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Food Waste caused by Excess Inventory at Retail Stores in Japan

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Abstract

In recent years, the sustainability of the global environment has become an attractive issue. The world is exposed to climate change, and there is an urgent need to protect the environment and secure natural resources for the future. Environmental protection and the securing of natural resources require efforts from various stakeholders. This study focuses on food waste in the retailing industry.

While many developing countries are having difficulties to secure food, a large amount of food is disposed mainly in developed countries. Food waste produces greenhouse gases and has a negative impact on the environments. A significant amount of food is wasted in the retailing industry, which is mainly due to their excessive stocking. Such excessive stocking is to avoid losing customers because of going out of stock. Although this behaviour is optimal for retailers' business strategy, it is not preferable from the perspective of preserving the global environment. We theoretically demonstrate humans' behavioural choice in relation to the use of natural resources and a mechanism of retailers' overstocking behaviour using economic models. Moreover, we also examine the current state of food disposal and food recycling in Japan. Although, awareness of reducing food disposal is increasing, and various efforts such as food recycling are being carried out in Japan, sufficient reduction of food disposal is hardly be achieved. We argue that in addition to food recycling, measures to discourage retailers from overstocking food products (e.g., tax imposition) are necessary for the sufficient reduction of food waste and the sustainability of the global environment.

Keywords: Food loss; Food waste; Retailers; Overstock; Japan

Introduction

In recent years, the sustainability of the global environment has become a burning issue. The world is facing climate change, and there is an urgent need to protect the environment and secure natural resources for the future. This requires efforts from various stakeholders, including food management. Many poor countries are unable to secure food, whereas large amounts of food are discarded without being consumed, especially in developed countries. Such food disposal adversely affects the global environment and natural resources because discarded food can be a source of greenhouse gases. There are various reasons for food disposal. For example, some industries, such as farmers and food manufacturers mainly handle post-harvest vegetables and ingredients for processed foods. Therefore, they often dispose fresh foods (i.e., non-standard vegetables), whereas other industries, such as retailers and restaurants, mostly dispose of processed food. However, food waste at the storage and transportation stages is mainly found in developing countries, but compared with food disposal by retailers and restaurants, the amount is not large.

This study uses economic theoretical models to demonstrate the behavioural choice of humans' use of natural resources by considering environmental sustainability and the mechanism of generating food disposal in the retailing industry and its potential improvement measures. This study also investigates the current status of food disposal and its measurement (i.e., food recycling) by looking at relevant data.

The remainder of this chapter is organised into 6 sections. Section 2 reviews the existing literature about food disposals. Sections 3 and 4 present the economic model to demonstrate the behavioural choice of humans' use of natural resources and the mechanism of generating food disposal in the retailing industry, respectively. Section 5 investigates the current status of food disposal and its measurement in Japan. Then, Section 6 concludes.

Literature Review

Conservation of natural resources is an important issue; however, achieving it requires solving various problems, including food disposal. Although food disposal is the opposite of food security, they coexist in the world. The United Nations' Sustainable Development Goal (SDG) 2 of the Post-2015 Development Agenda aims to "end hunger, achieve food security and improved nutrition and promote sustainable agriculture" [1]. The problem of food security is mainly found in developing countries, and SDG 2 is calling on the world to invest in and support food production capacity in developing countries [1].[1] Although there are countries where food cannot be secured due to poverty, there are other countries that dispose of excess food in large quantities. Thus, the world must try to secure food supply in some countries while reducing food disposal in other countries.

Food disposal adversely affects the global environment and natural resources. This is because discarded food can be a source of greenhouse gases. The amount of greenhouse gas generated depends on the type of food. For example, in six Swedish supermarkets, fresh fruits and vegetables were responsible for 85% of the total food waste, whereas the corresponding carbon footprint was 46% of the total [3]. However, meat was only responsible for 4% of the total food waste, whereas the corresponding carbon footprint was 29% of the total [3].[2]

The food disposal situation in developed countries indicates that the food harvested to meet consumers' demand is more than necessary. The United Nations' SDGs also advocate the reduction of food disposal. According to the SDGs (Target 12.3), by 2030, the world should halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses [5]. To correctly recognise the latter target, we need to establish the difference between food loss and food waste. On the one hand, food loss is the decrease in the quantity or quality of food due to the decisions and actions of food suppliers in the chain, excluding retailers, food service providers, and consumers [6]. Empirically, food loss refers to any food that is discarded, incinerated, or disposed of along the food supply chain, from harvest/slaughter/catch to the retail level, and is not utilised in any other productive activity, such as feed or seed [6]. On the other hand, food waste refers to the decrease in the quantity or quality of food due to the decisions and actions of retailers, food service providers, and consumers [6]. From the definitions of food loss and food waste, they are distinguished based on the stage of disposal in the food supply chain.

The stages of food disposal in developed and developing countries are different in the supply chain.[3] In developing countries, foods are discarded at the stage of storage and logistics (i.e., food loss). Moreover, in developing countries, the humidity and temperature of storage are poorly controlled, and transportation takes time, so food often rots before it is sold [8]. However, in developed countries, foods are mainly discarded at the retailing stage (i.e., food waste).

One of the causes of food waste in retail stores in developed countries is food safety regulations. For example, grocery retailers need to follow the market standards that foods have to meet, such as the visual appearance and product characteristics [9]. Moreover, grocery retailers are not allowed to sell foods after their expiration date [9]. Food waste is also due to retailers' sales strategies. This is because retailers try to keep on-shelf availability and a large variety of food to increase their customer satisfaction [10]. However, this strategy contributes to a significant amount of overstock, which generates food waste [10]. Such overstock of food is caused by fierce competition between retailers [11]. As out-of-stock products lead to the loss of customers, retailers purchase more than necessary [11]. Such competition is especially fierce among convenience stores in Japan [11].

To reduce food disposal, it is necessary to achieve a circular economy by reusing food. To achieve a circular economy, the active involvement of consumers, producers and retailers is needed. However, in many cases, consumers are not very active in contributing to a circular economy; hence, measures to induce consumers' active involvement

1 However, developing countries are not the only ones facing the problem of food security. For example, Japan imports a large amount of licorice from China, and it is challenging for Japan to secure licorice with its own production capacity alone [2].

2 Therefore, there is an idea that the mitigation of greenhouse gases emission should be suppressed from people's eating habits. For example, if we change our eating habits to curb the consumption of food, whose waste is likely be a source of greenhouse gas (i.e., meat), the burden on the environment will be curtailed [4].

3 One might think that food disposal is only a problem in developed countries. As many know, production capacities for cereals in developing countries are lower than those of developed countries. This is mainly due to lack of capital (i.e., machineries) and inadequate skills of farmers [7]. However, even in developing countries, a certain amount of food is discarded after harvesting.

are needed. For example, offering discounts for purchasing animal products makes customers return their organic food waste to retailers [12]. This indicates that many customers would be willing to participate in a circular economy if there is a sufficient reward for participation [12].

Thus, food disposal is likely due to strict management of food safety and fierce competition for customers among retailers in developed countries. Although these are necessary efforts to provide quality food to customers, developed countries must work to reduce food waste to sustain the global environment.

Humans' Behavioural Choice in Relation to the Use of Natural Resources

This section considers humans' behavioural choice in relation to the use of natural resources from an economic perspective. We use a simple economic model to determine how humans decide to use natural resources to maximise their utility.[4] As a prerequisite, in the model, we assume that the natural resource grows naturally and reduces through human consumption.[5] We express the changes in the amount of the natural resource as follows:

$$X_{t+1} = X_t(1+\delta) - Y_t, \tag{1}$$

where X_{t+1} and X_t are the existing amount of the natural resource at time t+1 and t, respectively. X_t naturally grows at a rate of δ. Y_t is the use of the natural resource by humans at time t. Humans gain a utility from using the natural resource, but Y_t reduces the future amount of the natural resource X_{t+1}. Moreover, humans also enjoy the natural resource X_t (i.e., enjoying clean water and air). Therefore, the utility function of humans is expressed as follows:

$$U_t = X_t^{\alpha} Y_t^{1-\alpha} \tag{2}$$

where U_t is the utility of humans; α measures the degree of the natural resource's contribution to the utility.[6] In the above situation, humans try to maximise U_t subject to Equation (1). This maximisation problem can be solved by using the following Lagrange function:

$$L_t = \sum_{t=0}^{T} X_t^{\alpha} Y_t^{1-\alpha} - \lambda_{t+1}(X_{t+1} - X_t(1+\delta) + Y_t) \tag{3}$$

where L_t is the value to be maximised, and λ_{t+1} is the Lagrange multiplier. By differentiating L_t by Y_t X_t and λ_{t+1}, we obtain Equations (4), (5), and (6) as follows:

$$\frac{\partial L_t}{\partial Y_t} = (1-\alpha)\left(\frac{X_t}{Y_t}\right)^{\alpha} - \lambda_{t+1} \tag{4}$$

$$\frac{\partial L_t}{\partial X_t} = \alpha\left(\frac{X_t}{Y_t}\right)^{\alpha-1} + \lambda_{t+1}(1+\delta) - \lambda_t \tag{5}$$

$$\frac{\partial L_t}{\partial \lambda_{t+1}} = X_{t+1} - X_t(1+\delta) + Y_t \tag{6}$$

By setting $\frac{\partial L}{\partial Y_t}, \frac{\partial L}{\partial X_t}$ and $\frac{\partial L}{\partial \lambda_{t+1}}$ equal to 0, we obtain Equations (7), (8), and (9) as follows:[7]

$$(1-\alpha)\left(\frac{X^*}{Y^*}\right)^{\alpha} = \lambda^* \tag{7}$$

$$\alpha\left(\frac{X^*}{Y^*}\right)^{\alpha-1} + \lambda^*(1+\delta) = \lambda^* \tag{8}$$

$$X^* = X^*(1+\delta) + Y^* \tag{9}$$

Using Equations (7) and (8), we can obtain Equation (10):

$$\delta - \frac{\alpha Y^*}{(1-\alpha)X^*} = 0 \tag{10}$$

As shown in Equation (10), the growth rate of the natural resource δ is equivalent to $\frac{\alpha Y^*}{(1-\alpha)X^*}$. Assuming δ remains constant, if people are highly dependent on the natural resource (i.e., a high level of α), X^* needs to be large, or Y^* needs to be small for Equation (10) to hold, and the opposite is also true. This indicates that when people are highly dependent on a natural resource, they are more likely to maintain the natural resource by reducing their consumption of the resource.

Food Waste in the Retailing Industry

Sustaining natural resources poses many challenges. One of the challenges is the mitigation of food disposal. Whereas

4 The economic model in this section is based on the study of Conrad [13].

5 Humans use natural resources for various purposes (i.e., producing energy).

6 Equation (2) takes the form of the Cobb-Douglas function. We assume that satisfies the condition of $0 \leq \alpha \leq 1$.

7 To find an optimal level of X_t, Y_t and λ_{t+1}, we consider a case with infinitely long period of interest. When the period of interest becomes infinitely long, the variables reach a steady state (i.e., $X_{t+1} = X_t = X^*$, $Y_{t+1} = Y_t = Y^*$ and $\lambda_{t+1} = \lambda_t = \lambda^*$) [13].

many developing countries are in shortage of food, developed countries waste a significant amount of food. The disposal of food puts a burden on the environment and has a negative effect on the sustainability of natural resources. In this section, we analyse the overstocking behaviour of retailers in developed countries and its potential countermeasures.[8] In developed countries, retailers keep have large inventories. One of the reasons for keeping large inventories is that they are exposed to fierce business competition, and out-of-stock makes them lose their customers. For retailers, the cost of losing their customers is larger than the cost of disposing of food products; hence, their inventories exceed their expected sales. This situation can be explained by the logic of negative externalities in economics.[9]

Equation (11) expresses the profit of retailer π_t, where p is the price of the product; Q_t is an amount of the product sold; c is cost of the product (i.e., expenses for stocking); B is the cost of disposing of the product; S_t is the amount of the product disposed of; e is the cost incurred by retailers when they lose customers,[10] and subscript t denotes time. We assume that $B < e$; hence, the retailer decides to overstock the products.

$$\pi_t = (\mathrm{p}-\mathrm{c})\mathrm{Q}_t - (\mathrm{B}-e)\mathrm{S}_t \tag{11}$$

One of the effective measures for reducing disposal is to impose tax on it. Equation (12) reveals the retailer's profit when the disposal of the product is taxed at τ_t rate.

$$\pi_t = (\mathrm{p}-\mathrm{c})\mathrm{Q}_t - (\mathrm{B}+\tau_t-e)\mathrm{S}_t \tag{12}$$

Regarding the situation expressed in Equation (12), the retailer is trying to maximise π_t with respect to goods wastes transformation frontier frontier $\phi(Q_t, S_t)$,[11] where L_t is the value to be maximised, and λ_t is the Lagrange multiplier.

$$L_t = (\mathrm{p}-\mathrm{c})\mathrm{Q}_t - (\mathrm{B}+\tau_t-e)\mathrm{S}_t - \lambda_t\phi(\mathrm{Q}_t,\mathrm{S}_t) \tag{13}$$

By taking the derivation of L_t with respect to Q_t, S_t and λ_t and equating to zero, we obtain Equations (14), (15), and (16) as follows:[12]

$$\frac{\partial L_t}{\partial Q_t} = p - c - \lambda_t\phi_{\mathrm{Q}_t} \tag{14}$$

$$\frac{\partial L_t}{\partial S_t} = (\mathrm{B}+\tau_t-e) - \lambda_t\phi_{\mathrm{S}_t} \tag{15}$$

$$\frac{\partial L_t}{\partial \lambda_t} = -\phi(\mathrm{Q}_t,\mathrm{S}_t) \tag{16}$$

Next, we assume that $\phi(Q_t, S_t)$ takes the form of Equation (17).[13] Then ϕ_Q and ϕ_S are as expressed in Equations (18) and (19), respectively.

$$\phi(\mathrm{Q}_t,\mathrm{S}_t) = (\mathrm{Q}_t - m)^2 - nS_t \tag{17}$$

$$\phi_{\mathrm{Q}} = 2(\mathrm{Q}_t - \mathrm{m}) \tag{18}$$

$$\phi_s = -n \tag{19}$$

Using Equations (14), (15), (16), (18), and (19), we obtain the following:

$$Q_t^* = \frac{n(\mathrm{p}-\mathrm{c})}{2(\mathrm{B}+\tau_t-e)} + m \tag{20}$$

$$S_t^* = \frac{n}{4}\left(\frac{\mathrm{p}-\mathrm{c}}{\mathrm{B}+\tau_t-e}\right)^2 \tag{21}$$

As shown in Equations (20) and (21), the Q_t^* and S_t^* of the retailer is negatively related to τ_t, indicating that imposing a higher rate of tax is effective in making the retailer reduce inventories and the disposal of products.[14]

Current Status of Food Disposals in Japan

In this section, we analyse the case of Japan as an example of food waste at retail stores in developed countries using relevant data. As theoretically demonstrated in the previous section, retailers have the incentive to excessively stock and waste food products as part of their business strategy. Among developed countries, the Japanese retail industry (i.e., convenience stores) is in fierce competition for customer acquisition and is thus suitable for the data analysis in our study.

Table 1 presents the annual amount of food disposal

8 The economic model in this section is based on the study of Conrad [13].

9 Negative externalities occur when a transaction negatively affects a third party; however, the parties of the transaction do not take any responsibility for the effect [14]. In this case, retailers overstock and dispose the products to maximise their profit, without considering the impact on the environment.

10 Here, we assume that avoiding to lose customers is a type of the retailers' profit. As excessive inventory of food helps the retailer to prevent customer loss, we assume that eS_t is positively related to π_t. Moreover, to make the setup simple, we assume that p, c, B, and e are constant. Furthermore, we assume that S_t does not exceed certain amount w.

11 We borrowed the idea and notation of goods wastes transformation frontier and the functional form of Equation (17) from the study of Conrad [13]. $\phi(Q_t, S_t)$ denotes the minimum level of S_t for a given amount of Q_t and vice versa [13].

12 ϕ_{Q_t} and ϕ_{S_t} denote the derivation of $\phi(Q_t, S_t)$ with respect to Q_t and S_t, respectively.

13 We borrowed the functional form of $\phi(Q_t, S_t)$ from the study of Conrad [13].

14 Q_t^* and S_t^* are the optimal value to maximise π_t.

generated by food businesses in Japan. Among the industries in Table 1, the food manufacturing industry has the largest amount of food disposal. This is because food manufacturers discard foods when they process raw materials into packaged foods. Although the quantity is smaller than that of the food manufacturing industry, food retailers and restaurants also dispose of a significant amount of food. Food disposal in the food retailing industry can be considered to be due to the mechanisms described in the previous section.[15]

Year/ Industry	Food Manufacturing	Food Whole sale	Food Retailing	Restaurant
2019	14,224	247	1,185	1,900
2018	13,998	284	1,223	2,148
2017	14,106	268	1,230	2,062
2016	16,167	267	1,271	1,994
2015	16,533	294	1,275	1,995
2014	16,055	270	1,269	1,938
2013	15,936	210	1,239	1,884

Table 1: Annual Amount of Food Disposal Generated by Food Businesses in Japan
(Unit: 1,000 tonnes)
Data Source: The Ministry of Agriculture, Forestry, and Fisheries of Japan[16]
https://www.maff.go.jp/j/shokusan/recycle/syokuhin/kouhyou.html [15]

The awareness of reducing food disposal is increasing in Japan. For example, a food recycling act was enforced in May 2001 in Japan, and food recycling is currently being actively pursued [16].[17]

Table 2 presents the rate of food recycling in Japan from 2013 to 2019. As is clear from Table 2, the food recycling rate varies greatly among the industries. Specifically, in the food manufacturing industry, recycling was always carried out at a high level (i.e., 95%). In contrast, food recycling by food retailers and restaurants was always at a lower level than in the food manufacturing industry.

Year/ Industry	Food Manufacturing	Food Whole sale	Food Retailing	Restaurant
2019	96	64	51	32
2018	95	62	51	31
2017	95	67	51	32
2016	95	65	49	23
2015	95	60	47	23
2014	95	57	46	24
2013	95	58	45	25

Table 2: Rate of Food Recycling.
Data Source: The Ministry of Agriculture, Forestry, and Fisheries of Japan[18]
https://www.maff.go.jp/j/shokusan/recycle/syokuhin/kouhyou.html [15]

Next, we take a closer look to confirm the actual state of recycling. Table 3 presents the use of food recycling in the four industries. As presented in the table, the most common recycling uses are fertiliser and feed. Moreover, the amount of recycled feed and fertiliser in the food manufacturing industry is much higher than that in other industries. This is likely because most food disposals in the food manufacturing industry are fresh foods, which can easily be processed into fertiliser and feed. However, foods in the retailing and restaurant industries are cooked, which are difficult to reuse.[19]

Use for Recycling/ Industry	Food Manufacturing	Food Whole sale	Food Retailing	Restaurant
Fertiliser	1,653	76	123	122
Feed	8,814	43	181	149
Solid Medium Used for Mushroom Cultivation	40	1	-	-
Methane	456	4	31	12
Oil Product	288	8	95	81
Fuels and Reducing Agents	38	1	7	1
Ethanol	3	0	0	0

Table 3: Breakdown by Use of Food Recycling
(Unit: 1,000 tonnes)
Data Source: The Ministry of Agriculture, Forestry, and Fisheries of Japan[20]
https://www.maff.go.jp/j/shokusan/recycle/syokuhin/attach/pdf/kouhyou-13.pdf [17]

15 Food disposal by restaurants is considered to be due to the same reasons as those of the food retailing industry. Restaurants also purchase more ingredients than what can meet expected sales to avoid not being able to serve menus because of running out of ingredients.

16 The data source is in Japanese.

17 The food recycle act in Japan promotes the recycling of food by food-related businesses (i.e., food manufacturing, retailing, and restaurants) [16]. The act tries to control food disposal generated in the process of manufacturing, unsold food, and leftover food by recycling to produce raw materials for feed and fertilizer [16]. The Ministry of Agriculture, Forestry, and Fisheries of Japan's "Outline of the Act on Promotion of Recycling of Food Circulation Resources" [16] is in Japanese.

18 The data source is in Japanese.

19 Waste food from restaurants contains a lot of leftovers from customers, which are very difficult to reuse.

20 The data source is in Japanese.

As the table reveals, reducing food waste in Japan has attracted attention, and the industries are making efforts. However, a considerable amount of food is still discarded in Japan, so their efforts to reduce food waste have not been sufficient. The food recycling discussed in this section is an effective measure for reducing food waste; however, as the data indicates, processed foods are difficult to be recycled. Hence, food recycling alone can hardly be a complete solution for reducing food waste. To reduce food waste, efforts will be needed to reuse food, and the right amount of food should be supplied and demanded.

Conclusion

In recent years, the sustainability of the global environment has become an attractive issue. The world is exposed to climate change, and there is an urgent need to protect the environment and secure natural resources for the future. To address this issue, in this study, we theoretically analysed the causes of food waste in the retailing industry and propose a potential improvement measure. Currently, many poor countries are unable to secure food, whereas large amounts of food are discarded, especially in developed countries. Such food disposal is adversely affecting the global environment and natural resources. This is mainly because discarded food can be a source of greenhouse gases. There are multiple causes of food waste, such as unsold food from retail stores, and most of the waste comes from developed countries. As revealed in Section 4, retailers in a fierce competition for customers stock a large amount of food, although some of their stocks are discarded. Such behaviour can be considered as optimal in terms of their management strategy; however, it is not preferable when considering the global environment. Food waste should be mitigated for the future of the global environment, and some efforts (i.e., food recycling) have been taken in Japan, as discussed in Section 5. However, the results are not sufficient. This is because most of the foods discarded from retail stores and restaurants are processed and difficult to reuse. Although food recycling is effective in mitigating food waste, it will be necessary to reduce excess inventories (as introduced in Section 4) and promote the production and consumption of appropriate amounts of food. Lastly, due to data source constraints and other reasons, contribution of this study is limited to provide the theoretical analyses and the data analysis related to food disposal and food recycling in Japan. However, to empirically confirm the claims provided by the theoretical analysis, an empirical analysis using the larger sized data will be necessary. We will make the empirical analysis as a subject for future analysis.

Conflicts of Interest

The author has no conflict of interest associated with this manuscript.

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