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

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Abstract

Consumer price inflation in Japan has been below zero since the mid-1990s. Given this, it is difficult for firms to raise product prices in response to an increase in marginal costs. 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 raising 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 were accompanied by a size/weight reduction. The number of product replacements with downsizing has been particularly high since 2007. 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, resulting in an effective price increase. However, comparing the magnitudes of product downsizings, our results indicate that prices declined more for product replacements that involved a larger decline in size or weight. Finally, we show that the quantities sold decline with product downsizing, and that the responsiveness of quantity purchased to size/weight changes is almost the same as the price elasticity, indicating that consumers are as sensitive to size/weight changes as they are to price changes. This implies that quality adjustments based on per-unit prices, which are widely used by statistical agencies in countries around the world, may be an appropriate way to deal with product downsizing.

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

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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) has been around 1 percent annually, 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 costs, 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.[1] There is considerable evidence for such behavior. For example, according to the Statistics Bureau, which collects information on the size and weight of products to make quality adjustments of prices in the CPI statistics, Meiji Co., Ltd., reduced the weight of its "Meiji Milk Chocolate" from 70 to 65 grams in May 2008, which was followed by further reductions in weight from 65 to 58 grams in October 2009 and from 58 to 55 grams in October 2012. In this case, the weight of a bar of chocolate was reduced by 21 percent over 53 months, so that if the nominal price remained unchanged, this would translate into a per-gram price increase of 27 percent.[2] More recently, Nippon Meat Packers, Inc., announced on May 13, 2013 that they would reduce the weight of ham and sausage products in July without changing factory prices, thereby raising effective prices by 8 percent. This was followed by their competitor, ITOHAM FOODS, Inc., announcing on June 13, 2013 that they would reduce the weight of ham and sausage products by 5 to 15 percent without changing factory prices.

[1] Balk (2008) provides some episodes of price setting behavior in the Middle Ages in which prices for daily necessity were fixed by the authorities to maintain social, economic, and political stability. In those periods, producers or merchants reacted to fixed nominal prices by reducing product sizes or weights, thereby raising effective prices.

[2] Other examples of product downsizing reported by the Statistics Bureau include the reduction by Crecer Co., Ltd., of "Kleenex Facial Tissue" in January 2008 from 360 to 320 sheets per box; by Kao Corporation of "Attack" (detergent) in July 2008 from 1.1 to 1.0 kilograms; and by Meiji Co., Ltd., of "Hohoemi" (baby formula) in March 2008 from 930 to 850 grams.

However, the Statistics Bureau 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 is taken off the market and replaced by a new one). 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 we identified for 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 manufacturers keep factory 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. Specifically, for the 15,000 replacement events, we regress the change in quantities sold at the time of product replacement on the associated change in prices as well as the change in size/weight to find that the coefficient on the price change, which is negative, is almost equal (in absolute value) to the coefficient on the size/weight change, which is positive. This result contradicts the finding by Gourville and Koehler (2004) using US data suggesting that that consumers are sensitive to price changes but not to size/weight changes. In addition, the result that the estimated coefficients on the price and size/weight terms are not very different implies that quality adjustments based on per-unit prices (i.e., nominal prices divided by size/weight), which are widely used by statistical agencies in countries around the world, 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

Table 1: Number of Outlets, Products, and Observations

	All products in dataset		
	No. of outlets	No. of products	No. of observations
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

statistics compiled by the Statistics Bureau.[3] Sales of these products are recorded through the 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.

[3]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 2: Turnover of Products in the 103 Outlets

	No. of products in the 103 outlets	Entries	Exits	Entry rate	Exit rate
2000	203,563	-	-	-	-
2001	208,164	57,526	52,925	0.276	0.254
2002	217,139	66,035	57,060	0.304	0.263
2003	206,172	51,696	62,663	0.251	0.304
2004	222,486	74,655	58,341	0.336	0.262
2005	224,705	62,158	59,939	0.277	0.267
2006	242,669	80,361	62,397	0.331	0.257
2007	254,887	78,060	65,842	0.306	0.258
2008	268,541	89,557	75,903	0.333	0.283
2009	256,824	75,495	87,212	0.294	0.340

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. Next, Table 2 shows the turnover (entry and exit) of products sold at the outlets that are included in the dataset throughout the entire sample period, the number of which is 103. The number of products sold by these 103 outlets in 2000 was approximately 203,000 and has subsequently risen steadily, reaching roughly 256,000 in 2009. During this 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 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, as shown in the lower panel of Table 1, 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, given that product downsizing has occurred at a non-trivial rate, the decline in the price index is clearly overestimated. To correct this, we follow the quality adjustment procedure adopted by the Statistics Bureau of Japan. Specifically, 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.[4] 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 minimal, at 0.04 percent per year, indicating that we see no deflation

[4]Note that 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. Fox and Melser (2011) empirically show that the price-size relationship is non-linear due to the presence of size discounts. If the price-size relationship is indeed non-linear, the per-unit price is not an appropriate way to adjust for quality changes. We will come back to this issue in Section 4.

over the last six years as long as we employ the per-unit price as a quality adjusted measure of inflation.

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 the 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.

It should be noted, however, that care should be taken in interpreting these results. That is, the decline in product size/weight shown in Figure 1 may reflect product downsizing introduced by firms to raise effective prices, but it may also reflect a shift in consumer demand toward smaller products, for example as a result of population aging, shrinking family sizes, and so on. It is difficult to distinguish between these two factors underlying product downsizing. However, as often argued in previous studies, when responding to demand shifts toward smaller products, firms tend to introduce new lines of products, thereby increasing the variety of products. On the other hand, when firms downsize products in order to raise effective prices, they only change the weight/size of products without changing the other attributes of products, including their name and appearance. Given this, our strategy in this paper is to focus on the sequence of "product generations" (i.e., which product is a successor to which product) in which both the product name and the brand name remain unchanged but the product size/weight changes across generations.

2.3 Identifying the sequence of product generations

Our first task is to identify the sequence of product generations. 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; and (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 $1 + \pi_i$, and the ratio of the quantity sold of a successor product to the quantity sold for the corresponding retiring product by $1 + q_i$.

Figure 5 shows an example of the sequence of product generations identified through the above process. This shows the prices and quantities sold for three different products in the margarine category (margarines A, B, and C), which were produced by the same firm and sold under the same brand name and the same product name. However, the product weights of the three differ, ranging from 450g for margarine A, 400g for margarine B, and 360g for margarine C. The figure shows that the quantities sold of margarine A rapidly fell toward zero after margarine B came onto the market in September 2007. This indicates that margarine

B was a successor to margarine A, representing product downsizing from 450g to 400g. This was followed by a second downsizing event from margarine B (400g) to margarine C (360g) in July 2008. However, we also see from the figure that the quantities sold of margarines A and B were small but not zero even after the successor product came onto the market as a result of the presence of trading inventories. As mentioned above, this makes it difficult for us to determine the exact timing of the alternation of generations. We also see that, despite the downsizing by 20 percent from margarine A to margarine C (from 450g to 360g), prices did not change much, and if anything, slightly went up over time.

Figure 6 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.

Next, Figure 7 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.

Finally, Table 3 presents the number of events, as well as a breakdown of these events into those involving no change in size/weight, those involving a downsizing, and those involving an upsizing, for each of the 26 product categories. The table indicates that the share of downsizing events exceeds 50 percent for pickled food and prepared food (#2), meat processed products

Table 3: 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

(#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 the price when they introduce a new product with a different size/weight? Do they reduce the price when the product is downsized, or do they keep the price unchanged? 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 8 presents the cumulative distributions of π for events with no change in size/weight, for events with downsizing, and for events with upsizing. The CDF for events with no change in size/weight, which is shown by the blue line, 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 considerably 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 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 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

Table 4: 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.

nominal prices. The median of changes in per-unit prices is positive at 0.117.[5]

To investigate the relationship between π and x across i in more detail, we define a measure of the responsiveness of nominal prices to changes in size/weight, which is given by $\frac{1+\pi_i}{1+x_i}$. We compute $\frac{1+\pi_i}{1+x_i}$ for all of the events with downsizing, the distribution of which is presented in Figure 9. As can be 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 reduction of 12 percent, implying that the per-unit price rises by 8 percent.

In Table 4, 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 (i.e., 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, 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", at 0.290, is considerably 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

[5]In contrast, the CDF of per-unit prices for events with upsizing, which is not shown in Figure 8, 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.

other food categories.

4 Consumers' Responses to Changes in Product Size/Weight

The next issue we would like to address is how consumers respond to changes in product size/weight. Do they reduce their demand for products when those products are downsized? To what extent are consumers sensitive to changes in product size/weight? We estimate demand equations to address these questions.

Figure 10 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 substantial difference between the three CDFs. In fact, comparing the three CDFs in terms of their median, this 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 the median. This is somewhat surprising given that declines in nominal prices are greater for events with downsizing than for events with upsizing, as we saw in Figure 8.

Figure 11 shows the CDFs for percentage changes in consumption, defined as the quantity sold multiplied by the product size/weight, so that the horizontal axis represents $q_i + x_i$. We now see substantial differences between the three CDFs. In terms of the median, this is -0.04 for events with downsizing, 0.23 for events with upsizing, and 0.15 for events with no change in size/weight, which is consistent with the fact that per-unit prices tend to increase for events with downsizing, while they tend to fall for events with upsizing. This result suggests that consumers take into account changes in product size/weight when making consumption decisions. Thus, the findings presented in Figures 10 and 11 suggest that consumers at least to some extent do appear to be sensitive to changes in product size/weight, which contradict the results obtained by Gourville and Koehler (2004) using US data that consumers tend to be sensitive to changes in nominal prices but not to changes in product size/weight.

Next, we estimate various consumer demand equations. We assume that there are three types of consumers. The first type consists of super-smart consumers, who look at per-unit prices to decide how much to consume. 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.[6] 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 of consumers is also smart, but not as smart as the first type. Specifically, the second type, as the first type, make decisions based on the per-unit price, but they pay 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 make decisions 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 of consumers are completely insensitive to changes in product size/weight, and their demand equation is given by

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

Eqs. (2), (3), and (4) show that the way q depends on x differs 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., demand is elastic), while it is negative if $0 < \beta \leq 1$ (i.e., demand is inelastic). 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 (i.e., the quantity purchased multiplied by the size/weight) does not decreases that much in response to an increase in the per-unit price, and consequently the quantity purchased (in terms of the number of units) 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

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

Table 5: 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)
δ	0.554	0.541	0.801	0.375	0.557	0.273
	(0.080)	(0.082)	(0.145)	(0.103)	(0.397)	(0.299)
p-value associated with test for parameter restriction						
$\delta + (1 - \beta) = 0$	0.105	0.059	0.131	0.361	0.854	0.886
$\delta - \beta = 0$	0.045	0.032	0.282	0.002	0.011	0.106
$\delta = 0$	0.000	0.000	0.000	0.000	0.161	0.361
No. of observations	5,173	4,694	1,433	2,984	277	479

Note: The numbers in parentheses represent standard errors.

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 by 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 following form:

$$q_i = \gamma - \beta\pi_i + \delta x_i + \epsilon_i, \tag{5}$$

where δ is defined as $\delta \equiv (\alpha_1 + \alpha_2)\beta - \alpha_1$. Note that we are able to identify γ and β by estimating this equation, but we cannot identify 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 5presents 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 a greater extent leads to lower demand. Also, note that β is positive but less than unity, so that demand is inelastic. We conduct tests for three sets of parameter restrictions, which correspond to the three types of consumers; that is, $\delta + (1 - \beta) = 0$ for the first type of consumers, $\delta - \beta = 0$ for the second type, and $\delta = 0$ for the third type. The table presents the p-values associated with these parameter restrictions, showing that $\delta + (1 - \beta) = 0$ and $\delta - \beta = 0$ are not rejected while $\delta = 0$ is easily rejected. This result implies that consumers are as sensitive to changes in product size/weight as they are to changes in prices.

Eq. (6) implies that

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

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

The table shows that α_1, α_2, and $1 - \alpha_1 - \alpha_2$ are all 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 of this regression result is that most consumers are of the second type; i.e., they reduce the quantity purchased in response 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 that for "All," but that for "Daily necessaries" differs from the other two results; namely, the coefficient on x_i for daily necessaries is positive but much smaller and no longer statistically significant.

5 Conclusion

In this paper, we empirically examined the extent to which product downsizing occurred in Japan as well as the effect of product downsizing on prices and quantities sold. Our main findings are as follows. First, about one third of product replacements that occurred in our sample period (2000-2012) were accompanied by a size/weight reduction. The number of product replacements with downsizing has been particularly high since 2007. Second, prices, *on average*, did not change much at the time of product replacement, even if a product replacement was accompanied by product downsizing, but 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. Third, the quantities sold decline with product downsizing, and the responsiveness of quantity purchased to size/weight changes is almost the same as the price elasticity, indicating that consumers are as sensitive to size/weight changes as they are to price changes.

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Figure 1: Size/Weight Index

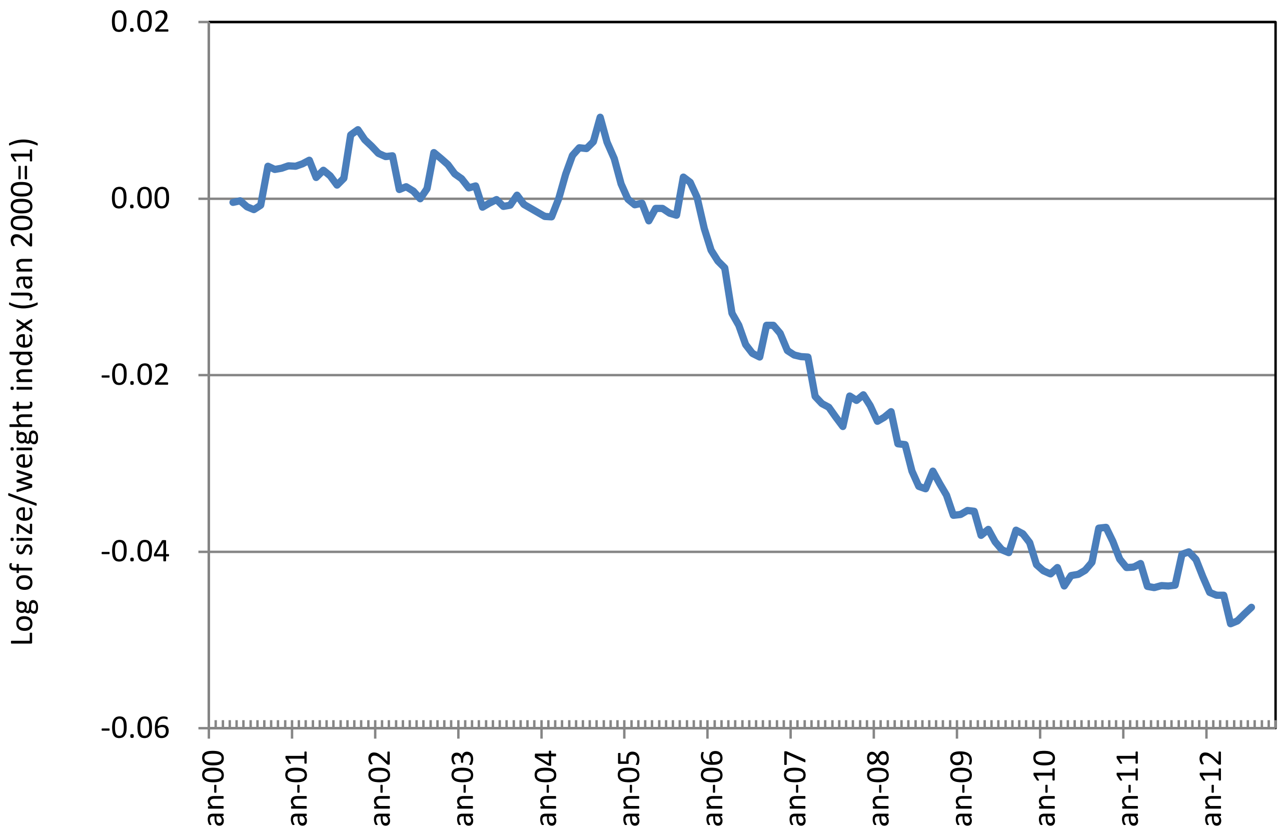

Figure 2: Price and Per-Unit Price Indexes

Figure 3: Changes in Size/Weight by Product Category

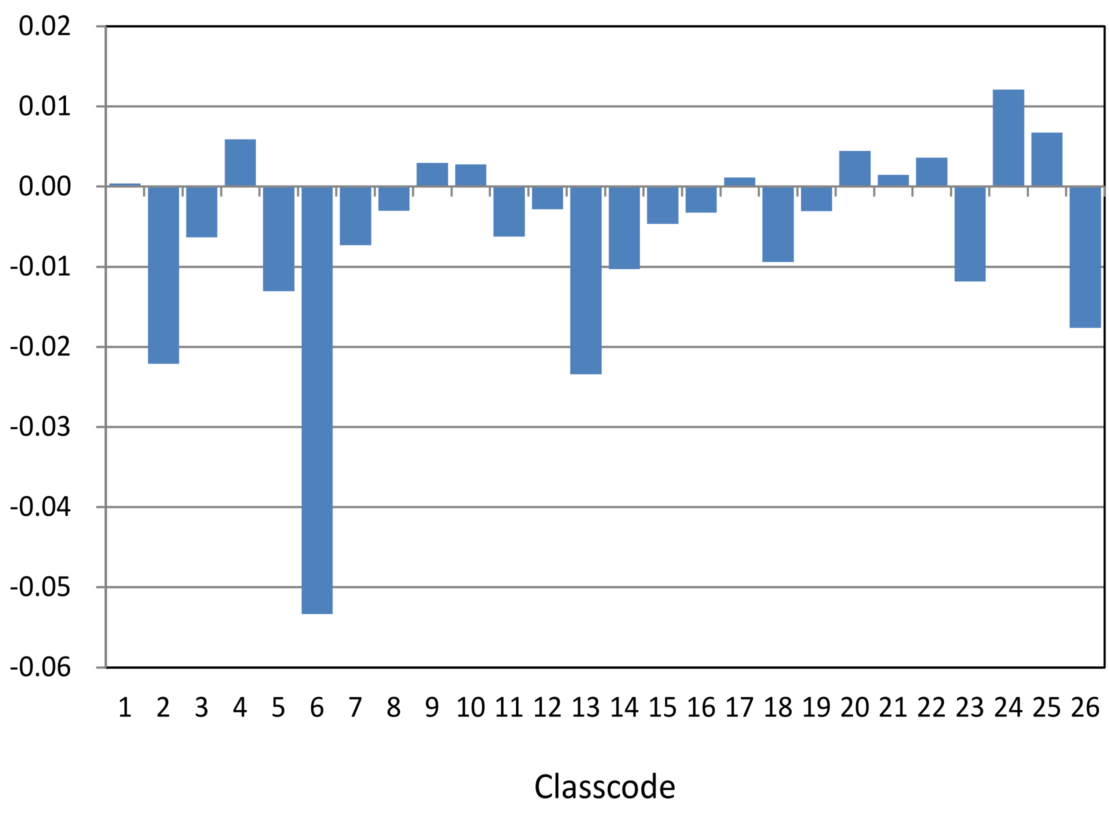

Figure 4: Changes in Nominal and Per-unit Prices by Product Category

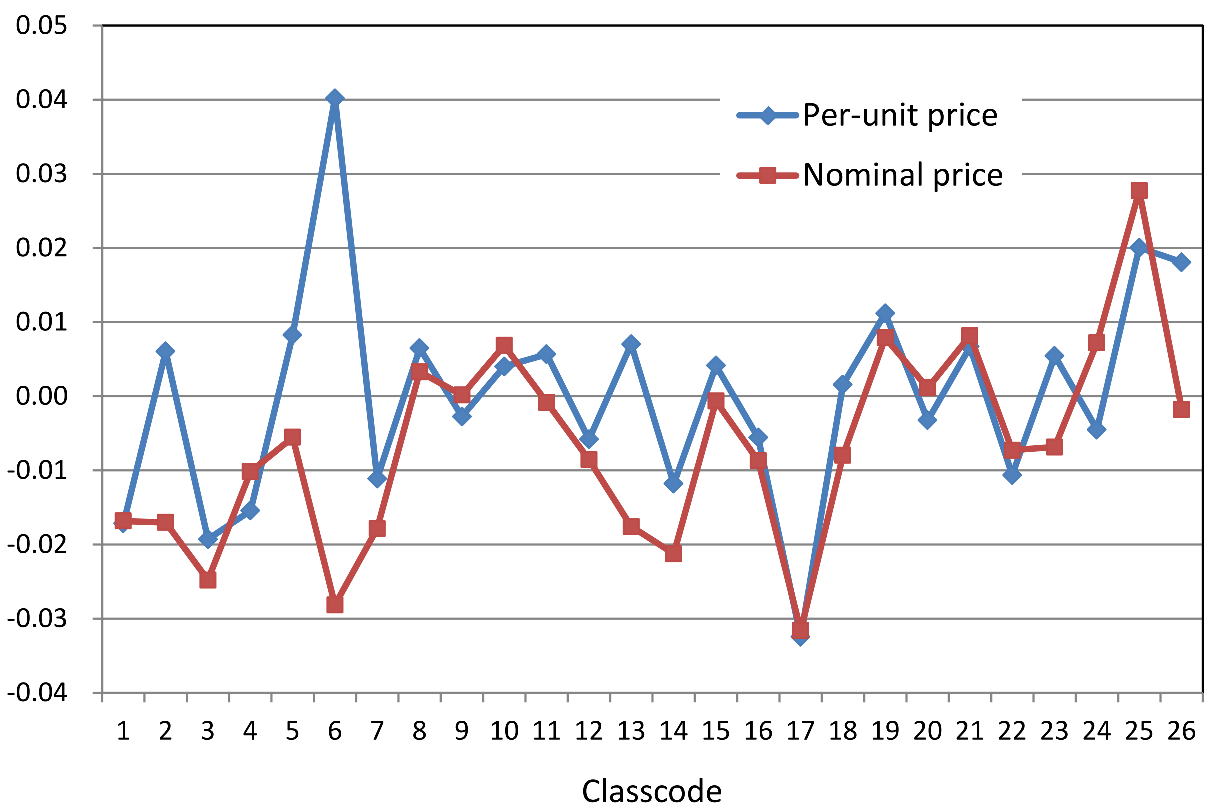

Figure 5: Sequence of Product Generations

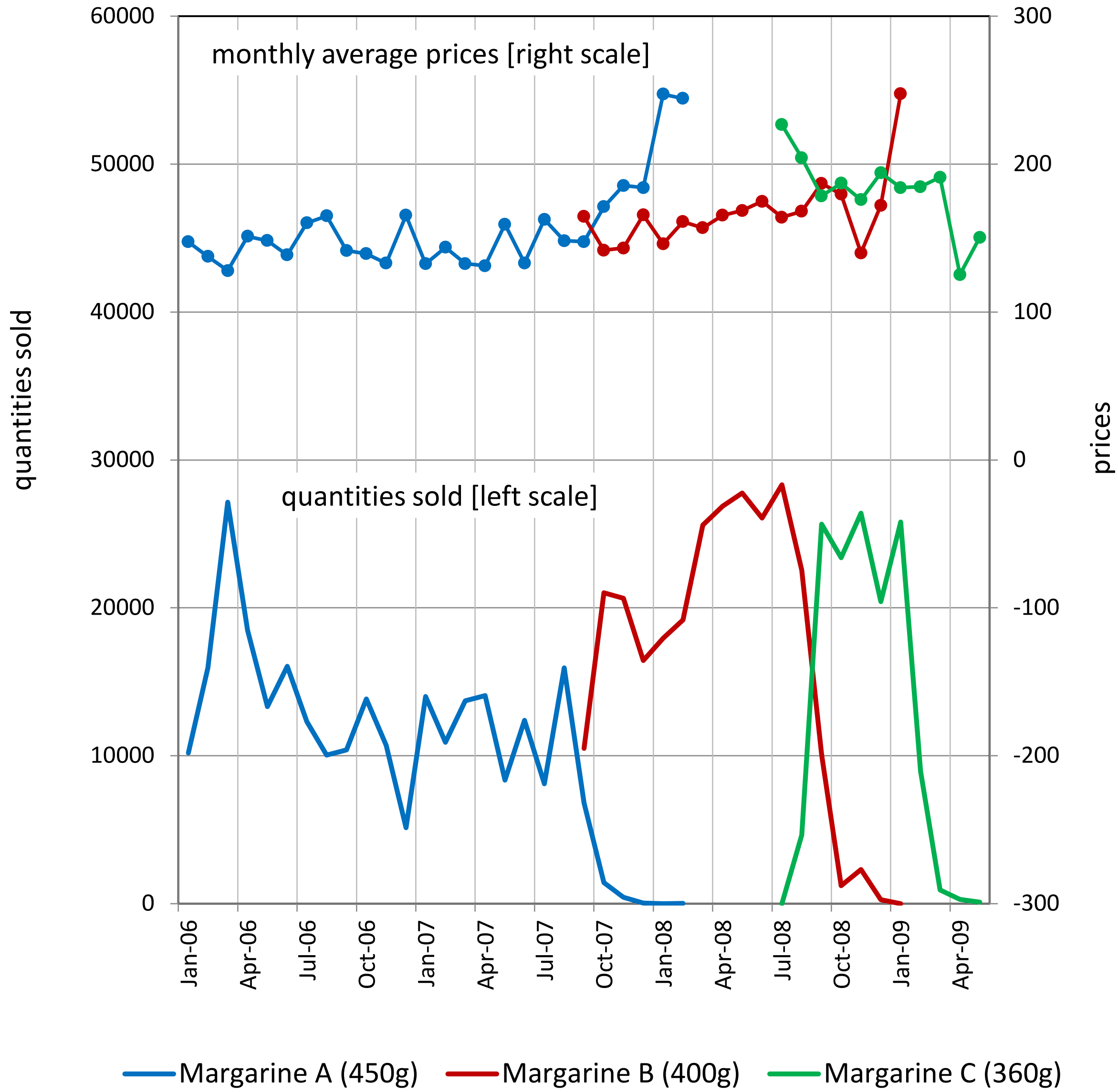

Figure 6: Cumulative Distribution of Changes in Size/Weight at the Time of Product Replacement

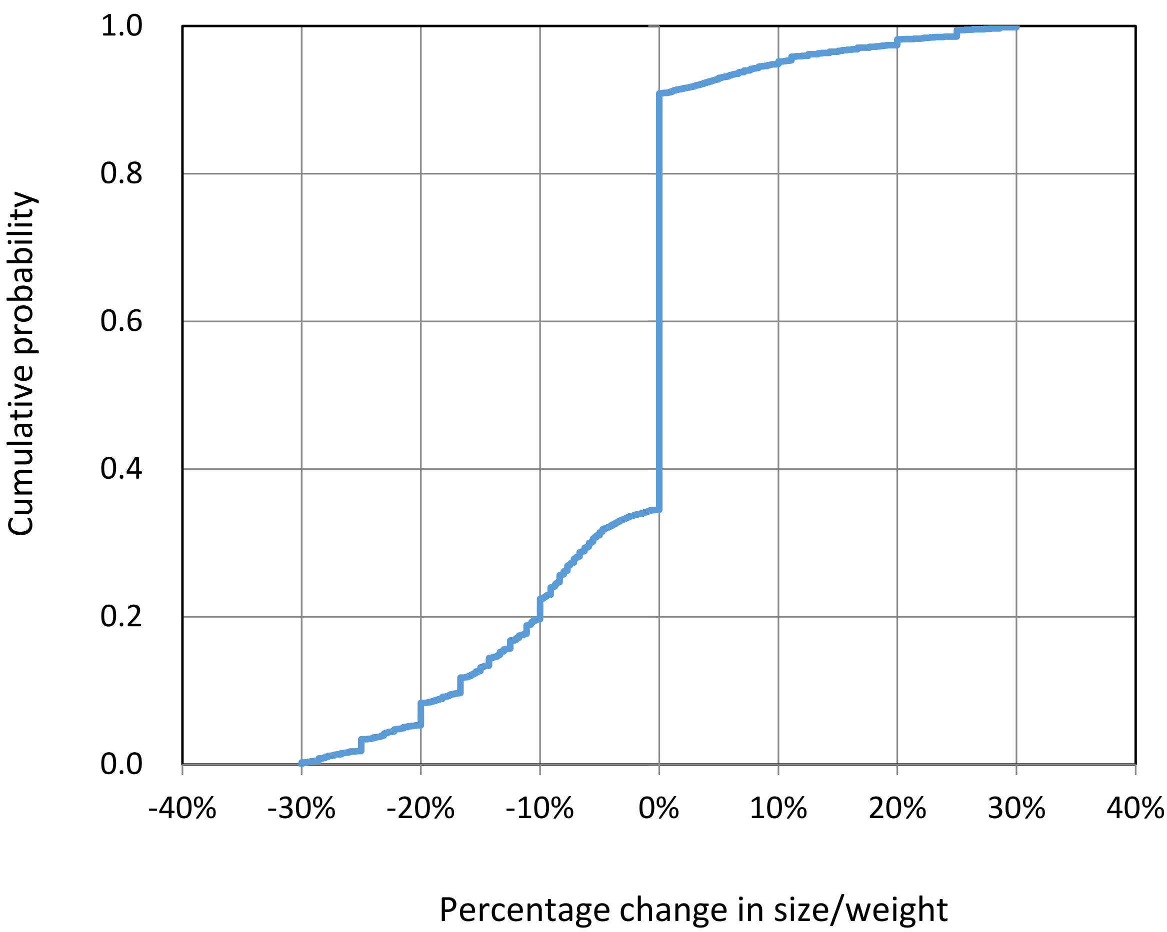

Figure 7: Number of Product Replacement Events by Year

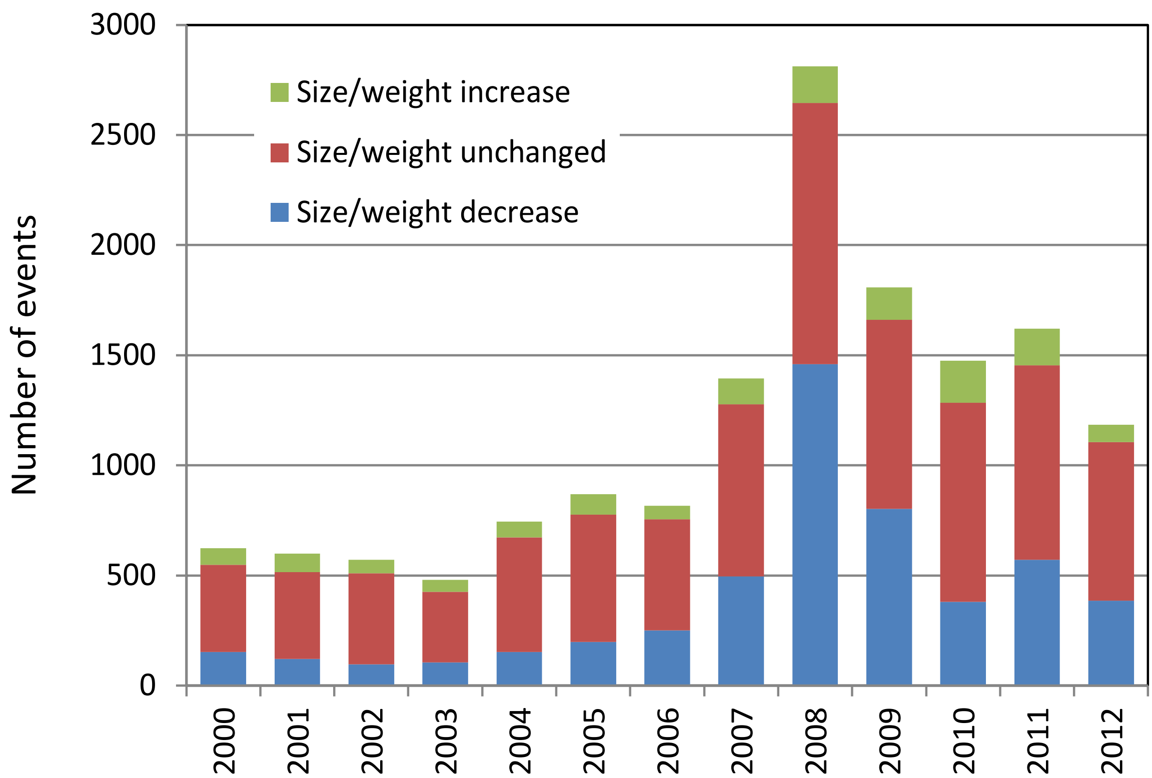

Figure 8: Cumulative Distributions of Price Changes at the Time of Product Replacement

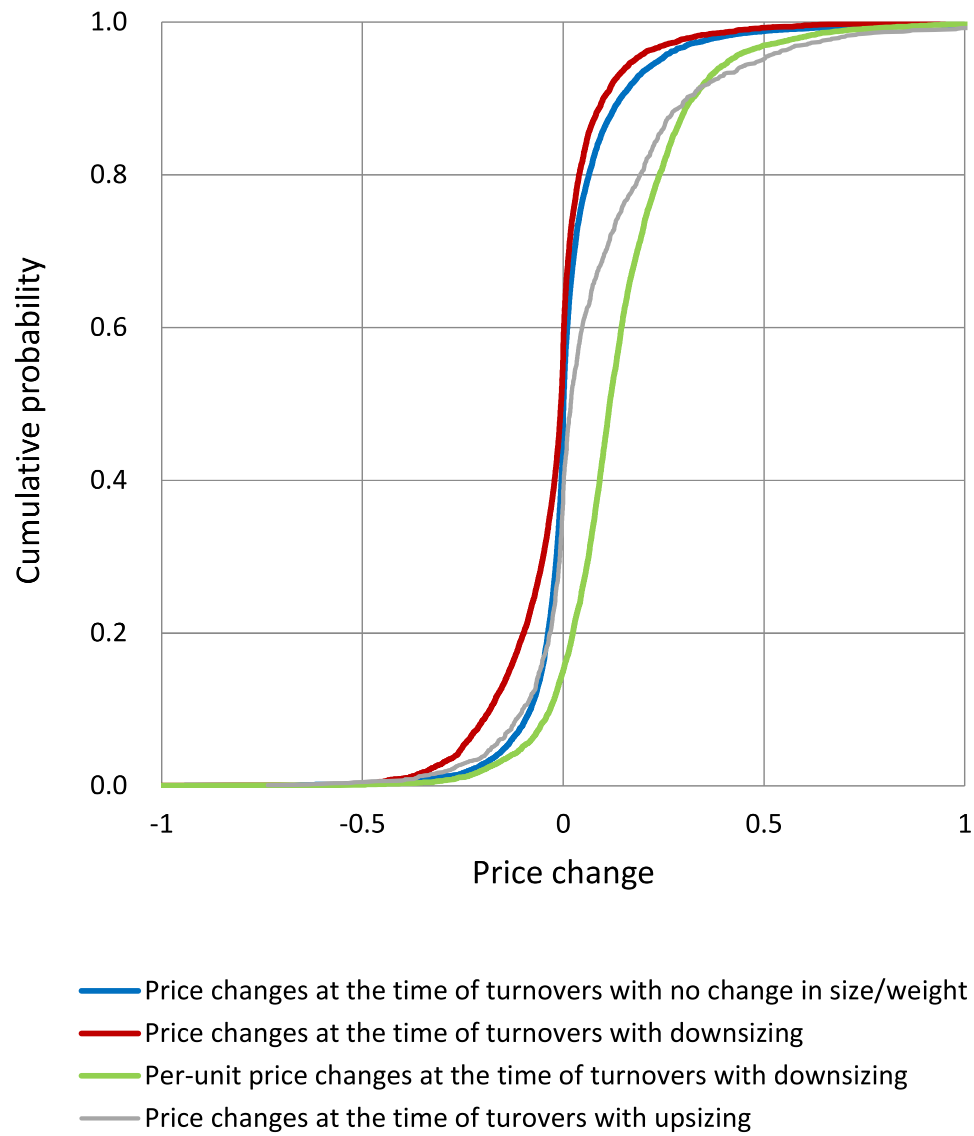

Figure 9: Responsiveness of Prices to Changes in Size/Weight

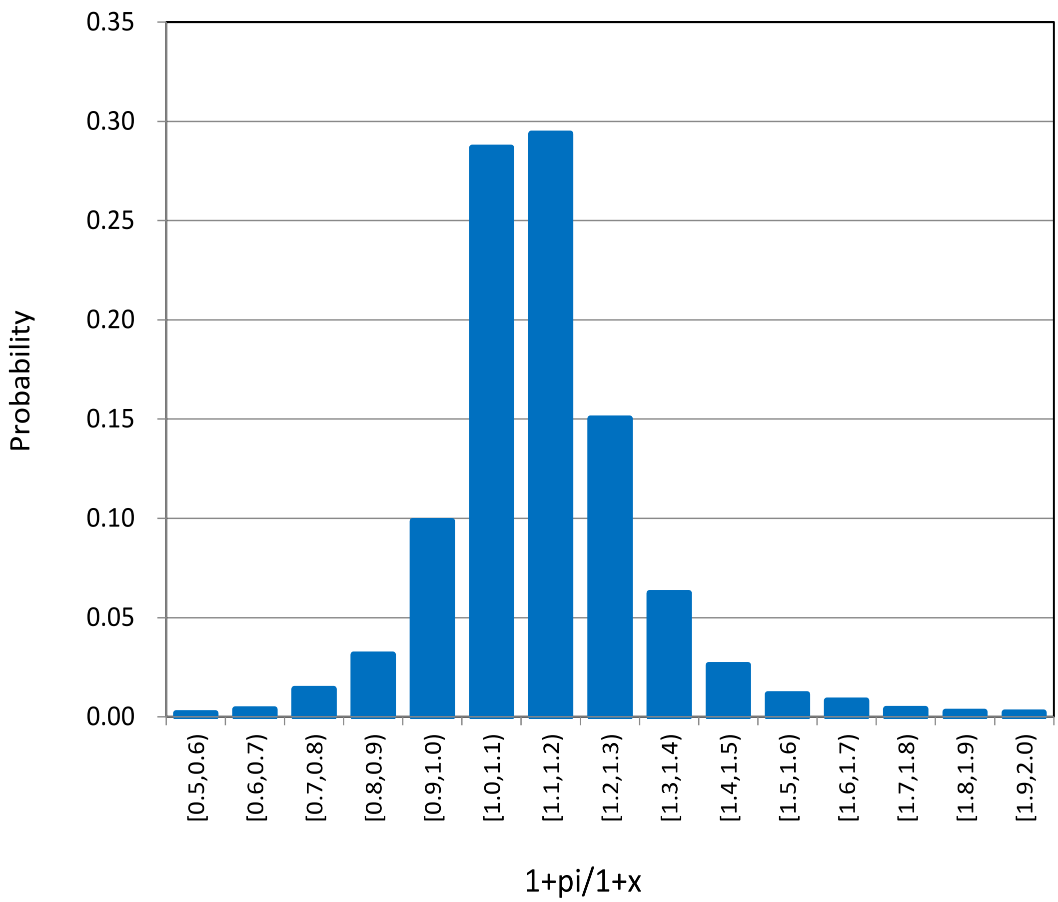

Figure 10: Cumulative Distributions of Changes in Quantity Sold at the Time of Product Replacement

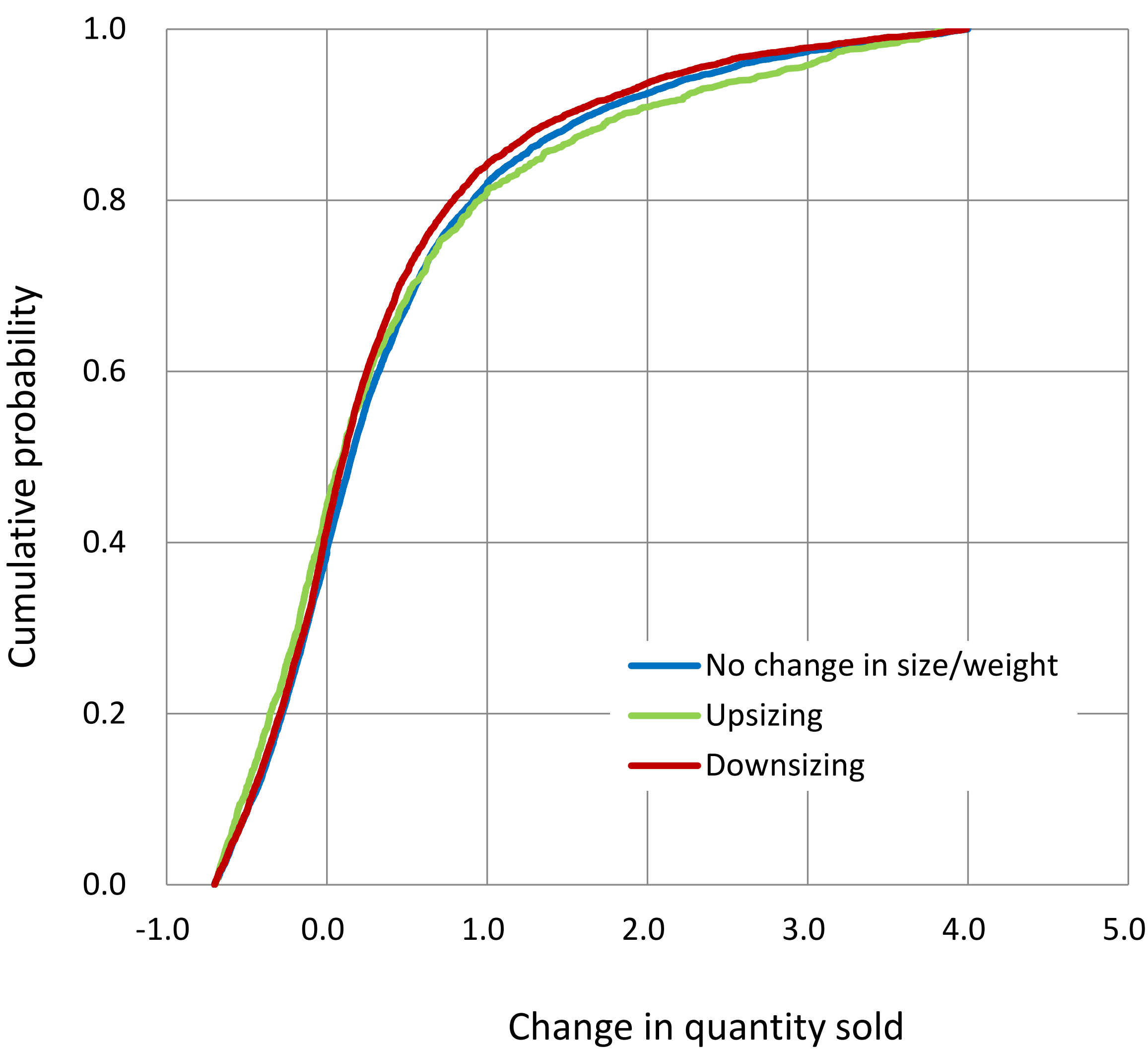

Figure 11: Cumulative Distributions of Consumption Changes at the Time of Product Replacement