Product Downsizing and Hidden Price Increases: Evidence from Japan's Deflationary Period

Satoshi Imai* Tsutomu Watanabe†

April 29, 2013

Abstract

Consumer price inflation in Japan has been below zero since the mid-1990s, indicating the emergence of deflation over the last 15 years. Given this, it is difficult for firms to raise product prices in response to an increase in marginal cost. One pricing strategy firms have taken in this situation is to reduce the size or the weight of a product while leaving the price more or less unchanged, thereby reducing the effective price. In this paper, we empirically examine the extent to which product downsizing occurred in Japan as well as the effects of product downsizing on prices and quantities sold. Using scanner data on prices and quantities for all products sold at about 200 supermarkets over the last ten years, we find that about one third of product replacements that occurred in our sample period (2000-2012) were accompanied by a size/weight reduction. We also find that prices, *on average*, did not change much at the time of product replacement, even if a product replacement was accompanied by product downsizing, but that prices declined more for product replacements that involved a larger decline in size or weight. Our regression results show that a 1 percentage point larger size/weight reduction is associated with a 0.45 percentage point larger price decline. Finally, we find evidence showing that consumers determine consumption based on per-unit prices rather than nominal prices.

Keywords: consumer price index; scanner data; product downsizing; quality adjustment; deflation

*Statistics Bureau of Japan. E-mail: s2.imai@soumu.go.jp.

†Graduate School of Economics, University of Tokyo. E-mail: watanabe@e.u-tokyo.ac.jp. This research forms part of a project on "Understanding Persistent Deflation in Japan" funded by a JSPS Grant-in-Aid for Scientific Research (24223003).

1 Introduction

Consumer price inflation in Japan has been below zero since the mid-1990s, clearly indicating the emergence of deflation over the last 15 years. The rate of deflation as measured by the headline consumer price index (CPI) each year has been around 1 percent, which is much smaller than the rates observed in the United States during the Great Depression, indicating that although Japan's deflation is persistent, it is only moderate. It has been argued by researchers and practitioners that at least in the early stages the main cause of deflation was weak aggregate demand, although deflation later accelerated due to pessimistic expectations reflecting firms' and households' view that deflation was not a transitory but a persistent phenomenon and that it would continue for a while.

Given this environment, it is difficult for firms to raise product prices in response to an increase in marginal cost, since they have to fear that they will lose a significant share of their customers if they raise their prices while their competitors do not. One pricing strategy firms can take in this situation is to reduce the size or the weight of a product without changing the price, thereby reducing the effective price. There is a lot of anecdotal evidence for such behavior. For example, @@@. Moreover, the Statistics Bureau of Japan, in the process of collecting prices to produce the CPI statistics, checks the size and weight of products and as part of their quality adjustment procedure make adjustments to the price recorded if they find any change in the size or weight of a product. For example, if a product is downsized by 10 percent with no change in the nominal price (i.e., the non-quality-adjusted price), the price of the product, once it is quality adjusted, increases by around 10 percent. However, the Statistics Bureau of Japan does not collect such information on product downsizing for all products that are sold, so that nobody is quite sure to what extent product downsizing prevails in Japan. This is problematic from the viewpoint of policymakers, including the central bank, since it implies that the rate of inflation is not precisely measured by the CPI and is possibly underestimated because of the presence of hidden price increases due to product downsizing.

This paper is the first attempt to empirically examine the extent to which product downsizing occurs in Japan and the consequence of product downsizing on prices and quantities sold. To do so, we use daily scanner data on prices and quantities for all products sold at about 200 supermarkets over the last ten years, during which the rate of inflation in Japan has been below zero. The number of products, for example, in 2010 is about 360,000. Among those 360,000 products, information on product size or weight is available for about 270,000, and it is the prices and quantities sold of these products that we focus on in this paper. Specifically, we start by identifying the "generation sequence" of products (i.e., which product is a successor to which product) and then identify the event of product replacement (i.e., an old product destroyed and a new one is created). The total number of replacement events we identify is about 15,000. We then look at what happened at the time of each product replacement in terms of the size or weight of the product, the price of the product, and the quantity sold.

Our main findings are as follows. First, we find that about one third of the replacement events that occurred in our sample period (2000-2012) were accompanied by a size/weight reduction. Specifically, among the 15,000 product replacement events, the size/weight was reduced in 5,000 cases, while it increased in 1,500 cases and remained unchanged in 8,500 cases. The annual number of replacement events involving downsizing was less than 200 from 2000 to 2006, but started to increase in 2007 and reached 1,500 in 2008, when firms faced substantial cost increases due to the price hike in oil and raw materials, most of which are imported.

Second, we find that prices, on average, did not change much at the time of product replacement, even if a product replacement was accompanied by product downsizing, which is consistent with anecdotal evidence that firms keep prices unchanged even when they reduce the size/weight of a product. However, we also find that, for replacement events with a large decline in size/weight, prices tend to decline, and that prices decline more for events with a larger decline in size/weight. Specifically, our regression results show that a 1 percentage point larger size/weight reduction is associated with a 0.45 percentage point larger price decline. The responsiveness of prices to reductions in size/weight is not zero but below unity. For example, comparing two events with a size/weight reduction, one involving a 10 percent reduction and the other a 20 percent reduction, the price decline is only 4.5 percentage points larger in the latter case, resulting in a larger effective price increase.

Third, we find that consumers decide how much they buy based not on the nominal price but on the effective price. To examine consumer behavior, we define the effective price of a product as P/X^{α}, where P is the nominal price and X is the size/weight of the product. The parameter α should be zero if consumers pay attention only to the nominal price, while it should be equal to unity if they pay attention to the per-unit price. We estimate a demand equation using P/X^{α} as the price measure on the right-hand side of the equation, thereby estimating the value of α. Our regression results show that α is quite close to unity, clearly rejecting the null hypothesis that α is zero. These results are inconsistent with the view that consumers are sensitive to price changes but not so to size/weight changes. Also, the results imply that quality adjustments based on per-unit prices (i.e., nominal prices divided by size/weight), which are widely adopted by statistical agencies in various countries, including Japan, may be an appropriate way to deal with product downsizing.

The rest of the paper is organized as follows. Section 2 explains the dataset we use in the paper and how we identify replacement events. Section 3 presents our results on the responsiveness of prices to changes in size/weight at the time of product replacement. In Section 4, we then investigate how consumers responded to changes in size/weight at the time of product replacement. Specifically, we estimate a demand equation to examine whether consumers' demand for a product fell when the size/weight of the product was reduced by more than the price. Section 5 concludes the paper.

2 Data and Empirical Approach

2.1 Overview of the dataset

The dataset we use consists of store scanner data compiled jointly by Nikkei Digital Media Inc. and the UTokyo Price Project. This dataset contains daily sales data for more than 300,000 products sold at about 200 supermarkets in Japan from 2000 to 2012. The products consist mainly of food, beverages, and other domestic nondurables (such as detergent, facial tissue, shampoo, soap, toothbrushes, etc.), which account for 125 of the items in the consumer price statistics compiled by the Statistics Bureau.[1] Sales of these products are recorded through the so-called point-of-sale system. Each product is identified by the Japanese Article Number (JAN) code, the equivalent of the Universal Product Code (UPC) in the United States.

Table 1 shows the number of outlets and products for each year, as well as the number of observations (no. of products × no. of outlets × no. of days) during the sample period. For example, the number of outlets covered in 2010 is 259, and the total number of different products sold in 2010 is about 363,000. The total number of observations for 2010 is about 420 million, while the total for the entire sample period is approximately 4.3 billion observations. During the sample period, tens of thousands of products were newly launched each year, but about the same number of products were also withdrawn. The ratio of the number of newly

[1] The total number of items in the consumer price statistics is 584. Our dataset thus covers about 20 percent of all the items in the consumer price statistics in terms of consumption weight.

Table 1: Number of Outlets, Products, and Observations

	No. of outlets	No. of products	No. of observations
All products in dataset			
2000	189	251,053	242,357,320
2001	187	265,629	274,319,027
2002	198	276,504	283,433,216
2003	188	259,897	242,425,055
2004	202	279,753	282,074,675
2005	187	288,634	309,888,190
2006	189	315,152	329,139,639
2007	274	359,207	386,389,129
2008	261	375,287	419,941,109
2009	264	364,106	422,389,029
2010	259	363,379	420,708,540
2011	249	363,208	408,357,242
2012	261	339,170	372,087,471
Products with information on size/weight			
	No. of outlets	No. of products	No. of observations
2000	189	224,673	233,703,499
2001	187	232,136	264,250,566
2002	198	231,638	271,121,529
2003	188	213,209	230,671,395
2004	202	221,606	266,704,652
2005	187	222,489	291,103,230
2006	189	232,586	303,091,138
2007	274	263,880	354,567,276
2008	261	276,495	386,306,225
2009	264	266,984	390,022,818
2010	259	268,649	388,693,268
2011	249	273,411	377,964,969
2012	261	263,699	345,605,595

launched products relative to existing products was about 30 percent, while the withdrawal rate was about 27 percent, indicating that the turnover in products was quite rapid.

2.2 Extracting products with information on product size/weight

For the purpose of our analysis, we focus on products for which size/weight information is available. Specifically, we look at the product description associated with each JAN code and extract products with information on the quantity, such as grams, liters, meters, and so on. All products in our dataset are classified into 1,788 six-digit class codes, which are defined by Nikkei Digital Media. Among them, products in 1,234 six-digit class codes come with information on the product size or weight. For example, the number of products with information on the size or weight is 268,000 for 2010, accounting for three-quarters of all products available in that year. The coverage ratio is slightly higher than this in the first half of the sample period and is above 80 percent in 2000-2003, for example.

To see to what extent product sizes/weights change over time, we construct a size/weight index as follows. For each of the six-digit class codes, we choose 10 products each month using the quantities sold in that month as the criterion, and calculate the geometric average of the size/weight for the ten products. We do this for each of the six-digit class codes and aggregate them to obtain a size/weight index. The result is presented in Figure 1, which shows that there were no significant changes in product sizes/weights in the first half of the sample period; however, the index then started to decline from 2006 onward, falling at an annual rate of 0.7 percent from 2006 to 2012 for a total decline of about 5 percent over the seven years.

In Figure 2, we choose the top ten products each month for each of the six-digit class codes, as we did in Figure 1, and then produce a price index for each of the six-digit class codes, which is defined as the geometric average of the prices for the top ten products. We aggregate the price indexes at the six-digit class code level. The price index obtained in this way is shown by the blue line in Figure 2. As can be seen, the price index followed a declining trend over the entire sample period, although it did slightly rise in 2008 reflecting the price hikes of imported raw materials and grain in that year. The price index declined by about 16 percent in 2000-2012, with the rate of deflation per year being 1.3 percent, which is comparable to the figures for the corresponding items in the official CPI (see Imai et al. 2012). However, it needs to be noted that, given that since 2006 product downsizing has occurred at a non-trivial rate, the decline in the price index is clearly overestimated. Following the quality adjustment procedure adopted by the Statistics Bureau of Japan, we calculate per-unit prices by simply dividing individual prices by the size/weight of the product and then aggregate them to obtain the per-unit price index, which is shown by the red line in Figure 2. The per-unit price index also follows a declining trend in 2000-2005, as the price index, but it starts to deviate from the price index in 2006 and has basically remained unchanged since then. Specifically, comparing the index values for January 2006 (91.4) and January 2012 (91.2), the rate of deflation was tiny, at 0.04 percent per year, indicating that we see no deflation over the last six years as long as we employ the per-unit price as a quality adjusted measure of inflation. Needless to say, we should be careful in interpreting this result, because the per-unit price may not be an appropriate way to adjust for quality, although the statistical agencies of many countries, including Japan, have adopted this approach. For example, Fox and Melser (2011) empirically show that the price-size relationship is non-linear due to the presence of size discount, arguing that using the per-unit price is not an appropriate way to adjust for quality. Nevertheless, the results in Figures 1 and 2 appear to show that hidden price increases through product downsizing in 2006-2012 were of a non-negligible magnitude and it is critically important to take these into account when judging whether Japan has been experiencing deflation or not.

Figure 3 presents the percentage changes over the period 2005-2012 for the size/weight indexes computed for each of the 26 categories, which are listed in Table 2. The figure shows that size/weight index increased slightly for some categories, such as meat processed products (#4), kitchen supplies (#24), and cosmetics (#25), but decreased for most other categories. Product downsizing is particularly notable for chilled desserts (#6), pickled food and prepared food (#2), and jams and spreads (#13). Figure 4 presents the percentage changes of the price indexes over the same period as well as the percentage changes of the per-unit price indexes for the 26 categories. The figure shows that prices (i.e., nominal prices) declined for 19 out of the 26 categories, but *per-unit* prices declined only for half of the 26 categories.

2.3 Identifying the sequence of product generations

Our next task is to identify the sequence of "product generations" (i.e., which product is a successor to which product). This information is key for our analysis in the subsequent sections. The provider of the scanner data, Nikkei Digital Media Inc., does not provide this type of information, but we produce it as follows. First, we identify the entry and exit months of a product. The entry month of a product is defined as the month in which the sales record for that product appears for the first time in our dataset. On the other hand, the exit month is defined as the month in which the producer of a product stops production. However, this is not easy to detect, because stock may remain on the shelves of outlets even after production has stopped, so that a small amount sales is recorded in our dataset. To minimize the risk of such errors, we regard a month as the exit month when the sales quantities for that month are more than 50 percent smaller than the average of the preceding three months, even if there are sales records after that month.

Second, we look for the successor to a product k that exits from the market in month m. We first specify candidates that satisfy the following quantitative conditions: (1) the entry month of the candidate product is between $m - 5$ and $m + 5$; (2) the quantities sold for the candidate product in month m lie between 0.3 $\times$ the average of the quantities sold for product k over the three months preceding month m and 5 $\times$ the average of the quantities sold for product k over the three months preceding month m; (3) the size/weight of the candidate product is within -30 to +30 percent of the size/weight of product k. Next, we use the product name information provided by Nikkei Digital Media to compare product k with the set of candidate products in terms of the product name and the brand name. The number of exit events we find in the dataset is 15,000 (so $k = 1, \ldots, 15,000$), and the number of candidate products satisfying the above requirements is 75,840, so that, on average, there are 5 candidates for each retiring product. Finally, we manually check each candidate to choose the best one as a successor.

In this way, we identify 15,000 pairs of retiring products and their successors. In the remainder of the paper, we refer to such a switch from a retiring product to its successor as a product replacement event. For each event i, we denote the ratio of the size/weight of the successor product to the size/weight of the corresponding retiring product by $1+x_i$, where x_i is the net growth rate. For example, if a new product is 30 percent lighter in terms of weight, then x is equal to -0.3. Similarly, we denote the ratio of the price of a successor product to the price of the corresponding retiring product by $1 + \pi_i$.

Figure 5 shows the cumulative distribution function for the size/weight of products, with the horizontal axis showing the value of x and the vertical axis representing the fraction of events with a size/weight exceeding the value indicated by the horizontal axis. For example, the corresponding number on the vertical axis for -10 percent on the horizontal axis is 0.2, indicating that the fraction of events with x less than -10 percent is 20 percent. As shown in the figure, the fraction of events with x less than 0 percent, i.e., events involving product downsizing, is 35 percent (the actual number of events is 5,173), while the fraction of events with x above 0 percent, i.e., events involving product upsizing, is about 10 percent (the actual number of events is 1,365). The fraction of events with $x = 0$, i.e., involving no change in size/weight, is 55 percent (the actual number of events is 8,462). Although the size/weight remains unchanged in more than half of the events, there exist a substantial number of events involving product downsizing.

Table 2: Number of Product Replacement Events by Product Category

		No. of events	Size/weight unchanged	Size/weight decreased	Size/weight increased
1	Bean curd and fermented soybeans	138	60	55	23
2	Pickled food and prepared food	763	167	487	109
3	Fish-paste	575	212	273	90
4	Meat processed products	332	97	189	46
5	Dairy products and soy milk	1003	641	318	44
6	Chilled desserts	23	18	5	0
7	Beverages	1987	1808	106	73
8	Noodles and dry food	592	210	317	65
9	Seasonings	706	429	232	45
10	Instant food	1298	615	469	214
11	Canned and bottled food	98	48	43	7
12	Bread and rice cake	116	67	27	22
13	Jams, spreads, and premixes	236	127	90	19
14	Coffee, tea, and green tea	346	180	126	40
15	Confectionery	2646	776	1551	319
16	Alcoholic beverages	630	594	23	13
17	Baby food, cereals, etc.	490	374	106	10
18	Frozen food	662	371	207	84
19	Ice cream and ice	260	170	70	20
20	Body care products	631	470	142	19
21	Oral care products	68	44	18	6
22	Hygiene products	110	76	31	3
23	Detergents	204	130	61	13
24	Kitchen supplies	76	65	7	4
25	Cosmetics and stationery	591	508	30	53
26	Pet food and sanitary products	419	205	190	24
Total		15000	8462	5173	1365

Figure 6 shows how the number of events evolves over time. The number of events stayed at a low level (about 500 events per year) for the first half of our sample period, but started to increase in 2007 and reached 2,800 in 2008, indicating that product replacements increased substantially in this year. More importantly, the increase in the number of events in 2008 was mainly due to an increase in the number of events involving product downsizing. Specifically, the number of events involving downsizing was 251 in 2006, but this increased to 496 in 2007 and 1,460 in 2008, when the prices of imported grain and raw materials rose, and these price hikes exerted upward pressure on the prices of domestic products, especially food prices.

Table 2 presents the number of events, as well as their breakdown, for each of the 26 product categories. We see from the table that the share of downsizing events exceeds 50 percent for "Pickled food and prepared food" (#2), "Meat processed products" (#4), "Noodles and dry food" (#8), and "Confectionery" (#15), while the share of downsizing events is small (less than 10 percent) for "Alcoholic beverages" (#16), "Kitchen supplies" (#24), and "Cosmetics and stationary" (#25).

3 Responsiveness of Prices to Changes in Product Size/Weight

How do firms set a price when they introduce a new product? Do they reduce the price when a new product is smaller or lighter than its predecessor? In this section, we address these questions using the 15,000 product replacement events we identified in the previous section.

Let us start by looking at how the π_i are distributed across events i. Figure 7 presents the cumulative distributions of π for events with no change in size/weight, for the events with downsizing, and for the events with upsizing. The CDF for events with no change in size/weight, which is shown by the blue line, clearly indicates that the probability density tends to be quite high in the vicinity of $\pi = 0$; for example, the probability that π is between -10 percent and +10 percent is 0.76. However, this does not necessarily mean that the probability of π taking a very high or very low value is zero. In fact, the probability of $\pi < -0.2$ is 0.03, while the probability of $\pi > 0.2$ is 0.06, neither of which can be regarded as negligibly small. Also, it should be noted that the CDF for events with no change in size/weight appears to be almost symmetric with respect to $\pi = 0$, and that the median, which is given by the number on the horizontal axis that corresponds to 0.5 on the vertical axis, is zero.

Turning to the CDF for events with downsizing, which is represented by the red line in the figure, this again shows that the probability density is high in the vicinity of $\pi = 0$ and that the median of π is equal to zero. This is consistent with anecdotal evidence suggesting that firms tend to keep prices unchanged when introducing new products which are lighter or smaller than the predecessor product. However, this does not mean that prices are kept unchanged in all events with downsizing. In fact, prices did change with non-trivial probabilities and, most importantly, the lower tail of the CDF is much heavier than that of the CDF for events with no change in size/weight. For example, the probability of $\pi < -0.2$ is 0.03 for events with no change in size/weight, but is significantly higher, at 0.08, for events with downsizing. On the other hand, the probability of $\pi > 0.2$ is not that different between the two CDFs: it is 0.06 for events with no change in size/weight and 0.05 for events with downsizing. This implies that prices tend to decline more in the case of events involving downsizing than in

Table 3: Responsiveness of Nominal Prices to a Change in Size/Weight at the Time of Product Replacement

	All	Food	Chilled food	Normal temperature food	Frozen food	Daily necessaries
Coefficient on x	0.445	0.454	0.645	0.369	0.354	0.290
	(0.028)	(0.029)	(0.057)	(0.034)	(0.111)	(0.106)
Intercept	0.039	0.038	0.045	0.037	0.019	0.041
	(0.004)	(0.004)	(0.008)	(0.005)	(0.014)	(0.015)
No. of observations	5,173	4,694	1,433	2,984	277	479

Note: The numbers in parentheses represent standard errors.

events with no change in size/weight. This tendency can be seen more clearly by comparing the CDF for events with upsizing, which is represented by the grey line, and the CDF for events with downsizing. The grey line shows that the probability of $\pi > 0.2$ is equal to 0.19, which is significantly greater than the corresponding probabilities for the other two cases, indicating that prices tend to increase in the events with upsizing.

Next, we examine how the per-unit price changes in events with downsizing. The green line in the figure represents the CDF of per-unit prices, which are calculated for each of the events with downsizing. Comparing the CDF for nominal prices (red line) and the CDF for per-unit prices (green line), we see that, not surprisingly, the green line is located to the right of the red line, indicating that changes in per-unit prices tend to be higher than changes in nominal prices. The median of changes in per-unit prices is now positive at 0.117.[2]

To investigate the relationship between π and x across i in greater detail, we define a measure of the responsiveness of nominal prices to changes in size/weight, which is given by $\frac{1+\pi_i}{1+x_i}$. Note that $1+\pi$ represents the *gross* rate of price change at the time of product replacement. We compute $\frac{1+\pi_i}{1+x_i}$ for all of the events with downsizing, the distribution of which is presented in Figure 8. As can be clearly seen in the figure, this measure of responsiveness is concentrated somewhere around 1.1. Specifically, $\Pr\left(\frac{1+\pi_i}{1+x_i} \in [1.0, 1.1]\right)$ is 0.286 while $\Pr\left(\frac{1+\pi_i}{1+x_i} \in [1.1, 1.2]\right)$ is 0.293, so that the sum of the two is well above 50 percent. The responsiveness measure of 1.1 indicates that a size/weight reduction by, say, 20 percent is associated with a price

[2]In contrast, the CDF of per-unit prices for events with upsizing, which is not shown in Figure 7, indicates that per-unit prices tend to fall in events with upsizing, and that the median of changes in per-unit prices is -6.3 percent.

reduction of 12 percent, implying that the per-unit price rises by 8 percent.

In Table 3, we regress π on x to estimate the responsiveness as a slope coefficient. The column labeled "All" presents the regression result obtained when we use all observations with downsizing. It shows that the estimated coefficient on x is 0.445, rejecting the null that the coefficient on x is unity (that is, that firms reduce prices in proportion to changes in size/weight), thereby providing statistical support to the anecdotal evidence. However, more importantly, the null that the coefficient on x is zero is also rejected, clearly indicating that prices tend to decline more the larger the extent of downsizing. The next column of the table shows the result for "Food," while the final column shows the result for "Daily necessaries." The coefficient on x for daily necessaries is, at 0.290, significantly smaller than that for food, which is 0.454. The table also shows that the coefficient is larger for "Chilled food," at 0.645, than for the other food categories.

4 Consumers Responses to Changes in Product Size/Weight

How do consumers respond to changes in product size/weight? Do they reduce their demand for products when they are downsized? To what extent are they sensitive to changes in product size/weight? In this section, we address these questions by estimating a demand equation.

Let us start by looking at how the quantity sold changed at the time of product replacement event. Figure 9 shows the cumulative probability function for percentage changes in the quantity sold at the time of product replacement, which is denoted by q_i. The horizontal axis represents q_i while the vertical axis shows the cumulative probability. The blue, red, and green lines represent, respectively, the CDF for events with no change in size/weight, the CDF for events with downsizing, and the CDF for events with upsizing. It appears that there is no significant difference between the three CDFs. In fact, comparing the three CDFs in terms of median, it is 0.15 for events with no changes in size/weight, 0.10 for events with downsizing, and 0.09 for events with upsizing, showing that there is little difference between the three distributions in terms of median. This is somewhat surprising given that nominal prices are significantly lower for events with downsizing than for events with upsizing, as we saw in Figure 7.

Figure 10 shows the CDFs for percentage changes in consumption, which is defined by the quantity sold multiplied by the product size/weight, so that the horizontal axis represents $q_i + x_i$. We now see significant difference between the three CDFs. In terms of median, it is -0.04 for events with downsizing, 0.23 for events with upsizing, and 0.15 for events with no changes in size/weight, which is consistent with the fact that per-unit prices tend to be higher for events with downsizing compared to events with upsizing. This result suggests that consumers take into account changes in product size/weight in making decision on their consumption. Gourville and Koehler (2004) presents evidence, based on US data, that consumers tend to be sensitive to changes in nominal prices but not so to changes in product size/weight. However, what we found in Figures 9 and 10 suggests that consumers are more or less sensitive to changes in product size/weight, which is inconsistent with the finding by Gourville and Koehler (2004).

Next, we proceed to the estimation of consumer's demand equation. We assume that there are three types of consumers, each of which is described as follows. The first type is super-smart consumers, who look at per-unit prices to make decision on how much they consume. Specifically, their demand equation is given by

$$q + x = \gamma - \beta(\pi - x), \tag{1}$$

where β and γ are parameters, $\pi - x$ is the percentage change in the per-unit price, and $q+x$ is the percentage change in consumption.[3] Note that β takes a positive value, with $\beta > 1$ if demand is elastic and $0 < \beta \leq 1$ if demand is inelastic. We rewrite (1) to obtain a more familiar form of demand equation with only q on the left hand side:

$$q = \gamma - \beta\pi - (1 - \beta)x. \tag{2}$$

The second type is also smart but not so smart as the first type. Specifically, the second type makes decision based on the per-unit price as the first type does, but it pays attention not to consumption (i.e. the quantity multiplied by the size/weight) but to the quantity purchased. In other words, the variable the second type makes decision on is not $q+x$ but q. The demand equation for the second type is given by

$$q = \gamma - \beta(\pi - x). \tag{3}$$

Finally, the third type is insensitive to changes in product size/weight at all, whose demand equation is given by

$$q = \gamma - \beta\pi. \tag{4}$$

[3]Equation (1) can be seen as an approximation to the following equation: $(1 + q)(1 + x) - 1 = \gamma - \beta[(1 + \pi)(1 + x)^{-1} - 1]$.

Eqs (2), (3), and (4) show that q depends on x differently for each of the three types. As for the first type, the coefficient on x is $-(1-\beta)$, so that it is positive if $\beta > 1$ (i.e., elastic demand) while it is negative if $0 < \beta \leq 1$ (i.e., inelastic demand). In the case of elastic demand, consumption decreases substantially in response to an increase in the per-unit price due to downsizing, and thus the quantity purchased also decreases. However, in the case of inelastic demand, consumption does not decreases that much responding to an increase in the per-unit price, and consequently the quantity purchased increases rather than decreases. Turning to the second type, the coefficient on x is positive in eq (3), suggesting that consumers of this type always reduce the quantity they purchase in response to an increase in the per-unit price due to downsizing. Finally, for the third type, the coefficient on x in eq (4) is zero, indicating that consumers of this type do not respond at all to changes in product size/weight.

We denote the share of the first, second, and third type as α_1, α_2, and $1-\alpha_1-\alpha_2$, respectively, and estimate α_1 and α_2 using the data on product replacement events we constructed in Section 2. Specifically, we sum up (2), (3), and (4) with weights given by α_1, α_2, and $1-\alpha_1-\alpha_2$, and add a disturbance term to obtain an estimating equation of the form

$$q_i = \gamma - \beta\pi_i + [(\alpha_1+\alpha_2)\beta - \alpha_1]x_i + \epsilon_i. \tag{5}$$

Note that we are able to identify γ and β by estimating this equation, but we cannot do so for α_1 and α_2. The best we can do is to obtain an estimate for a linear combination of the two parameters. Also, note that the coefficient on x is given by $(\alpha_1+\alpha_2)\beta - \alpha_1$, indicating that it will take a positive value either if α_2 is large or if α_1 is large with elastic demand ($\beta > 1$), but otherwise it will take a negative value.

Table 4 presents the regression results, which are obtained using all replacement events (i.e., events with downsizing and with upsizing, as well as events with no change in size/weight). The main result, which is shown in the column labeled by "All", is given by

$$q_i = 0.41 - 0.72\pi_i + 0.55x_i \tag{6}$$

with all of the estimated parameters significantly different from zero. An important thing to note is that the coefficient on x_i is positive and significantly different from zero, implying that product downsizing of the greater extent leads to a lower demand. Also, note that β is positive but less than unity, so that demand is inelastic. Eq (6) implies that

$$0.72(\alpha_1+\alpha_2) - \alpha_1 = 0.55. \tag{7}$$

Table 4: Demand Equations

	All	Food	Chilled food	Normal temperature food	Frozen food	Daily necessaries
γ	0.410	0.385	0.394	0.370	0.460	0.558
	(0.008)	(0.008)	(0.014)	(0.011)	(0.032)	(0.024)
β	0.722	0.724	0.645	0.721	1.649	0.781
	(0.048)	(0.051)	(0.081)	(0.068)	(0.266)	(0.132)
Coefficient on x_i	0.554	0.541	0.801	0.375	0.557	0.273
	(0.080)	(0.082)	(0.145)	(0.103)	(0.397)	(0.299)
No. of observations	5,173	4,694	1,433	2,984	277	479

Note: The numbers in parentheses represent standard errors.

As we explained earlier, we are not able to estimate α_1 and α_1 individually, but we are still able to learn about the possible combinations of these two parameters, which are shown below.

α_1	α_2	1-α_1-α_2
0.000	0.764	0.236
0.100	0.803	0.097
0.200	0.842	-0.042
0.300	0.881	-0.181
0.400	0.919	-0.319
0.500	0.958	-0.458
0.600	0.997	-0.597
0.700	1.036	-0.736
0.800	1.075	-0.875
0.900	1.114	-1.014
1.000	1.153	-1.153

This shows that all of α_1, α_2, and $1-\alpha_1-\alpha_2$ are between 0 and 1 only when α_1 is sufficiently close to zero and α_2 is somewhere around 0.8. In this sense, the regression result indicates that $\alpha_1 \approx 0.1$, $\alpha_2 \approx 0.8$, and $1-\alpha_1-\alpha_2 \approx 0.1$. An important message we can learn from this regression result is that most consumers are of the type two, who reduces the quantity purchased responding to product downsizing. We conduct similar regressions for each of the product sub-categories to find that the result for “Food” is almost the same as the result for

"All" but the result for "Daily necessaries" differs from them; namely, the coefficient on x_i for daily necessaries is positive but much smaller, and not statistically significant any more.

5 Conclusion

[To be completed]

References

[1] Fox, Kevin J., and Daniel Melser (2011), "Non-linear Pricing and Price Indexes: Evidence and Implications from Scanner Data," Paper presented at the Ottawa Group Meeting 2011.

[2] Gourville, John T., and Jonathan J. Koehler (2004), "Downsizing Price Increases: A Greater Sensitivity to Price than Quantity in Consumer Markets." Harvard Business School Working Paper, No. 04-042, March 2004.

[3] Imai, Satoshi, Chihiro Shimizu, Tsutomu Watanabe (2012), "How Fast are Prices in Japan Falling?" CARF Working Paper Series, CARF-F-298, October 2012.

[4] Snir, Avichai and Daniel Levy (2011), "Shrinking Goods and Sticky Prices: Theory and Evidence," Bar-Ilan University, 13 March 2011.

Figure 1: Size/Weight Index

Figure 2: Price and Per-Unit Price Indexes

Figure 3: Changes in Size/Weight by Product Category

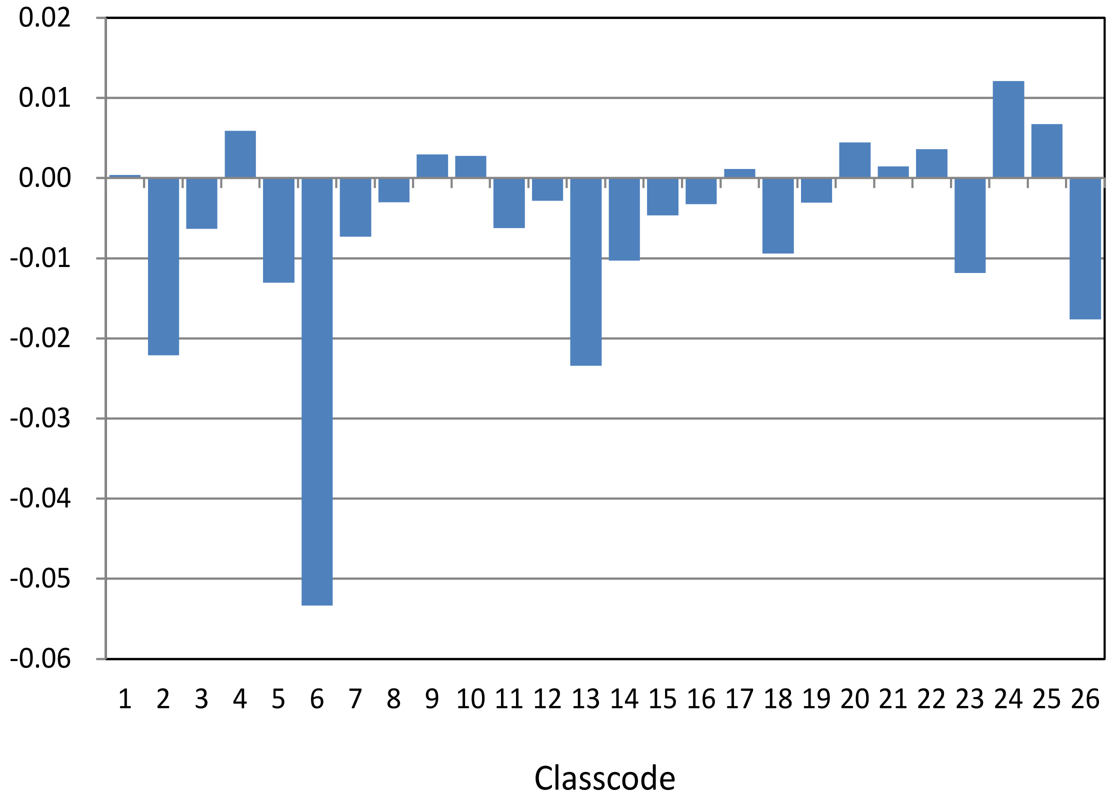

Figure 4: Changes in Nominal and Per-unit Prices by Product Category

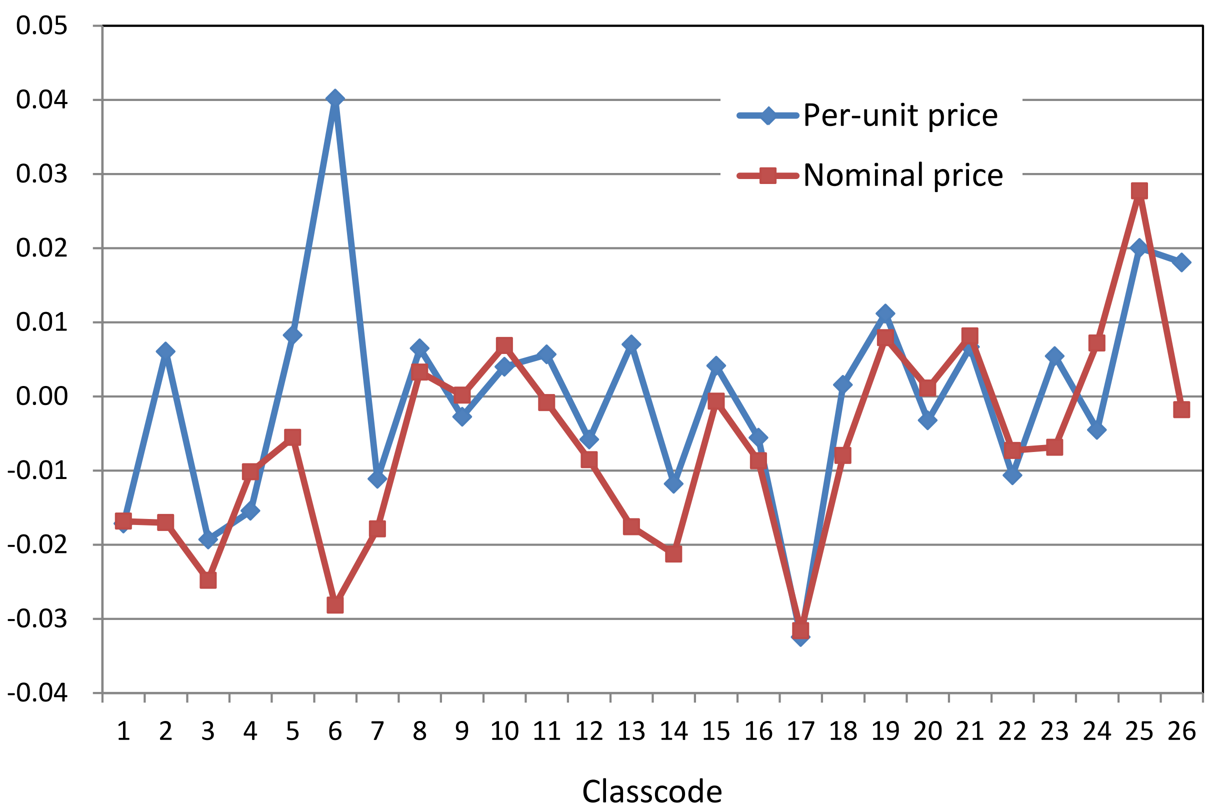

Figure 5: Cumulative Distribution of Changes in Size/Weight at the Time of Product Replacement

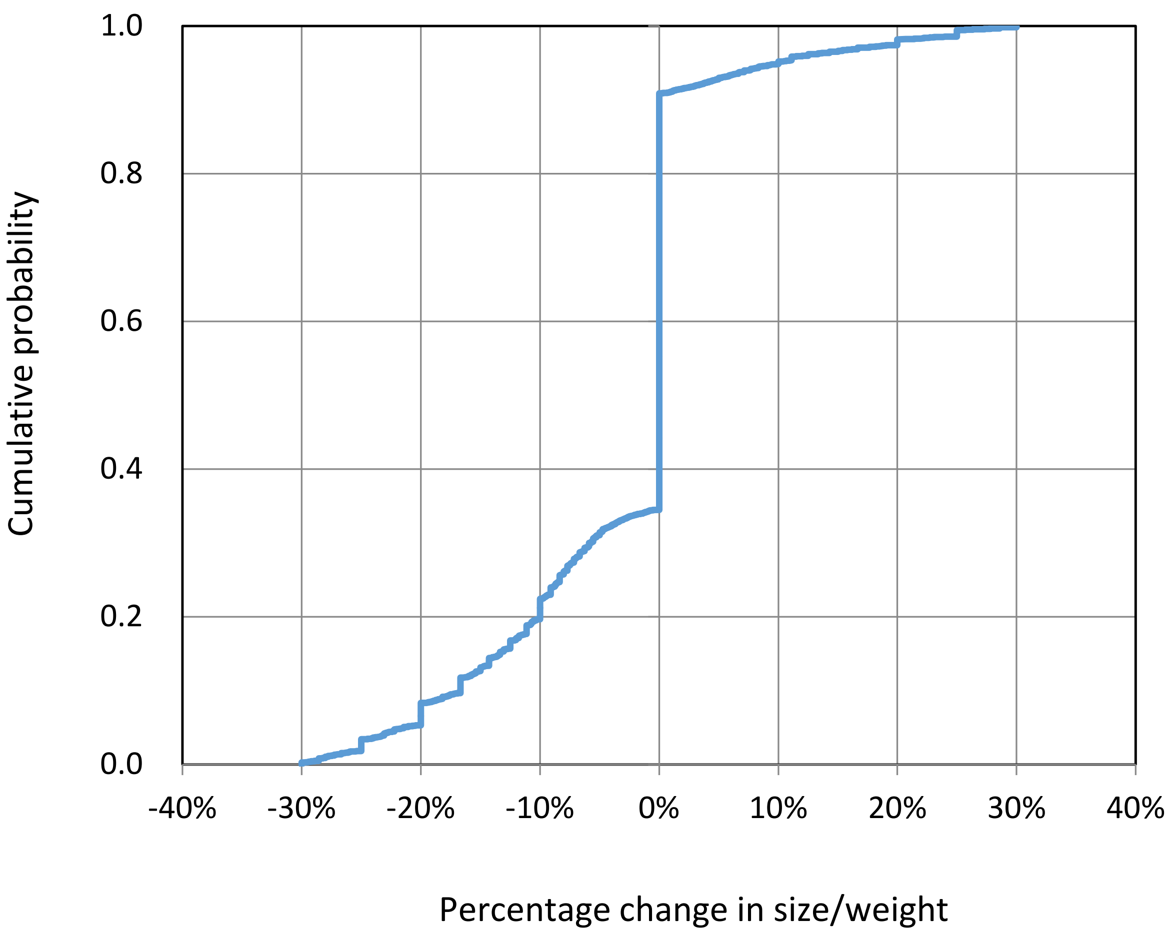

Figure 6: Number of Product Replacement Events by Year

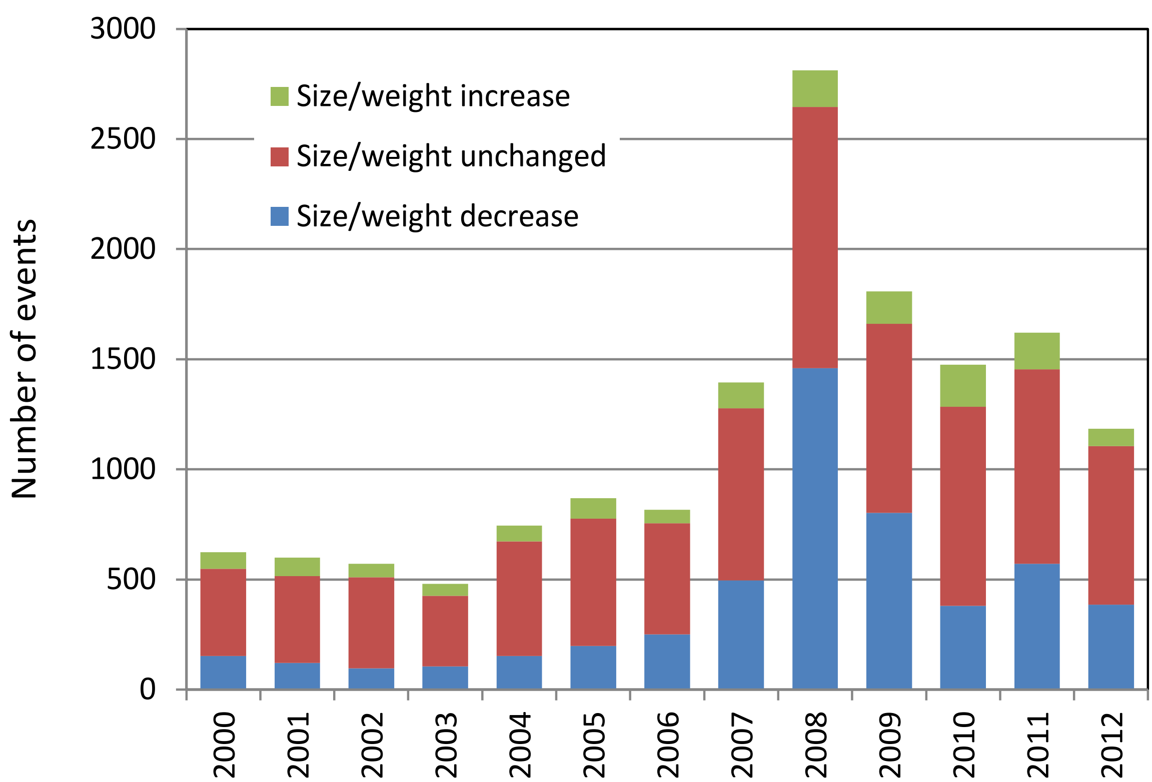

Figure 7: Cumulative Distributions of Price Changes at the Time of Product Replacement

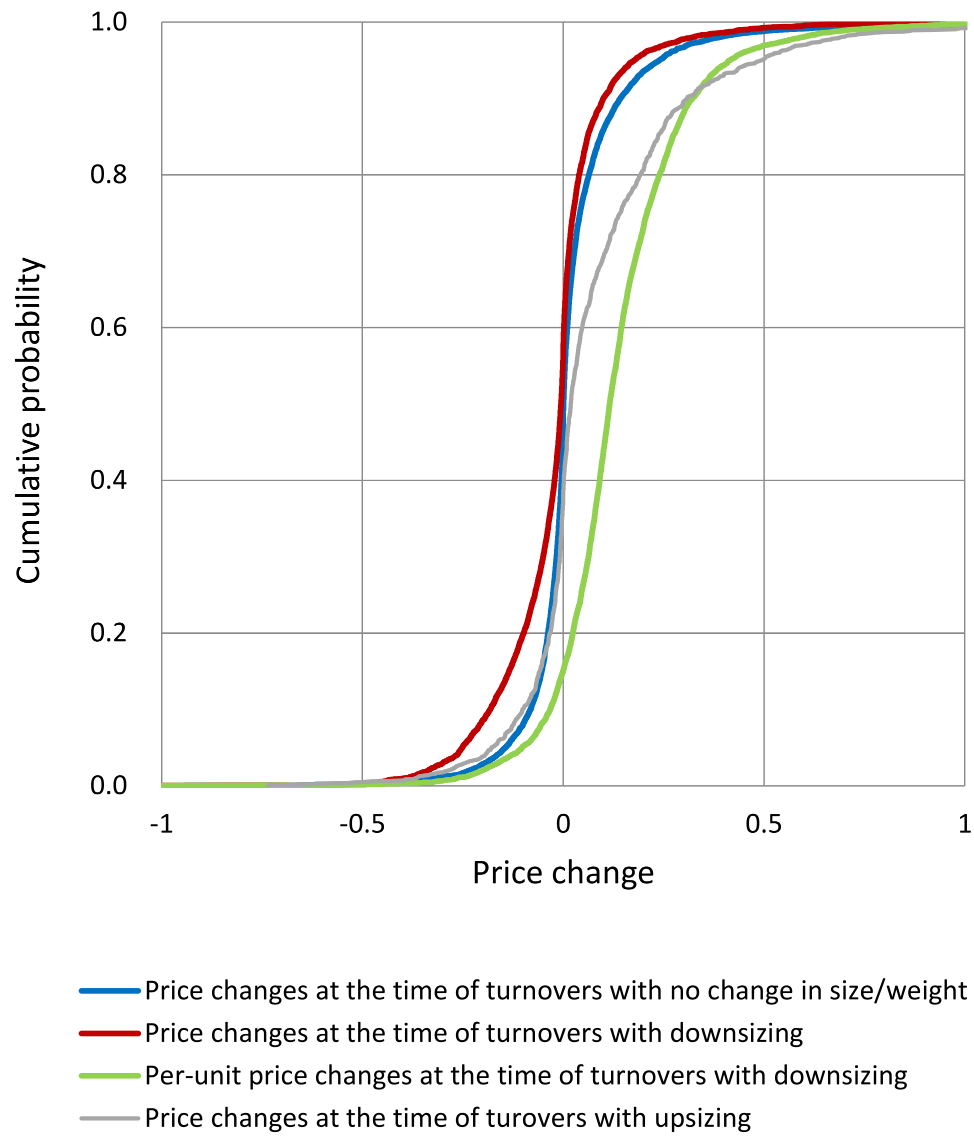

Figure 8: Responsiveness of Prices to Changes in Size/Weight

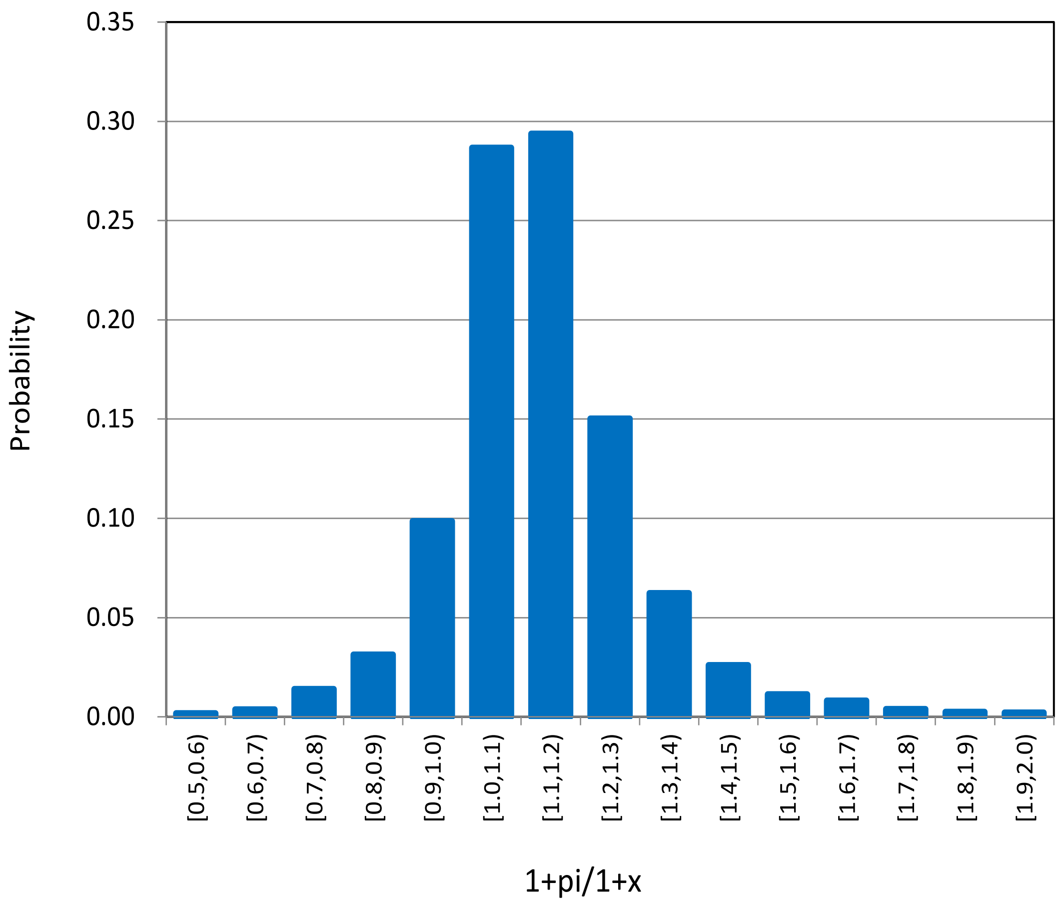

Figure 9: Cumulative Distributions of Changes in Quantity Sold at the Time of Product Replacement

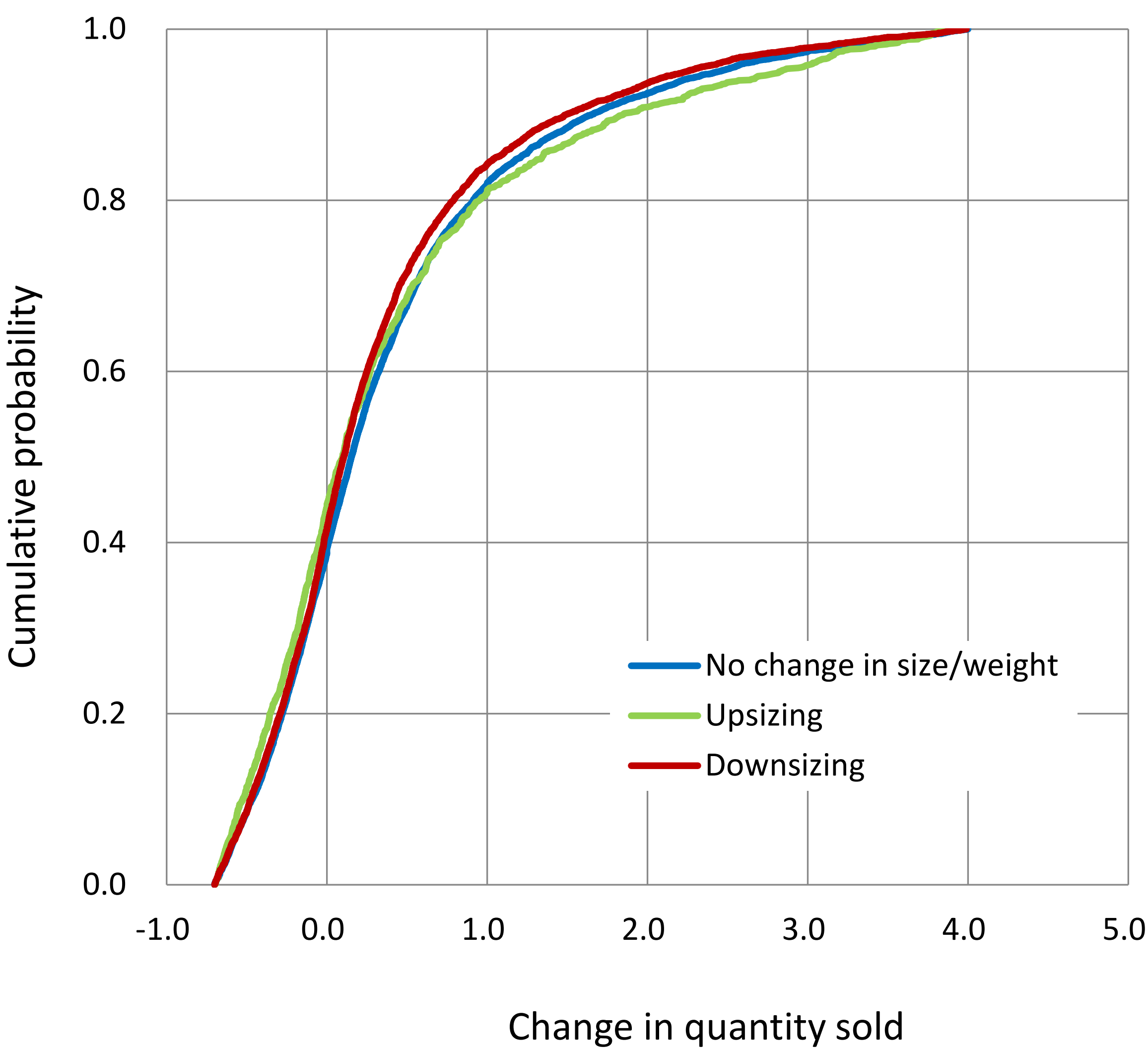

Figure 10: Cumulative Distributions of Consumption Changes at the Time of Product Replacement