price and the supply decreases accordingly. As a result, the total surplus decreases from $ACFB$ to $AEGB$. In the Chinese market, the consumer surplus decreases, the producer surplus increases, and the total surplus also decline. The consumer surplus decreases from HIM to HP_cK and producer surplus increases from IJL to P_cJK. For the importer, the consumer surplus decreases because of the price increase and demand decreases due to the import quota. The producer surplus increases because of the price and supply increase. As a result, the total surplus decreases from $HJLM$ to HJK. Based on this model, we quantitatively evaluate the change in economic surplus in both countries in the next section.

4. Data and empirical analysis

4.1 Data

To quantitatively evaluate the impact of China's import ban, we develop a demand and supply curve for the plastic waste market. For the international price of plastic waste (in yen/ton), we use the weighted average price of the plastic waste exported from Japan to China in 2017. The figures on the export volume of plastic waste (in million tons) are obtained from the Trade Statistics of Japan (URL: http://www.customs.go.jp/toukei/info/index.htm). This study takes plastic scrap data as the target data for plastic waste. The harmonized system code of plastic scrap is 3915. Of all the plastic products (code 39) in the HS, code 3915 refers to plastic waste, parings, and scrap. Here plastic waste refers to the products belonging to code 3915 (3915 includes the value and quantity of plastic waste trade). Data on the domestic generation of plastic waste are collected from the Plastic Waste Management Institute (Plastic Waste Management Institute, 2020, 2017). For representing the Chinese market, we use China's domestic generation of plastic waste and the volume of imports (National Development and Reform Commission, 2014). The data are reported in **Table 1**.

< **Table 1**>

We use the price elasticity of demand to construct a linear demand curve. However, there are few previous estimations of the price elasticity of demand for plastic waste. For example, a study showed that the elasticity for plastic material is – 0.9 in OECD countries (Mannaerts, 2000), while another work showed that this elasticity is – 0.1 in the PET bottle recycling market (Palmer et al., 1997). Based on the range of demand elasticities suggested by these studies, we use three hypothetical elasticities for Japan and China in this study to consider the sensitivity of the results to the elasticities.

4.2 Empirical analysis

This subsection first develops the Japanese demand curve based on different assumptions of the price elasticity of demand (–1, –1.5, –0.5). This study denotes the price elasticity of demand by a negative value. When the price elasticity is –1, 1% increases in price is associated with 1% decreases in demand. When the price elasticity is smaller (larger) than –1, demand is elastic (inelastic). We consider three cases to examine the sensitivity of results to the assumption on the elasticity of demand. We assume that the Japanese supply curve is at first horizontal and then vertical at the amount of domestic supply as shown in **Fig 3**. The vertical axis represents the yen per ton and the horizontal axis represents the volume of recyclable plastics.

< **Fig 3**>

We also estimate the Chinese demand curve based on three assumptions of price elasticity of demand (– 0.1, – 0.15, – 0.05). We assume more inelastic demand than Japan because large demand and resource scarcity in China make waste plastics necessity goods. While recycled materials are substitutes for virgin materials, the price of the former is typically much cheaper than the latter. Thus, we assume that China imports recycled materials to save the production cost. As regards the Chinese supply curve, we assume that it is initially horizontal and then vertical at the amount of domestic supply as shown in **Fig 4**. The vertical axis represents the yen per ton and the horizontal axis represents the volume of recyclable plastics.

< **Fig 4**>

We can define the arc price elasticity of demand in Japan and China as follows (Porter, 2002):

$$\varepsilon_p = \frac{\frac{x_2 - x_1}{(x_2 + x_1)/2}}{\frac{p_2 - p_1}{(p_2 + p_1)/2}}$$

where x is domestic demand for recyclable plastic and p is the domestic price of recyclable plastics. p_1 is the price of x_1 and p_2 is the price of x_2. When the demand curve is linear, the price elasticity of demand takes different values at different points along the curve. By using the midpoint of the price change, the arc elasticity gives an approximate measure of price elasticity at any particular point on the curve (Allen, 1934). Assuming a particular arc elasticity, we can estimate the change in volume of waste in Japan as follows:

$$-1 = \frac{\frac{x_2 - 670{,}000}{(x_2 + 670{,}000)/2}}{\frac{47{,}300 - 43{,}000}{(47{,}300 + 43{,}000)/2}}$$

We assume that $p_1 = 43{,}000\ (\text{yen/ton})$ and $x_1 = 670{,}000\ (\text{tons})$ (Japanese Ministry of Finance, 2019; Plastic Waste Management Institute, 2017). The price is the average price between 2014 and 2018. When the arc elasticity is –1 and the price increase is 10%, we obtain $x_2 = 609{,}090\ (\text{tons})$ by solving the above equation. The result implies that the slope of the demand curve is –0.071. Therefore, the domestic demand curve in Japan's plastic recycling market is:

$$P = -0.071x + 90{,}300$$

The domestic supply curve in Japan's plastic waste recycling market is assumed as

$$x = 211, when\ P > 0$$

Fig 3 represents a demand and supply curve when Japan's arc elasticity is –1. When the arc elasticity is –1, consumer surplus (the dark gray area) is 15.8 billion yen and producer surplus (the light gray area) is 90.7 billion yen. The price at the intersection of the demand and supply curve is –58,659 yen/ton. From this, we surmise that plastic waste will have a negative price if it is traded domestically. If Japan's domestic demand increases to one million tons under China's import ban, Japan's domestic price decreases to 19,703 yen/ton. When we convert this value to kilograms, this is 19.7 yen/kg. This implies that Japan's domestic price of recycled plastic waste decreases from 43 yen/kg to 19.7 yen/kg before and after China's import ban. With China's import ban, consumer surplus is 35.3 billion yen and producer surplus is 41.6 billion yen. Japan's consumer surplus increases by 19.5 billion yen and producer surplus decrease by 49.1 billion yen due to the ban.

Similarly, we develop a demand and supply curve for China's plastic recycling market: when the arc elasticity is –0.1, the domestic demand curve in China's plastic recycling market is:

$$P = -0.021x + 496{,}650$$

The domestic supply curve in China's plastic waste recycling market is:

$$x = 1{,}366, when\ P > 0$$

Fig 4 represents a demand and supply curve when China's arc elasticity is –0.1. When the arc elasticity is –0.1, consumer surplus (the dark gray area) is 4885.8 billion yen and producer surplus (the light gray area) is 587.3 billion yen. By implementing the ban, China's imports reduce to zero. China's domestic price is determined by the intersection of domestic demand and supply and is 208,959 yen/ton. This implies that China's domestic price of plastic waste increases 4.8 times. After the ban, consumer surplus is 1966.2 billion yen, and producer surplus is 2853 billion yen. China's consumer surplus decreases by 2919.5 billion yen, and producer surplus increases by 2265.7 billion yen after the ban.

<Table 2>

These results are summarized in **Table 2**. In all cases, Japan's consumer surplus increases, its producer surplus decreases, and its total surplus decrease due to China's import ban. This implies that the firms purchasing plastic waste can benefit from the price decrease. However, the price decrease might lead to the exit of the recycler that sells plastic waste from the market. In effect, the total surplus also decreases. China's consumer surplus decreases its producer surplus increases, and its total surplus decreases due to the ban. This implies that the firm purchasing plastic waste faces economic losses due to the decrease in imports.

The results in **Table 2** show that the sign of the economic surplus does not change by varying the price elasticity of demand for plastic waste. The economic surplus differs in terms of size, and the negative impact becomes larger when demand is more inelastic. The result implies that the decrease in economic surplus may be more if recyclable plastics becomes a necessary good for an economy. The results also suggest that the import ban has a larger negative impact in China than in Japan.

5. Policy response by Japan

In this section, we consider the possible response of the Japanese government. As China's import ban affects Japan's domestic market, it may lead to policy action by the

Japanese government. The Japanese government may promote the export of plastic waste to other countries, increase the recycling of plastic waste domestically, and reduce the generation of plastic waste. In the following sections, we consider the promotion of domestic recycling and the reduction of plastic waste generation as probable policy responses.

5.1 Promotion of domestic recycling

The Japanese Ministry of the Environment has been promoting domestic recycling and reuse (Japanese Ministry of the Environment, 2019). The ministry aims to attain a 60% recycling/reusing rate for containers and packaging by 2030. Furthermore, it aims for 100% utilization of used plastics by 2035 including thermal recovery. These strategies aim to increase the utilization of plastic waste through technological innovation and by stimulating the demand for recyclables. In this subsection, we investigate the impact of achieving a 60% recycling/reusing rate and analyze the surplus change. The promotion of domestic recycling is therefore likely to increase domestic demand and shift the demand curve to the right.

Let us assume that the rate of recycling and reuse of plastic waste increases to 60% from the current material recycling rate of 23%, and the domestic demand for plastic waste increases by the same percentage. Hence, when the arc elasticity is –1, the domestic demand curve can be expressed as:

$$P = -0.058x + 203{,}869$$

Fig 5 displays the shift in the demand curve caused by the promotion of domestic recycling. The price of recyclable plastics is estimated to be $54{,}909(\mathrm{yen/ton})$. The results suggest that the promotion of domestic recycling increases the price of plastic waste. Compared to the case with no policy response to the import ban, the consumer surplus increases from 35.3 billion yen to 157.2 billion yen. The producer surplus also increases from 41.6 billion yen to 115.9 billion yen. Thus, this policy response will increase the economic surplus.

< Fig 5>

The above scenario might be too ambitious when we consider the past trend in plastic recycling. As an alternative scenario, we consider the case in which the material recycling rate increases from 23% to 34.8%. The scenario is based on the fact in Japan that the amount of material recycling increased from 1.39 million tons to 2.11 million tons between 2000 and 2017 (Plastic Waste Management Institute, 2020). We translate the increase of material recycling by 51.7% in 17 years into the increase of recycling rate from 23% to 34.8% (=23% multiplied by 1.517). Assuming the increase, we estimate the domestic price of recyclable plastics as $-22{,}440(\text{yen/ton})$. In this case, the consumer surplus increases from 35.3 billion yen to 112.7 billion yen, but the producer surplus does not change. In this case, it is impossible to process all of the supply by domestic recycling.

To increase material recycling, the conversion from thermal recovery is necessary. By improving the solid waste collection services and strengthening the recycling industry, we can promote the shift from thermal recovery to material recycling. An economic incentive to improve the quality of waste separation will also help the transition to material-based recycling.

5.2 Reducing the generation of plastic waste

The Japanese Ministry of the Environment set the target for reducing the generation of plastic waste by 25% by 2030 (Japanese Ministry of the Environment, 2019). This policy aims to reduce the use of single-use plastics and develop substitutes for oil-derived plastic products. This policy will shift the supply curve to the left in Japan’s recycling market. If the target is achieved, the policy will shift the supply from 2.11 million tons to 1.58 million tons, as shown in **Fig 6**.

< Fig 6>

Fig 6 shows the shift of the supply curve under this policy response. Japan's consumer surplus does not change, but producer surplus changes from 41.6 billion yen to 31.1 billion yen when the arc elasticity is –1. Thus, reducing the generation of plastic waste might shrink the recycling market.

As shown, the reduction of plastic waste results in a decrease in the producer surplus in the recycling market. This also indicates that the supply of recyclables decreases in this market. The Japanese government may emphasize the development of biodegradable plastics or the use of alternative materials to reduce the generation of plastic waste. Such policy responses will negatively affect the firms that supply recyclable plastics.

6. Conclusions

This study investigates the impact of China's ban on the import of plastic waste, on the recycling markets in Japan and China. The results obtained are interpreted as follows:

first, the price of plastic waste would change substantially after the ban; indeed, the price of plastic waste in Japan decreases from 43,000 yen/ton to 19,702 yen/ton. Additionally, the price of plastic waste in China increases from 43,000 yen/ton to 208,959 yen/ton, and for both countries, the total surplus falls significantly due to the ban. Regarding the surplus, Ishimura (2019) concluded that at a minimum, the ban caused trade surpluses in Japan and China to fall by 451 million yen and 14.3 billion yen respectively. Ishimura's estimation of the change in surpluses is smaller than our estimates.

Second, we found that the economic surplus changes significantly. Due to the import ban, Japan's consumer surplus increases, and its producer surplus decreases in all cases. This result implies that consumers (the buyers of plastic waste) benefit from the import ban as they are enabled to purchase more plastic waste. Moreover, Japan's policy response toward the import ban will cause further changes in the economic surpluses. It will increase the economic surplus when domestic recycling is promoted and decreases producer surplus when waste reduction is promoted. These results and their interpretation allow a better understanding of the impact of policy responses.

The following issues were not addressed in this study. First, we do not consider the environmental benefit. The main reason for the import ban is to reduce environmental pollution and plastic marine debris in China. A full-fledged economic surplus analysis should consider the environmental benefit induced by the ban. Because of China's import ban, 7.88 million tons of plastic waste is not imported in 2018. By using 0.114 as the ratio of plastic marine debris to plastic waste in China (Jambeck et al., 2015) and assuming that the specific gravity of plastic is 1 gram per 1cm^3, we can estimate that China reduced 900,000 ton of plastic marine debris by the import ban. Multiplying this figure by the average cost of collecting the marine debris (8,010 yen/m^3) (Japanese Ministry of Land, Infrastructure, 2010), the environmental benefit of the import ban is estimated as 7.2 billion yen at least. Second, the analysis is limited in scope. In this study, we focus on the recycling market for plastic waste. However, plastic waste is materially recycled and used as an input for manufacturing new goods. Thus, a more comprehensive analysis should also consider the secondary impact on the goods and services market. Third, we do not consider the storage capacity of plastic waste for both countries. In the short run, garbage is stored at stockyards and could potentially lead to its mismanagement.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

References

Allen, R.G.D., 1934. The concept of arc elasticity of demand. Rev. Econ. Stud. 1, 229. https://doi.org/10.2307/restud/1.3.229

Balkevicius, A., Sanctuary, M., Zvirblyte, S., 2020. Fending off waste from the west: The impact of China's Operation Green Fence on the international waste trade. World Econ. 43, 2742–2761. https://doi.org/10.1111/twec.12949

Berglund, C., Söderholm, P., 2003. Complementing empirical evidence on global recycling and trade of waste paper. World Dev. 31, 743–754. https://doi.org/10.1016/S0305-750X(03)00007-X

Brooks, A.L., Wang, S., Jambeck, J.R., 2018. The Chinese import ban and its impact on global plastic waste trade. Sci. Adv. 4, 1–8. https://doi.org/10.1126/sciadv.aat0131

Geyer, R., Jambeck, J.R., Law, K.L., 2017. Production, use, and fate of all plastics ever made. Sci. Adv. 3, 25–29. https://doi.org/10.1126/sciadv.1700782

Grace, R., Turner, R.K., Walter, I., 1978. Secondary materials and international trade. J. Environ. Econ. Manage. 5, 172–186. https://doi.org/10.1016/0095-0696(78)90025-6

Higashida, K., Managi, S., 2014. Determinants of trade in recyclable wastes: Evidence from commodity-based trade of waste and scrap. Environ. Dev. Econ. 19, 250–

270. https://doi.org/10.1017/S1355770X13000533

Higashida, K., Managi, S., 2008. The Determinants of Trade in Recyclable Wastes, the Structure of Recycling Sectors, and the Effects of Trade Restriction.

Hoornweg, D., & Bhada-Tata, P., 2012. What a Waste: A Global Review of Solid Waste Management, Urban deve. ed. World Bank, Washington, DC.

Huang, Q., Chen, G., Wang, Y., Chen, S., Xu, L., Wang, R., 2020. Modelling the global impact of China's ban on plastic waste imports. Resour. Conserv. Recycl. 154, 104607. https://doi.org/10.1016/j.resconrec.2019.104607

Ichinose, D., Higashida, K., Shinkuma, T., Kojima, M., 2013. Should the trade of hazardous waste be uniformly regulated? An empirical analysis of export demand for "waste and scrap." Environ. Dev. Econ. 18, 773–793. https://doi.org/10.1017/S1355770X13000302

Ino, H., 2011. Optimal environmental policy for waste disposal and recycling when firms are not compliant. J. Environ. Econ. Manage. 62, 290–308. https://doi.org/10.1016/j.jeem.2011.03.007

Ishimura. M, 2019. Policy challenges by China's import ban on plastic waste. Kankyokeizai Seisakukenkyu 12, 41–45,(in Japanese).

Jambeck, J., Geyer, R., Wilcox, C., Siegler, T.R., Perryman, M., Andrady, A., Narayan, R., Law, K.L., 2015. Plastic waste inputs from land into the ocean. Sci. Adv. 347, 768–771.

Japanese Ministry of Finance, 2019. Trade Statistics [WWW Document]. URL http://www.customs.go.jp/toukei/info/index.htm (in Japanese) (Last access: May 30, 2019)

Japanese Ministry of Land, Infrastructure, T. and T., 2010. Casebook on efficient treatment of beach wreckage, etc. [WWW Document]. URL https://www.mlit.go.jp/common/000124380.pdf (in Japanese) (Last access: November 4, 2020)

Japanese Ministry of the Environment, 2019. Strategy for Plastic Resources Circulation. [WWW Document]. URL https://www.env.go.jp/press/files/jp/111747.pdf (in Japanese) (Last access: May 30, 2019).

Kellenberg, D., 2012. Trading wastes. J. Environ. Econ. Manage. 64, 68–87. https://doi.org/10.1016/j.jeem.2012.02.003

Krugman, P.R., 2018. International Economics: Theory and policy, 8/E. ed. Pearson Education, India.

Krutilla, K., 1991. Environmental regulation in an open economy. J. Environ. Econ. Manage. 20, 127–142. https://doi.org/10.1016/0095-0696(91)90046-L

Liang, Y., Tan, Q., Song, Q., Li, J., 2021. An analysis of the plastic waste trade and management in Asia. Waste Manag. 119, 242–253. https://doi.org/10.1016/j.wasman.2020.09.049

Mannaerts, H., 2000. STREAM: substance throughput related to economic activity model. A partial equilibrium model for material flows in the economy., No. 165. ed. CPB Research Memorandum, The Hague.

National Development and Reform Commission, 2014. Report on Comprehensive Resource Utilization in China.

Palmer, K., Sigman, H., Walls, M., 1997. The cost of reducing municipal solid waste. J. Environ. Econ. Manage. 33, 128–150. https://doi.org/10.1006/jeem.1997.0986

Plastic Waste Management Institute, 2020. The Basics of Plastic Recycling 2020 [WWW Document]. URL https://www.pwmi.or.jp/pdf/panf1.pdf (Last access: May 2020)

Plastic Waste Management Institute, 2019. The Basics of Plastic Recycling 2019 [WWW Document]. URL https://www.pwmi.or.jp/pdf/panf1.pdf (in Japanese) (Last access: May 2019)

Plastic Waste Management Institute, 2017. The Status of Production, Disposal, Recycling and Treatment Disposal of Plastic Products. [WWW Document]. URL https://www.pwmi.or.jp/pdf/panf2.pdf (Last access: May 2019)

Porter, R.C., 2002. The Economics of Waste. Routledge.

Qu, S., Guo, Y., Ma, Z., Chen, W.Q., Liu, J., Liu, G., Wang, Y., Xu, M., 2019. Implications of China’s foreign waste ban on the global circular economy. Resour. Conserv. Recycl. 144, 252–255. https://doi.org/10.1016/j.resconrec.2019.01.004

Sasaki, S., 2020. The effects on Thailand of China’s import restrictions on waste: measures and challenges related to the international recycling of waste plastic and e-waste. J. Mater. Cycles Waste Manag. 1–7. https://doi.org/10.1007/s10163-020-01113-3

Van Beukering, P.J., 2002. Recycling, international trade and the environment. Springer Science & Business Media.

Van Beukering, P.J.H., Bouman, M.N., 2001. Empirical evidence on recycling and trade of paper and lead in developed and developing countries. World Dev. 29, 1717–1737. https://doi.org/10.1016/S0305-750X(01)00065-1

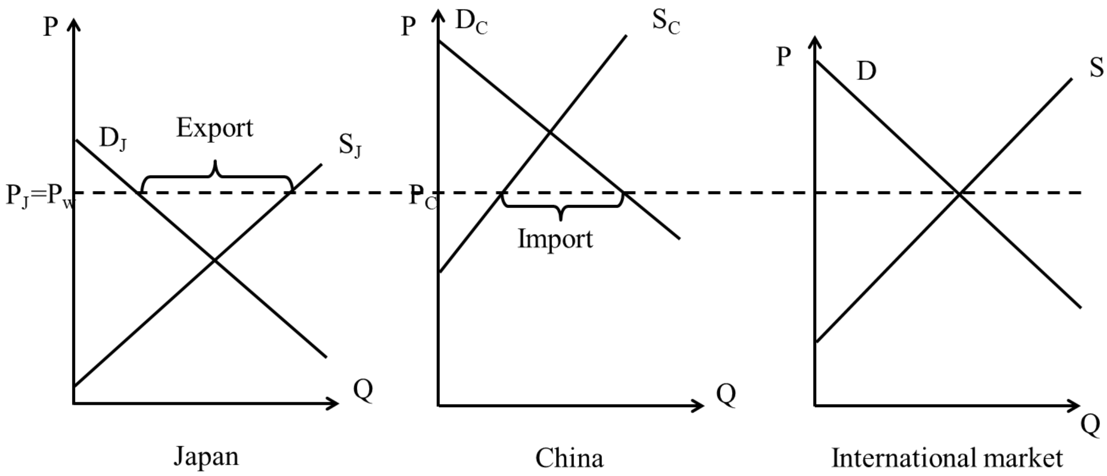

Fig 1 Basic model in international trade theory

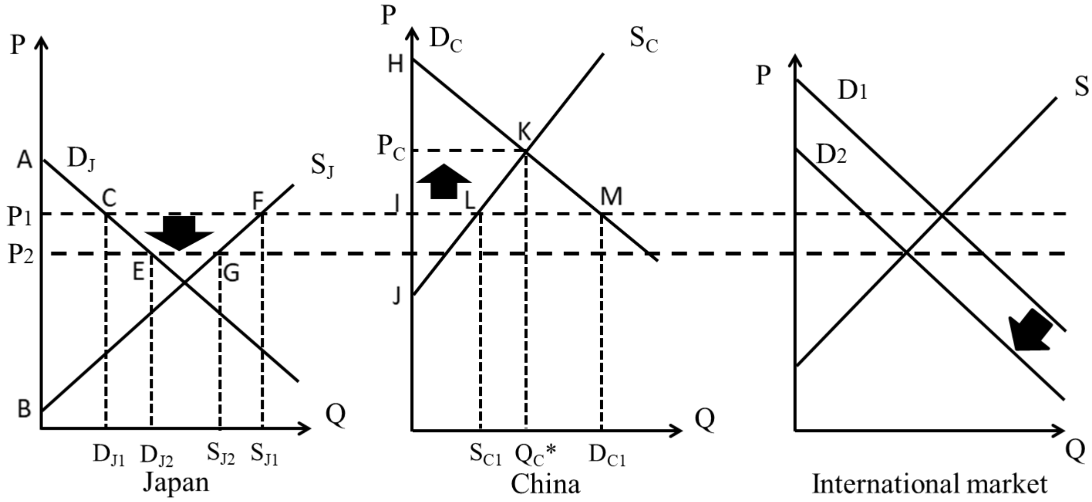

Fig 2 Impact of China's import ban

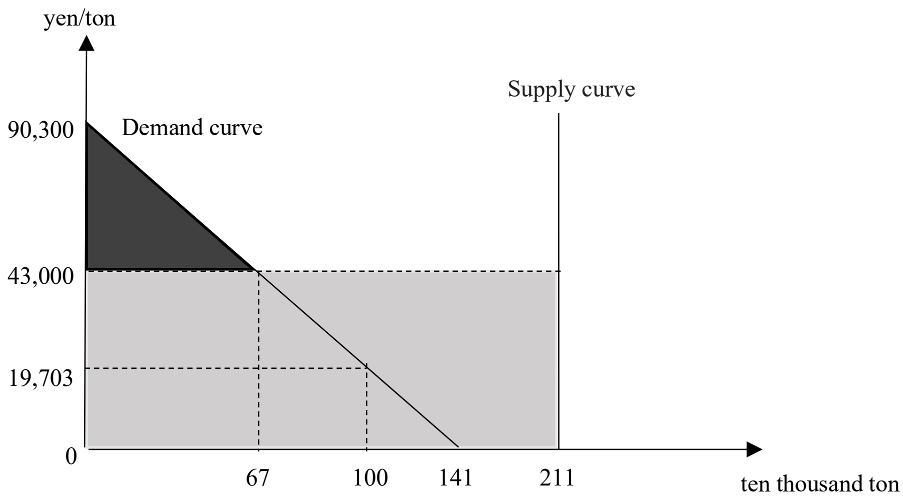

Fig 3 Recycling market in Japan (arc elasticity = –1)

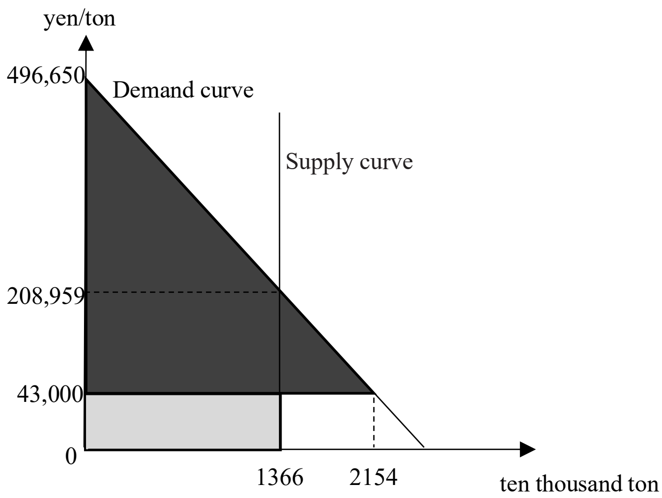

Fig 4 Recycling market in China (arc elasticity = –0.1)

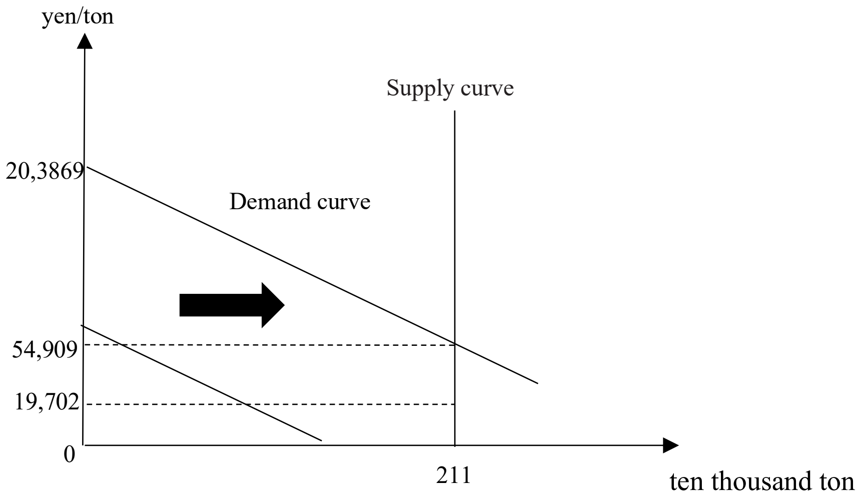

Fig 5 Japan's promotion of domestic recycling

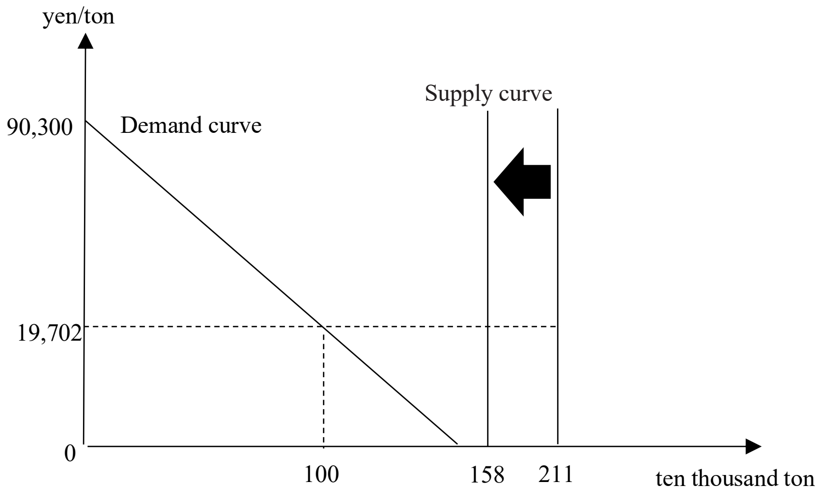

Fig 6 Japan's reduction of plastic waste

Table 1

Data on Plastic Waste

Variables	Values
International price	43,000 yen/ton
Domestic demand (Japan)	0.67 million ton
Domestic supply (Japan)	2.11 million ton
Amount of export (Japan)	1.44 million ton
Domestic demand (China)	21.54 million ton
Domestic supply (China)	13.66 million ton
Amount of import (China)	7.88 million ton

Note: 43,000 yen/ton of international price converts to 43 yen/kg. The yen/dollar exchange rate is 109 yen/dollar as of August 1, 2019. Amounts of export and import are the average from 2014 to 2018.

Table 2

Summary of the economic surplus analysis

The price elasticity of demand for plastic waste		Japan's surplus			China's surplus		
		-1	-1.5	-0.5	-0.1	-0.15	-0.05
Consumer surplus	Before import ban	15.8	10.8	31	4885.8	3264.9	9748.5
	After import ban	35.3	24.1	69	1966.2	1313.9	3923.2
	Surplus Change	19.5	13.3	38	-2919.5	-1951	-5825.3
Producer surplus	Before import ban	90.7	90.7	90.7	587.3	587.3	587.3
	After import ban	41.6	57.2	-5.3	2853	2101.4	5108
	Surplus Change	-49.1	-33.5	-96	2265.7	1514.1	4520.7
Total surplus	Before import ban	106.5	101.5	121.7	5473.1	3852.2	10335.8
	After import ban	76.9	81.2	63.6	4819.2	3415.4	9031.2
	Surplus Change	-29.7	-20.3	-58	-653.8	-436.9	-1304.6

Note: The unit is billion yen. Total surplus is the sum of each consumer surplus and producer surplus. These producer surpluses measure the maximum value of the producer surplus because the supply curve is assumed to be horizontal at P=0.