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神戸大学大学院経済学研究科

経済学専攻

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（プラスチック廃棄物の経済学的実証研究）

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Chapter 1

Introduction

Plastics are used to make various products in modern society, such as PET bottles, shopping bags, lunch boxes, cars, home appliances, and medical equipment. Plastic materials are relatively cheap and can be found in many places in different forms. They can easily change their shape and have excellent electrical insulation, water resistance, and chemical resistance. Using plastics is extremely convenient, and they have become an indispensable material in our daily life.

Consequently, the use of plastics has led to the massive production, consumption, and disposal of plastic waste, which has caused many environmental problems. For example, the use of shopping bags by consumers causes marine debris problems (Kuo and Huang, 2014; Possatto et al., 2015; Jung et al., 2018), and the direct incineration of plastic waste generates carbon dioxide (Sevigné-Itoiz et al., 2015; Chen, 2018; Shen et al., 2020). Further, the massive production of plastics may cause wastage of natural resources because naphtha—required to produce virgin plastic—is obtained by refining crude oil.

This dissertation describes an empirical study conducted on the economics of plastic waste. We focus on the behavior of firms that produce plastic products. We investigate the effects of different policies on the flow of plastic waste in international trade, the use of recycled plastic materials in the production process, and the relationship between plastic usage and the financial performance of firms. Corporate responses for reducing and recycling plastics play an essential role in building a circular economy. Thus, our analysis of the use of plastic material provides broad policy implications for addressing the issue.

The rest of this dissertation is structured as follows. Chapter 2 explores the impact of China's import ban on the plastic waste market. Over the years, China has imported a vast amount of plastic waste from the rest of the world. However, in December 2017, it implemented a ban on the import of plastic waste, used paper, and miscellaneous scrap goods. This regulation has forced Japan and other countries to look for alternative export destinations or promote the domestic use of plastic waste that they have been exporting. Therefore, the chapter aims to provide new insights on the international waste trade, specifically focusing on the market for recyclable plastics. By using an economic surplus analysis, we investigate the impact of China's import ban on the market for plastic waste in China and Japan and the corresponding response of the Japanese government.

Chapter 3 examines how the Container and Packaging Recycling Law (CPR Law) affected the usage of recycled plastics in the plastic production process. The CPR Law aims to reduce municipal solid waste and promote the recycling of resources. Despite the increase in the collection and recycling of plastic waste due to the CPR Law, its impact on the domestic production process has rarely been studied. By employing a difference-in-differences (DID) approach, this chapter aims to analyze whether the use of recycled plastics for primary plastic products has increased since 1997 after the implementation of the CPR Law in Japan. Furthermore, it also examines the impact of the CPR Law on the use of virgin plastic materials derived from crude oil other than recycled plastics.

Chapter 4 investigates the relationship between the usage of plastics and corporate performance. The CPR Law mandates specific businesses that manufacture and use plastic containers and packaging to pay the recycling fee since 2000. Payment of the fees has operated as an incentive for companies to reduce the use of plastics; in fact, it is considered that the profit per plastic input has increased because of the efforts for plastic reduction. In this chapter, we estimate the impact of the recycling fee paid by companies on the amount of plastic usage to determine the viability of economic incentives. Furthermore, we analyze the relationship between corporate plastic use and financial performance to explore how corporate productivity in the context of plastic usage has evolved since the enforcement of the CPR Law.

Chapter 5 concludes the dissertation and posits goals for future research.

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Chapter 2

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

2.1 Introduction

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

China has imported a vast amount of plastic waste from across the world. It is estimated that China accounted for a 45.1% share of the global cumulative imports of plastic waste since 1992 (Brooks et al., 2018). This can be attributed to the high demand for resources to sustain China's economic growth. However, in December 2017, China implemented a ban on the import of plastic waste, used paper, and miscellaneous scrap goods, primarily for two reasons. The first reason was to reduce environmental pollution in China (Kellenberg, 2012; Qu et al., 2019). In 2010, the volume of mismanaged plastic waste in China was 8.82 million tons—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 into the ocean as plastic marine debris each year. Therefore, the resulting microplastic and marine pollution have attracted much attention (Jambeck et al., 2015; Plastic Waste Management Institute, 2019). The second reason was to promote domestic recycling in China. Chinese firms and consumers generate excessive plastic waste. Therefore, the domestic supply of recyclable materials is sufficient to meet the capacity of China's recycling facilities and industry requirements for recycled virgin materials. A study showed that this implication of the trade policy adjustment has prevented 1.4 million tons of waste plastic from flowing into Asia (Liang et al., 2021).

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

Several researchers have investigated the factors that affect 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. Therefore, the objective of this study is two-fold. First, we seek to investigate the impact of China's import ban on economic welfare. For this, we employ an economic surplus analysis to explore the welfare implications of the ban on waste trade. While extant research has focused on the determinants of waste trade, discussion on the benefits and costs of restricting it remains scant. Using economic surplus analysis enables us to assess the impact of the ban on recycling industries and its economic consequences in the recycling market. Consequently, it is significant for investigating waste import ban. Second, we aim to quantitatively assess Japan's response to the Chinese ban on plastic waste imports. It is important to understand the Japanese government's response to China's ban because it affects the flow of Japan's domestic waste. Therefore, this study discusses the implications of Japan's policy response, including increased domestic recycling and the reduction of plastic waste generation.

The remainder of this chapter is organized as follows. Section 2.2 presents the literature review. Section 2.3 describes the theoretical model of international waste trade. Section 2.4 presents the empirical results of the economic surplus analysis. Section 2.5 discusses Japan's potential responses and their economic implications. Finally, Section 2.6 concludes the chapter.

2.2 Literature review

Some studies have empirically examined the impact of trade liberalization on the environment. Pioneering research by Grace et al.(1978) on the international trade of waste investigated the relationships between the amount of recycling of secondary materials and volume traded internationally. Since then, many empirical studies have addressed recycling in open economies(Van Beukering, 2002), such as waste paper and lead scrap (Berglund and Söderholm, 2003; Van Beukering and Bouman, 2001) because waste trade mostly 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 a cheap resource.

Previous research has reviewed the impact of 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 observed that the substitutability of waste and scrap was weak among exporting countries. Higashida and Managi (2014) have highlighted that trade restrictions may impair production efficiency by making it harder for more advanced developing countries to procure materials at low prices. Krutilla (1991) suggested that environmental regulation enacted 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.

Nevertheless, studies on the economic impact of waste policy on international waste trade remain limited. 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 have not explored the impact on economic welfare. We fill this gap by estimating the demand and supply curve for plastic waste in Japan and China. Subsequently, we employ an economic surplus analysis of policy evaluation to analyze the impact of China's import ban on both countries. Examining the impact of economic welfare facilitates the understanding of the consequences of trade restrictions from an economic perspective through the partial equilibrium analysis. Focusing on the bilateral trade between Japan and China enables a simpler investigation of the changes in economic surplus. The ban might have caused waste exporters to divert waste away from China to other countries with less stringent waste import policies. However, Balkevicius et al.(2020) revealed that there is no statistically significant evidence that China's import restrictions on 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. As import ban is stricter than import restrictions, we postulate 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 for analysis. While Ishimura only used the data on trade in plastic waste, we additionally used the data on domestic supply and expanded the scope of the analysis.

2.3 The theory of international trade

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

To examine the impact of China's import ban, this study analyzes a large importing economy in a competitive market. The import ban is expected to significantly impact not only Japan but also other countries (Sasaki, 2020) because it changes the international waste flow. Employing the small country assumption implies that a policy change does not affect the world market (Krugman, 2018). Therefore, in this study, we assume that the policy of China affects the world market but that of Japan does not.

Figure 2.1 illustrates international trade theory under the large country assumption. D_J and D_C represent the domestic demand for plastic waste in Japan and China, respectively. Note that D_J and D_C signify 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 signify the domestic recycling price in Japan and China, respectively. The subscripts J and C imply Japan and China, respectively. D is international demand, and S is the international supply of plastic waste. P_w represents the international price and is determined in the international market. It is assumed that P_w equals both P_J and P_C.

< **Figure 2.1**>

Figure 2.2 graphically illustrates the impact of China's import ban using the large country assumption. Japan is an exporter of plastic waste, whereas 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 decreased its imports to zero $(D_{C1} - S_{C1} = 0)$, and its domestic equilibrium price and quantity increased to P_C. The dramatic decrease in import volume

caused a decrease in demand in the international market; therefore, the demand curve shifts to the left (from D_1 to D_2). Based on the large country assumption, it can be said that 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. Owing to the reduction in price from P_1 to P_2, demand increased from D_{J1} to D_{J2}, and supply decreased from S_{J1} to S_{J2}. Subsequently, Japan's export volume decreased from $S_{J1} - D_{J1}$ to $S_{J2} - D_{J2}$.

<Figure 2.2>

In summary, China's import ban induced a drop in the domestic price of recyclable goods in Japan. Furthermore, in the Japanese market, the consumer surplus increased while the producer surplus decreased; therefore, the total surplus decreased. The change in economic surplus is apparent in Figure 2.2. In the Japanese market, the consumer surplus increased from ACP_1 to AEP_2, and producer surplus decreased from BFP_1 to BGP_2. For the exporter, the consumer surplus increased because the price decreased, and the demand increased due to the import quota. The producer surplus decreased because of the decrease in price and supply. Consequently, the total surplus decreased from $ACFB$ to $AEGB$. In the Chinese market, the consumer surplus decreased, producer surplus increased, and total surplus declined. The consumer surplus decreased from HIM to HP_cK, and producer surplus increased from IJL to P_cJK. For the importer, the consumer surplus decreased because of the price increase, and demand decreased due to the import quota. The producer surplus increased because of the increase in price and supply. Therefore, the total surplus decreased from $HJLM$ to HJK. Based on this model, we quantitatively evaluate the change in economic surplus in both countries.

2.4 Data and empirical analysis

2.4.1 Data

To quantitatively evaluate the impact of China's import ban, we develop a demand and supply curve for the plastic waste market. We use the weighted average price of plastic waste exported from Japan to China in 2017 as the international price of plastic waste (in yen/ton). Data on the export volume of plastic waste (in million tons) were obtained from the Trade Statistics of Japan (URL: http://www.customs.go.jp/toukei/info/index.htm).

This study considers plastic scrap data as the target data of 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 that belong to code 3915 (3915 includes the value and quantity of plastic waste trade). Data on the domestic generation of plastic waste were 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 2.1.

< **Table 2.1**>

We use the price elasticity of demand to construct a linear demand curve. However, previous estimations of the price elasticity of demand for plastic waste are limited. For example, a study showed that the elasticity of plastic material is – 0.9 in OECD countries (Mannaerts, 2000), while another study proved 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 to account for the sensitivity of the results to the elasticities.

2.4.2 Empirical analysis

Here, we develop 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 using a negative value. One percent increase in price is associated with a one percent decrease in demand if the price elasticity is –1. When the price elasticity is less (more) than –1, demand is elastic (inelastic). We consider three cases to examine the sensitivity of the results to the assumption of the elasticity of demand. We assume that the Japanese supply curve is initially horizontal and then vertical at the amount of domestic supply, as shown in Figure 2.3. The vertical axis represents the yen per ton, and the horizontal axis represents the volume of recyclable plastics.

< **Figure 2.3**>

We also estimate the Chinese demand curve based on three assumptions of the price elasticity of demand (– 0.1, – 0.15, – 0.05). Here, the Chinese elasticity of demand is considered as more inelastic than Japan because large demand and resource scarcity in China make waste plastics necessity goods. As recycled materials are substitutes for virgin materials, the former's price is typically much cheaper than the latter. Thus, we postulate that China imported recycled materials to save the production cost. In the context of the Chinese supply curve, we assume that it is initially horizontal and then vertical at the amount of domestic supply, as shown in Figure 2.4. The vertical axis represents the yen per ton, and the horizontal axis represents the volume of recyclable plastics.

< **Figure 2.4**>

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

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

Here, x represents domestic demand for recyclable plastic, and p represents the domestic price of recyclable plastics. p_1 denotes the price of x_1, and p_2 denotes the price of x_2. When the demand curve is linear, the price elasticity of demand assumes different values at different points along the curve. Regarding 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 the 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 $p_1 = 43{,}000$ (yen/ton) and $x_1 = 670{,}000$ (tons) (Japanese Ministry of Finance, 2019; Plastic Waste Management Institute, 2017). The price is denoted by the average price between 2014 and 2018. When the arc elasticity is –1 and the price increase is 10%, we obtain $x_2 = 609{,}090$ (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 as follows:

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

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

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

Figure 2.3 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. Consequently, 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, its domestic price decreases to 19,703 yen/ton (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. In Japan, the consumer surplus is 35.3 billion yen, and the producer surplus is 41.6 billion yen. This implies that consumer surplus increases by 19.5 billion yen, and producer surplus decreases 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 as follows:

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

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

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

Figure 2.4 represents a demand and supply curve when China's arc elasticity is –0.1. Here, 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—208,959 yen/ton. This implies that China's domestic price of plastic waste increases by 4.8 times. In China, consumer surplus is 1966.2 billion yen, and producer surplus is 2853 billion yen. This means that consumer surplus decreases by 2919.5 billion yen, and producer surplus increases by 2265.7 billion yen after the ban.

<Table 2.2>

These results are summarized in Table 2.2. In all the cases, Japan's consumer surplus increases, producer surplus decreases, and total surplus decreases 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 cause the recycler who sells plastic waste from the market to exit from the market. Consequently, the total surplus also decreases. China's consumer surplus decreases, producer surplus increases, and total surplus decreases due to the ban. This implies that the firms purchasing plastic waste face economic losses due to the decrease in imports.

The results in Table 2.2 show that the sign of the economic surplus does not change due to the varying price elasticity of demand for plastic waste. Economic surplus differs in terms of size, and the negative impact becomes greater when demand is more inelastic. The result implies that there may be a significant decrease in economic surplus if recyclable plastics become a necessary good for an economy. Further, the import ban has a greater negative impact in China than in Japan.

2.5 Policy response by Japan

In this section, we consider the possible response of 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 subsections, we consider the promotion of domestic recycling and reduction of plastic waste generation as probable policy responses. However, we assumed that the increased cost associated with increased plastic recycling is zero.

2.5.1 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% rate of recycling/reusing 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% rate of recycling/reusing 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 reusing 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 follows:

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

Figure 2.5 displays the shift in the demand curve caused by the promotion of domestic recycling. The price of recyclable plastics is estimated to be $54{,}909(\text{yen/ton})$. The results suggest that the promotion of domestic recycling increases the price of plastic waste. Therefore, the consumer surplus increases from 35.3 billion yen to 157.2 billion yen compared to a scenario without any policy response to counter the ban. The producer surplus also increases from 41.6 billion yen to 115.9 billion yen. Thus, this policy response will increase the economic surplus.

< Figure 2.5>

The abovementioned scenario may be a little too ambitious when we consider the past trends in plastic recycling. As an alternative scenario, we consider the case wherein the material recycling rate increases from 23% to 34.8%. This is based on the fact that in Japan, 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). Consequently, 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. Therefore, it is impossible to process the entire supply by domestic recycling.

To increase material recycling, using thermal recovery for conversion is necessary. By enhancing 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.

2.5.2 Reducing the generation of plastic waste

The Japanese Ministry of the Environment’s aim to reduce the generation of plastic targets the use of single-use plastics and develops 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 Figure 2.6.

< Figure 2.6>

Figure 2.6 depicts 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’s elasticity is –1. Thus, reducing the generation of plastic waste may shrink the recycling market.

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

2.6 Conclusions

This study investigates the impact of China's ban on the import of plastic waste and recycling markets in Japan and China. The results obtained are interpreted as follows. First, the price of plastic waste changes substantially after the ban; in fact, the price of plastic waste decreases from 43,000 yen/ton to 19,702 yen/ton in Japan. The actual data confirm that the price of plastic waste after 2018 was approximately 41,000 yen/ton, which is not as low as the estimated value. 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 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 slightly less than our estimates.

Second, we found that the economic surplus changes significantly. Owing to the import ban, Japan's consumer surplus increases, and producer surplus decreases in all cases. This implies that consumers (the buyers of plastic waste) benefit from the import ban as they can 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 decrease producer surplus when waste reduction is promoted. These results and their interpretation allow a better understanding of the impact of Japan's policy responses.

The following issues were not addressed in this study. First, we did not consider the environmental benefit of recycling plastics. The main reason behind the import ban was to reduce environmental pollution and plastic marine debris in China. Therefore, a full-fledged economic surplus analysis should consider the environmental benefit induced by the ban. Owing to China's import ban, 7.88 million tons of plastic waste were 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 tons of plastic marine debris due to 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 did not consider the storage capacity of plastic waste for both countries. In the short run, garbage is stored in stockyards, which could potentially lead to its mismanagement.

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Table 2.1: Data on plastic waste

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

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 2.2: 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 a 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.

Figure 2.1: Basic model in international trade theory

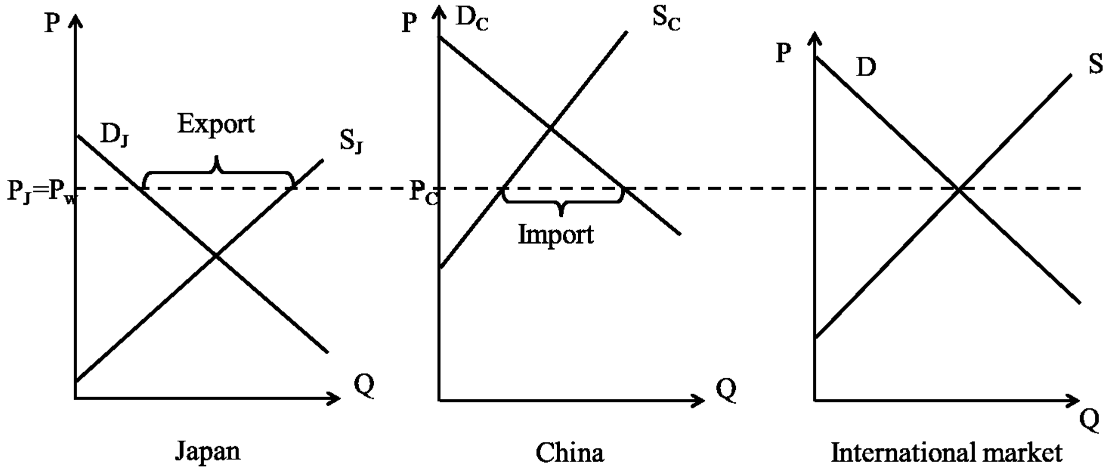


Figure 2.2: Impact of China's import ban

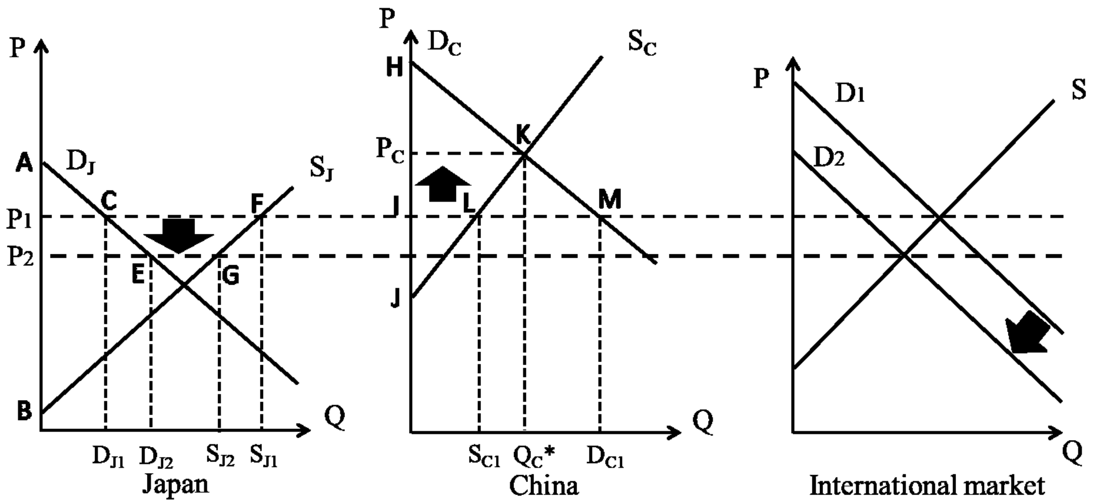


Figure 2.3: Recycling market in Japan (arc elasticity = –1)

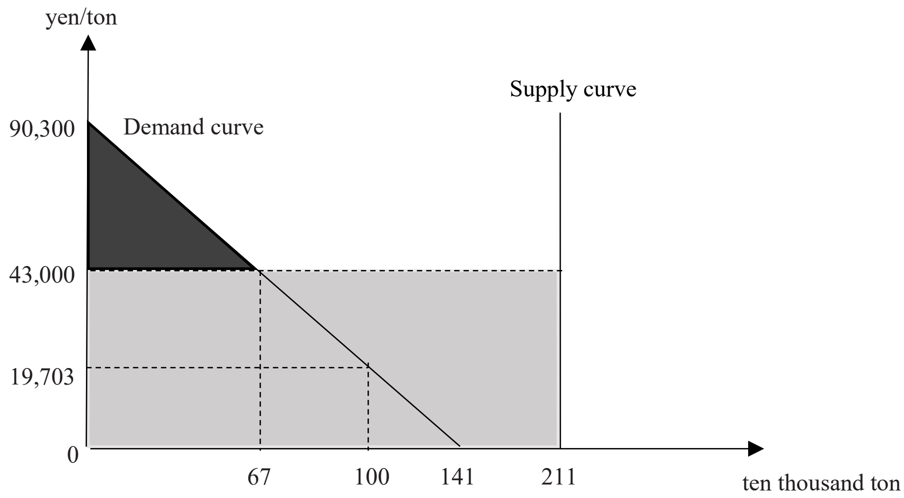


Figure 2.4: Recycling market in China (arc elasticity = –0.1)

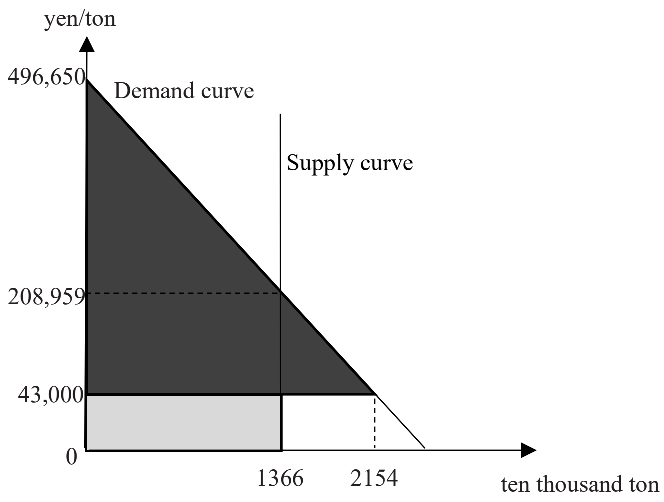


Figure 2.5: Japan's promotion of domestic recycling

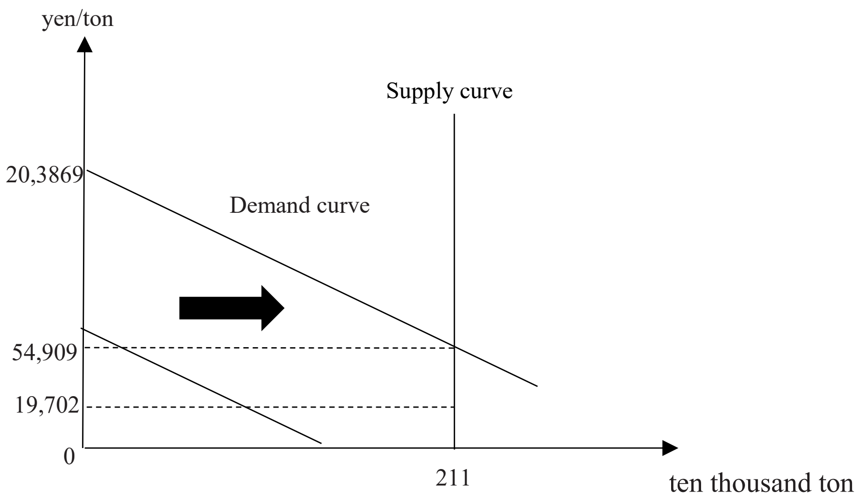
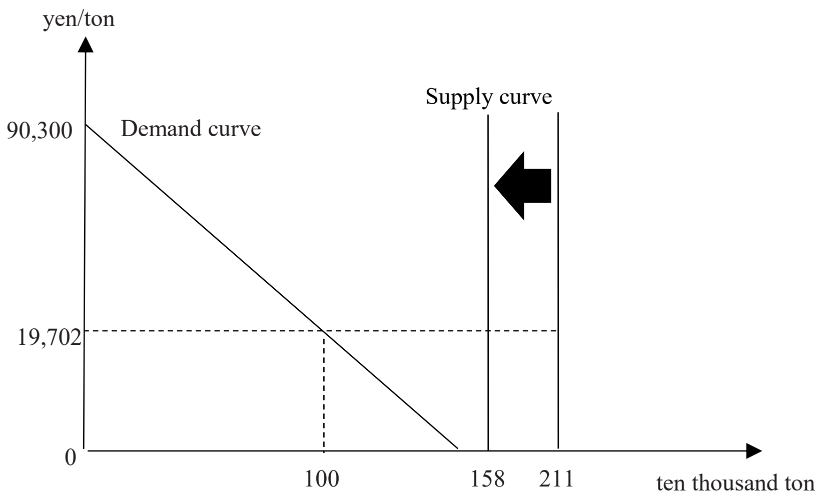


Figure 2.6: Japan's reduction of plastic waste



Chapter 3

The Recycled Content of Plastic Products: Examining the Impact of the Container and Packaging Recycling Law

3.1 Introduction

The global production of plastics increased from 2 million tons in 1950 to 380 million tons in 2015, and the cumulative generation of plastic waste amounted to 6.3 billion tons during this period (Geyer et al., 2017). The vast amount of plastic waste poses a serious threat to the environment, including marine litter and pollution (Carney Almroth and Eggert, 2019).

The generation of plastic waste in Japan increased from 3.26 million tons in 1980 to more than 8.91 million tons in 2018 (Plastic Waste Management Institute, 2020a). Meanwhile, the mechanical recycling of plastic waste in Japan increased from 1.39 million tons in 2000 to 2.08 million tons in 2018. One of the driving forces behind this increase is the Container and Packaging Recycling Law (CPR Law) enacted in 1995 and enforced in 1997.[1] The CPR Law aims to reduce household waste by collecting containers and packaging waste for recycling. It mandates consumers to separate packaging waste from garbage, municipalities to collect recyclable materials, and producers of packaging and packaged goods to pay the cost of recycling. Producers take partial financial responsibility for recycling by paying a recycling fee to the Japan Containers and Packaging Recycling Association that contracts with recyclers.

Although plastic recycling in Japan has advanced during the last two decades, some caveats exist. First, while mechanical recycling has increased, thermal recycling, or

[1] Nakatani et al. (2020) estimated that the domestic demand for plastics for containers and packaging was 4.1 million tons, and it accounted for 40% of the total demand for plastics in 2015.

energy recovery by incineration has also increased, specifically, from 3.12 million tons in 2000 to 5.02 million tons in 2018 (Plastic Waste Management Institute, 2020a).[2] In terms of greenhouse gas emissions, mechanical recycling is preferred to energy recovery (Nakatani et al., 2010).[3] Second, materially recycled plastics are not necessarily used in the domestic production of new plastic products. A substantial proportion of them is exported to other countries or disposed of as residuals during the recycling process. According to the Plastic Waste Management Institute (2020a), the amount of materially recycled plastics was 2.08 million tons in 2018, of which more than half (1.29 million tons) was exported. Exported plastic waste is not always managed properly, which causes pollution in destination countries (Kellenberg, 2012; Jambeck et al., 2015). Thus, it is relevant to examine the extent to which the use of recycled plastics in domestic production increased after the implementation of the CPR Law.

This study focuses on the production of primary plastic products that use virgin or recycled materials. Figure 3.1 shows several steps taken to produce plastic goods. First, virgin plastic materials are typically made from crude oil. Then, these materials and recycled plastics are processed to produce primary plastic products, such as film, sheets, plates, and containers. These primary products are used as intermediate goods to make secondary plastic products that are consumed, disposed of, and recycled. As the CPR Law increases the collection of recyclable plastics, we expect that producers of primary products find more opportunities to shift their input mix toward used plastics and to increase the recycled content of products. For example, Hosoda (2004) documented that manufacturers began to increase the use of recycled plastics as inputs for various products after the law. Although the CPR Law does not directly require producers to use recycled plastics, it indirectly affects the producer behavior by increasing the supply of recycled plastics.

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[2] The Japanese Ministry of the Environment categorizes recycling methods into material recycling, thermal recycling, and chemical recycling. Material recycling corresponds to mechanical recycling, a process that uses waste materials for new products. Thermal recycling is generally referred to as energy recovery. Materials are burned in incinerators while generating electricity and heat. Chemical recycling is called feedstock recycling, in which waste is broken down into its constituent components and then recombined to produce new materials.

[3] Gradus et al. (2017) investigated the cost-effectiveness of incineration and recycling of household plastic waste in the Netherlands. The result suggests that the implicit CO_2 price in the case of plastic recycling is much higher than that for other viable opportunities.

Our study empirically evaluates the effect of the CPR Law on the change in the input mix by utilizing data from the Monthly Report of Current Production Statistics Survey published by Japan's Ministry of Economy, Trade, and Industry. The report provides data on the monthly production of various categories of plastic products and the amounts of inputs used for their production. This allows us to investigate the changes in the input share of recycled plastics according to product category. Consequently, we examine whether the recycling law had any impact on the use of recycled plastics in the domestic production process.

<Figure 3.1>

This study is related to several strands of literature on waste management. First, there are numerous empirical studies on the economics of recycling. Specifically, scholars have investigated the impact of recycling programs on households (Ek and Miliute-Plepiene, 2018), professional recyclers (Ashenmiller, 2009), municipalities (Dijkgraaf and Gradus, 2017, 2020; Ferreira et al., 2017), and technological innovation (Nicolli et al., 2012). This study differs from these works by focusing on producer behavior. As the supply side plays a substantial role in determining the total amount of material used in an economy, our study has significant implications for policies to establish a sustainable production process with lower environmental impacts. Second, while several studies have theoretically investigated the impact of various policies on extended producer responsibility (Calcott and Walls, 2000; Ino, 2011; Matsueda and Nagase, 2012), empirical investigation of actual recycling programs remains scant (Kaffine and O'Reilly, 2015). This study fills this research gap and contributes to the literature by quantitatively examining the impact of recycling law on the change in inputs in the production process.

Japan's CPR Law provides a unique opportunity to examine the potential impact of the recycling policy on the supply side of the economy. The separate collection of PET bottles increased from 21,000 tons in 1997 to 298,000 tons in 2016 (Ministry of the Environment, 2018). The separate collection of plastic containers and packaging increased from 101,000 tons in 2000 to 739,000 in 2016. Yamakawa (2004) reported that the implementation of the CPR Law has led to a weight reduction of plastic containers and packaging and increased recycling of PET bottles, but has not promoted the use of returnable containers. According to the Council for PET Bottle Recycling (2001, 2011, 2020), the collection rate of PET bottles increased from 9.8% in 1997 to 34.5% in 2000 and 93% in 2019, and the recycling rate of PET bottles increased from 75% in 2006 to

86% in 2019. Meanwhile, the total production volume of PET bottles increased from 124,000 tons in 1993 to 593,000 tons in 2019, and waste volumes were larger than before the law's enforcement (Yasuda, 2001; Council for PET Bottle Recycling, 2020). While this anecdotal evidence suggests a potential effect of the CPR Law on the production process, a thorough empirical analysis has not been conducted to date.

Our estimation results indicate that the usage of recycled plastics doubled and recycled content increased by 1% after the enforcement of the CPR Law in 1997. The results suggest that the CPR Law indirectly affected both the amount and percentage of recycled plastics used as inputs. However, the stark contrast of the impact suggests that the increase in the total production of plastic products outweighs the increase in the number of recycled plastics used as inputs. Regarding product category, the use of recycled plastics for plastic film and sheets as well as plastic containers significantly increased after 1997. Furthermore, the use of virgin plastic materials, such as polyethylene (PE), polypropylene (PP), and vinyl chloride (VC), has significantly decreased since 1997. Irrespective of the small size of the impact, it implies that recycled plastics replaced virgin plastic materials.

The remainder of the chapter is organized as follows. Section 3. 2 describes the data and our empirical model. Section 3.3 explains the main results. Section 3.4 discusses an extension of the results. Section 3.5 concludes.

3.2 Data and empirical analysis

3.2.1 Data

We use a panel of monthly data for 11 categories of plastic products in Japan from January 1989 to July 2019.[4] Data on the amounts of materials used in plastic products were obtained from the Monthly Report of Current Production Statistics Survey (Ministry of Economy Trade, and Industry, 1989–2019), which covers all establishments of plastic products employing more than 50 people. We collect the total amount of various plastic products and inputs used in these productions monthly.[5]

<Table 3.1>

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[4] Refer to Table 3.3 for the categories of plastic products.

[5] The disaggregated data at the firm level are not available.

Table 3.1 reports the descriptive statistics. On average, recycled plastics used for plastic products amount to 1,223 tons per month per category. The data reveal that, in 2018, the total amount of recycled plastics used in our sample establishments was approximately 235,725 tons.[6] This is smaller than the total amount of recycled plastics used in domestic production (760,000 tons in 2018), as reported by the Plastic Waste Management Institute (2020a). This gap can be attributed to the coverage of the dataset. First, our data do not include establishments with fewer than 50 employees. These establishments comprise 91% of the total number of establishments and account for 47% of the total number of employees. Second, recycled plastics refer to those purchased or provided by other firms and offices of the company and are directly used in the manufacturing process. This does not include plastic waste generated during the manufacturing process within the establishment.

As a measure of the material used in the production process, we define the input share of recycled plastics as follows:

$$S_{kit} = \frac{Input_{kit}}{Production_{it}}$$

where S_{kit} represents the input share of material k used as the input for manufacturing product i in period t. In the context of recycled material, the input share is often called recycled content. It is calculated by dividing the input of recycled plastics by the production of plastic products. For example, if 1 ton of recycled plastic is used as an input for 100 tons of plastic products, the recycled content is 1%. The input share of recycled plastics in our sample is 2.2% on average and 8.5% at the highest. This is much lower than the input share of virgin plastic materials, as the average input share of PE is 14.8%, that of PP is 12.8%, that of polystyrene (PS) is 10.7%, and that of VC is 21.7%.

[6] These recycled plastics include emissions from the municipal sector and the industrial sector. Because the CPR Law matters only for the container and packaging waste emitted by the municipal sector, we may overestimate the impact of the law. However, an estimate by the Plastic Waste Management Institute (1996, 2020) indicates that mechanically recycled plastic waste emitted by the industrial sector increased marginally from 1.01 million tons in 1996 to 1.16 million tons in 2018, while that emitted from the municipal sector increased substantially from 0.02 million tons in 1996 to 0.7 million tons in 2018. Thus, the change during the treatment period can mostly be attributed to the increase in the municipal sector.

Table 3.2 summarizes the characteristics of plastic materials used for production. PE, PP, PS, and VC are representative plastic materials made from crude oil. PE and PP are widely used in plastic products, such as plastic bags, plastic wraps, and product packaging. They are lighter than water, soft, water-resistant, oil, and chemicals, and excellent as electrical insulation. PS is hard plastic and is used to produce rigid products, such as food packaging and disposable cutlery. It can also be converted into a foam material used to protect packaging, such as single-use food containers. VC is the precursor to polyvinyl chloride (PVC), which is typically used in plastic products in the construction and automotive industries.

<Table 3.2>

The CPR Law was enacted in 1995 and enforced in 1997 for glass and PET bottles, and expanded its scope in 2000 to include containers and packages made of paper and plastics. To capture the stepwise impact of the CPR Law, the following dummy variables are introduced in this study: After1997, After2000, After2018, and three dummy variables that indicate the period between these timelines (1995–1997, 1997–2000, and 2000–2017).[7] The dummy variable 1995–1997 represents the announcement effect of the CPR Law. After1997 and After2000 represent the partial and full enforcement of the Law, respectively. After2018 is used to capture the impact of China's import ban on waste plastics in December 2017. Before the ban, more than 50% of plastic waste exports from Japan were directed to China.[8] After the import ban, the amount of domestically recycled plastics was expected to increase. We use WTI crude oil prices to control the effect of oil prices on the usage of recyclables and other plastic materials. The data are from the World Bank Commodity Price Data (Pink Sheet) and adjusted from nominal prices to real prices in 2015 using the consumer price index.

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[7] Specifically, 1995–1997 is a dummy variable that equals 1 from June 1995 to March 1997, or 0 otherwise. After1997 is a dummy variable that equals 1 from April 1997 to July 2019, or 0 otherwise. Furthermore, 1997–2000 is a dummy variable that equals 1 from April 1997 to March 2000, or 0 otherwise. After2000 is a dummy variable that equals 1 from April 2000 to July 2019, or 0 otherwise. 2000–2017 is a dummy variable that equals 1 from April 2000 to December 2017, or 0 otherwise. After2018 is a dummy variable that equals 1 from January 2018 to July 2019, or 0 otherwise.

[8] Trade Statistics of Japan (http://www.customs.go.jp/toukei/info/index.htm)

3.2.2 Empirical methodology

This subsection describes the empirical method used to investigate the effect of the CPR Law on input share. The estimated model is expressed as follows:

$$S_{kit} = \beta_0 Target_i * Post_t + \beta_1 OilPrice_t + \delta_i + \lambda_t + \varepsilon_{it} \qquad \cdots (3.1)$$

where S_{kit} represents the input share of material k used for plastic product i in period t. $Treatment_i * Post_t$ represents the interaction term to measure the impact of the CPR Law, where $Treatment_i$ is the dummy variable for the product category that is strongly affected by the CPR law (see the next paragraph for details), and $Post_t$ is a dummy variable representing the implementation of the CPR Law, as defined in the previous subsection. $OilPrice_t$ denotes the logged oil prices in period t, δ_i represents the category fixed effects, λ_t denotes the year-by-month or year and month fixed effects, and ε_{it} represents the error term.

This study uses a difference-in-differences (DID) method to examine the effect of the CPR Law on the use of recycled plastics in primary plastic products. We divide the 11 categories of plastic products into treatment groups or control groups. Table 3.3 presents the classification of the product categories. We hypothesize that the effect of the law on the product mix is stronger in the treatment group because of the difference in product characteristics. Although the CPR Law might affect all categories of plastic products, the impact is expected to be heterogeneous among the categories because of the technical difficulty in increasing inputs of recycled plastics.

The treatment group comprises the following five product categories: film and sheets, products for machine tools and parts, pipes and joints, containers, and other products. According to the Council for PET Bottle Recycling (2020), collected PET bottles have been used domestically to produce PET bottles (24.3%), film and sheets (43.5%), synthetic fibers (20.7%), and products for logistics, construction, and offices (2.3%). The control group contains the other product categories: plates, building materials, synthetic leathers, products for general goods, foam products, and reinforced products. In general, it is more difficult to use recycled plastic materials in these product categories because of their durability and stability. Plastic plates are hard plastic products made of VC, acrylic resin, and other materials. Plastic products for building materials, such as rain gutters and floor tiles, are typically made of VC. Plastic synthetic leathers are mainly made of VC and nylon. Plastic products for general goods, such as tableware and lunch boxes, are mainly made of melamine resin. Plastic foam products are mainly made of PS. Plastic reinforced products are formed by adding glass and carbon fibers to plastic materials. Figure 3.2 illustrates the share of the production amount of primary plastic products in the treatment and control group. The treatment group accounts for nearly 80% of the total amount of primary plastic products. We consider that the additional use of recycled plastics in the treatment group does not affect the use of recycled plastics in the control group because both groups are independent of each other.

<**Table 3.3**>

<**Figure 3.2**>

Figure 3.3 depicts the amount of recycled plastics used as inputs in the treatment and control groups during the study period. It suggests that recycled plastics used as inputs for the treatment group began to increase in the late 1990s, while that for the control group remained relatively stable. Throughout the study period, the total monthly usage of recycled plastics was 11,263 tons on average for the treatment group and 2,193 tons on average for the control group.

<**Figure 3.3**>

Figure 3.4 depicts the recycled contents of the treatment and control groups. When we divide the amount of recycled plastics by the total amount of production, the contrast between the treatment and control groups becomes less clear. Nevertheless, Figure 3.4 suggests that the recycled contents in the treatment group increased in the late 1990s. The average recycled content before the enforcement of CPR law was 2% for the treatment group and 1.5% for the control group. After the enforcement, the average recycled content was 3.1% for the treatment group and 2.3% for the control group.

<**Figure 3.4**>

We also investigate the change in input share of virgin plastic materials after the implementation of the CPR Law. For this purpose, we use the input share of virgin plastic materials as the dependent variable. Owing to the substitutability between recycled plastics and virgin plastic materials, the increase in the input share of recycled plastics is expected to reduce the input share of virgin materials.

3.3 Main results

3.3.1 Effect of CPR Law on recycled plastics

We begin our analysis by using the number of recycled plastics as the dependent variable in the model (1). Table 3.4 reports the estimation results. Columns (1) to (3) present the models with year-by-month fixed effects, while columns (4) to (6) present the models that contain year and month fixed effects independently. Overall, the interaction terms between the treatment group dummy and the CPR Law dummy are positive and statistically significant. The results suggest there was an increase of recycled plastic materials in the production process after the implementation of the CPR Law. Specifically, in column (3), the coefficient for Treatment*1995–1997 implies that the announcement effect of the CPR Law is as much as 657 tons. The same model suggests that the effect of the law was estimated as 882 tons between 1997 and 2000 and 1,324 tons between 2000 and 2017. The results suggest that firms substantially increased their inputs of recycled plastics in the treatment group after both the partial and full implementation of the CPR Law. Furthermore, the interaction term between the treatment group and After2018 (Treatment*After2018) is positive and statistically significant. This implies that the use of recycled plastics in the treatment group increased by approximately 2,300 tons after China's import ban on waste plastics. Indeed, the estimated impact is double that of the CPR Law.

In summary, the CPR Law substantially impacted the amount of recycled plastics used as inputs for primary plastic products. The usage of recycled plastics increased by 1,336 tons after the implementation of the CPR Law. As the average monthly usage of recycled plastics in the treatment group before 1997 was 1,315 tons, the result implies that the usage of recycled plastics doubled from before the implementation of the law. However, the estimated impact of the law was less than the increase after China's import ban. Moreover, the analysis does not consider the increase in the total amount of plastic products.

<Table 3.4>

3.3.2 Effect of CPR Law on the recycled content

The analysis in the previous subsection does not consider the increase in the total amount of plastic products. The increase in the amount of recycled materials used for production after the implementation of the CPR Law may be attributed to the increase in the total amount of plastic production. Thus, this subsection focuses on the change in the input share of recycled plastics after the implementation of the CPR Law.

<Table 3.5>

Table 3.5 reports the estimation results for the recycled content. The interaction term between the treatment group and all policy dummies is positive and statistically significant. The results suggest that the recycled content increased after the implementation of the CPR Law. The size of the coefficient implies that the recycled content increased by approximately 1% after the implementation of the Law. The estimated impact of the CPR Law is small: taking column (3) in Table 3.5 as an example, the impact is 1.08% after the initial enforcement in 1997 and 0.99% after the complete enforcement in 2000. Contrary to the result found in the previous subsection, the impact of initial enforcement is similar to the full enforcement in this model. Finally, the effect of China's import ban is positive and statistically significant, as suggested by the interaction term between the treatment group and After2018 (Treatment*After2018). The impact is estimated to be 1.2%, which is almost the same as the effect of the initial enforcement of the CPR Law.

These results imply that the CPR Law caused a small increase in the recycled content in the production process (about 1%). In contrast, the impact of the law on the amount of recycled plastics is substantial. This implies that although the amount of recycled plastics used as inputs increased, the increase in the total production of plastic products outweighed the effect.

To confirm the parallel trend during the baseline years, we also estimate a model that includes the interaction term between the treatment group dummy and year dummy, taking 1994 as the baseline year. Figure 3.5 presents the coefficients of the interaction term using DID analysis. The results indicate that all coefficients before 1995 have 95% confidence intervals that overlap with zero. Therefore, we can assume that the trends of recycled content are similar between the treatment and control groups before the enactment of the CPR Law. The figure also shows that many coefficients after 1995 are positive and statistically significant, suggesting an increase in the amount of recycled content in the treatment group particularly after the implementation of the CPR Law.

<Figure 3.5>

3.4 Extensions

3.4.1 Heterogeneous effects among product categories

In this subsection, we investigate the heterogeneous effects of the CPR Law among product categories. We divide the treatment group into the following five categories: film and sheets, products for machine tools and parts, pipes and joints, containers, and other products. By comparing the impact among categories, we can analyze the different impacts on the recycled content in more detail and identify the most affected categories.

<Table 3.6>

Table 3.6 presents the estimation results. First, DID indicators are positive and statistically significant for many product categories. This indicates that the recycled content of the categories increased after the implementation of the CPR Law. Particularly, the change in the amount of recycled content for containers and other products is larger than that of the remaining three product categories. The estimated impact of the law on containers is 1.4%, and that on other products is 1.6%. A similar effect is observed for China’s import ban in 2018. Treatment*After2018 is positive and statistically significant in the case of film and sheets, products for machine tools and parts, and containers. Thus, we interpret this to meant that recycled plastics are particularly used to manufacture film and sheets, containers, and other products.

3.4.2 Effect of CPR Law on virgin plastic materials

This subsection investigates the impact of CPR Law on the input share of virgin plastic materials. To consider potential substitution, we focus on five materials: PE, PP, PS, VC, and other materials.[9] Table 3.7 presents the estimation results for the input shares of these plastic materials.

<Table 3.7>

In the case of PE, PP, and VC, the interaction between the treatment group and 1997–2000 (Treatment*1997–2000) is negative and statistically significant. This finding suggests that the input shares of these materials decreased after the initial implementation of the CPR Law in 1997. The impact is also significantly negative after 2000. Thus, the input shares of these materials decreased after the implementation of the CPR Law, while that of recycled content increased. However, we must be cautious about assuming that recycled materials perfectly substitute petroleum-derived plastic materials, because the coefficients of these materials are larger than those of recycled plastics.

Furthermore, notably, the use of VC might be driven by reasons other than the recycling policy. VC is considered a primary source of dioxin contamination and has been highlighted as a serious environmental issue in Japan in the late 1990s (Sekine, 1997; Sakamoto, 2020). This concern coupled with social pressure, such as the Act on Special Measures against Dioxins, on the producers during the period may lead to a reduction in the usage of the material, regardless of the CPR law (Sakai, 2007).

3.5 Conclusions

This study investigated the impact of the CPR Law on the input share of recycled plastics. The findings are summarized as follows. First, the recycled content of plastic products increased after the implementation of the law. This implies that the use of plastic waste for plastic production was promoted after law enforcement. Thus, we conclude that the CPR Law has affected not only the collection of recyclables but also the production

[9] According to the Plastic Waste Management Institute (2020a), the share of plastic materials in total plastic waste is 33% for PE, 22% for PP, and 12% for PS.

process of plastics. Second, the estimated impact on recycled plastic product content was small. This is attributable to the fact that the CPR Law does not directly incentivize producers to use recycled plastics but instead affects them indirectly through the increased supply of recycled plastics. When we analyzed the treatment group in more detail, the impact of the CPR Law was found to be higher in such categories as plastic film and sheets, and plastic containers. Third, the usage of PE, PP, and VC decreased after the implementation of the CPR Law. However, evidence suggests that the decrease of these plastic materials was far greater than the increase in recycled plastics.

To promote the use of recycled plastics further in Japan's production process, decision-makers should consider policies that directly affect it, such as recycled content standards. For example, the EU approved a single-use plastic product directive in 2019, which determined that plastic bottles must contain 25% recycled plastic by 2025 and 30% by 2030. Japan has also pledged to reduce single-use plastics by 25% by 2030 through the Plastic Material Cycle Strategy. Our results for the input share of plastic materials suggest that there is weak substitutability between recycled plastics and other plastic materials. Additional measures are required to facilitate the shift of inputs from virgin to recycled materials or other materials with a lower carbon footprint, such as biomass plastics.

A limitation of this study is that our dataset does not consider the increase in the use of biomass and biodegradable plastics in the production process. These newly developed plastic materials are derived from biomass and can be decomposed by microorganisms. Therefore, future research should address the use of these new materials as input for primary plastic products. Furthermore, two other recycling laws implemented during the 2000s (the Building Material and Home Appliance Recycling Law) might have impacted the use of recycled plastics.[10] However, we could not separate these impacts owing to data availability and the limits of our empirical framework. Examining the effects of these policies on the production process of plastic goods remains for further study.

[10] An estimate by the Plastic Waste Management Institute (2020b) suggests that mechanically recycled plastics are mainly sourced from container and packaging waste: among the 1.86 million tons of mechanically recycled plastics in Japan, 0.51 million tons are sourced from PET bottles, 0.24 million tons from packaging film, 0.22 million tons from home appliances, and 0.04 million tons from automobile parts.

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Table 3.1: Descriptive statistics

Variables	Obs	Mean	Std. Dev.	Min	Max	Unit
Recycled Plastics	4037	1223	1849	0	13521	t
Input Share of Recycled Plastics (Recycled Content)	4037	2.24	1.64	0	8.5	%
Input Share of Polystyrene	4037	10.74	11.57	0	47.6	%
Input Share of Polyethylene	4037	14.88	16.48	0	63.8	%
Input Share of Polypropylene	4037	12.83	18.73	0	73.5	%
Input Share of Vinyl Chloride	4037	21.79	25.67	0	92.6	%
Input Share of Other	4037	12.74	13.12	0.12	63.4	%
Oil Price	4037	5055	2780	1326	14519	Yen per gallon
1995–1997	4037	0.03	0.16	0	1	
After 1997	4037	0.73	0.44	0	1	-
1997–2000	4037	0.01	0.3	0	1	-
After 2000	4037	0.63	0.48	0	1	-
2000–2017	4037	0.58	0.49	0	1	-
After 2018	4037	0.05	0.22	0	1	-

Table 3.2: Characteristics of plastic materials

Materials	Characteristics	References
Polyethylene (PE)	The attractive features of PE include its low price, excellent electrical insulation over a wide range of frequencies, excellent chemical resistance, good processability, toughness, flexibility, and—in thin films of certain grades—transparency. The ability to manufacture several variations allows producers to tailor resins for specific applications, such as packaging films, rigid containers, drums, and pipes.	Patel (2016) Ronca (2017)
Polypropylene (PP)	Polypropylene has excellent strength, low surface energy, low gas, and liquid permeability, and the relative ease of processing makes it an attractive option for use in multilayer films. Polypropylene may be used to manufacture single-layer films or as a component in multilayer films via both cast and blown film processing.	Calhoun (2016)
Polystyrene (PS)	Polystyrene is the simplest plastic based on styrene. Polystyrene is used as a packaging material for food and non-food applications, casings in the electric/electronic and communication industry, building insulation and liners in the refrigeration industry, and disposable medical ware.	McKeen (2014) Niessner and Gausepohl (2003)
Vinyl chloride (VC)	Vinyl chloride is used primarily to manufacture polyvinyl chloride (PVC) resin, a common plastic used in the fabrication of pipes, packaging materials, and insulation. The worldwide production of PVC is extensive, estimated at 59 billion pounds in 2002.	Gospe (2009)

Table 3.3: Treatment and control

Treatment Group	Control Group
• Plastic film and sheets • Plastic products for machine tools and parts • Plastic pipes and joints • Plastic containers • Other plastic products	• Plastic plates • Plastic products for building materials • Plastic synthetic leathers • Plastic products for general goods • Plastic foam products • Plastic reinforced products

Source: Monthly Report of Current Production Statistics Survey (Ministry of Economy, Trade, and Industry, 1989–2019).

Table 3.4: Effect of the CPR Law on the amount of recycled plastics usage

	Recycled Plastics					
	(1)	(2)	(3)	(4)	(5)	(6)
Target*1995 –1997	657.002***	657.002***	657.004***	616.456***	586.317***	586.044***
	[115.846]	[115.270]	[114.061]	[101.554]	[101.137]	[100.075]
Target*After 1997	1336.730***			1311.490***		
	[61.961]			[58.909]		
Target*1997 –2000		882.815***	882.815***		874.391***	870.477***
		[96.271]	[95.262]		[89.153]	[88.218]
Target*After 2000		1407.165***			1383.664***	
		[62.711]			[59.646]	
Target*2000 –2017			1324.997***			1301.797***
			[62.739]			[59.677]
Target*After 2018			2328.310***			2308.347***
			[120.862]			[115.917]
Oil Price				67.088	53.626	53.572
				[88.383]	[87.952]	[87.029]
Constant	676.636***	676.636***	676.636***	126.986	233.975	233.500
	[238.610]	[237.423]	[234.935]	[700.955]	[697.539]	[690.218]
Category FE	YES	YES	YES	YES	YES	YES
Year-by-Month FE	YES	YES	YES	NO	NO	NO
Year FE + Month FE	NO	NO	NO	YES	YES	YES
R-squared	0.2552	0.2628	0.2784	0.2499	0.2578	0.2735
Adj-R-squared	0.1782	0.1864	0.2033	0.2398	0.2476	0.2633
N	4037	4037	4037	4037	4037	4037

* p<0.1, ** p<0.05, *** p<0.01, standard error in parentheses

Table 3.5: Effect of the CPR Law on the recycled content

	Recycled Content					
	(1)	(2)	(3)	(4)	(5)	(6)
Target*1995–1997	0.0112***	0.0112***	0.0112***	0.0096***	0.0096***	0.0096***
	[0.0014]	[0.0014]	[0.0014]	[0.0012]	[0.0012]	[0.0012]
Target*After 1997	0.0101***			0.0099***		
	[0.0008]			[0.0007]		
Target*1997–2000		0.0108***	0.0108***		0.0105***	0.0105***
		[0.0012]	[0.0012]		[0.0011]	[0.0011]
Target*After 2000		0.0100***			0.0097***	
		[0.0008]			[0.0007]	
Target*2000–2017			0.0099***			0.0096***
			[0.0008]			[0.0007]
Target*After 2018			0.0119***			0.0116***
			[0.0015]			[0.0014]
Oil Price				-0.0008	-0.0007	-0.0007
				[0.0011]	[0.0011]	[0.0011]
Constant	0.0187***	0.0187***	0.0187***	0.0255***	0.0254***	0.0254***
	[0.0029]	[0.0029]	[0.0029]	[0.0086]	[0.0086]	[0.0086]
Category FE	YES	YES	YES	YES	YES	YES
Year-by-Month FE	YES	YES	YES	NO	NO	NO
Year FE + Month FE	NO	NO	NO	YES	YES	YES
R-squared	0.2094	0.2095	0.21	0.1984	0.1985	0.1989
Adj-R-squared	0.1277	0.1276	0.1279	0.1875	0.1874	0.1877
N	4037	4037	4037	4037	4037	4037

* p<0.1, ** p<0.05, *** p<0.01, standard error in parentheses

Table 3.6: Heterogeneous effects among product categories

Category	
Film and Sheets*1997–2000	0.0082***
	[0.0020]
Film and Sheets*2000–2017	0.0080***
	[0.0012]
Film and Sheets*After 2018	0.0308***
	[0.0025]
Pipe*1997–2000	0.0051***
	[0.0020]
Pipe*2000–2017	0.0014
	[0.0012]
Pipe*After 2018	0.0013
	[0.0025]
Machine*1997–2000	-0.0019
	[0.0020]
Machine*2000–2017	0.0081***
	[0.0012]
Machine*After 2018	0.0080***
	[0.0025]
Container*1997–2000	0.0140***
	[0.0020]
Container*2000-2017	0.0080***
	[0.0012]
Container*After 2018	0.0219***
	[0.0025]
Others*1997–2000	0.0161***
	[0.0020]
Others*2000–2017	0.0114***
	[0.0012]
Others*After 2018	-0.0148***
	[0.0025]
Oil Price	0.002
	[0.0022]
Constant	0.0031
	[0.0195]
R-squared	0.2733
Adj-R-squared	0.1953
N	4037

* p<0.1, ** p<0.05, *** p<0.01, standard error in parentheses

Table 3.7: Effect of the CPR Law on input share of virgin plastic materials

	Polystyrene (PS)	Polyethylene (PE)	Polypropylene (PP)	Vinyl chloride (VC)	Other materials
Target*1995–1997	0.0057	-0.0130***	-0.0310***	-0.0082	0.0017
	[0.0049]	[0.0042]	[0.0049]	[0.0063]	[0.0061]
Target*1997–2000	0.0041	-0.0212***	-0.0365***	-0.0126**	0.0216***
	[0.0041]	[0.0035]	[0.0041]	[0.0053]	[0.0051]
Target*2000–2017	-0.0158***	-0.0405***	-0.0098***	-0.0214***	0.0524***
	[0.0027]	[0.0023]	[0.0027]	[0.0035]	[0.0034]
Target*After 2018	-0.0450***	-0.0337***	0.0112**	-0.0384***	0.0583***
	[0.0051]	[0.0044]	[0.0052]	[0.0067]	[0.0065]
Oil Price	-0.0137*	-0.003	0.0218***	-0.0234**	0.0238**
	[0.0080]	[0.0069]	[0.0080]	[0.0104]	[0.0100]
Constant	0.2616***	0.1429**	-0.0494	0.4417***	-0.1015
	[0.0697]	[0.0601]	[0.0701]	[0.0909]	[0.0877]
R-squared	0.2119	0.1584	0.2948	0.2377	0.2834
Adj-R-squared	0.13	0.0709	0.2215	0.1585	0.2089
N	4037	4037	4037	4037	4037

* p<0.1, ** p<0.05, *** p<0.01, standard error in parentheses

Figure 3.1 Production and recycling of plastic products

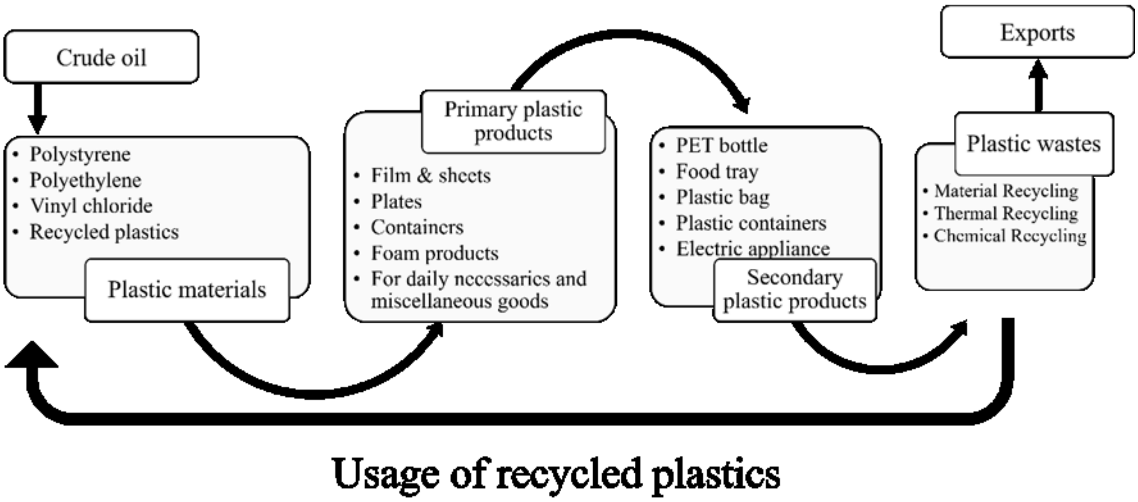
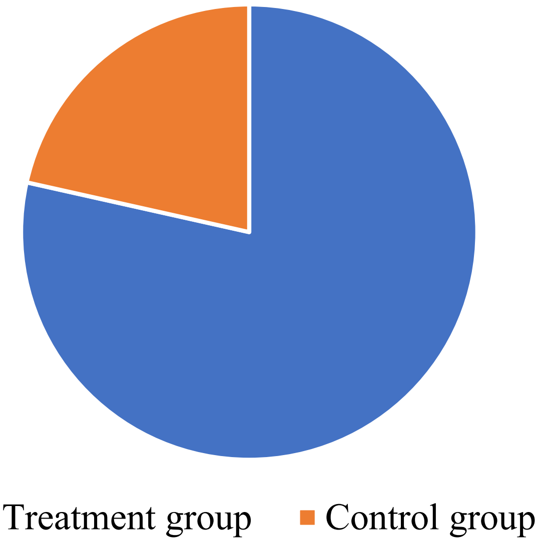


Figure 3.2: Share of primary plastic products



Source: Monthly Report of Current Production Statistics Survey (Ministry of Economy, Trade, and Industry, 1989–2019).

Figure 3.3: Amount of recycled plastics used as input

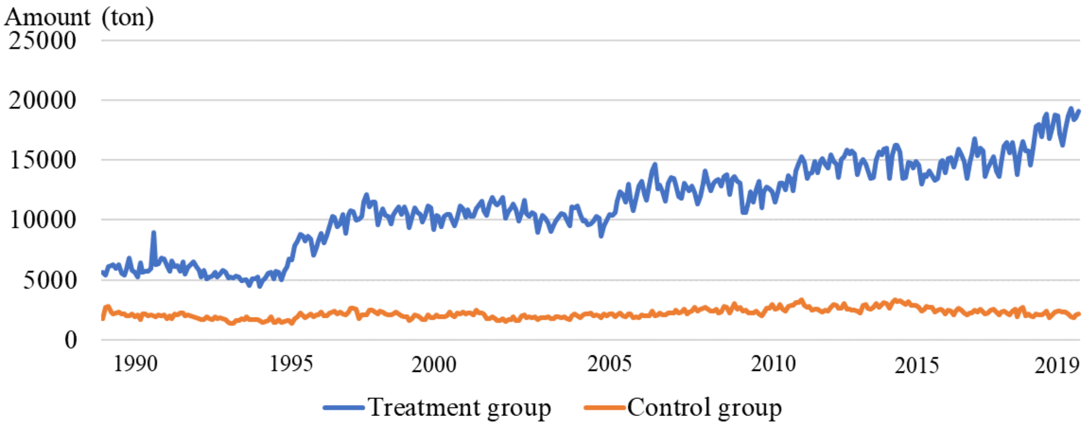


Figure 3.4: Recycled contents of plastic products

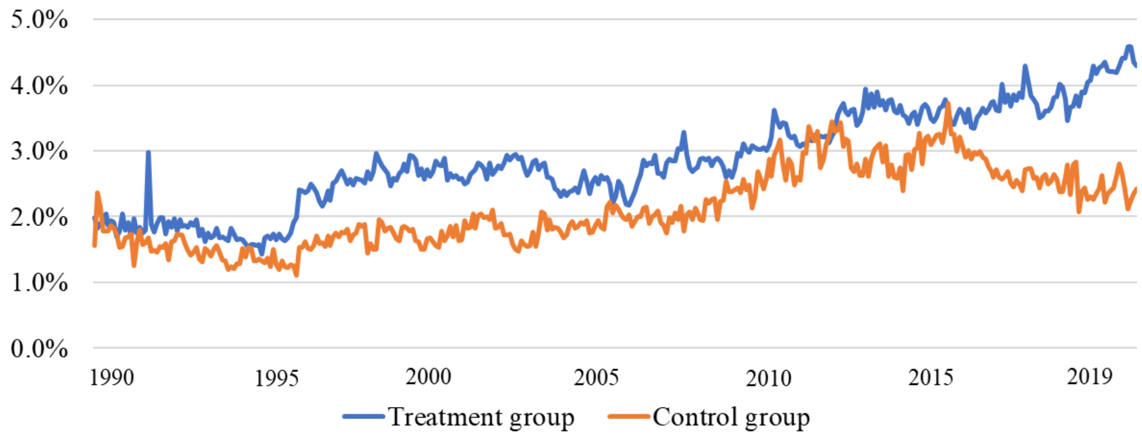
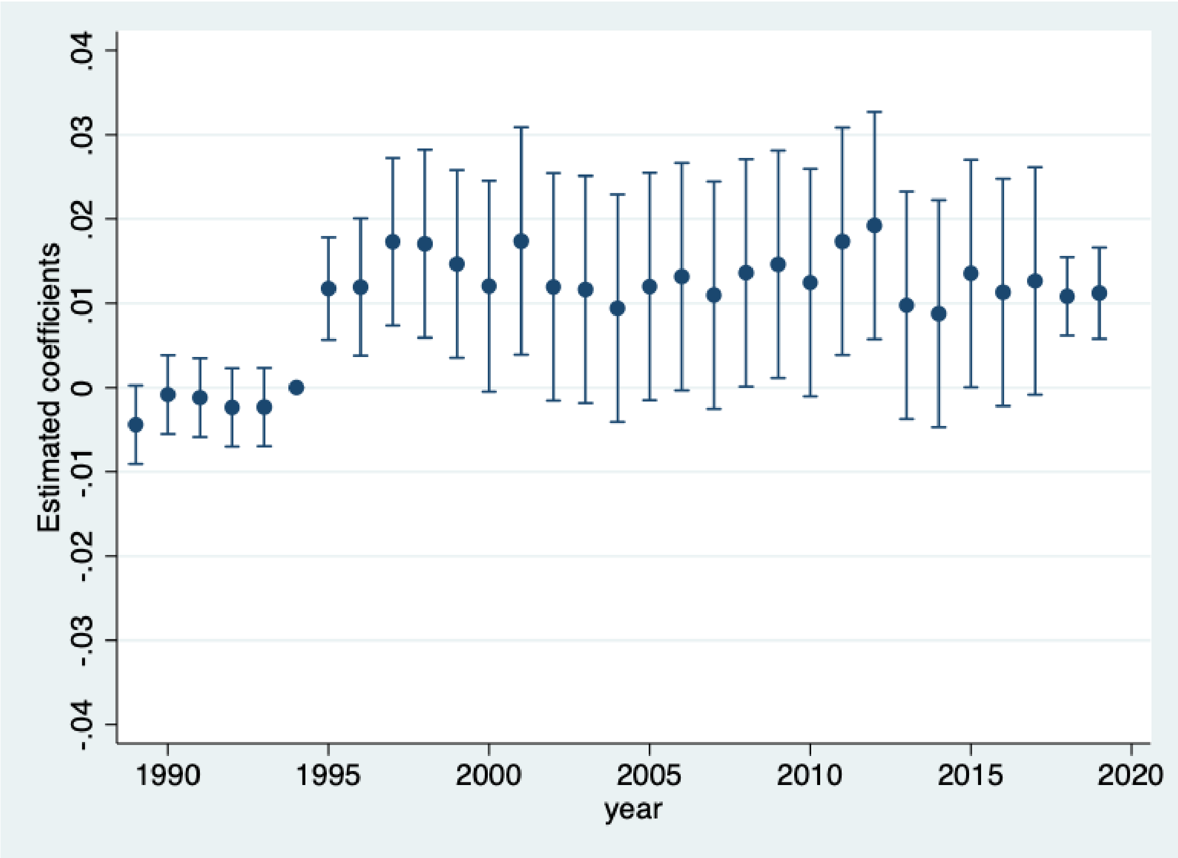


Figure 3.5: Testing the parallel trend during the baseline years



Note: Dots represent the estimated coefficients for the interaction term between the treatment group and each year. The dashed lines indicate 95% confidence intervals for these coefficients.

Chapter 4

Plastic Use and Corporate Performance

4.1 Introduction

Plastic materials have been used in the production of various goods and services (Geyer et al., 2017; Plastics Europe, 2019). As the environmental consequences of plastics have become increasingly apparent, however, firms are changing their corporate strategy to reduce plastic usage. For example, Starbucks will ban the use of plastic straws in stores by 2020, and McDonald's introduces paper straws in the UK and Ireland and abolishes plastic straws in stores by 2025. These changes are reflecting the social demand for the reduction of plastics and corporate response to such demand.

This study empirically investigates the relationship between plastic use and corporate performance. Particularly, we focus on the change in Japanese corporate behavior during the last decade (from 2007 to 2018). Japan has implemented the Containers and Packaging Recycling Law (CPR Law) in 1995 to reduce waste and promote the recycling of packaging waste, including PET bottles and plastics. Under the CPR Law, businesses are obliged to recycle after separate discharge by consumers and separate collection by municipalities. Many companies fulfill the obligation of recycling by paying the recycling fee: a commission fee to the Japan Containers and Packaging Recycling Association. Therefore, we can expect that Japanese firms are reducing the volume of plastic use in response to the payment of recycling fee, and thereby changing the revenue structure by improving resource efficiency in terms of marginal return on material input. In other words, we examine whether the CPR Law promoted firms' cleaner production that minimizes resource consumption and waste and maximizes product output (Yacooub & Fresner, 2006). Cleaner production is not a method of removing pollutants generated in the final stage of manufacturing but reduces the environmental burden by changing the basis of the manufacturing process.

Containers and packaging wrap and protect market goods. They are necessary input for producing various goods including food, beverage, and medical products. Reducing the amount of input improves economic efficiency, by reducing the cost of production. The introduction of the CPR Law increased the benefit of reducing input, in terms of the reduction of the recycling fee. On the other hand, the input reduction might lead to a decrease in return on input, because of lower consumer satisfaction. Thus, we firstly analyze the impact of plastic usage on corporate performance and how the relationship has changed from 2007 to 2018. We will analyze the corporate sales and gross profit because the input reduction will affect the sales and the cost of firms. Further, we analyze the impact of recycling fees on plastic usage to explore the mechanism behind the firm response to the Law.

This study contributes to the literature on corporate environmental behavior by empirically examining the relationship between the environment and corporate productivity. Although there are empirical studies that analyze the impact of environmental regulations and policies on productivity, few studies have analyzed how changes in inputs in response to regulations and policies affect corporate performance. For example, Eli & Bui (2001) showed that air quality regulation has a positive impact on corporate productivity, while they did not mention the impact on that input. By using the data of plastic use in Japanese firms, we extend the analysis to include changes in inputs.

The remainder of this paper is organized as follows. Section 2 reviews the previous studies that estimate the impact of environmental regulation/policy on corporate financial performance. Section 3 describes the data and models for empirical analysis. Section 4 presents the empirical results of the impact on the firm under the CPR Law. We estimate the impact of recycling fee and unit cost on corporate plastic use, and the impact of plastic use on corporate performance. Section 5 concludes this paper.

4.2 Literature review

We build on Bay (2015)'s a pioneering study on the relationship between recycling fees and plastic use under the CPR Law. The study examined the effect of recycling fees on plastic use after the introduction of the CPR Law, by using data from 111 Japanese firms from 2007 to 2012. She found that the estimated plastics intensity shows a statistically significant negative correlation with recycling fee, with a two-year time lag.

Several studies have also investigated the relationship between environmental regulation and productivity. Albrizio et al., (2017) investigated the impact of changes in environmental policy stringency on the industry- and firm-level productivity growth in a panel of OECD countries to test the Porter Hypothesis[11]. For the average productive firm, they did not find a statistically significant relationship between policy stringency and productivity. However, the most productive firms see a temporary boost in productivity growth, while the less productive ones experience a productivity slowdown (Albrizio et al., 2017). Orlitzky et al., (2003) showed that corporate social/environmental performance is positively correlated with corporate financial performance, and the relationship tends to be bidirectional and simultaneous by conducting a meta-analysis of 52 studies. Eli & Bui (2001) examined the effect of air quality regulation on productivity in the oil refineries of Los Angeles. They used direct measures of local air pollution regulation to estimate their effects on abatement investment between 1979 and 1992. As a result of their measurement of total factor productivity, despite high costs associated with the local regulations, productivity in the oil refineries rose sharply between 1987 and 1992. Zhang & Du, (2020) estimated the impact of China's environmental regulations on firm productivity and efficiency. They used the Above-scale Industrial Dataset from 1998 to 2013 and other firm datasets to explore how efficiency and productivity changed after the policies were put into place by a difference-in-difference-in-differences estimation. The results indicate that the environmental regulation significantly reduced total factor productivity and return on assets of high-polluting firms. Zeng et al. (2010) analyzed that different types of efforts linked to a cleaner production program may have different implications for business performance in 125 Chinese companies. They found that the cleaner production activities of the low-cost scheme such as strictly enforce rules on cleaner production have a bigger contribution to financial performance, while cleaner production activities of the high-cost scheme such as using renewable resources have a greater contribution to nonfinancial performance. However, some studies have shown that there is no relationship between environmental and business performance (Wagner, 2005; Sarkis and Dijkshoorn, 2007; Iraldo et al., 2009). Thus, it is inclusive whether environmental management and regulations do contribute to corporate productivity.

[11] M. Porter (1991) and M. E. Porter & Linde (1995) argued that pollution is often a waste of resources and that a reduction in pollution may lead to an improvement in the productivity with which resources are used .They argued that more stringent but properly designed environmental regulations can trigger innovation that may partially or more than fully offset the compliance cost.

4.3 Data and empirical analysis

4.3.1 Data

The data on the recycling fee paid by companies that make or use plastic containers and packaging is sourced from the Japan Containers and Packaging Recycling Association (The Japan Containers and Packaging Recycling Association, n.d.).[12] Because the data is available from 2007 to 2018, we cannot investigate how to cooperate behavior changed before and after the CPR Law. In our analysis, we include companies that meet the following three conditions:

1. Disclosed their data on the JCPRA's website
2. Paid the recycling fee every year throughout the study period (from 2007 to 2018)
3. Listed companies on the stock exchange in Japan

There are 9,576 firms agreed to disclose the data on the website of the JCPRA. The number of firms accounts for 46.7% of the total firms that paying recycling fees to JCPRA. After selecting firms based on the above three conditions, our panel dataset includes 411 listed companies that use or manufacture plastic containers and packaging from 2007 to 2018. The corporate performance of listed companies is collected from the SPEEDA database. Figure 4.1 shows the ratio of the number of firms by sector in this study. The retail sector accounts for 35% of all companies, the food sector accounts for 15%, and the pharmaceutical sector accounts for 7%. These three sectors account for approximately 60% of the total. In this study, we investigate all of 411 listed companies as a baseline, and also analyzed a subsample of the above three sectors to see the impact on each sector.

<Figure 4.1>

Table 4.1 reports the summary statistics. On average, the sample firms use 1,227 tons of plastic containers and packaging in one year. Plastic user firms use 564 tons of plastic containers and packaging and plastic manufacture firms produce 11,474 tons of plastic containers and packaging on average annually. The average annual sales is 250 billion yen and the average annual gross profits is 46 billion yen. Sales is defined as the total

[12] https://www.jcpra.or.jp/

sales of firms in one year. Gross profits is defined by subtracting total variable costs from sales. Asset represents the fixed capital and Labor represents the number of workers in the firm. On average, the sample firms pay 20.8 million yen per year as the recycling fee to JCPRA. The percentage of recycling fees in corporate sales is 0.008%. Unit cost represents the price of recycling one kilogram of plastics and is used to calculate the recycling fee to the association. The mean value of the unit cost of recycling during the study period is 38.2 yen/kg.

<Table 4.1>

The recycling fee is paid by obliged firms that commission recycling to JCPRA. Each company reports the amount of plastics that they must recycle in the current year (the obligation amount). The recycling fee is calculated by multiplying the obligation amount and the unit cost for the relevant year. The obligation amount for recycling for each company is calculated by multiplying the emission coefficient and the estimated number of containers and packaging usage based on the national survey conducted every year. The emission coefficient is the ratio of the amount of container and packaging waste that must be recycled by companies to the amount discharged from households and is designated for each industrial sector. The unit cost is calculated by dividing the total cost of recycling for the relevant fiscal year divided by the estimated amount of recycling obligations.

The data published by JCPRA only contains the recycling fee, emission coefficient, and unit cost but not the actual amount of plastic use in each firm. Thus, we derived the expected amount of plastic use in each firm by dividing the recycling fee by emission coefficient and unit cost, as shown in the equation below:

$$recycling\ \ fee = \ \ total\ \ plastic\ \ use\ \ \times emission\ \ coefficient\ \ \times unit\ \ cost$$

$$\frac{recycling\ fee}{emission\ coefficient\ \times unit\ cost} = expected\ plastic\ amount$$

Figure 4.2 represents the change of the total recycling fees paid by firms that owe recycling obligations under the CPR Law in Japan. When the CPR Law was introduced in 1997 for the glass bottles and PET bottles, the recycling fees of PET bottle was very high. After several years, the unit cost of PET bottles has dramatically decreased (from 84.5 yen/kg in 1997 to 4.5 yen/kg in 2021). In contrast, albeit the unit cost for plastics has reduced by half from 2007 to 2010, the recycling fee paid remains very high due to the large increase in plastic use. In 2019, the total recycling fee paid is about 38.5 billion yen and the recycling fee of plastic containers and packaging is 90.5% of the total. The study period of this study is from 2007 to 2018.

<**Figure 4.2**>

Figure 4.3 shows the recycling fees for plastic containers and packaging paid by all obliged firms and the firms in our sample. The recycling fee paid by all firms is approximately 43 billion in 2007 and the fee has been decreasing. While the share of the latter is about 20% to 30 % of the total fees paid, the figure indicates that the total amount of payment by both groups shows a similar trend.

<**Figure 4.3**>

Figure 4.4 shows the change in the unit cost per kilogram for plastic containers and packaging. The unit cost dropped from 100 yen in 2000 to 49 yen in 2020.

<**Figure 4.4**>

4.3.2 Empirical methodology

This subsection describes the empirical method used to investigate the effect of the CPR Law on corporate plastic use. First, we begin by analyzing the resource efficiency in the firms' production structure. The model investigates how the usage of plastic containers and packaging related to corporate performance:

$$\Omega_{it} = \beta_0 Amount_{it} + \beta_1 Amount_{it} * numyear + \beta_2 Asset_{it} + \beta_3 Labor_{it} + \delta_i + \lambda_t + \varepsilon_{it} \cdots (4.1)$$

where Ω_{it} is the corporate performance such as Sales and Gross profits of firm i in year t; $Amount_{it}$ is the expected amount of plastic usage; $Amount_{it} * numyear$ is the interaction between the expected amount of plastic usage and the number of years since 2007; $Asset_{it}$ is the corporate asset; $Labor_{it}$ is the number of workers; λ_t is year fixed effect; δ_i is a firm fixed effect; and ε_{it} is an error term. By including $Amount_{it} * numyear$, which is the interaction term between the expected amount of plastic usage and the number of years since 2007, we explore the change in corporate behavior during the study period. We hypothesize that, in response to the increase in the recycling cost, firms use plastic inputs more and more efficiently. Thus, we expect that the coefficient for the interaction term is negative. Dependent variables and explanatory variables except fixed effects are measured in natural log form.

Next, we analyze the relationship between the fees and the amount of plastic usage. The estimated model can be written as:

$$\frac{\Delta Amount_{it}}{Amout_{it}} = \beta_0 Fees_{it-n} + \delta_i + \lambda_t + \varepsilon_{it} \cdots (4.2)$$

where $Amount_{it}$ is the expected amount of plastics used by firm i in year t; $\Delta Amount_{it}$ is the change in the expected amount of plastics use, which means $\Delta Amount_{it} = Amount_{it+1} - Amount_{it}$; $\frac{\Delta Amount_{it}}{Amout_{it}}$ is the rate of change for the expected amount of plastic usage; $Fees_{i,t-n}$ is the total recycling fee paid by firm i in year $t-n$; λ_t is year fixed effect; δ_i is a firm fixed effect; and ε_{it} is an error term. Model (2) investigates how past recycling fees affect the change in the plastic amount used by firms. The expected sign of the impact is negative because the firm decreases plastic use when they recognize that the payment of the fee is substantial.

4.4 Results

In this section, we explore the relationship between the plastic amount used by firms and corporate performance. Table 4.2 provides the estimation results of the impact on sales. The coefficients for the log of plastic amount are positive and statistically significant in the baseline. This result suggests that sales increase by 0.03% as the plastic amount increases by 1% in the full model. However, the coefficients for the log of amount*numyear are not statistically significant in the full model (1). When we investigate the impact in a specific sector that uses a large volume of plastic containers and packaging, the effect is positive and statistically significant in the retail sector, but not significant in food and pharmaceuticals. The results suggest that sales in the retail sector correlate with the usage of plastics. Further, the coefficients for the log of amount*numyear are positive and statistically significant in full models (5) and (7). It implies that the impact of the plastic amount on sales increases over time and marginal returns on plastic input are becoming ever greater.

<Table 4.2>

Second, we focus on the gross profit as corporate performance. Gross profit differs from sales in that it considers the cost. If gross profit is high, it is considered that companies are making good profits in their core business. Table 4.3 provides the estimation results of the impact on gross profit. The coefficients for the log of plastic amount are positive and statistically significant in the baseline model, but the coefficients for the log of amount*numyear are not statistically significant in this model. When we investigate by sector, the coefficient for the log of the plastic amount is positive in the retail and pharmaceutical sector, while it is negative in the food sector. Gross profit decreases if the increase in costs outweighed the increase in sales when plastic use increases. For the food sector, a larger amount of plastic containers and packaging bring a significant cost. Plastic use in the Japanese food sector has been dramatically reduced through the thinning and weight saving of plastic containers and packaging. For example, in NH Foods Ltd., the weight of the plastic tray for a chilled pizza has decreased by 47% compared to 2012 and the packaging of the sweet and sour pork has decreased by 24% compared to 2003. Further, Japan Food Industry Association reported that the bread wrapping film has been thinned by 7% and the mayonnaise container weight has been decreased by 10% to 15% as DfE’s initiatives. In this way, the food sector in Japan has been working on the reduction of plastic containers and packaging. However, the use of new materials will be required in the future to increase gross profit because there is a limit to reducing plastic use.

<Table 4.3>

Results obtained above, particularly the subsample analysis based on the industrial sector, suggest that the impact of plastic use on financial performance might be changing year by year. Thus, we further explore the change in return on plastic usage by comparing cross-sectional analysis in 2007 and that in 2018. Table 4.4 presents these estimation results. Regarding sales, the coefficient for the log of the plastic amount is not statistically significant in 2007, while that is positive and statistically significant in 2018. Regarding gross profit, the coefficients for the log of plastic amount are positive and statistically significant both in 2007 and 2018, and the coefficient in 2018 is larger than that in 2007. To summarize, these results suggest that added value per ton of plastic is higher in 2018 than in 2007. It might imply that firms' production structure is becoming efficient during the decade.

<Table 4.4>

Table 4.5 presents the estimation results of the relationship between the past fee and the amount of plastic in the model (4.2). We consider this relationship to see why the improvement of plastic production efficiency. The dependent variable of these estimation results is the rate of change in the amount of plastic. The coefficients for the past recycling fees are negative and statistically significant. The results suggest that in the past, firms decreased the amount of plastic when they had to pay a higher fee. The size of the coefficient implies that the change in the amount of plastic for all the firms decreased by 0.36% when the fee paid in the past year increased by 1%. The estimated effect of the recycling fee on the change in the amount of plastic is –0.27% if we consider the fee lagged by two periods. From there, the higher past recycling fee the firm is, the less plastic amount for this term it is.

<Table 4.5>

4.5 Conclusion

This chapter has investigated the relationship between the firm's plastic amount and corporate performance in Japan. We conclude that the firm has responded to the CPR Law by decreasing plastic usage to save production costs. Moreover, firms' corporate performance increase for larger plastic amount. This suggests that the firm increases its performance while reducing plastic usage under the CPR Law. Furthermore, firms that pay higher recycling fees tend to reduce plastic usage during the last decade. It implies that the firms are incentivized to reduce their plastic input by the Extended Producer Responsibility built in the CPR Law.

The CPR Law increased the cost of using plastic containers and packaging. The impact of the law might be significant as it changes the production structure of firms. The firm can increase its performance by using plastics more efficiently. However, plastic usage reduces the gross profit for firms in the food sector. Most of the plastic use in the food sector is the packaging of bread, confectionery, and frozen/refrigerated foods. Although we can take measures such as thinning the packaging, it is considered that the production cost has exceeded sales because it is very difficult to eliminate plastic use. If we were to further promote sustainable production, it is essential to consider financial support programs such as a subsidy to promote the efficiency of plastic input and the use of biomass plastics.

The limitations of this study are the following three. First, our sample firm only contains listed companies. The reason is that we can easily obtain the corporate performance data because the listed company submits a securities report. If performance data for unlisted companies are available, a more detailed analysis is possible. The second limitation is related to the firm's plastic amount. This chapter estimated the firm's plastic amount from recycling fees by using emission coefficients in each sector. Although there are companies with multiple industrial sectors, we are forced to choose one to use the emission coefficient of a particular sector. Thus, there may be a gap between the original industry and our definition. The third is that other environmental laws, such as Home Appliance Recycling Law, are not taken into consideration. Examining the effect of these laws or policies on the production process of goods will be a good extension of this study.

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Table 4.1: Descriptive Statistics

Variable	Obs.	Mean	Std.Dev.	Min.	Max.	Unit
Plastic amount(Full)	4932	1227.9	5932	0	95362.3	t
Plastic amount(user)	4632	564.3	2340	0	46574.8	t
Plastic amount(manufacture)	300	11474.1	19579	0	95362.3	t
Sales	4890	250.9	837	0.23	12600	billion yen
Gross Profits	4853	47.0	128.8	-0.20	2744	billion yen
Asset	4894	169.6	588	37	10600	billion yen
Labor	4840	2296.4	6467	6	79809	person
Fees	4932	20.8	8.23	0	1400	million yen
Unit cost	4932	38.2	14.1	0.12	62	yen/kg

Table 4.2: Estimation results of sales in plastic users

	Baseline(All sector)		Retail		Food		Pharmaceuticals	
Model	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ln(Amount)	0.0301***	0.0590***	0.0387***	0.1213***	-0.002	-0.0105	0.0145	0.0444**
	[0.0044]	[0.0063]	[0.0068]	[0.0120]	[0.0108]	[0.0140]	[0.0152]	[0.0196]
ln(Amount) *Numyear	0.0003	0.0008**	0.0006	0.0033***	0.0021***	0.0028***	0.0025***	0.0013
	[0.0002]	[0.0003]	[0.0004]	[0.0007]	[0.0006]	[0.0008]	[0.0008]	[0.0010]
ln(Labor)	0.7386***		0.9021***		0.5735***		0.8457***	
	[0.0127]		[0.0177]		[0.0289]		[0.0713]	
ln(Asset)	0.1319***		0.1043***		0.1614***		0.0421	
	[0.0123]		[0.0185]		[0.0317]		[0.0342]	
Constant	4.6482***	10.8021***	3.9622***	10.7568***	5.4654***	10.6328***	4.5504***	10.9437***
	[0.1301]	[0.0214]	[0.1798]	[0.0429]	[0.3419]	[0.0711]	[0.5168]	[0.0748]
Year Fe	YES	YES	YES	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES	YES	YES	YES
R-squared	0.5347	0.042	0.7273	0.0999	0.4624	0.0424	0.6319	0.3799
Adj-R-squared	0.489	-0.0505	0.6988	0.0083	0.3988	-0.0657	0.5745	0.2899
N	4368	4417	1638	1657	682	691	290	293

* p<0.1, ** p<0.05, *** p<0.01, standard error in parentheses

Table 4.3: Estimation results of gross profit in plastic users

	Baseline(All sector)		Retail		Food		Pharmaceuticals	
Model	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ln(Amount)	0.0373***	0.0610***	0.0384***	0.1103***	-0.0500***	-0.0546***	0.0411**	0.0696***
	[0.0061]	[0.0070]	[0.0101]	[0.0124]	[0.0156]	[0.0172]	[0.0180]	[0.0229]
ln(Amount) *Numyear	0.0001	0.0004	0.0009	0.0029***	0.0007	0.0008	-0.0004	-0.0019
	[0.0003]	[0.0004]	[0.0006]	[0.0007]	[0.0009]	[0.0010]	[0.0009]	[0.0012]
ln(Labor)	0.5400***		0.5699***		0.5160***		0.9113***	
	[0.0181]		[0.0274]		[0.0438]		[0.0845]	
ln(Asset)	0.1795***		0.2858***		0.1891***		0.0757*	
	[0.0170]		[0.0270]		[0.0457]		[0.0405]	
Constant	4.0764***	9.4185***	2.9363***	9.4409***	4.2842***	9.3528***	3.0142***	10.2358***
	[0.1786]	[0.0238]	[0.2575]	[0.0441]	[0.4986]	[0.0872]	[0.6120]	[0.0874]
Year Fe	YES	YES	YES	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES	YES	YES	YES
R-squared	0.316	0.0882	0.4465	0.1006	0.3611	0.1688	0.4814	0.1689
Adj-R-squared	0.2484	-0.0002	0.3882	0.0085	0.2848	0.074	0.4005	0.0483
N	4330	4379	1607	1626	676	685	290	293

* p<0.1, ** p<0.05, *** p<0.01, standard error in parentheses

Table 4.4: Comparison between 2007 and 2018

	Sales		Gross profit	
Year	2007	2018	2007	2018
ln(amount)	0.0076	0.0282***	0.0394***	0.0654***
	[0.0110]	[0.0107]	[0.0104]	[0.0105]
ln(labor)	0.4674***	0.3849***	0.4725***	0.3649***
	[0.0334]	[0.0316]	[0.0329]	[0.0309]
ln(asset)	0.6051***	0.6490***	0.4537***	0.5413***
	[0.0415]	[0.0424]	[0.0416]	[0.0413]
Constant	2.2323***	2.4872***	1.3776***	1.8204***
	[0.2032]	[0.1951]	[0.1934]	[0.1915]
R-squared	0.8654	0.8608	0.8608	0.8486
Adj-R-squared	0.8613	0.8568	0.8565	0.8442
N	377	392	372	389

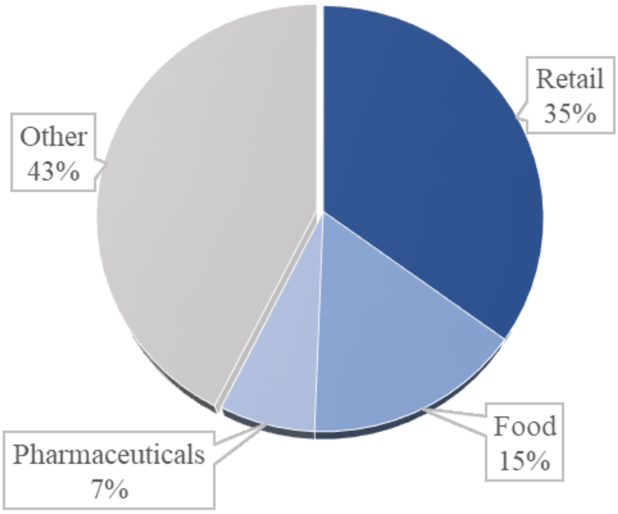
* p<0.1, ** p<0.05, *** p<0.01, standard error in parentheses

Table 4.5: Estimation result for the recycling fee and plastic amount

	Dependent variable: rate of change in the plastic use			
	All Firms		Firms Using Plastics	
	(1)	(2)	(3)	(4)
$\ln(Fee_{t-1})$	-0.3633***		-0.3704***	
	[0.0122]		[0.0126]	
$\ln(Fee_{t-2})$		-0.2706***		-0.2709***
		[0.0140]		[0.0145]
ln(Asset)	0.03	0.0394	0.0341	0.0401
	[0.0367]	[0.0414]	[0.0362]	[0.0412]
Constant	4.5810***	3.4283***	4.6795***	3.4439***
	[0.4090]	[0.4652]	[0.4056]	[0.4648]
Year FE	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES
R-squared	0.2233	0.1367	0.229	0.1362
Adj-R-squared	0.1413	0.0354	0.1475	0.0346
N	4303	3904	4046	3671

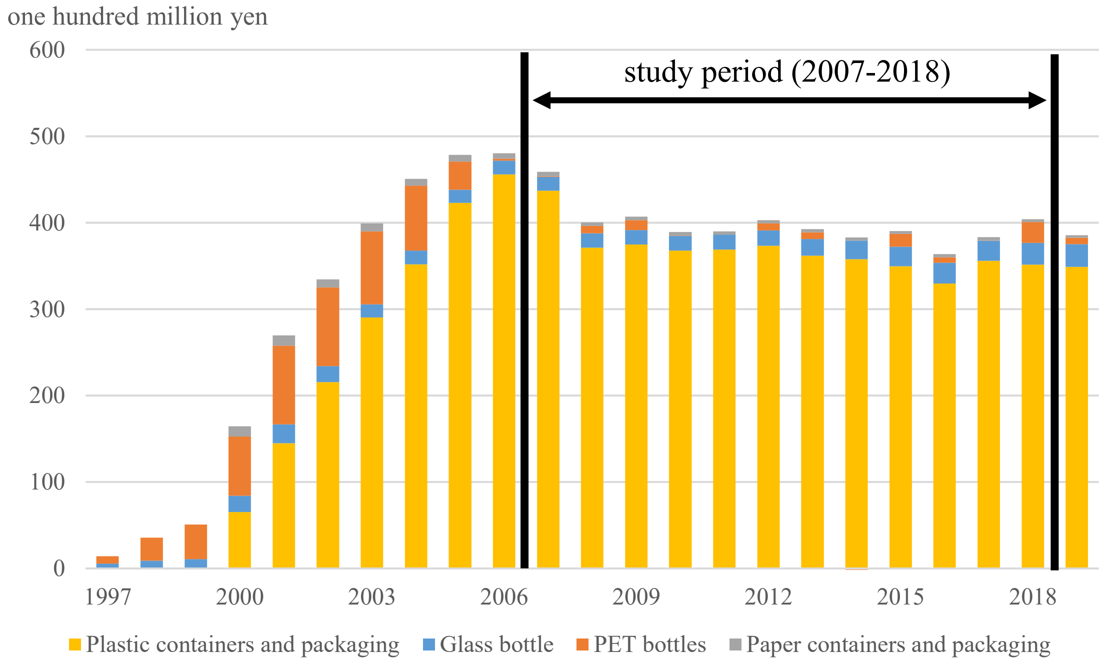
* p<0.1, ** p<0.05, *** p<0.01, standard error in parentheses. All firms include firms using or producing plastic containers and packaging.

Figure 4.1: Number of firms by sector



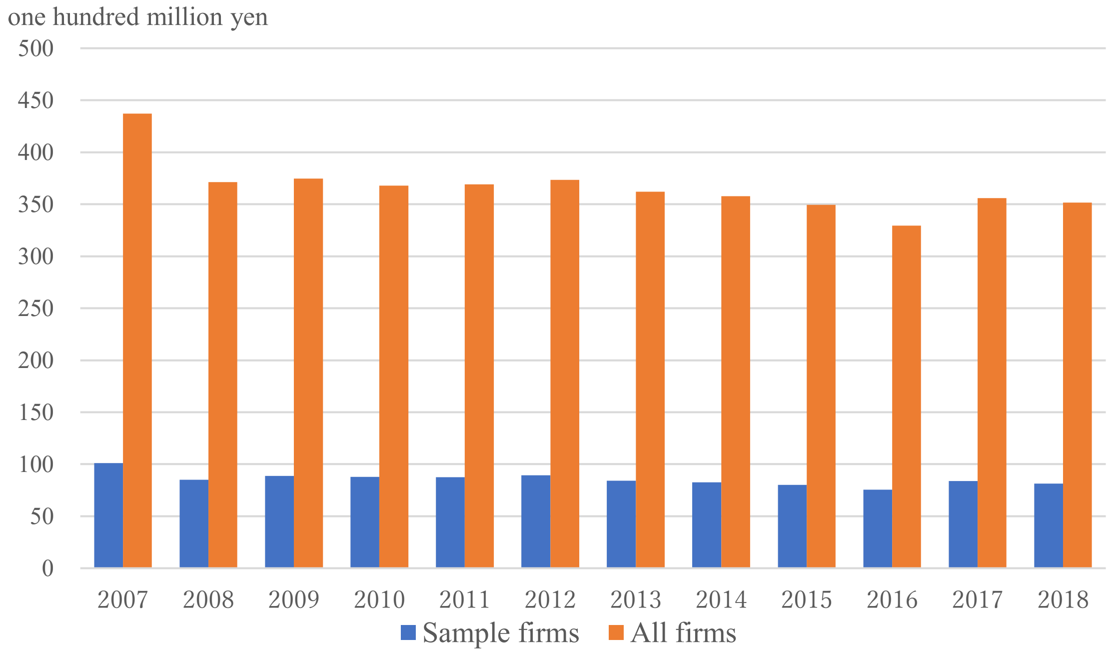
Source: The Japan Containers and Packaging Recycling Association

Figure 4.2: Total recycling fees paid by firms



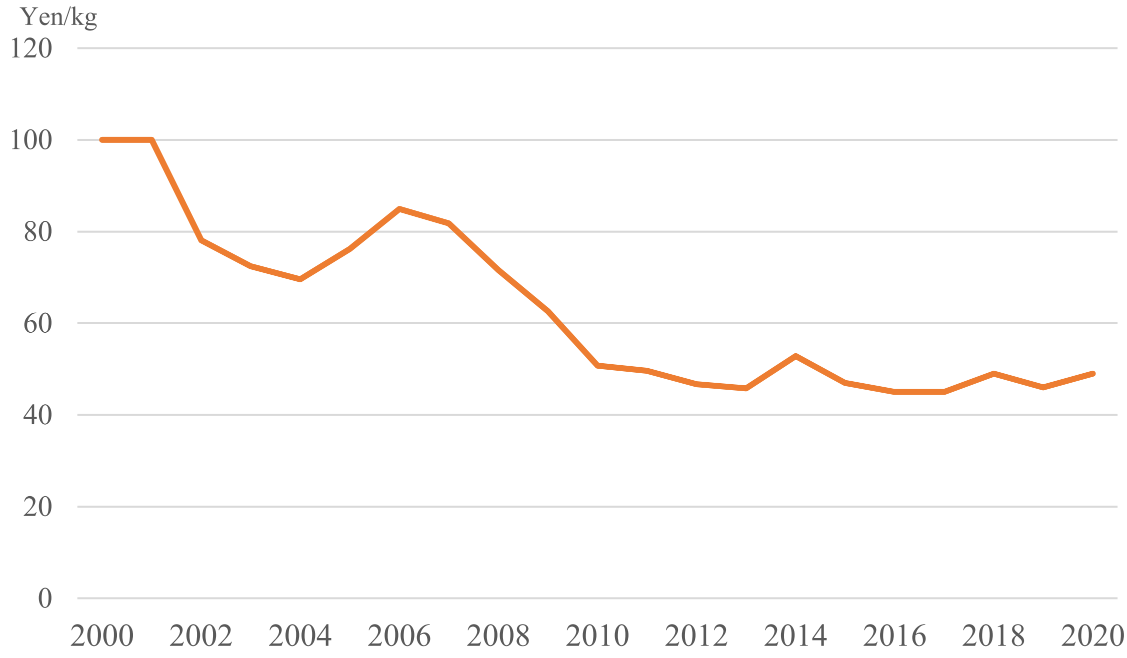
Source: The Japan Containers and Packaging Recycling Association

Figure 4.3: Total recycling fees for plastics paid by firms



Source: The Japan Containers and Packaging Recycling Association

Figure 4.4: Recycling fee per kilogram of plastics



Source: The Japan Containers and Packaging Recycling Association

Chapter 5

Conclusion

This dissertation has conducted an empirical investigation on the economics of plastic waste.

We consider China's import ban in 2017 in Chapter 2. This import ban is a big opportunity to reconsider Japanese domestic plastic recycling and reuse. Thus, we consider this import ban in Chapter 2 and focus on domestic plastic use in Chapters 3 and 4 to consider domestic plastic circulation in the production side.

The conclusion of this dissertation can be summarized as follows. First, based on the results from the economic surplus analysis, we conclude that China's import ban negatively affects Japan's plastic recycling market. Japan's policy response toward the import ban will further alter the economic surpluses. The promotion of domestic recycling will increase the economic surplus, whereas the reduction of plastic waste will decrease the producer surplus. Consequently, the import ban provides a good opportunity to reconsider the economic consequences of the reduce, reuse, and recycle policy of plastic waste in Japan for establishing a circular economy.

Second, this dissertation re-evaluated the impact of the CPR Law, focusing on the use of recycled plastic materials in the domestic production process. Consequently, we determined that there is an increase in the amount of recycled plastics used for primary plastic products after the implementation of the law. Decision-makers should consider the policies that directly affect the production process, such as the recycled content standards, to promote domestic recycling further.

Third, it was found that plastic usage in the production process of listed firms decreased, while their financial performance increased after reducing plastic usage during the last decade. This implies that listed firms that manufacture or use plastics for containers and packaging have produced more efficiently under the CPR law.

According to the Resource Circulation Strategy for Plastics approved by the cabinet of the Japanese government in 2019, Japan strongly promotes the reduction of one-way plastic containers and packaging products, use of reusable and recyclable product designs, and biodegradable plastics and biomass plastics by 2030s. Firms are required to actively try new approaches to reduce, reuse, and recycle plastic materials. A further change in the producer behavior will significantly affect the amount of plastic waste and plastic recycling, which will play a significant role in realizing the circular economy.

Reference

Consumer Affairs Agency, Ministry of Foreign Affairs, Ministry of Finance, Ministry of Education, Culture, Sports, Science and Technology, Ministry of Health, Labor and Welfare, Ministry of Agriculture, Forestry and Fisheries, ... & Ministry of the Environment. (2019). Resource Circulation Strategy for Plastics. *Tokyo.* *https://www.env.go.jp/press/files/jp/111747.pdf* (in Japanese)