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Abstract

This study investigates the impact of Japan's recycling legislation on the usage of recycled materials in the production process of primary plastic products. By employing a difference-in-differences approach, we examine whether the recycled content of primary plastic products increased after the implementation of the Container and Packaging Recycling Law (CPR Law) in Japan. The results suggest that the usage of recycled plastics doubled and the usage of recycled plastics per plastic product increased by 1% after the implementation of the law. Meanwhile, the use of virgin plastic materials, such as polyethylene, polypropylene, and vinyl chloride, per plastic product decreased by 3% on average. These results suggest that the CPR Law helped shift inputs from virgin plastics to recycled plastic materials, although the size of the impact is small. To promote the use of recycled plastic materials further, policy interventions should directly incentivize producers to increase recycled content.

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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 the 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 energy recovery by incineration has also increased, specifically, from 3.12 million tons in

[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.

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 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

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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.

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.

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 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 this paper is organized as follows. Section 2 describes the data and our empirical model. Section 3 explains the main results. Section 4 discusses an extension of the results. Section 5 concludes.

2. Data and Empirical Analysis

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]

[4] Refer to Table 3 for the categories of plastic products.

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

<Table 1>

Table 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:

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

[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.

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%.

Table 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 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.

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:

$$S_{kit} = \beta_0 Treatment_i * Post_t + \beta_1 OilPrice_t + \delta_i + \lambda_t + \varepsilon_{it} \quad \cdots (1)$$

[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)

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 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 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.

<Table 3>

<Figure 2>

Figure 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>

Figure 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 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 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. Main Results

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 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 4>

3.2 Effect of CPR Law on 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 5>

Table 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 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 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 5>

4. Extensions

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 6>

Table 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.

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 7 presents the estimation results for the input shares of these plastic materials.

<Table 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

[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.

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).

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 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.

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[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 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	
After1997	4037	0.73	0.44	0	1	-
1997–2000	4037	0.01	0.3	0	1	-
After2000	4037	0.63	0.48	0	1	-
2000–2017	4037	0.58	0.49	0	1	-
After2018	4037	0.05	0.22	0	1	-

Table 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: Treatment and control groups

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

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

Table 4: Effect of CPR Law on the amount of recycled plastic usage

	Recycled Plastics					
	(1)	(2)	(3)	(4)	(5)	(6)
Treatment *1995–1997	657.0024***	657.0024***	657.0024***	616.4561***	586.3174***	586.0445***
	[115.8466]	[115.2700]	[114.0619]	[101.5542]	[101.1374]	[100.0758]
Treatment *After1997	1336.7306***			1311.4900***		
	[61.9611]			[58.9093]		
Treatment *1997–2000		882.8152***	882.8152***		874.3914***	870.4771***
		[96.2716]	[95.2626]		[89.1534]	[88.2187]
Treatment *After2000		1407.1658***			1383.6641***	
		[62.7112]			[59.6467]	
Treatment *2000–2017			1324.9979***			1301.7971***
			[62.7399]			[59.6779]
Treatment *After2018			2328.3106***			2308.3479***
			[120.8629]			[115.9174]
Oil Price				67.0887	53.6268	53.572
				[88.3830]	[87.9522]	[87.0291]
Constant	676.6364***	676.6364***	676.6364***	126.986	233.9757	233.5009
	[238.6109]	[237.4233]	[234.9350]	[700.9551]	[697.5395]	[690.2181]
Year-by-Month FE	YES	YES	YES	NO	NO	NO
Year FE + Month FE	NO	NO	NO	YES	YES	YES
Category FE	YES	YES	YES	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 4: Effect of CPR Law on the amount of recycled plastic usage (robust)

	Recycled Plastics					
	(1)	(2)	(3)	(4)	(5)	(6)
Treatment *1995–1997	657.0**	657.0**	657.0**	616.5***	586.3***	586.0***
	[207.5]	[207.5]	[207.6]	[187.8]	[181.7]	[181.6]
Treatment *After1997	1336.7*			1311.5*		
	[677.1]			[640.4]		
Treatment *1997–2000		882.8**	882.8**		874.4**	870.5**
		[376.8]	[376.8]		[359.3]	[356.3]
Treatment *After2000		1407.2*			1383.7*	
		[731.8]			[693.8]	
Treatment *2000–2017			1325.0*			1301.8*
			[647.6]			[613.4]
Treatment *After2018			2328.3			2308.3
			[1708.1]			[1633.2]
Oil Price				67.1**	53.6**	53.6**
				[26.8]	[22.2]	[22.1]
Constant	676.6**	676.6**	676.6**	127	234	233.5
	[265.0]	[265.1]	[265.1]	[390.6]	[307.0]	[307.1]
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

Table 5: Effect of CPR Law on recycled content

	Recycled Content					
	(1)	(2)	(3)	(4)	(5)	(6)
Treatment	0.0112***	0.0112***	0.0112***	0.0096***	0.0096***	0.0096***
*1995–1997	[0.0014]	[0.0014]	[0.0014]	[0.0012]	[0.0012]	[0.0012]
Treatment	0.0101***			0.0099***		
*After1997	[0.0008]			[0.0007]		
Treatment		0.0108***	0.0108***		0.0105***	0.0105***
*1997–2000		[0.0012]	[0.0012]		[0.0011]	[0.0011]
Treatment		0.0100***			0.0097***	
*After2000		[0.0008]			[0.0007]	
Treatment			0.0099***			0.0096***
*2000–2017			[0.0008]			[0.0007]
Treatment			0.0119***			0.0116***
*After2018			[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]
Year-by-Month FE	YES	YES	YES	NO	NO	NO
Year FE + Month FE	NO	NO	NO	YES	YES	YES
Category FE	YES	YES	YES	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 errors in parentheses

Table 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*After2018	0.0308***
	[0.0025]
Pipe*1997–2000	0.0051***
	[0.0020]
Pipe*2000–2017	0.0014
	[0.0012]
Pipe*After2018	0.0013
	[0.0025]
Machine*1997–2000	-0.0019
	[0.0020]
Machine*2000–2017	0.0081***
	[0.0012]
Machine*After2018	0.0080***
	[0.0025]
Container*1997–2000	0.0140***
	[0.0020]
Container*2000-2017	0.0080***
	[0.0012]
Container*After2018	0.0219***
	[0.0025]
Others*1997–2000	0.0161***
	[0.0020]
Others*2000–2017	0.0114***
	[0.0012]
Others*After2018	-0.0148***
	[0.0025]
Oil Price	0.002
	[0.0022]
Constant	0.0031
	[0.0195]
Year-by-Month FE	YES
Category FE	YES
R-squared	0.2733
Adj-R-squared	0.1953
N	4037

* p<0.1, ** p<0.05, *** p<0.01, standard errors in parentheses.

Table 7: Effect of CPR Law on input share of virgin plastic materials

	Polystyrene (PS)	Polyethylene (PE)	Polypropylene (PP)	Vinyl chloride (VC)	Other materials
Treatment *1995–1997	0.0057	-0.0130***	-0.0310***	-0.0082	0.0017
	[0.0049]	[0.0042]	[0.0049]	[0.0063]	[0.0061]
Treatment *1997–2000	0.0041	-0.0212***	-0.0365***	-0.0126**	0.0216***
	[0.0041]	[0.0035]	[0.0041]	[0.0053]	[0.0051]
Treatment *2000–2017	-0.0158***	-0.0405***	-0.0098***	-0.0214***	0.0524***
	[0.0027]	[0.0023]	[0.0027]	[0.0035]	[0.0034]
Treatment *After2018	-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]
Year-by-Month FE	YES	YES	YES	YES	YES
Category FE	YES	YES	YES	YES	YES
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 errors in parentheses

Figure 1: Production and recycling of plastic products

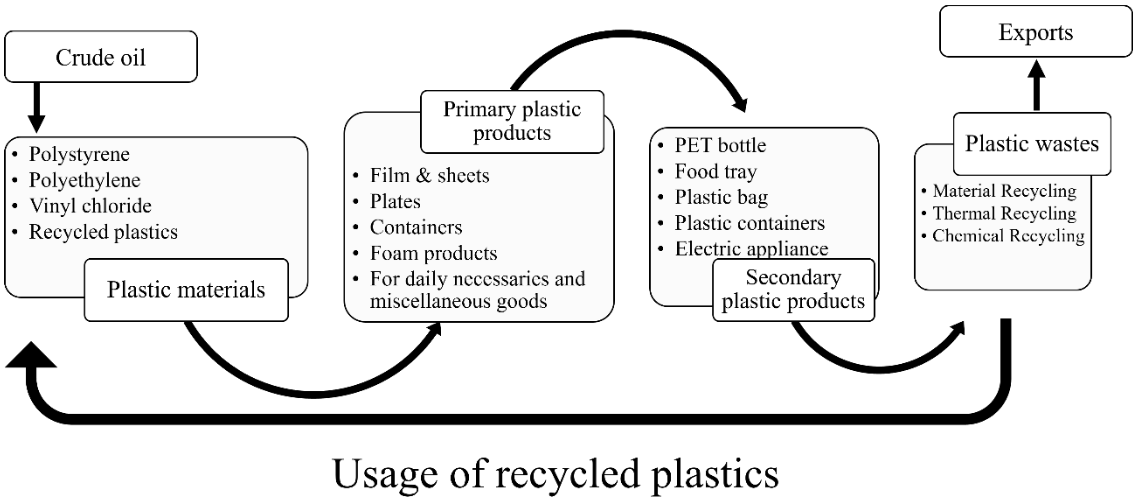
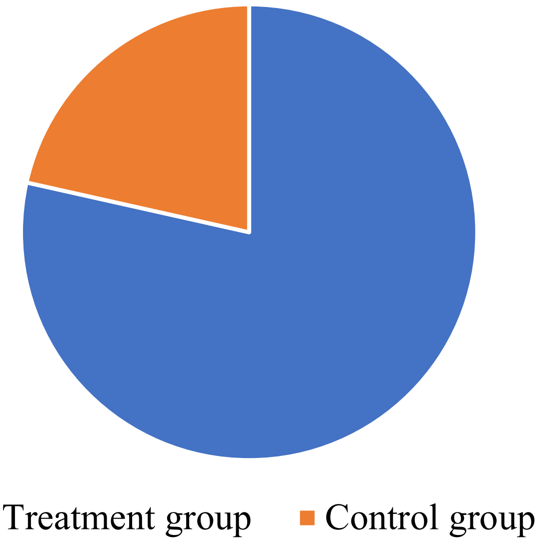


Figure 2: Share of primary plastic products



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

Figure 3: Amount of recycled plastics used as inputs

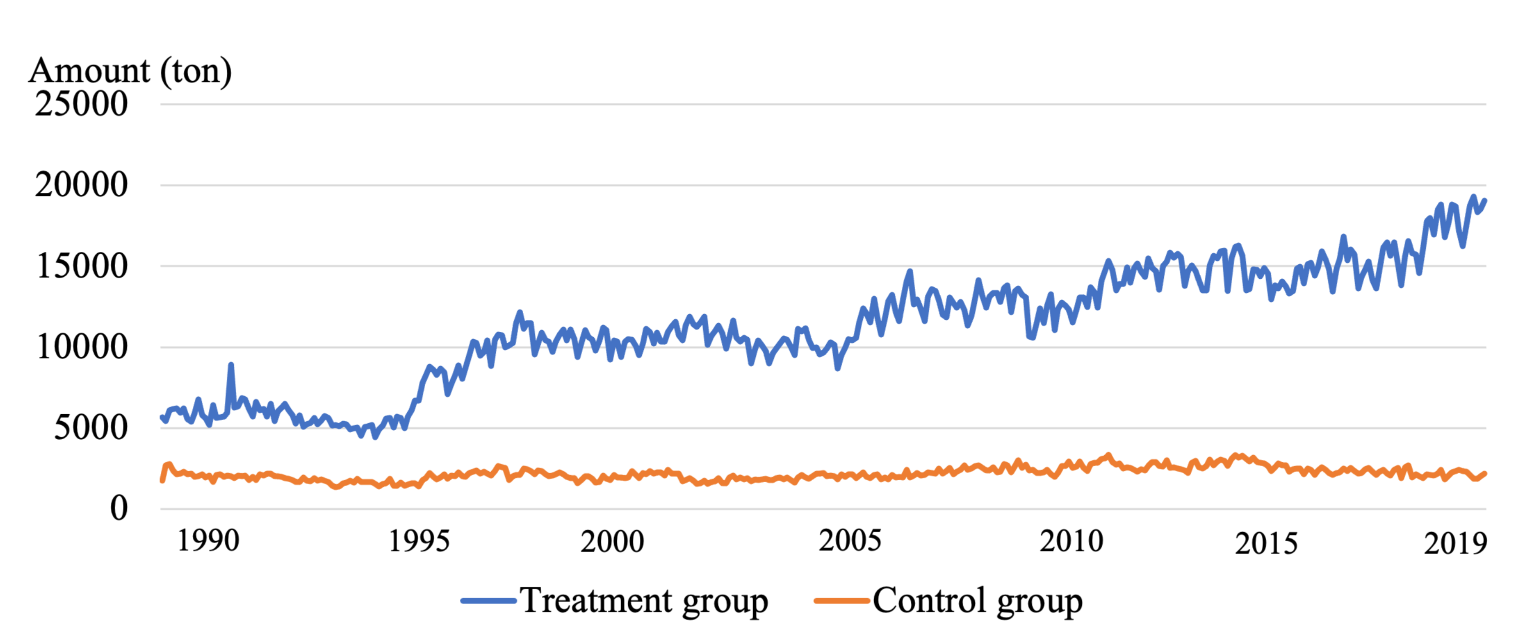


Figure 4: Recycled contents of plastic products

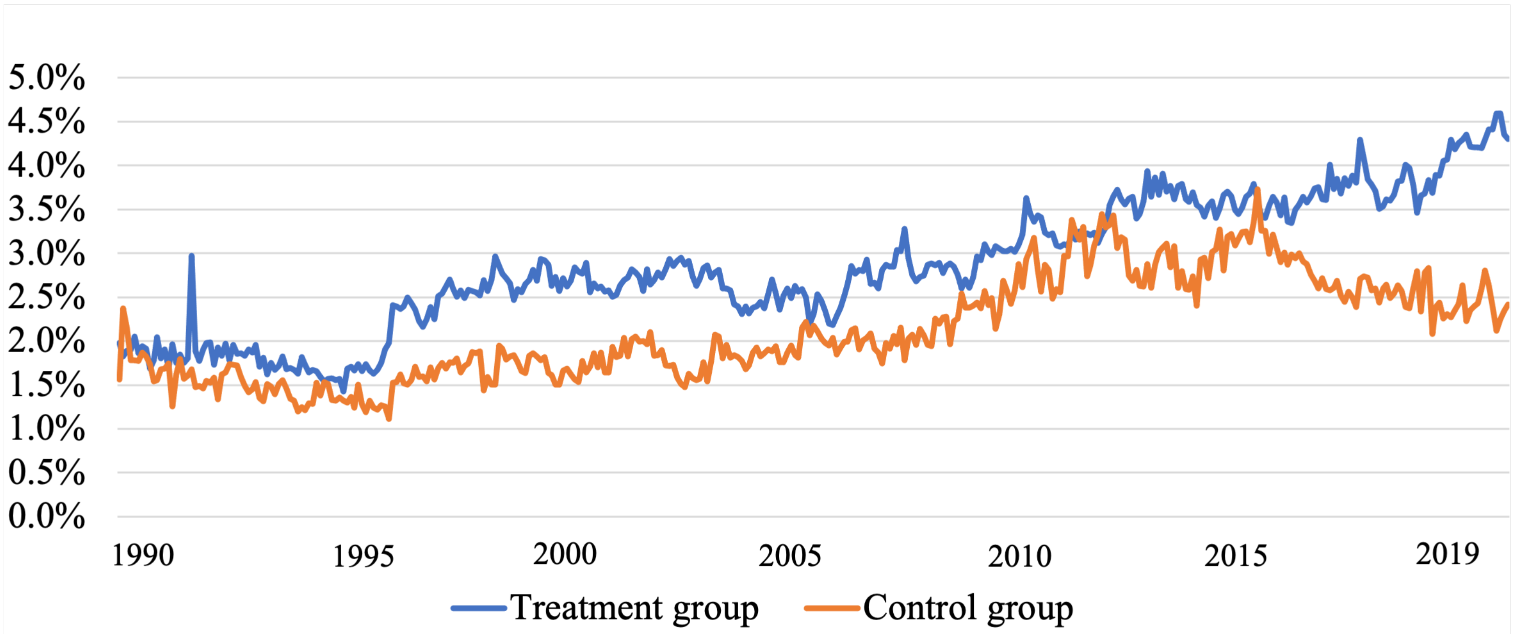
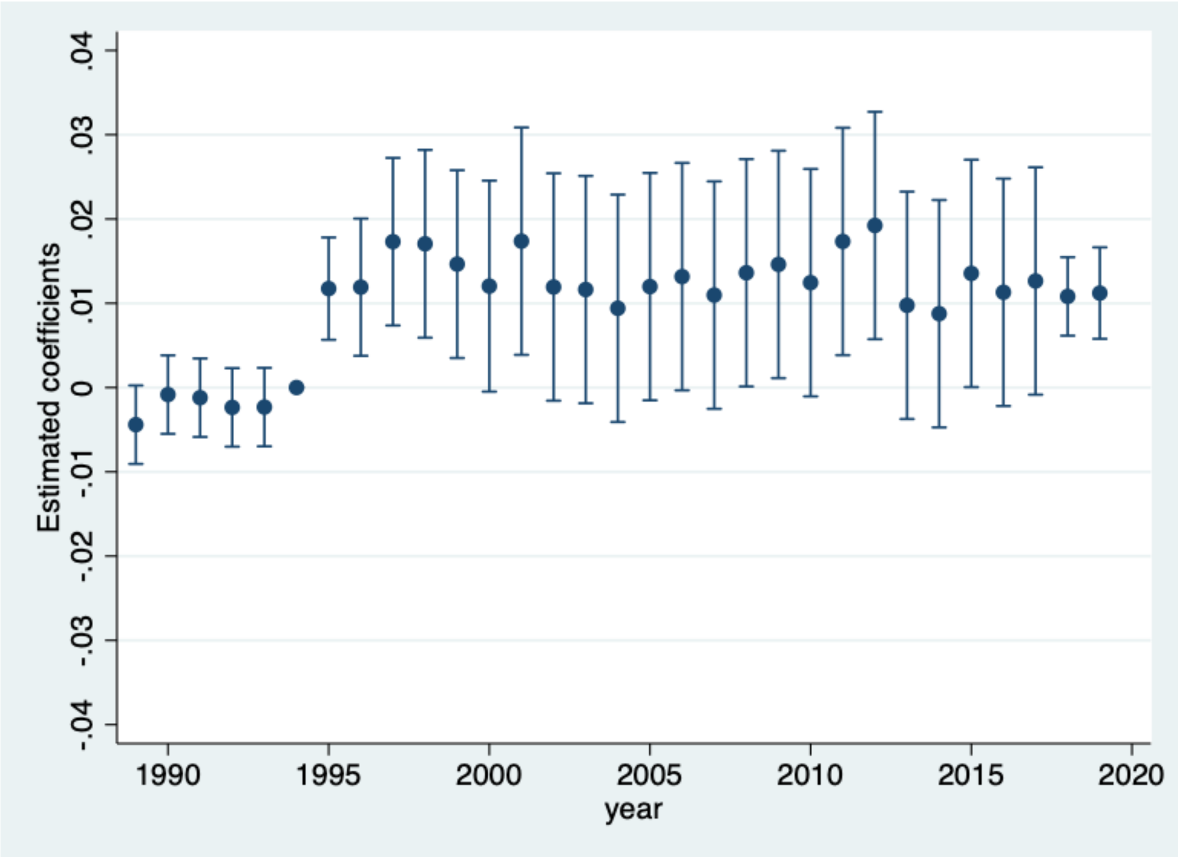


Figure 5: Testing the parallel trend during the baseline years



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.