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An Economic Valuation on the External Cost of Alternative Milk Packaging

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Abstract

This paper investigates the degree to which glass bottled milk is an environmentally friendly alternative. A recent life cycle assessment for fluid milk packaging alternatives is utilized to quantify the environmental costs associated with each packaging type. We conduct a sensitivity analysis to identify the return and reuse rates under which the glass bottle has a lower environmental impact than the alternatives. With eight reuses and 95 percent return rate, glass bottled milk has a lower environmental cost than the alternatives. Twelve reuses and a 100 percent return rate is necessary for glass packaging to have the lowest social cost.

Keywords: milk; life cycle assessment; packaging; external costs

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Introduction

Starting in the 1970s, consumers have become more conscious about the environmental impact associated with their personal consumption choices, thus creating a demand for environmentally sound products (Byrne 1991). In recent years, firms have worked to segment markets in order to attract consumers who wish to purchase the environmentally friendly products. The primary method by which this product differentiation has occurred is eco-labeling, which has been used to identify goods as being organic, hormone free, non-GMO, Rainforest Alliance Certified, and energy efficient; as examples.

While eco-labeling is an effective method for providing information to the consumer about otherwise unobservable product attributes, product packaging may also be used to attract the environmentally conscientious consumer. Examples of such packaging are that which is more easily recycled and which is comprised of post-consumer recycled materials. Such packaging could make the difference for a consumer deciding between two relatively similar products.

In the past, dairies and creameries shipped glass bottles of milk to consumers within a 100 mile radius. Glass bottles may be reused a number of times prior to recycling the glass, resulting in the appearance of being environmentally friendly packaging. As technology advanced, especially in the production of alternative materials for packaging, plastic milk jugs became the standard as they were less expensive (Zaleski 1963). Although they have several significant advantages, disposable plastic milk containers have generated considerable controversy in the United States. According to Fischer and Hammond (1978), the disposable plastic container is a heavy user of nonrenewable hydrocarbon resources and presents greater solid waste disposal problems than reusable containers.

Given the increased demand for products which represent reduced negative environmental impact, it is not surprising that a number of dairies in the United States have either begun or expanded glass bottled milk operations. And while the glass bottle is not an option at all grocery outlets, a quick internet search returns results for glass bottled milk at some locations for nearly every major grocery chain.

It is clear that a market for locally produced milk in glass bottles exists; and that consumers perceive the product to represent a reduction in environmental impact. However, there is no guarantee to the consumer that what they are purchasing is, in fact, an environmentally friendly product. The first objective of this study is to evaluate the external environmental costs, private production costs, and total social costs associated with various packaging options of liquid milk. While the reduction of environmental impact is desirable, the benefit to society may be undone if the cost of production for the environmentally friendly alternative is sufficiently large. The second objective is to conduct a sensitivity analysis on the aforementioned costs to account for uncertainty in the reuse and return rates of glass bottles.

Theoretical Framework

Prices for goods and services traded in the market reflect the private valuation of those goods and services by the participants in the market. The market price, however, does not account for the

effects that the transaction might have on third parties. These third-party effects are called externalities, and may be either positive or negative in nature. In the case of liquid milk packaging we are interested in the negative externalities associated with the environmental impact of the packaging life cycle. A graphical representation of a negative externality is presented in Figure 1. The marginal private benefit (MPB) is the value that buyers place on the good or service and the marginal private cost (MPC) is the cost to the seller of providing the good to the market. The sum of the MPC and the external cost generated yields the marginal social cost (MSC), which is the cost to society of an additional unit of the good. If there isn't an externality associated with the transaction of the good or service, the market price of P* and market quantity of Q* occur. However, at the quantity of Q*, the MSC exceeds the MPB, which is inefficient because the external environmental cost is not being accounted for in the transaction of the good in the market.

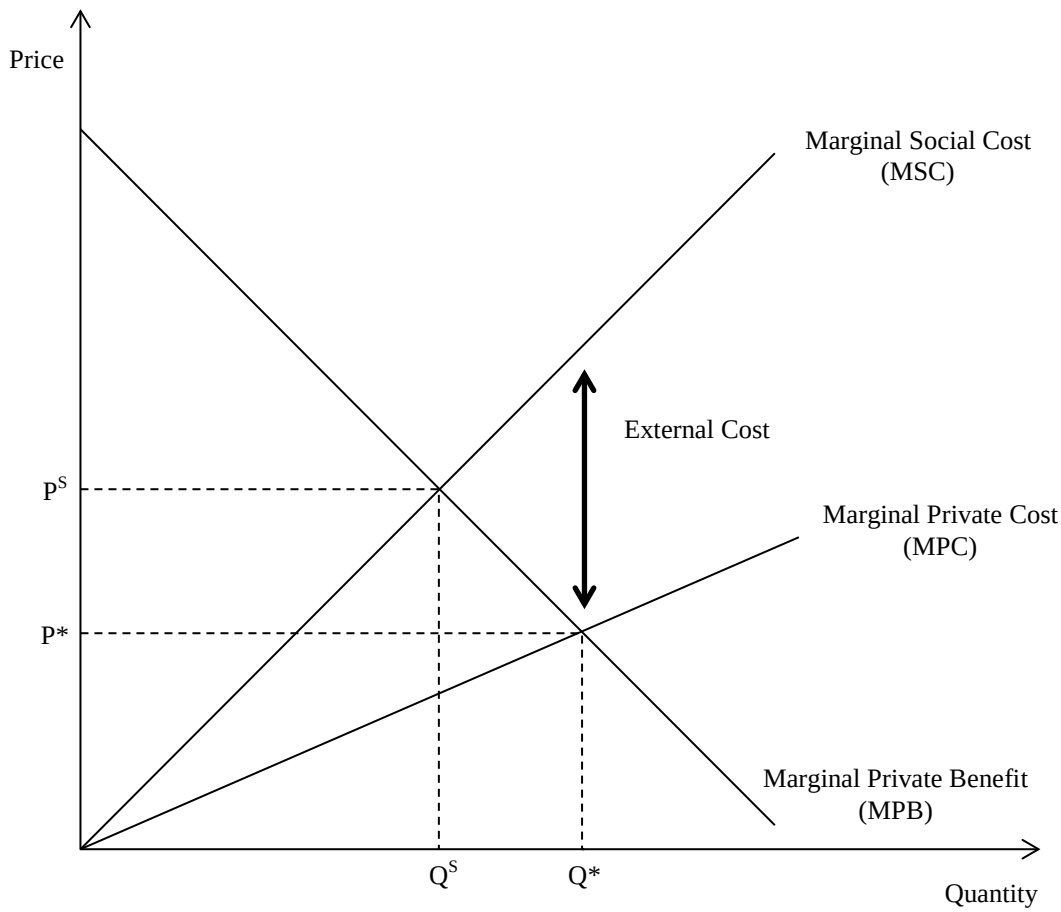

Figure 1. Graphical Representation of a Negative Externality

The assessment of negative externalities associated with the life cycle of alternative milk packaging options will be based on both direct and indirect environmental impacts. These impacts will be comprised of production and transportation energy, atmospheric emissions, and postconsumer waste. Estimated environmental costs are added to the private costs of production to obtain the social costs, which are then compared across packaging options.

Over the past 30 years, there has been a significant amount of research on the external and environmental effects of alternative types of milk packaging. Many of the previous studies focus on a life cycle assessment of each type of milk packaging; other studies focus on specific aspects of the production process. Environmental life cycle assessment (LCA) has evolved over the last three decades to become a standard method by which externalities are calculated. LCA evolved from energy analysis to a comprehensive environmental burden analysis in the 1970s (Guinee et al., 2011). Interestingly, alternative milk packaging LCAs are relatively sparse in the literature. Those that do exist discuss items such as atmospheric emissions, energy requirements, wastewater, postconsumer waste, and transportation weights, although not necessarily in a comprehensive fashion.

In a study conducted by Fischer and Hammond (1978), the LCA was conducted using an economic engineering approach, which standardizes all capital and operating costs to the current price level. Fischer and Hammond initially determined the capital cost involved in the finished fluid milk product depending on the type of packaging. They also include energy requirements, wastewater, and atmospheric emissions in their study. However, all of these environmental LCA results focused only on the external costs resulting from transportation. Due to the focus on transportation, they neglect the external cost associated with the base production of the alternative packaging. The Fischer and Hammond (1978) study is still quite useful because it reveals some of the indirect external costs associated with milk packaging alternatives. Additionally, this study exposes the private costs associated with alternative milk packaging so that both the producer and consumer decisions are presented.

O'Connor and Ford (1977) take a pure cost approach to the LCA. This study focused on plant size, as well as alternative packaging, to determine which combination would be the most effective milk processing facility. They establish an average unit expense for each type of alternative packaging by including the cost of the raw product, the cost of processing and packaging, and the general plant expense. This data provides a reference for the actual cost of each alternative packaging, upon which the other external costs, both direct and indirect, can be calculated.

Boustead (1974) used the LCA to determine the energy requirements for glass and plastic milk bottles. This study, while limited to energy requirements, includes the energy use from the mining of raw materials to delivery and return of milk bottles. The study did not include, however, any indirect energies for which data were not yet available (Boustead, 1974). Even without the indirect energies cost, the information that was presented allows for a solid starting point for calculating one facet of the overall external cost in the present work.

Keoleian and Spitzley (1999) incorporated more indirect external costs that Boustead (1974) was missing in his study by including variables such as the mass of the packaging and recycling rates, along with energy data. Keoleian and Spitzley (1999) also introduced time series analysis to determine whether there were significant changes in the data among recycling weights and recycled material value. This enhances the base of knowledge to be used in a comprehensive external cost LCA.

Recently, a comprehensive LCA has been conducted on alternative milk packaging which addresses many of the external costs associated with the entire process. The study conducted by Franklin Associates (2008) covers the amount of energy used (including fuel type), atmospheric emissions with emphasis on greenhouse gases, waterborne emissions, and postconsumer solid waste. This is the most extensive study to date and is the primary source of information for the data used in the current work. However, Franklin Associates (2008) does not place economic cost on all of the externalities, which does not allow for the determination of which milk packaging possesses the lowest external cost. A summary of the key findings from the Franklin Associates (2008) LCA is presented in Table 1.

Table 1. Summary of Franklin and Associates (2008) LCA Study

Energy Requirements	*Glass*	25% of total energy is due to transportation.
	Plastic	Net energy with recycling is significantly less from paperboard.
	Paperboard	Total energy without recycling is not significant significantly different from plastic.
Greenhouse Gas Emissions	*Glass*	Produces the most carbon dioxide equivalents.
	Plastic	Produces the least carbon dioxide equivalents.
	Paperboard	Produces the middle amount of carbon dioxide equivalents.
Postconsumer Waste	*Glass*	Weight of solid waste is 3 times higher than other other containers.
	Plastic	Weighs the least of all the containers and includes a 29% recyling rate.
	Paperboard	In the middle of the weight and volume postconsumer waste amount.

Methods and Data

The data used within this assessment of external costs is derived from a LCA of each milk packaging option. Estimates of external costs associated with energy requirements (including transportation), emissions, and post-consumer waste are included. The Franklin Associates (2008) study serves as the primary source of data because it is both the most recent and the most comprehensive. The values contained therein fall within the range of estimates presented in the other studies mentioned in the previous section. Social and economic costs are applied to the externalities that the life cycle of each milk packaging type imposes. A sensitivity analysis is performed to determine the effects of variation among consumer return rates and bottle reuse rates. The sensitivity analysis allows for determining the option with the lowest overall social cost among milk packaging alternatives under different glass bottle return and reuse rate scenarios.

The Life Cycle Assessment includes three different milk packaging methods: glass bottles, paperboard gable top containers, and high-density polyethylene (HDPE) plastic jugs. These three packaging methods are the most commonly purchased among consumers and can all be made to hold up to one-half gallon of milk. In 2005, the most recent report of packaged fluid milk sales in

federal milk order markets found that the market share for plastic was 85 percent, paper at less than 15 percent, and glass at less than 0.5 percent (AMS 2005).

Several variables were included in quantifying external cost. First, the production of container materials and the manufacturing process of the containers from the component materials require the use of energy and specific materials that may have adverse effects on the environment. Second, transportation of package to the filling destination and from the filling to the retail area is important to consider in external cost because vehicles release harmful atmospheric emissions. Finally, postconsumer disposal, as well as reuse and recycling of the container systems, are included in external cost calculations because they add to the space of a landfill or decrease the amount of trash that is being created.

It is also assumed that the ink production and printing process of any labels are the same across all production methods. Furthermore, current recycling rates were used in the calculations for the glass and HDPE plastic milk bottles but not for the gable top containers, as they are not easily recycled. In addition, the reuse rate of glass milk bottles is also based off of current market data and is incorporated into the life cycle process of the container outside of the actual recycling rate. It should be noted that by separating recycling and the reuse of the glass bottles, a better quantification of the cost of production of new glass bottles can be obtained (Franklin Associates 2008).

Throughout the analysis, some assumptions were incorporated in the original studies that must be taken into account. First, the reuse rate for the glass bottle was eight trips while the gabletop and the high density plastic containers had a single use. Second, in order to have a significant number for comparison, the data is based on a 10,000 half-gallon container production model. In other words, the total external cost of the various containers is based on producing enough containers for 10,000 uses. In this case, the 10,000 uses of the returnable glass bottle would only constitute a total production of 1,250 bottles instead of the full 10,000 containers. Finally, the returnable glass milk bottle has an assumed return rate of 100% with a 1% breakage rate.

Table 2 illustrates the range of energy used during the life cycle of each type of milk packaging. Due to the variability among the previous studies, this table represents the range of energy usage throughout the life cycles across the different studies. It is noted that the returnable glass has the lowest amount of energy usage and the paperboard gabletop container has the highest amount of usage. To clarify, energy usage consists of the production of the container, the filling process, and all transportation involved in the process. Franklin Associates (2008) reported energy use in million BTU (MM BTU), which we have converted to kilowatt hours (kWh) due to energy costs being available for that measure.

Table 2. Energy Use Total

Package Type	**Range of Reported Life Cycle Energy Use (kWh/10,000 containers)**		
	Low End	**High End**	**Franklin Associates, 2008 Study**
Returnable Glass	4,700	9,400	9,385.56
High Density Plastic	4,000	12,000	11,731.94
Paperboard Gabletop	9,700	13,200	12,553.06

Table 3 shows the level of atmospheric emissions in carbon dioxide equivalents for each container alternative. Atmospheric emissions refer to multiple particulates in which Franklin and Associates (2008) provides an itemized list. All atmospheric emissions were converted to carbon dioxide equivalents to provide an increased level of consistency across production processes. Additionally, there exists "markets" for carbon, aiding in the defense of placing a cost on the emissions.

Table 3. Greenhouse Gas Emissions

Package Type	Emissions (lbs CO2 equivalent per 10,000 containers)
Returnable Glass	5,398
High Density Plastic	3,336
Paperboard Gabletop	4,411

Source. (Franklin Associates 2008)

Table 4 presents a compilation of data on postconsumer waste, which includes disposal of all materials that are not part of recycling in the life cycle analysis and eventual disposal of all packaging. In Table 4, we provide a list of the volumes that the containers would occupy in a landfill as well as the weight of the postconsumer waste. It can be seen that glass occupies the least amount of space while plastic occupies the greatest. It is interesting to note that despite glass occupying the least amount of space in a landfill, its weight contributes significantly to the cost of disposal. Finally, Table 4 provides the private costs to the producer for each type of milk packaging, assuming that they have the appropriate equipment.

Table 4. Postconsumer Waste

Package Type	Cubic Feet per 10,000 containers	Pounds per 10,000 containers
Returnable Glass	42.2	3,733
High Density Plastic	58.0	763
Paperboard Gabletop	46.5	1,248

Source. (Franklin Associates 2008)

Table 5. Private Cost of Milk Packaging per 10,000 Containers

Package Type	Container	Handle	Cap/Overwrap	Total (1978 dollars)	Total (2012 dollars)
Returnable Glass	$918.80	$144.40	$83.40	$1,146.70	$3,382.46
High Density Plastic	$900.00	N/A	$76.00	$976.00	$2,878.94
Paperboard Gabletop	$842.50	$93.40	N/A	$935.90	$2,760.66

Source. (Fischer and Hammond 1978)

In order to obtain measures of external costs, the values presented in Tables 2-4 are multiplied by their respective costs and then summed to arrive at a total. For energy use, the 2012 average energy price provided by the U.S. Energy Information Administration of $0.11 per kWh was used. To quantify the cost of postconsumer waste, the estimation from Huhtala (1996) was used as it takes into account the process and weights associated with postconsumer waste.

The economic value used to quantify the carbon emissions in this analysis is derived from Tol (2005) as it has been cited regularly throughout the existing literature. Tol (2005) combines

social cost ranges for carbon from a multitude of other studies and creates a distribution in which a mean cost is computed. This mean cost of $25.30 per tonne of carbon is then applied to the carbon estimates of the current work to quantify the greenhouse gas emission external cost. Recent literature in carbon social cost valuation has shown a wide range of values based off of different assumptions with discount rates, risk aversion, and global temperature changes (Roe and Baker 2007; Ackerman and Stanton 2012; Anthoff and Tol 2013; Kousky et al. 2011; Howarth et al. 2014). The social value of carbon is still heavily debated due to the uncertainty of society's willingness to tolerate potentially catastrophic environmental risks (Howarth et al., 2014). The Tol (2005) estimate reflects a relatively high level of risk aversion and a mid-range time horizon of damages, which places it in the middle of the range of estimated values.

The three packaging options are then compared for their resulting external costs and social costs. Because the relative costs largely depend on the return rate and reuse rate for the glass packaging, we conduct a sensitivity analysis for those two variables. A sensitivity analysis provides the range of these rates for which glass packaging for liquid milk might be preferred from an environmental standpoint. The sensitivity analysis is conducted by calculating the external costs and social costs for the glass milk packaging under varying reuse and return rates. These resulting values are then compared to the external and social costs of the high density plastic and paperboard gabletop packaging options.

Results

The initial calculations of external cost and social cost for each milk packaging type are presented in Table 6 and Table 7, respectively. The values in these tables represent an assumed glass bottle return rate of 100% and 8 reuses, with a 1% breakage rate. Under these conditions the glass bottle represents the lowest external cost of the three options; therefore, it possesses the lowest environmental impact. However, this does not imply that the glass bottled packaging of milk is preferred.

Table 6. External Cost of Milk Packaging per 10,000 Containers

Package Type	Returnable Glass		High Density Plastic		Paperboard Gabletop	
Total Energy Costs	$	1,032.41	$	1,290.51	$	1,380.84
Atmospheric Emissions Cost	$	61.99	$	38.20	$	50.60
Postconsumer Waste Cost	$	186.65	$	38.15	$	62.40
Total External Cost (2008 Dollars)	$	1,281.05	$	1,366.86	$	1,493.84
Adjusted 2012 Dollars Total	$	1,329.96	$	1,419.04	$	1,550.86

The total social cost for each packaging option is calculated by summing the external cost and the private cost borne by the producer. The private cost represents the cost of all resources used in production, at a rate that purchases them away from their next highest valued use in society. This is the value that society places on the tangible aspects – traded in a market – of the packaging, whereas the external cost is an estimate of the societal value of aspects of the packaging not traded in a market. Table 7 presents the social cost comparisons of the three packaging options under the same assumptions mentioned above. While the glass bottled option represented the lowest environmental cost, it represents the highest social cost. The private cost

of production is sufficiently high so as to make it the least preferred option from a social valuation standpoint. We also find that, under this scenario, the high density plastic packaging has the lowest social cost.

Table 7. Overall Social Cost of Alternative Milk Packaging per 10,000 Containers in 2012 USD

Package Type	Returnable Glass		High Density Plastic		Paperboard Gabletop	
External Cost	$	1,329.96	$	1,419.04	$	1,550.86
Private Cost	$	3,382.46	$	2,878.94	$	2,760.66
Total Social Cost	$	4,712.42	$	4,297.99	$	4,311.52

In the above results we have assumed a 100% customer return rate for glass bottles and an average of eight uses per bottle. The results are potentially sensitive to those assumptions, so we investigate the degree to which the results hold as those parameters vary. Tables 8 and 9 (see Appendix) demonstrate the sensitivity of the above results to varying combinations of return and reuse rates.

The sensitivity analysis for our external cost results are presented in Table 8. The values in the table are the estimated external costs for various return rates and number of reuses. The shaded area of the table represents the combinations that yield a lower external cost for glass bottles as compared to the alternatives. If the typical bottle is reused eight times then a consumer return rate of 95% is necessary for the glass bottle to have the lowest external cost. However, if the number of reuses increases to 10 then the necessary return rate drops to 75%. This suggests that increasing the ability of the bottle to withstand multiple cleanings, fills, and transports ultimately increases the degree to which the glass bottle is the more environmentally friendly packaging option for milk.

In Table 9 we have provided the sensitivity analysis for the total social costs of returnable glass bottles. Again, the shaded portion of the table represents the conditions under which the glass bottle represents a lower cost than the alternative packaging options. It is worth noting that, in this case, the glass bottle must be reused 12 times – a 50% increase over today's standard – with a 100% consumer return rate in order for the glass packaging to be preferred.

Discussion

In this research we have evaluated the conditions under which glass bottles for fluid milk packaging can be considered preferred over its alternatives in terms of its environmental impact and total cost to society. Results from a comprehensive life cycle assessment were used to value the environmental costs associated with high density plastic, paperboard gabletop, and glass milk packaging options. A sensitivity analysis was conducted in order to identify the reuse and return rates necessary for glass milk packaging to be preferred.

After reviewing the results of our analysis, we find that the high density plastic milk container has the lowest social cost among the alternatives. However, the glass bottle represented the lowest external cost, which is why they may be perceived to be more environmentally friendly by some consumers. An increase in the reuse and return rates can increase the likelihood that the

glass packaging competes with the high density plastic in terms of its social cost. Efforts to educate the consumer about the importance of returning the glass packaging, as well as research aimed at increasing the number of times that a bottle may be reused, could have a significant impact on which packaging type is socially preferable. When the costs are brought to a unit by unit measurement, it was found that a consumer would need to pay an extra $0.04 to $0.19 per container use above the price of milk in a plastic container to compensate the producer for the added cost of producing milk in a returnable glass bottle. This extra cost is significant because future research should focus on consumer willingness to pay for glass bottled milk within regional areas, as well as producer willingness to switch milk packaging. This will help to determine if local dairies would be able to successfully implement a glass bottled milk operation.

This study adds to the existing literature on the environmental impacts of milk packaging alternatives. The previous literature on the subject took into account various parts of the production process but failed to create an environmental economic focused LCA that encompassed the entire production and distribution process. Also, this study accounts for the external and social cost involved with each alternative so that comparisons between the three alternatives are consistent. The results of this study can be used by producers and consumers who have a desire to make an environmentally conscious choice on milk packaging alternatives.

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Appendix

Table 8. Sensitivity Analysis of External Cost of Returnable Glass Bottles

Return Rates	40%	45%	50%	55%	60%	65%	70%	75%	80%	85%	90%	95%	100%
Number of Reuses													
7	3732.27	3317.57	2985.81	2714.38	2488.18	2296.78	2132.72	1990.54	1866.13	1756.36	1658.78	1571.48	1492.91
8	3265.74	2902.88	2612.59	2375.08	2177.16	2009.68	1866.13	1741.72	1632.87	1536.82	1451.44	1375.05	1306.29
9	2902.88	2580.33	2322.30	2111.18	1935.25	1786.38	1658.79	1548.20	1451.44	1366.06	1290.17	1222.26	1161.15
10	2612.59	2322.30	2090.07	1900.06	1741.73	1607.75	1492.91	1393.38	1306.29	1229.45	1161.15	1100.04	1045.03
11	2375.08	2111.18	1900.06	1727.33	1583.39	1461.59	1357.19	1266.71	1187.54	1117.68	1055.59	1000.03	950.03
12	2177.16	1935.25	1741.73	1583.39	1451.44	1339.79	1244.09	1161.15	1088.58	1024.54	967.63	916.70	870.86
13	2009.68	1786.39	1607.75	1461.59	1339.79	1236.73	1148.39	1071.83	1004.84	945.73	893.19	846.18	803.87
14	1866.14	1658.79	1492.91	1357.19	1244.09	1148.39	1066.36	995.27	933.07	878.18	829.39	785.74	746.45
15	1741.73	1548.20	1393.38	1266.71	1161.15	1071.83	995.27	928.92	870.86	819.64	774.10	733.36	696.69
16	1632.87	1451.44	1306.29	1187.54	1088.58	1004.84	933.07	870.86	816.43	768.41	725.72	687.52	653.15
17	1536.82	1366.06	1229.45	1117.69	1024.54	945.73	878.18	819.64	768.41	723.21	683.03	647.08	614.73
18	1451.44	1290.17	1161.15	1055.59	967.63	893.19	829.39	774.10	725.72	683.03	645.08	611.13	580.58
19	1375.05	1222.26	1100.04	1000.03	916.70	846.18	785.74	733.36	687.52	647.08	611.13	578.97	550.02
20	1306.29	1161.15	1045.04	950.03	870.86	803.87	746.45	696.69	653.15	614.73	580.58	550.02	522.52

Note. *Highlighted portion represents the combinations at which returnable glass has the lowest external cost.

Table 9. Sensitivity Analysis of Social Cost of Returnable Glass Bottles

Return Rates											
	50%	55%	60%	65%	70%	75%	80%	85%	90%	95%	100%
Number of Reuses											
7	6368.28	6096.84	5870.64	5679.24	5515.19	5373.00	5248.59	5138.82	5041.25	4953.94	4875.37
8	5995.05	5757.54	5559.62	5392.14	5248.60	5124.19	5015.33	4919.28	4833.90	4757.51	4688.75
9	5704.76	5493.64	5317.71	5168.85	5041.25	4930.66	4833.90	4748.52	4672.63	4604.72	4543.61
10	5472.53	5282.53	5124.19	4990.21	4875.37	4775.84	4688.76	4611.91	4543.61	4482.50	4427.50
11	5282.53	5109.79	4965.85	4844.05	4739.65	4649.17	4570.00	4500.15	4438.05	4382.50	4332.49
12	5124.19	4965.85	4833.90	4722.25	4626.55	4543.61	4471.04	4407.01	4350.09	4299.16	4253.32
13	4990.21	4844.05	4722.25	4619.19	4530.85	4454.29	4387.30	4328.19	4275.65	4228.64	4186.33
14	4875.37	4739.65	4626.55	4530.85	4448.82	4377.73	4315.53	4260.64	4211.85	4168.20	4128.92
15	4775.84	4649.17	4543.61	4454.29	4377.73	4311.38	4253.32	4202.10	4156.56	4115.82	4079.15
16	4688.76	4570.00	4471.04	4387.30	4315.53	4253.32	4198.90	4150.87	4108.18	4069.98	4035.61
17	4611.92	4500.15	4407.01	4328.20	4260.64	4202.10	4150.87	4105.67	4065.49	4029.54	3997.19
18	4543.61	4438.05	4350.09	4275.65	4211.85	4156.56	4108.18	4065.49	4027.55	3993.59	3963.04
19	4482.50	4382.50	4299.16	4228.64	4168.20	4115.82	4069.99	4029.54	3993.59	3961.43	3932.48
20	4427.50	4332.49	4253.32	4186.34	4128.92	4079.15	4035.61	3997.19	3963.04	3932.48	3904.98

Note. *Highlighted portion represents the combinations at which returnable glass has the lowest social cost.