Product Lifetimes And The Environment 2017 - Conference Proceedings
C. Bakker and R. Mugge (Eds.)

DOI: 10.3233/978-1-61499-820-4-319

PLATE conference
Delft University of Technology
8-10 November 2017

PLATE
Product Lifetimes And The Environment

Measuring the historical change in the actual lifetimes of consumer durables

Oguchi M.[(a)] and Daigo I.[(b)]

a) National Institute for Environmental Studies, Tsukuba, Japan
b) The University of Tokyo, Tokyo, Japan

Keywords

Actual lifetime
Consumer durables
Methodology
Lifetime extension
Indicator

Abstract

Product lifetime extension would contribute to establishing a circular economy and reducing the environmental impacts of mass consumption. Showing the situation of the historical change in the product lifetimes with quantitative data is needed for evaluating the contribution of product lifetime extension. The present study observed the historical change in the actual lifetimes of consumer durables in Japan by three different ways; direct observation; model calculation; simple indicator calculation. The average lifetimes of common consumer durables including home appliances, electronics, and passenger cars have been increasing in Japan over the past few decades. To evaluate the trend of the product lifetimes accurately, product lifetimes need to be observed or estimated based on actual data of discarded, collected, or in-use products. A questionnaire survey that relies on respondents' memory would not provide precise results enough to detect the historical change in the actual product lifetimes. Calculating the ratio of the number of in-use products against the sales would generally be useful to understand the common trend in the product lifetimes over the years when the penetration of the products is saturated. The ratio could also be used as substitutes of the average of the lifetime distribution that is approximated by a statistical distribution function.

Introduction

Product lifetime extension would contribute to establishing a circular economy and reducing the environmental impacts of mass consumption. Product lifetimes may have been increased recently in general, but understanding the situation with quantitative data is needed in order to evaluate the contribution of product lifetime extension. Approaches for measuring the actual product lifetimes have been well established in past studies (Oguchi et al., 2010); however, product lifetime extension would progress gradually and therefore, it is needed to assess the applicability of each approaches to detecting the change in product lifetimes over time.

The present study observed the historical change in the actual lifetimes of consumer durables in Japan by three different ways; direct observation; model calculation; simple indicator calculation based on stock and sales data of products. The study then discussed the similarities and the dissimilarities in the measured product lifetimes by different approaches and the past trend in actual lifetimes of consumer durables in Japan.

Approaches for measuring actual product lifetimes

According to a review by Oguchi et al. (2010), approaches for estimating actual product lifetime distribution found in literature can be classified into four approaches (Table1). These approaches estimate product lifetime distribution based on the past sales and the number of in-use products or discarded products. The product-age profile of the in-use or discarded products is required for three of the four approaches (approaches 1–3). To apply these approaches to measure the change in the actual product lifetimes of consumer durables over the years, we need to conduct an extensive sample survey on the age profile of in-use or discarded products in each year. It is generally time-consuming and cost-intensive unless such data is readily available by statistics etc. On the other hand, because the approach 4 does not need to know the product-age profile of the in-use products, measuring the change in the actual product lifetimes by this approach is relatively less time-consuming and cost-intensive.

Materials and methods

We observed or estimated the historical change in the actual product lifetimes of consumer durable goods in Japan by different approaches: a direct observation and a model calculation by a simplified estimation method. We also examined the applicability of a simple indicator which can be calculated based on stock and sales data of products. In this study, we selected five types of electrical and electronic equipment: refrigerators, washing machines, room air conditioners, televisions, and mobile phones (including smartphones) and passenger cars as case studies.

Approach	Required data (number of…)			Survey method for primary data (definition of estimated lifetime)
	End-of-life	In-use	Sales	
(1) Calculate discard rate distribution for a certain period	X (for each age)		X (time-series)	- Survey of collected EoL products at facilities - Questionnaire to consumers who discarded products
(2) Calculate survival rate distribution at a certain time point		X (for each age)	X (time-series)	- Questionnaire to consumers to ask the number and product age of in-use products
(3) Calculate failure rate distribution for a certain period		X (for each age, at least two time points)		- Questionnaire to consumers to ask the number and product age of in-use products
(4) Estimate from the total number of in-use products based on mass balance equation		X (only the total number)	X (time-series)	- Questionnaire to consumers to ask the number of in-use products - Use of statistics

Table 1. Approaches for estimating actual product lifetime distribution.

Direct observation of the age profile of the discarded products

We observed the actual lifetimes of the selected product types in Japan on the basis of the data from surveys by mean of direct observation approach.

"Consumer Confidence Survey" by the Cabinet Office of the Japanese government (CAO) surveys annually the average lifetimes of 11 consumer durables including home appliances and electronics by means of questionnaire surveys to consumers. The survey asks consumers the lifetimes of their old products if they had experiences of replacing their products in the survey year. The primary purpose of the survey is to obtain a basic data for understanding the economic trend, but we may also understand the trend in the actual lifetimes of various products in the country.

Another survey has been annually conducted on electrical and electronic equipment by the Association for Electric Home Appliances (AEHA) of Japan (AEHA, 2002-2016). It reports the investigation results of the lifetimes of four types of home appliances: room air conditioners; televisions; refrigerators (including freezers); washing machines, which are collected to collection centers under the Japanese home appliances recycling law.

Regarding passenger cars, Automobile Inspection and Registration Information Association in Japan (AIRIA) publishes annually the average lifetimes of several types of motor vehicles including passenger cars, which are calculated from the complete dataset from the registration system (AIRIA, n.d.).

All of the surveys above report the arithmetic average of the surveyed lifetimes of replaced, collected (discarded), or de-registered products as "average lifetimes."

Model calculation by a simplified method

We calculated the average lifetimes by using the method which was proposed by Oguchi & Fuse (2015) based on the population balance model. This method estimates the product lifetime distribution on the basis of mass-balance of products. The product-age profile of the in-use products is not required, so it is relatively less time-consuming and cost-intensive to investigate the historical change of the product lifetimes.

Assuming that the lifetime distribution (survival rate distribution) of products follows any parametric distribution function, the average of the distribution (average lifetimes) was optimized so that the total number of in-use products calculated from past sales and the survival rate distribution (equation (1)) consists with the observed number.

$$N_t = \Sigma \{S_{t-i} * R_t(i)\} \quad (1)$$

where, N_t is the calculated total number of in-use products at the end of the year t, S_{t-i} is the number of sales in the year t-i, $R_t(i)$ is the survival rate of the products with a product age i year(s) at the end of the year t.

In this study, we assumed the survival rate distribution of products follows the Weibull distribution function with two parameters, which was expressed by equation (2):

$$R(i) = \exp\left[-(i/\mu)^m * \{\Gamma(1+1/m)\}^m\right] \quad (2)$$

where, μ is the average, m is the shape parameter, Γ is the gamma function. The shape parameter value was assumed to be a common value of the product category, i.e. 3.6 for passenger cars (Oguchi & Fuse, 2015) and 2.4 for other products (Oguchi et al. 2006).

The total number of in-use products was calculated for refrigerators, washing machines, room air conditioners, and televisions by multiplying the number of in-use products per household and the number of households in Japan. The number of in-use products per household was obtained from the Consumer Confidence Survey by CAO and the National Survey of Family Income and Expenditure by Statistics Bureau of Japan. The data was used after being smoothed by fitting with the logistic function. The total number of in-use mobile phones were obtained from statistics by Telecommunications Carriers Association of Japan and that of passenger cars was obtained from statistics by AIRIA.

The time-series sales data was obtained from statistics by the Japan Electrical Manufacturers' Association (refrigerators, washing machines), the Japan Refrigeration and Air Conditioning Industry Association (room air conditioners), Japan Electronics and Information Technology Industries Association (televisions, mobile phones), and AIRIA (passenger cars).

A simple indicator for actual product lifetimes based on stock and flow data

We examined the applicability of the ratio of the number of in-use products against the sales in the same year (hereinafter referred as "stock/flow ratio") as a simple indicator. The stock/flow ratio was calculated by equation (3):

$$\text{Stock/flow ratio} = N_t / S_t \quad (3)$$

This ratio could be used as a simple indicator for average product lifetimes especially when the penetration of the products was already saturated because in such a case most of the end-of-life products would be generated by replacement purchases.

In this study, the total number of in-use products and the sales were obtained from the same data sources as the model calculation.

Results and discussion

Figure 1 shows the observed or estimated historical trend of the average lifetimes of the selected product types. The results generally showed an increasing trend, suggesting that the average lifetimes of the selected products have been increasing in Japan over the past few decades.

The investigation results by CAO, however, have remained stable over the years in the case of home appliances: refrigerators, washing machines, room air conditioners, and televisions. The investigation by CAO were based on respondents' memory (the answers to the question "how many years did you use your old products until you replaced it?"), whereas the other results were calculated based on actual data on collected or in-use products. The results suggested that a questionnaire survey to consumers on the discarded products may not provide precise results enough to detect the historical change in the actual product lifetimes.

The investigation by AEHA and the model calculation generally showed similar values and trend of average lifetimes for washing machines and room air conditioners. A significant difference, however, was seen for the results of refrigerators and televisions—longer average lifetimes were observed by the investigation of AEHA.

The investigation by AEHA was conducted on the collected products at the collection centers. The collected products were not necessarily representative for the entire end-of-life products in Japan because products that were not collected through the official home appliances collection scheme in Japan were excluded. For example, the exported secondhand products were excluded (if existed) in their investigation. In general, secondhand products with relatively younger age are exported, so the age distribution of the collected products at the collection center should be biased toward older direction. This could be a reason for the difference. This suggests that the direct observation of the product age of the domestically collected products would not be suitable for investigating the change in product lifetimes, for example, in the case where active export of secondhand products exists. Another possible reason for these differences is the sampling error of the sample surveys of discarded or in-use products.

The stock/flow ratio as a simplified indicator also showed an increasing trend. The calculated stock/flow ratios generally showed similar values to the estimated average lifetimes by the model calculation except for room air conditioners. Because the penetration of room air conditioners has been increasing during the calculation period—the sales includes a certain amount of sales for additional purchase—the values of the simple indicator were a few years smaller than the average lifetimes that were calculated by the population balance principle. Although the penetration has also been increasing in the case of mobile phones, the lifetime of mobile phones was short. Therefore, this effect on the stock/flow ratio was not significant and the ratios showed quite similar values to those by model calculation.

The stock/flow ratio can be calculated only from the stock and sales in a certain year (does not require time-series datasets) and therefore, the ratio can be used as an indicator for understanding the general order and the trend of the change in the product lifetimes over time when the penetration of the products is saturated. The indicator could also be used as the substitute for the average of the lifetime distribution that is approximated by a statistical distribution function.

A significant reduction in the lifetime of televisions was seen around the year 2010. This is the consequence of the transition from analog to digital broadcasting. In Japan, analog terrestrial broadcasting was stopped in July, 2011. We had to replace our old televisions that could not receive analog broadcasting with digital televisions or add external digital tuners by the shutdown date, so a significant number of televisions were replaced, making the lifetime of televisions shorter temporary. All of the measurement approaches examined in this study (except the data by CAO) were able to detect the temporary reduction (shortening) in the lifetimes of televisions due to this event.

The order of the detected reduced lifetime, however, was different by the approaches. The largest reduction was shown by the stock/flow ratio (6-7 years). The stock/flow ratio does not consider the distribution of product lifetimes and therefore, the calculated values were directly influenced by the change in the sales in the year. The sales of televisions increased 2.5 times of the year 2008, which means the stock/flow ratio was reduced to 0.4 (1/2.5) times. So, the ratio may have not reflect the magnitude of the reduction in the actual product lifetimes in this

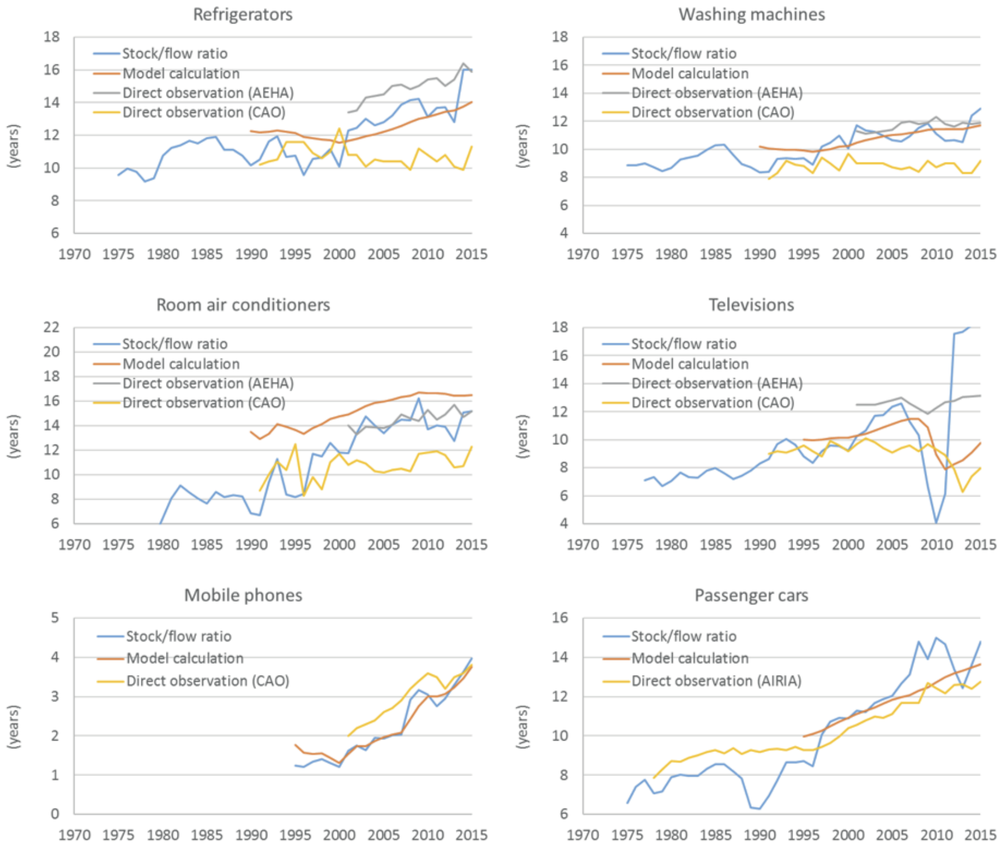

Figure 1. Observed or calculated average lifetimes by different approaches.

case. The stock/flow ratio is useful as a proxy indicator of average lifetimes of products in a steady-state, but cannot measure the temporal change in the product lifetimes resulting from big changes of social systems, economic situation, etc.

The reduction shown by the model calculation was approximately 3 years and that by the reported value by AEHA was approximately 1 year. The model calculation was conducted by assuming the shape parameter of the Weibull distribution function to be a constant value. The shape parameter is not so sensitive to the values of the estimated average lifetime (Oguchi & Fuse, 2015) under normal situation, but the shape parameter may take a significantly different value from normal situation when a big change of social systems happens such as this case. On the other hand, quite a large number of end-of-life televisions were collected at the collection center right before and after the analog broadcasting shutdown, so the product-age profile of the collected products, which were investigated by AEHA, may have been different from the normal situation. Although it is difficult to say which of the model calculation and the investigation by AEHA was more appropriate, at least a few years' reduction in the lifetimes of televisions happened around the event.

Conclusions

The present study observed the historical change in the actual lifetimes of consumer durables in Japan by three different ways; direct observation of the discarded or collected products; model calculation by using the population balance model; calculation of stock/flow ratio as a simple indicator. The average lifetimes of common consumer durables including home appliances, electronics, and passenger cars have been increasing in Japan over the past few decades.

To evaluate the trend of the product lifetimes accurately, product lifetimes need to be observed or estimated based on actual data of discarded, collected, or in-use products. Investigating the product lifetimes based on the questionnaire survey that relies on respondents' memory would not provide precise results enough to detect the historical change in the actual product lifetimes.

Calculating the stock/flow ratio would generally be useful to understand the common trend in the product lifetimes over the years when the penetration of the products is saturated. The ratio could also be used as substitutes of the average of the lifetime distribution that is approximated by a statistical distribution function.

Acknowledgments

The presented work was partly funded by Policy Study for Green Economy, Ministry of the Environment, Japan ("Investigation and Study on the stock of resources that have been accumulated in Japan").

References

AEHA (2002-2016). *Shiyouzumi kaden 4 hinmoku no keika nensuu chousa houkokusyo* [Report of lifespan survey of four types of home appliances collected under the home appliances recycling low in Japan] (in Japanese).

AIRIA (n.d.). *Waga kuni no jidousya hoyu doko* [Trend of automobiles possession automobiles in Japan], Retrieved June 1, 2017, from https://www.airia.or.jp/publish/statistics/trend.html (in Japanese).

Oguchi, M. & Fuse, M. (2015) Regional and longitudinal estimation of product lifespan distribution: A case study for automobiles and a simplified estimation method. *Environmental Science and Technology*, 49, 1738–1743.

Oguchi, M., Kameya, T., Tasaki, T., Tamai, N., Tanikawa, N. (2006) Estimation of lifetime distributions and waste numbers of 23 types of electrical and electronic equipment. *Haikibutsu Gakkai Ronbunshi* [Journal of the Japan Society of Waste Management Experts], 17, 50–60 (in Japanese with English abstract, figures, and tables).

Oguchi, M., Murakami, S., Tasaki, T., Daigo, I., Hashimoto, S. (2010). Lifespan of commodities, Part. II: Methodologies for estimating lifespan distribution of commodities. *Journal of Industrial Ecology*, 14 (4), 613–626.