6.2 Waste Problems and Economics

Waste is defined in the "Waste Disposal and Cleaning Law" (Waste Disposal Law) issued on December 25, 1970, as "garbage, bulky garbage, cinders, sludge, feces and urine, waste oil, waste acid, alkaline wastes, animal carcasses, and other dirty or unwanted materials in solid or liquid form" (Ministry of the Environment 2016). Wastes, by law, contain only solid and liquid substances; emissions that are air pollution, such as SO_2 and NO_x, and soot from factories are not considered as wastes.

Figure 6.8 shows how Europe and Japan have prioritized waste disposal. The waste hierarchy of Europe is presented in Fig. 6.8a; it was established under the EU Waste Framework Directive (Directive 2008/98/EC) in 2008. Figure 6.8b illustrates a similar hierarchy for waste management in Japan under the Fundamental Plan for Establishing a Sound Material-Cycle Society (basic Act for recycling) issued in 2000.

As shown in the figure, the highest priority in waste disposal management is to control (reduce) the generation of waste. An example of this type of management is to reduce the amount of plastic bags disposed as garbage by controlling their use. The next priority is to reuse the resources as much as possible and use them as components for other goods. Reusing plastic bags is one solution. Recycling entails reusing goods by reforming those that cannot be used in their original form into a usable form. There are three types of recycling: material, chemical, and thermal. Material recycling involves recycling physical products; chemical recycling involves decomposing wastes to molecular levels and reusing them as raw materials for chemical products; thermal recycling means recovering and using energy that is generated when wastes are burned in incinerators. Recycling in Fig. 6.8 refers to material and chemical recycling. The fourth hierarchy—other recovery and energy recovery—corresponds to thermal recycling. Finally, the last category of disposal occurs when materials cannot be recycled and are thus disposed in landfills or incinerated.

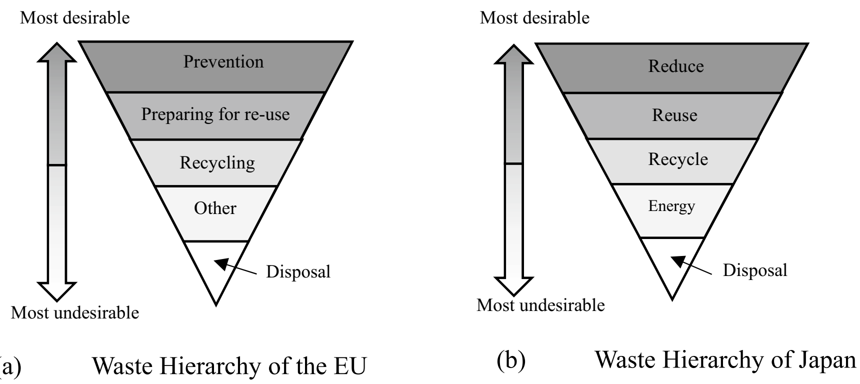
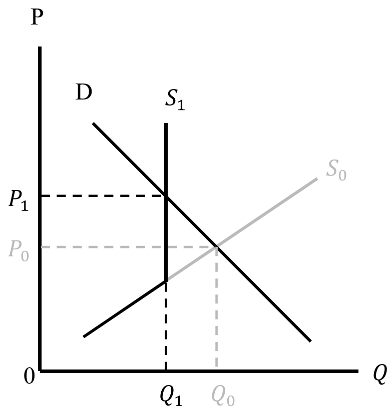


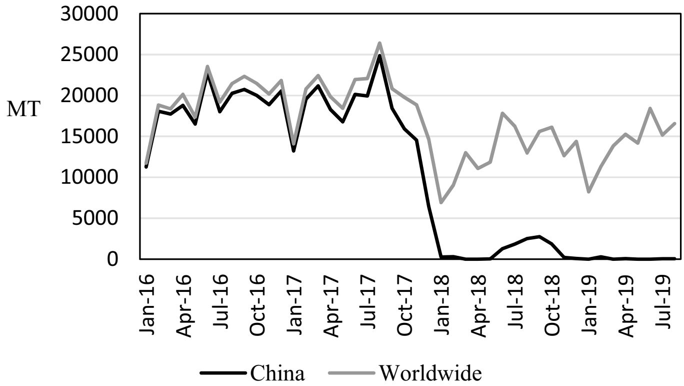
Fig. 6.8 Prioritization of waste disposal

In this section, I will explain policies that promote the principle of "reduce, reuse, and recycle," called the 3Rs. These 3Rs are the top-three waste disposal priorities presented in Fig. 6.8. One example of a policy to reduce waste is quantitative regulation. This policy is often targeted at the waste that causes significant environmental pollution; the need to reduce it is urgent and dramatic. For example, the Chinese government banned the import of waste plastics on December 31, 2017. Before then, China was the largest importer of plastic wastes in the world. The Government of China justified its halt of plastic waste imports as an environmental measure against contamination and water pollution from the chemical cleansing of plastic bottles; it also seeks to reconstruct its domestic recycling industry. These import restrictions decrease the supply of waste plastics distributed within China (see Fig. 6.9). In the figure, D is the demand from vendors that process or reuse plastic wastes, and S_0 and S_1 are the supply of plastic wastes before and after the implementation of the import restriction. Assuming that Q_1 is the amount of the domestic waste plastic supplied within China, the total supply of waste plastics in China becomes Q_1 when importing plastic wastes become prohibited. When the volume of plastic wastes is controlled at Q_1, the price of plastic waste will increase to P_1 owing to the short supply compared to the demand.

The ban of plastic waste import by China had wide-reaching effects on plastic bottle disposal companies around the world. Japan exported more than 90% of its plastic bottles that could not be disposed domestically to China until the plastic waste import regulations were implemented. As shown in Fig. 6.10a, after the exports of plastic wastes to China were prohibited in 2018, these exports have declined dramatically. After 2018, Japan shifted its export to countries in Southeast Asia, and these exports from Japan to the world began to increase again. As shown in Fig. 6.10b, the export volume of plastic bottle wastes to Thailand increased remarkably in 2018. Countries that were exporting their plastic bottle wastes to China are aware that shifting the export destinations from China to other countries will not be a solution in the long run. Thus, these countries are now planning to implement policies to reduce the use of plastic bottle containers such as having people bring their bottles to

Fig. 6.9 Quantitative restriction to promote reduction and reuse





(a) Exports to China and the rest of the world

(b) Exports to Thailand

Fig. 6.10 Changes in the exports of waste plastic bottles for Japan. *Source* Created based on the Trade Statistics of the Ministry of Finance

drinking fountains or developing non-plastic containers that can become substitutes for plastic bottles.

As another example of a waste reduction policy, I now examine price policy. For example, in July 2020, Japan began to provide incentives to reuse plastic bags by imposing a fee on them. After this regulation was executed, all retail stores in Japan were required to charge customers for plastic shopping bags. As of 2018, 127 out of 192 countries reviewed by the UN have enacted some type of plastic bag regulations (UNEP, 2018), while Japan lagged in implementing nationwide restrictions for plastic bags. In Fig. 6.11, *D* and *S* represent the demand and supply curves for plastic bags, respectively. Figure 6.11a shows the relationship between supply and demand before the price policy was applied to plastic bags. As seen in the figure, the supply curve

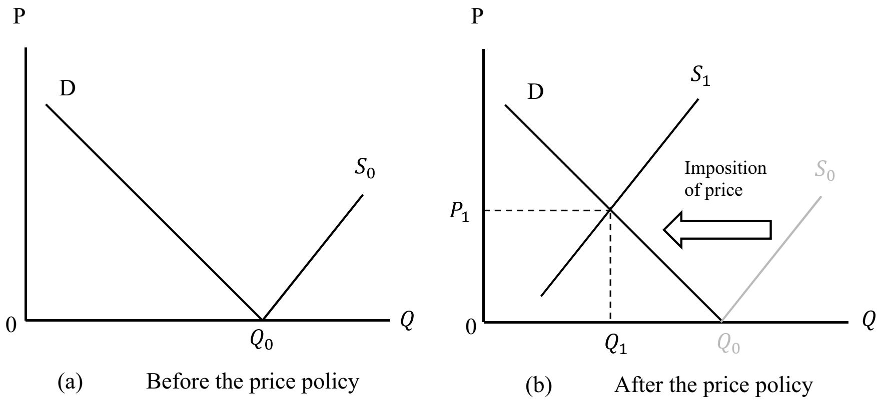


Fig. 6.11 Price policies that promote plastic bags reduction and reusing them

did not play its role, because, before the price policy, plastic bags were provided for free of cost to customers. However, after the price policy, a fee was imposed on plastic bags, shifting the supply curve to the left (see Fig. 6.11b). After the price policy, the plastic bags will be sold at P_1, which is the cross point of the demand and the supply curves. If people's willingness to pay for a plastic bag is lower than the equilibrium price (P_1), they will not pay for the bag and bring their shopping bag. For example, if P_1 was JPY 10, people who think this price is too high for a new bag will not purchase it. As a result, the number of plastic bags used in society will decrease from Q_0 to Q_1, reducing the total plastic bag use by ($Q_0 - Q_1$) (see Fig. 6.11b).

I will now discuss a policy that encourages recycling. In Fig. 6.12, D and S are the demand and supply curves for the plastic bottle containers. S_R is the supply curve for the plastic bottle produced through recycling (hereinafter referred to as recycled bottles), and S_V is that for the bottles newly manufactured using naphtha,[7] which is produced from crude oil. Because raw materials made from natural resources such as naphtha are often referred to as virgin resources, the supply curve of plastic bottles made from naphtha (hereinafter referred to as virgin bottles) is represented as V. In Fig. 6.12a, if the price of a virgin bottle is constant at P_V, the price of a virgin bottle is higher than the recycled bottle price when the volume of the plastic bottle is smaller than Q_R. Thus, the recycled bottles will be used on the left side of Q_R until the supply curve of the virgin bottle (S_V) intersects that of the recycled bottle (S_R). On the other hand, on the right side of Q_R, the virgin bottles will be used because their price is cheaper than the recycled bottles. The total number of plastic bottles supplied in this market is the volume when the supply curve of the virgin bottle crosses the demand curve at Q_V. However, because Q_R is the amount of recycled plastic bottles supplied to this market, the amount of plastic bottles supplied by the virgin bottle is $Q_V - Q_R$.

[7] Naphtha is obtained by distilling crude oil and is the technical term for petroleum fractions.

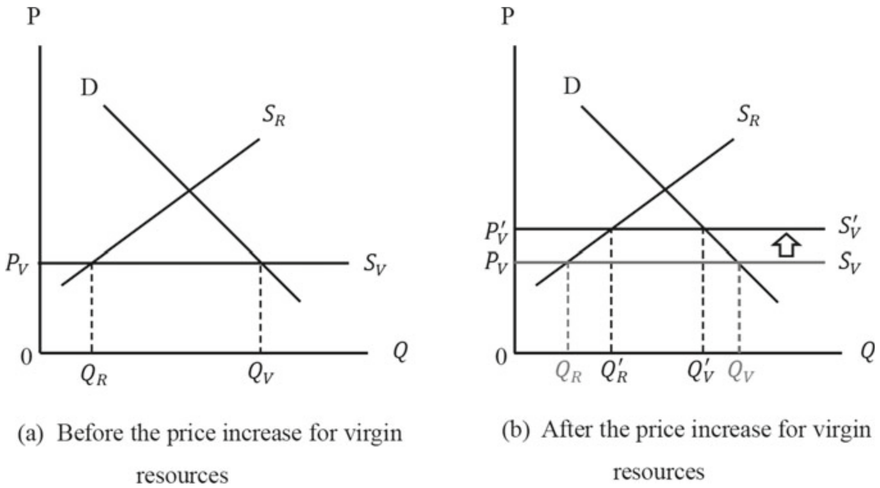


Fig. 6.12 Example of a policy that promotes recycling

The ratio of the recycled plastic bottle within the total volume of plastic bottles is $\frac{Q_R}{Q_V}$, and this can be interpreted as the recycling rate of plastic bottles in this market.

Here, I would like to explain a policy that will help increase the recycling rate in this example. The recycling rate is stagnant in Fig. 6.12a because the price of the virgin bottle was kept low. Hence, a policy to increase the price of the virgin bottle is needed to enhance the use of the recycled bottle. Figure 6.12b shows a case wherein the waste management authority imposes a tax on the virgin bottle to increase the recycling rate. When the price of the virgin bottle increases from P_V to P'_V after the taxation, the supply of the recycled bottle will rise from Q_R to Q'_R. In contrast, the supply of the virgin bottle will decline from Q_V to Q'_V owing to the increase in the virgin bottle price. Thus, it is observable from Fig. 6.12b that the taxation will increase the recycling rate of the plastic bottle to $\frac{Q'_R}{Q'_V}$, which is higher than the recycling rate of Fig. 6.2a.

Exercise 6.1

Q_D, Q_S^R, and P_V are the demand curve of a plastic bottle, the supply curve of a recycled plastic bottle, and the price of a virgin plastic bottle, respectively. Q_D, Q_S^R, and P_V defined as below solve the problems a through c. It is assumed that this market satisfies the conditions of perfect competition.

$$Q_D = -4P + 32; \quad Q_S^R = P + 2; \quad P_V = 2$$

a. What will be the optimal volumes of recycled and virgin plastic bottles? What is the volume of virgin plastic bottles supplied in this market under the condition that the recycled bottles will be used when their price is lower than the virgin plastic bottles?

b. What will be the recycling rate in this market?
c. To improve the recycling rate, the regulation authority decides to increase the price of virgin plastic bottles to 4. How will the recycling rate change when this regulation is applied?

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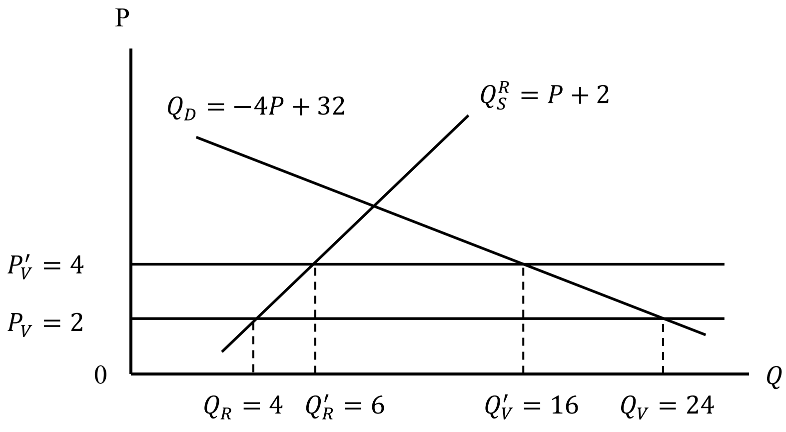
Chapter 6

Exercise 6.1



a. The volume of the recycled plastic bottle: 4. The volume of the virgin plastic bottle: 20.

Because the price of virgin plastic bottles is 2, the volume of recycled plastic bottles supplied in this market can be calculated by applying this price to the recycled plastic bottle supply curve: $Q_R = 2 + 2 = 4$.
The volume of virgin plastic bottles produced can be obtained by calculating the plastic bottle demand when $P_V = 2$. Thus, the volume of virgin plastic bottles produced is $Q_V = -4 \cdot 2 + 32 = 24$. However, at the left of $Q_R = 4$, the price of a virgin bottle will be higher than the recycled bottle. When $Q < 4$, the recycled bottle will be used. Hence, the total volume of virgin bottles supplied in the market will be $24 - 4 = 20$.

b. $\frac{1}{6}$
The recycling rate can be calculated by $\frac{Q_R}{Q_V} = \frac{4}{24} = \frac{1}{6}$.

c. The recycling rate will be reduced to $\frac{3}{8}$ after the regulation.
When $P'_V = 4$, $Q'_R = 4 + 2 = 6$, $Q'_V = -4 \cdot 4 + 32 = 16$.
Hence, the recycling rate $\frac{Q'_R}{Q'_V} = \frac{3}{8}$.