Menu Costs and Information Rigidity: Evidence from the Consumption Tax Hike in Japan

Toshiaki Shoji*

October 30, 2018

Abstract

Feldstein (2002) assumes that consumption tax hikes are immediately passed through to prices, and argues that raising consumption taxes generates inflation. To test this argument, I examine firms' price-setting behavior after Japan's consumption tax hike in 2014. I find that the tax hike made tax-excluded prices less sticky than in the previous year. This fact suggests that firms incurred menu costs when changing tax-included prices, which contradicts Feldstein's assumption. This finding is similar to the finding obtained by Hobijn, Ravenna, and Tambalotti (2006) that prices became flexible after the adoption of the euro. Additionally, I provide evidence for information rigidity.

JEL codes: E31, E62, H32

Keywords: Unconventional fiscal policy, price stickiness, intensive and extensive margins, tax-included and tax-excluded prices, consumption tax pass-through

*Graduate School of Economics, University of Tokyo. 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan (e-mail: tshoji@g.ecc.u-tokyo.ac.jp). I would like to thank Tsutomu Watanabe for fruitful discussions. I thank seminar participants of Summer Workshop on Economic Theory for helpful comments. Financial support from the Japan Society for the Promotion of Science (JSPS Grant Numbers: 16J09620 and 18H05217) is gratefully acknowledged. All errors are my own.

1 Introduction

When nominal interest rates hit the zero lower bound, conventional monetary policy will not work, meaning that new policies to stimulate the economy are needed. To solve this problem, Feldstein (2002) proposes a unique solution: raising consumption taxes and reducing labor income taxes. Raising consumption taxes would generate inflation in consumer prices, so that real interest rates would decline, while the reduction in the labor income taxes would neutralize the impact on the overall tax burden. This idea has been further explored by Correia et al. (2013), who argue that this tax policy could provide appropriate stimulus to achieve the first-best allocation even at the zero lower bound.

The argument by Feldstein (2002) and Correia et al. (2013) builds on the important assumption regarding firms' price-setting behavior. Specifically, they assume that tax-excluded prices—rather than tax-included prices—are sticky, so that consumption tax hikes are fully and immediately passed through to prices. However, this assumption is not uncontroversial, and Eggertsson and Woodford (2006), Gagnon, Lopez-Salido, and Vincent (2012), and Karadi and Reiff (2018), for example, argue that it is tax-included prices that are sticky, based on the observation that consumption taxes (value-added taxes, VAT) are usually included in posted prices. Therefore, in order to determine whether Feldstein and Correia et al.'s proposal would work in practice, it is important to know which of these views is correct.[1]

To this end, this paper examines firms' price-setting behavior in response to Japan's consumption tax hike in April 2014. The main findings of the paper are as follows. First, more than half of tax-excluded prices remained unchanged after the tax hike. This finding suggests that tax-excluded prices are sticky, which is consistent with the argument by Feldstein (2002) and Correia et al. (2013). Second and more importantly, tax-excluded prices were less sticky in the week after the tax hike than a year earlier. This finding suggests that the tax hike

[1] There are a number of studies examining how the burden of an increase in the consumption tax is distributed between consumers and firms (e.g., Carbonnier, 2007; Benedek et al., 2015). However, the focus of these studies is not on the degree of price stickiness.

affected the degree of stickiness of tax-excluded prices, so that firms incurred menu costs to revise posted prices that include taxes after the tax hike. This is not consistent with the assumption by Feldstein (2002) and Correia et al. (2013) and instead supports the view of Eggertsson and Woodford (2006), Gagnon, Lopez-Salido, and Vincent (2012), and Karadi and Reiff (2018).

These two findings cannot be explained by saying that *either* tax-included *or* tax-excluded prices are sticky. Rather, they suggest that *both* tax-included *and* tax-excluded prices are sticky. Specifically, this paper presents the hypothesis that tax-included prices are sticky due to menu costs. This hypothesis is suggested by Gagnon, Lopez-Salido, and Vincent (2012) and Karadi and Reiff (2018), based on the observation that posted prices usually include consumption taxes. Moreover, this paper also argues that tax-excluded prices are sticky due to information rigidity. Information rigidity is a rigidity that makes firms' information updating infrequent or requires firms to incur a cost of collecting information on the desired price, as noted by previous studies (e.g., Mankiw and Reis, 2002; Woodford, 2003, 2009; Zbaracki et al., 2004; Alvarez, Lippi, and Paciello, 2011).

To examine whether firms face menu costs and information rigidity, I focus on the price-setting behavior of multi-product firms. The effect of menu costs and information rigidity on multi-product firms' price-setting behavior has been analyzed in existing studies. For example, Midrigan (2011), Alvarez and Lippi (2014), and Bhattarai and Schoenle (2014) argue that firms selling more products change prices more frequently (but by smaller amounts). Their rationale for this argument is that once fixed menu costs are incurred, the firm can reset the price of all its products. Similarly, Pasten and Schoenle (2016) argue that in an environment where information updating is costly, firms selling more products have a stronger incentive to update information on shocks that are common across products, meaning that these firms change prices more frequently. They provide a rationale that is similar to the one used in the context of menu costs for this argument; once information on common shocks is updated, the firm can use such information to reprice all its products.

Based on these arguments, I provide theoretical predictions on how Japan's tax hike affected firms' price-setting behavior. Specifically, on the one hand, the tax hike provided an incentive for firms to incur menu costs to change tax-included prices across the board. Therefore, the extent that firms selling more products change tax-included prices more frequently should have been weakened by the tax hike. On the other hand, the tax hike was a shock that was uncorrelated with shocks to tax-excluded prices, so that firms' decision of whether they updated information on these shocks was not affected by the tax hike. In this sense, the argument that firms selling more products change tax-excluded prices more frequently should have been satisfied.

This paper tests these predictions by analyzing the relationship between the number of products sold and the probability of price changes at the time of the tax hike and in the previous year, respectively. This paper provides evidence supporting these predictions, which means that firms face both menu costs and information rigidity when they adjust prices.

The closest study to this study is that by Hobijn, Ravenna, and Tambalotti (2006), who examined the impact of the introduction of the euro on firms' price-setting behavior. They argue that firms incurred menu costs when switching to the euro, so that prices in some sectors such as restaurants and cafes increased sharply at that time. Similarly, this paper argues that firms incurred menu costs when changing tax-included prices after the tax hike, so that tax-excluded prices were less sticky than in the previous year. Compared to their study, this study provides two additional observations regarding firms' price-setting behavior. First, this paper analyzes the change in both the probability and size of price changes after the tax hike, while Hobijn, Ravenna, and Tambalotti (2006) focus only on the increase in the probability of price adjustment after the euro adoption.[2] Second, this paper shows that firms selling more products were more likely to adjust tax-excluded prices after the tax hike.

[2]The probability and size of price changes are sometimes called the extensive and intensive margins, respectively. See Caballero and Engel (2007) for more detailed descriptions.

This observation suggests that tax-excluded prices are sticky due to information rigidity, even though firms incurred menu costs to revise posted prices after the tax hike. Similarly, Hobijn, Ravenna, and Tambalotti (2006) provide conjecture that information rigidity might have prevented firms from adjusting prices after the euro adoption; however, they did not provide evidence for their conjecture.

The remainder of the paper is organized as follows. The next section provides a brief overview of Japan's consumption tax hike and describes the data used for the analysis. Section 3 then presents several observations regarding firms' price-setting behavior in response to the tax hike, which suggest that both tax-included and -excluded prices are sticky. Section 4 focuses on multi-product firms' price-setting behavior and provides evidence that firms face both menu costs and information rigidity. Section 5 checks the robustness of the results. Finally, Section 6 provides concluding remarks.

2 Background

This section describes the salient features of Japan's consumption tax hike in 2014 as well as the data used for the analysis.

2.1 Brief Overview of Japan's Consumption Tax Hike

Consumption tax (value-added tax) was first introduced in Japan in 1989. The consumption tax covers a wide variety of goods, including food, necessities, durables, and services, and was initially set at 3 percent. The consumption tax rate was subsequently raised to 5 percent in 1997 and then to 8 percent in 2014. The main reasons given by the government were the need to reduce the government deficit and to sustain the social security system.

Since firms are encouraged to include the consumption tax in posted prices, consumption tax hikes are likely to affect firms' effective mark-ups over costs.[3] This means that consumption tax hikes provide an incentive for firms to reset prices.

However, consumption tax hikes do not necessarily force firms to reset prices. For example, when Japan's consumption tax rate was increased from 3 to 5 percent in 1997, according to a survey by the Japan Chamber of Commerce and Industry, more than half of small and medium-sized enterprises did not fully pass through the tax hike to their prices. This result indicates that even though the tax hike affected firms' effective mark-ups over costs, firms could not change prices given that their rivals did not change prices, which can be explained by coordination failure across firms. To address this issue, the Japanese government introduced a law in June 2013 stating that pass-through of the tax hike in April 2014 would be excluded from the application of antitrust laws.[4] This law allowed firms to form cartels to pass on the tax hike to prices, so that Japan's experience provides a useful case study to examine whether firms fully pass on consumption tax hikes to prices as suggested by Feldstein (2002) and Correia et al. (2013).

This is not the first study to use changes in the consumption tax rate in order to examine firms' price-setting behavior. Previous studies using VAT changes in other countries include, for example, Gagnon, Lopez-Salido, and Vincent (2012) focusing on Mexico and Karadi and Reiff (2018) focusing on Hungary. These studies show that the frequency of (tax-included) price changes increased in response to the tax hikes, which is consistent with menu cost models. However, they do not focus on the extent to which the assumption of full pass-through made by Feldstein (2002) and Correia et al. (2013) is satisfied.

[3]Although firms are not forced to quote tax-included prices in Japan, they are obliged to make efforts to do so.

[4]The official name of this law is "Act Concerning Special Measures for Pass-on of Consumption Tax."

2.2 Data

The data used for the analysis are daily scanner data collected by Nikkei. This dataset consists of sales records for a number of supermarkets in Japan, where typically food products and daily necessities are sold.[5] Since a barcode is printed on each of these products, they are distinguished by fairly detailed classifications. In addition, barcodes provide information about the product category (such as butter, yogurt, or shampoo) and the manufacturer of each product.

To observe firms' price-setting behavior, I focus on the period of two weeks centered on the day of the tax hike (April 1, 2014). The number of supermarkets for which observations during this period are available is more than 200, while the number of products sold in these supermarkets is approximately 170,000. For each of these products, the dataset includes both the turnover and the quantity sold at each retailer on a daily basis. Therefore, daily posted prices can be calculated as the turnover divided by the quantity sold.[6] The number of posted prices for which observations for April 1, 2014, for example, are available is approximately 1.1 million. Note that these posted prices exclude the consumption tax, since the turnover recorded in the dataset excludes the consumption tax.

The daily dataset provides high-frequency observations of prices. However, a potential concern is that these posted prices could be affected by daily promotional sales rather than the tax hike. To address this issue, I define the regular price at the retailer-product level before and after the tax hike as the modal price in the last week of March 2014 and in the first week of April 2014, respectively.[7] As a result, the number of regular price observations for each of these periods is approximately 2.4 million.

The data used in this paper have the advantage that they cover a much larger variety of products with different characteristics than previous studies. For example, Hobijn, Ravenna,

[5]Sales records for unprocessed food are excluded from the dataset.
[6]When the obtained price is not an integer, it is rounded to the nearest integer.
[7]Similarly, Abe and Tonogi (2010) define the regular price as the weekly mode of posted prices.

and Tambalotti's (2006) study of price stickiness after the adoption of the euro focuses only on the restaurant sector, so that prices analyzed in their study are fairly sticky. In contrast, this study analyzes price stickiness after the tax hike based on scanner data including a wide range of products, for which the degree of price stickiness varies.

3 Observations Regarding Firms' Price-Setting Behavior after the Tax Hike

This section presents three observations regarding firms' price-setting behavior in response to Japan's consumption tax hike in April 2014.

Observation 1: A sizable fraction of tax-excluded prices remained unchanged after the tax hike.

First, I examine the fraction of prices to which the tax hike was fully passed through. Recall that in the dataset prices are measured excluding taxes. Therefore, full pass-through of the tax hike means that prices remained unchanged, while incomplete or more than complete pass-through resulted in price changes (a decrease or increase, respectively).Thus, an item for which the difference between the regular price in the first week of April 2014 and the last week of March 2014 is no more than 1 yen is defined as one for which full pass-through was achieved.[8] Based on this criterion, the fraction of prices to which the tax hike was fully passed through is estimated to be 63 percent, while for the remaining 37 percent, the degree of pass-through was incomplete or more than complete.

A similar result is obtained when full pass-through is defined in relative terms instead of

[8] The reason for allowing a range of 1 yen rather than requiring prices to remain completely unchanged is that the regular price of an item before and after the tax hike may differ slightly due to rounding. That is, full pass-through of the tax hike from 5 to 8 percent may have resulted in decimal prices, so that retailers rounded these prices up or down. (Note that prices in yen have no decimals.)

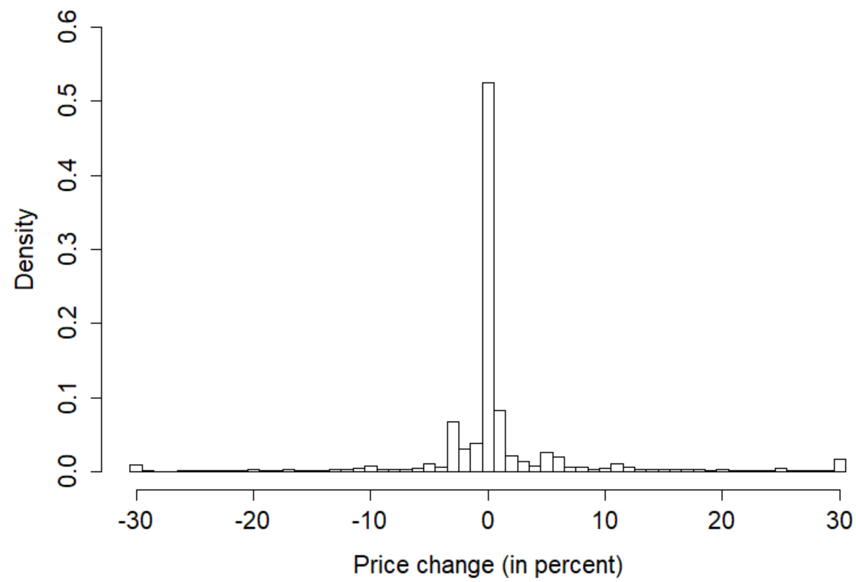

Figure 1: Distribution of price changes in April 2014

Notes: The price change is calculated as the percentage change between the regular price at the retailer-product level in the last week of March and the first week of April. Observations are grouped into bins of one percentage point. The bin including zero percent change ranges over the interval of [-0.5, 0.5). The number of observations is 2,384,954.

absolute terms. Figure 1 displays the distribution of price changes when these are calculated as the percentage change between the regular price in the last week of March and the first week of April. The figure shows that two pricing responses are particularly prevalent. First, more than half of all tax-excluded prices remained unchanged, while the remaining prices were revised either upward or downward. This suggests that the tax hike was fully passed through to the majority of prices, which is consistent with the argument by Feldstein (2002) and Correia et al. (2013). Second, a substantial fraction of prices decreased by about 3 percent, meaning that the tax-included prices of these items remained constant.

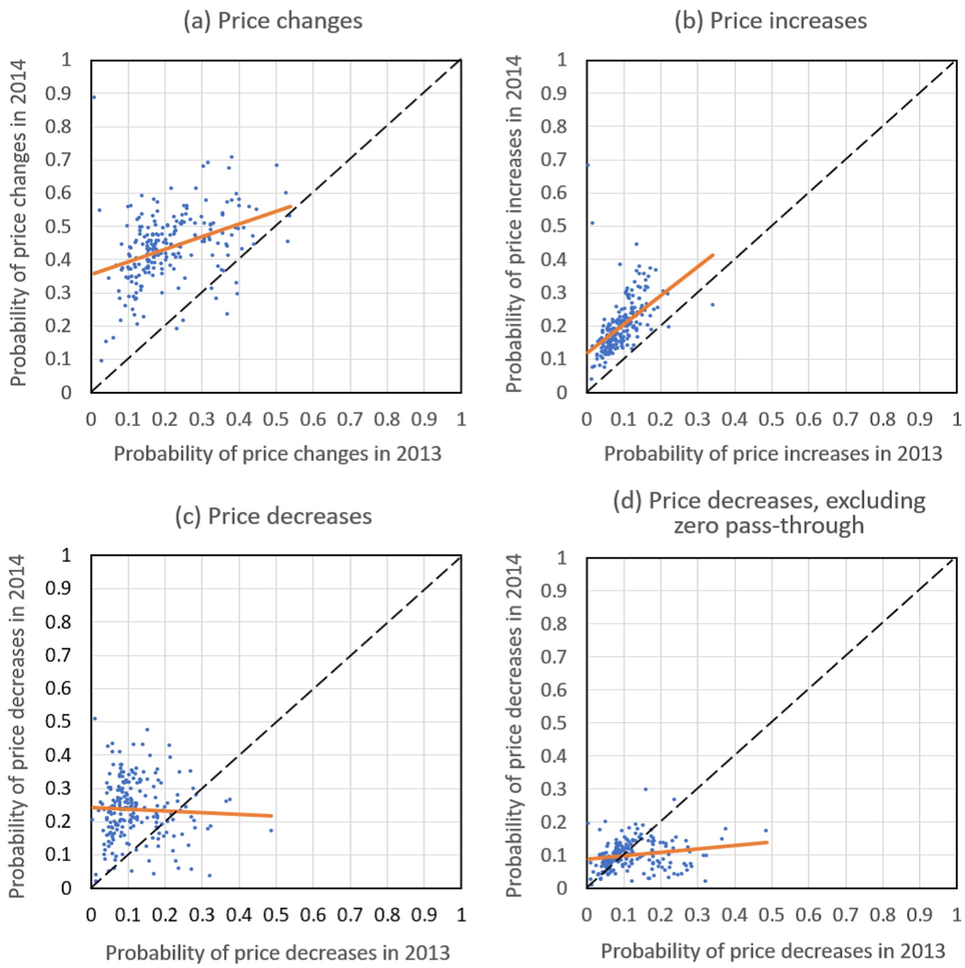

Figure 2: Probability of price changes for each product category

Notes: I calculate the empirical probability of price changes as the turnover share of items for which the regular price was changed in April in each product category. See text for more details. The orange line denotes the OLS fitted line, while the black dashed line denotes the 45 degree line.

Observation 2: The probability of price changes increased after the tax hike.

Second, I examine whether the probability of price changes was affected by the tax hike. To do so, I measure the probability of price changes at the product category level, because the degree of price stickiness is heterogeneous across product categories. Specifically, I calculate the empirical probability of price changes after the tax hike as follows. First, I construct a dummy that takes 1 if the regular price of an item sold at a retailer in April 2014 differs from that in March 2014 by more than 1 yen, and 0 otherwise. Second, I aggregate the turnover of items for which the dummy is 1 in each product category. Third, I divide this turnover by the turnover of all items in the product category.

In Figure 2(a), I compare this value with the corresponding value a year earlier, so that seasonal effects do not come into play.[9] The figure shows that the probability of price changes increased in response to the tax hike in April 2014 for most of the categories. This result is not consistent with the assumption by Correia et al. (2013) that tax-excluded prices are set as in Calvo (1983) and instead is consistent with the argument by Gagnon, Lopez-Salido, and Vincent (2012) and Karadi and Reiff (2018) that firms incur menu costs when changing tax-included prices.

Since price changes can be divided into price increases and decreases, I construct similar dummies for price increases and decreases separately and plot the probabilities in Figures 2(b) and 2(c), respectively. Figure 2(b) clearly indicates that the probability of price increases rose in April 2014. On the other hand, in Figure 2(c), no systematic rise in the probability of price decreases in April 2014 can be observed. A caveat related to this figure is that the probability of price decreases in April 2014 might be biased. Specifically, given that a certain fraction of prices including taxes remained constant as seen in Figure 1, these prices were revised downward excluding taxes. Such a pricing response does not mean that the firm

[9]The year-on-year comparisons are based on sales records for retailers for which observations are available in both years.

actively changed its price. To address this issue, I define price decreases in April 2014 in a narrow sense as prices that were decreased excluding taxes and were changed including taxes. (Note that a change in tax-included prices means that the degree of pass-through of the tax hike differed from zero.) Then I calculate the turnover share of items for which this condition is satisfied in each product category, which is displayed in Figure 2(d).

Observation 3: The size of price changes decreased after the tax hike.

Third, I examine the effect of the tax hike on the size of price changes. Again, I measure the size of price changes at the product category level to address heterogeneity in price stickiness. Specifically, I calculate the size of price changes after the tax hike in two steps. First, based on the dummy constructed above, I restrict the sample to items for which the dummy is 1. Second, I take the weighted average of the absolute value of price changes of these items in each product category, where the weight is the turnover share.

Figure 3(a) compares this value with the corresponding value a year earlier at the product category level. The figure suggests that the size of price changes decreased in the wake of the tax hike in April 2014 for most categories. Again, these price changes are divided into price increases and decreases, and the size of increases and the size of decrease are displayed in Figures 3(b) and 3(c), respectively. The figures indicate that the size of both price increases and decreases declined in April 2014. However, the latter result might be biased due to the same concern that the firm kept prices including taxes constant, instead of trying to revise prices excluding taxes downward, as noted in the measurement of the probability of price decreases. I therefore calculate the size of price decreases that are defined in a narrow sense as prices were decreased excluding taxes and were changed including taxes, which is shown in Figure 3(d). In this figure, the reduction in the size of price decreases in April 2014 is less clear than in Figure 3(c).

To explore why the size of price changes decreased in April 2014, I calculate the fraction

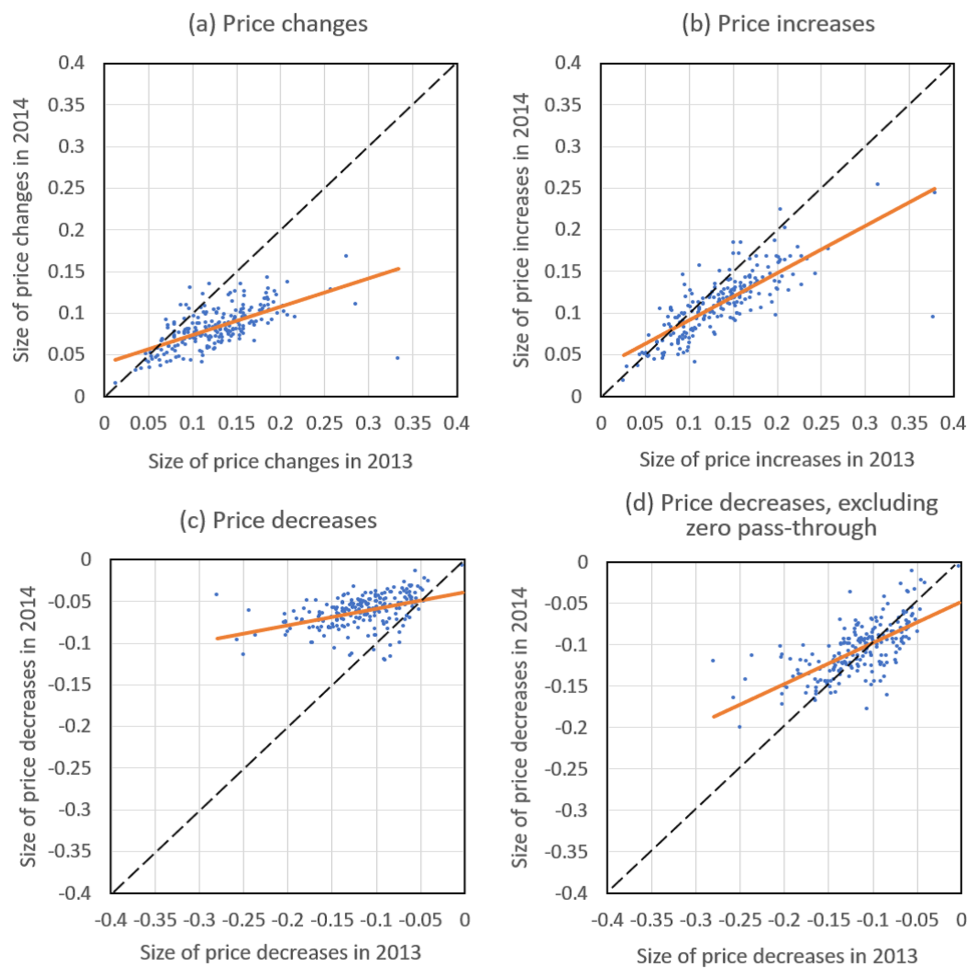

Figure 3: Size of price changes for each product category

Notes: I calculate the size of price changes as the turnover-weighted average of the absolute value of price changes of items for which the regular price was changed in April in each product category. See text for more details. The orange line denotes the OLS fitted line, while the black dashed line denotes the 45 degree line.

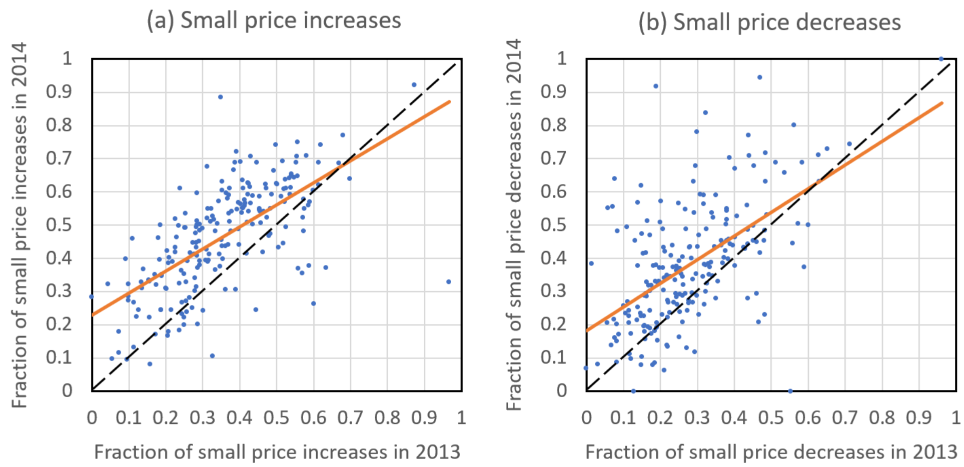

Figure 4: Fraction of small price changes in each product category

Notes: The fraction of small price increases and decreases is displayed. For an explanation of the way the figures are obtained, see the main text. The orange line denotes the OLS fitted line, while the black dashed line denotes the 45 degree line.

of small price increases (decreases) in the following way. First, I restrict the sample to items for which prices increased (decreased) by more than 1 yen. Second, I calculate the mean size of price increases (decreases) across items within each product category in April 2013. Third, following Midrigan (2011) and Bhattarai and Schoenle (2014), I define price increases (decreases) as small if they are less than the half of the mean price increase (decrease). Finally, I aggregate the turnover share of items for which price increases (decreases) were small in each product category in April 2013 and April 2014.[10]

The results are displayed in Figures 4(a) and 4(b). They show that the fraction of small price increases and decreases rose in the wake of the tax hike in April 2014 for most categories, although the degree of the rise in the fraction of small price decreases varies across product categories. This finding suggests that firms incurred fixed menu costs to revise tax-included prices after the tax hike, because they post prices including taxes. The fact that firms incurred menu costs resulted in adjustment of tax-excluded prices as well, in spite of the

[10]For price decreases, I exclude prices that remained constant including taxes in the calculation.

small difference between their current price and the desired price.

4 Price-Setting Behavior of Multi-Product Firms after the Tax Hike

The observations in the previous section can be summarized as follows. First, a sizable fraction of tax-excluded prices remained unchanged after the tax hike. Second, tax-excluded prices were less sticky after the tax hike than in the preceding year in that the probability of price changes increased, while the size of price changes decreased.[11]

The first finding suggests that tax-excluded prices are sticky, while the second finding suggests that firms incurred fixed menu costs when revising posted prices (including taxes), so that tax-included prices are sticky as well. Given that most firms incurred menu costs to pass through the tax hike to prices in April 2014, the fact that tax-excluded prices were sticky must be explained by another source of frictions. Therefore, this paper argues that tax-included prices are sticky due to menu costs, while tax-excluded prices are sticky due to information rigidity. This section examines this argument empirically by focusing on multi-product firms' price-setting behavior.

4.1 Menu Costs: Theoretical Prediction

A number of existing studies point out that when firms are subject to menu costs, their price-setting behavior crucially depends on the number of products each firm sells. For example, Midrigan (2011) and Alvarez and Lippi (2014) argue that small price changes can be generated by multi-product firms but not by single-product firms. Their theoretical assumption for this

[11]The previous section also showed that these results are driven by changes in the probability and size of price increases rather than price decreases. This asymmetry might reflect macroeconomic conditions in Japan, which has experienced about two decades of deflation or stagnating prices, so that firms may have refrained from increasing prices for a long time.

argument is that once fixed menu costs are incurred, the firm can reset the price of all its products. This assumption is supported by empirical evidence. Lach and Tsiddon (1996, 2007), for example, show that the timing of price adjustments of different goods sold by the same firm are highly synchronized,[12] while Bhattarai and Schoenle (2014) show that firms selling more products change prices more frequently but by smaller amounts.

The key idea of these studies is that the cost of changing prices is lumped together. In this situation, multi-product firms adjust some prices that are nearly optimal due to the need to revise other prices that are far away from the optimal price. However, this is not the case for single-product firms, because they will wait until the desired price sufficiently differs from the current price. As a result, firms' price-setting behavior is related to the number of products sold—something that has been characterized as economies of scope in price adjustment by Midrigan (2011) and Alvarez and Lippi (2014).

It should be noted that the above mechanism works in an environment where product-level (idiosyncratic) shocks play a large role in firms' price-setting behavior. The reason is that idiosyncratic shocks affect the gap between the current price and the desired price of each product, so that the incentive to change prices differs across multi-product and single-product firms. I extend this environment by introducing an aggregate shock and describe how the impact of the aggregate shock alters the relationship between the number of products sold and firms' price-setting behavior. First, as a benchmark case, suppose that the aggregate shock is quite small and negligible. In this case, the relationship between the number of products sold and firms' price-setting behavior will be maintained. Second, consider that the aggregate shock is large to some extent. Then, the relationship between the number of products sold and firms' price-setting behavior will be weaker than in the first case, because some firms change prices because of the aggregate shock instead of idiosyncratic shocks. Finally, as a limiting case, suppose that the aggregate shock is extremely large. In this case, all firms will

[12] Similar empirical evidence is provided by Levy et al. (1997) and Dutta et al. (1999).

Table 1: Top 10 firms with the largest number of products

Name	No. of products sold
Retailer A	4,728
Retailer B	2,231
Kao Corporation	1,773
Yamazaki Baking Co., Ltd.	1,591
Shiseido Company, Limited	1,261
Mitsubishi Pencil Co., Ltd.	1,243
Pilot Corporation	1,177
Kokuyo Co., Ltd.	1,007
Meiji Co., Ltd.	976
Kose Corporation	923

Notes: Number of products sold by each firm in April 2014 is reported.

change prices, meaning that firms' price-setting behavior does not depend on the number of products sold. Therefore, the relationship between the number of products sold and firms' price-setting behavior will be weaker in an economy with an aggregate shock than without such a shock. The next subsection tests this prediction regarding Japan's consumption tax hike as a large aggregate shock.[13]

4.2 Menu Costs: Empirical Tests

To examine the prediction discussed above, I calculate the number of products sold by each manufacturer. Focusing on the number of products sold by each manufacturer is useful in that the number of products sold has a larger variation across manufacturers than across retailers.[14] Table 1 lists the top 10 firms in Japan in terms of the number of products sold. As can be seen, the two top firms actually are retailers selling their own-brand products rather

[13] Karadi and Reiff (2018) similarly regard VAT changes in Hungary as large aggregate shocks which led firms to revise prices.

[14] While Midrigan (2011) empirically shows that firms face economies of scope in price adjustment based on retailer scanner data, Bhattarai and Schoenle (2014) obtain similar results using micro-data underlying U.S. producer (i.e., manufacturer) prices.

Table 2: Number of products sold and the probability and size of (tax-included) price changes

	Probability		Size	
No. of products sold	2013	2014	2013	2014
1	0.14	0.95	0.17	0.06
2-9	0.14	0.95	0.17	0.06
10-99	0.17	0.93	0.14	0.06
100-999	0.25	0.93	0.13	0.06
1000-	0.31	0.96	0.11	0.06

Notes: The probability and size of price changes for a group of manufacturers with a different number of products are reported. See text for how the numbers in this table are constructed.

than manufacturers.[15] These retailers have several store brands, so that they are recorded as the producer of a large number of products, even though they outsource manufacturing of these products to other firms. I exclude the products of these two retailers in the analysis below, since it is impossible to know the "true" producer of these products based on the scanner data. The top manufacturers in terms of the number of products sold are Kao Corporation (a chemicals and cosmetics company), Yamazaki Baking (a food company), Shiseido (another cosmetics company), and Mitsubishi Pencils (a company making pens and pencils).

Below, I examine the relationship between the number of products sold by each manufacturer and the probability as well as the size of (tax-included) price changes. It is especially useful to compare the result for April 2013 with that for April 2014, because the tax hike in April 2014 served as a large aggregate shock, so that the link between the number of products sold and firms' price-setting behavior should have been weaker in April 2014 than in April 2013.

This prediction is examined in Table 2, where I calculate the probability of (tax-included) price changes as follows. First, I construct a dummy that takes 1 if the tax-included price

[15] While names of these retailers are known to me, the data provider (Nikkei) does not allow me to disclose information regarding the source of their scanner data.

of an item sold at a retailer in April differs from that in March by more than 1 yen, and 0 otherwise. Second, I aggregate the turnover of items for which the dummy is 1 in each manufacturer. Third, I divide this turnover by the total turnover of each manufacturer. Finally, I divide manufacturers into 5 groups based on the number of products sold and take the mean of the turnover share for each group. Similarly, I calculate the size of non-zero price changes for each group as follows. First, I restrict the sample to items for which the dummy is 1. Second, I take the weighted average of the absolute value of price changes of these items produced by each manufacturer, where the weight is the turnover share. Table 2 shows that in April 2013 manufacturers selling more products were more likely to change tax-included prices, but by smaller amounts, while this pattern between the number of products sold and the likelihood and size of price changes disappeared almost entirely in April 2014.

To more precisely quantify the role of economies of scope in price adjustment, I conduct the following two estimations. First, I estimate the following logit model:

$$Pr(I^0_{i,r} = 1, 0 | X_{i,r} = x) = \Phi(\beta X_{i,r}), \tag{1}$$

where $I^0_{i,r}$ denotes an indicator variable that takes 1 if the tax-included price of item i sold at retailer r changed and 0 otherwise. $X_{i,r}$ is a vector consisting of the following three types of explanatory variables. The first is the log of the number of products sold by manufacturer m that produces product i, $\log_{10} N_m$. The second is a set of dummy variables for product categories, since the degree of price stickiness varies across product categories. The third is a set of dummy variables for retailers to control for the influence of retailers' attitude to price revisions.[16]

[16]Note that including dummies for all categories and retailers results in perfect collinearity. To avoid this, I include an intercept while omitting two dummies: one for a category and one for a retailer.

Table 3: Link between menu cost incurring and the probability and size of price adjustments

	Probability		Size	
	2013	2014	2013	2014
	(1)	(2)	(3)	(4)
$\log_{10} N_m$	0.0131	0.0017	-0.0064	0.0022
	(0.0006)	(0.0002)	(0.0005)	(0.0001)
R^2	0.09	0.18	0.15	0.05
Observations	1,845,880	2,104,793	376,883	1,961,611

Notes: Standard errors in parentheses. Categories and retailers for which the number of observations is quite small are omitted when estimating the logit model. Columns (1) and (2) report the marginal effects of a one unit change in the number of products sold on the probability of price change around the mean of $X_{i,r}$. Columns (3) and (4) report estimates of the coefficient on the number of products sold.

The second equation I estimate using ordinary least squares is as follows:

$$Size^0_{i,r} = \gamma X_{i,r} + \epsilon^0_{i,r}, \tag{2}$$

where $Size^0_{i,r}$ denotes the size of the price change for item i sold at retailer r, given that the price was changed. Again, $X_{i,r}$ includes the number of products sold by the manufacturer as well as dummy variables for product categories and retailers.

These equations are estimated based on observations in April 2013 and April 2014. The hypothesis that firms face economies of scope in price adjustment implies that manufacturers selling more products were more likely to change tax-included prices but by smaller amounts in April 2013. On the other hand, this link should be weaker in April 2014 as a result of the tax hike, since all manufacturers regardless of the number of products they sell were likely to adjust prices.

The estimation results are presented in Table 3 and indicate the following. First, in the observations for April 2013, there is a clear positive correlation between the number of products a manufacturer sells and the probability of price changes. The correlation is much weaker—i.e., the coefficient on $\log_{10} N_m$ much smaller—in the observations for April 2014.

This result is consistent with the prediction that the tax hike weakened the relationship between the number of products sold and the probability of price changes. Second, while there is a negative correlation between the number of products sold and the size of price changes in April 2013, there is a positive correlation in April 2014. This result is difficult to interpret, because the sign of the estimated coefficient in April 2013 differs from that in April 2014. However, the fact that the estimated coefficient in April 2014 is smaller than that in April 2013 in absolute value is consistent with the prediction.

These results are in line with the findings obtained in previous studies. Bhattarai and Schoenle (2014), for example, show that firms selling more products change prices more frequently but by smaller amounts. The estimation results for April 2013 in columns (1) and (3) are qualitatively similar to their finding.

4.3 Information Rigidity: Theoretical Prediction

The above results indicate that firms incurred menu costs after the tax hike to revise posted prices (including taxes), in that the probability of (tax-included) price changes did not depend on the number of products each manufacturer sold. This suggests that if menu costs are the only source of price stickiness, firms that changed tax-included prices should have been able to adjust their prices for free. However, this is not the case. Recall that more than half of tax-excluded prices remained unchanged after the tax hike, as reported in the previous section. This observation suggests that firms faced another friction when adjusting tax-excluded prices.

This paper presents the hypothesis that this friction is information frictions. The notion that firms face information frictions when adjusting prices has been explored by a number of existing studies. For example, Mankiw and Reis (2002) propose a theoretical framework called the sticky information model where firms update information only infrequently, while Woodford (2003) constructs an incomplete information model where firms receive a noisy signal and update their belief sluggishly.[17] Based on these theoretical models, Coibion and Gorodnichenko (2015) empirically show that the degree of information rigidity is heterogeneous across macroeconomic variables and argue that firms' incentive to update information depends on the precision of the signal. Their argument helps us understand why firms postponed adjusting tax-excluded prices after the tax hike while they quickly changed tax-included prices. This is because the tax hike differs from other shocks in that firms received a precise signal provided by the government.[18]

I therefore hypothesize that firms faced substantial information rigidity when adjusting tax-excluded prices, even though they incurred menu costs to revise posted prices (including taxes). To test this hypothesis, this paper focuses on the price-setting behavior of multi-product firms. The reason is that existing studies argue that in the context of information rigidities, too, firms' price-setting behavior depends on the number of products sold. Pasten and Schoenle (2016), for example, argue that in an environment where information updating is costly, firms selling more products have a stronger incentive to update information on common shocks, meaning that these firms change prices more frequently. Their argument implies that firms face economies of scope in information updating, so that in the setting examined here, firms selling more products were more likely to adjust tax-excluded prices after the tax hike, which I test in the next subsection.

4.4 Information Rigidity: Empirical Tests

In this part, I test the hypothesis that firms faced information rigidity when they adjusted tax-excluded prices after the tax hike. To do so, I examine the relationship between the number of products sold by a manufacturer and the probability of price changes in the same

[17] The infrequent and noisy update of information can be interpreted as the result of the cost of gathering or processing information on the optimal price. Such an interpretation has been theoretically argued by Woodford (2009) and Alvarez, Lippi, and Paciello (2011) and empirically examined by Zbaracki et al. (2006).

[18] Specifically, the Japanese government made a clear announcement in October 2013, stating that the tax hike from 5 to 8 percent would be implemented in April 2014.

Table 4: Number of products sold and the probability and size of price changes (that differ from the 3 percentage-point increase)

	Probability		Size	
No. of products sold	2013	2014	2013	2014
1	0.96	0.20	0.17	0.16
2-9	0.97	0.22	0.17	0.15
10-99	0.96	0.26	0.15	0.14
100-999	0.97	0.33	0.13	0.13
1000-	0.96	0.33	0.12	0.12

Notes: The probability and size of price changes for a group of manufacturers with a different number of products are reported. See text for how the numbers in this table are constructed.

way as in Section 4.2. However, an important modification is that the reference value of price changes is set to 3 percent instead of 0 percent; that is, the focus is on whether the change in tax-included prices is different from the 3 percentage-point increase that would keep the tax-excluded price unchanged. This modification enables me to examine whether firms incurred the cost to collect information on the optimal price excluding taxes. Note that the sample is restricted to prices that were changed in terms of tax-included prices, since I focus on whether firms increased prices by the exact amount implied by the tax hike, given that firms incurred menu costs.

The relationship between the number of products sold and the probability and size of price changes is examined in Table 4, where I calculate the probability and size in a way that is almost the same as in Section 4.2—only difference is that the reference value of price changes is set 3 percent instead of 0 percent. The results indicate that in April 2014 manufacturers selling more products were more likely to adjust tax-excluded prices, so that the price changes were more likely to differ from a 3 percentage-point increase. In contrast, this pattern cannot be observed in April 2013.

To quantify the impact of economies of scope in information updating, I estimate the

Table 5: Link between information updating and the probability and size of price adjustments

	Probability		Size	
	2013	2014	2013	2014
	(1)	(2)	(3)	(4)
$\log_{10} N_m$	-0.0023	0.0325	-0.0063	-0.0047
	(0.0004)	(0.0007)	(0.0005)	(0.0004)
R^2	0.11	0.08	0.15	0.12
Observations	376,111	1,961,611	364,772	582,822

Notes: Standard errors in parentheses. Categories and retailers for which the number of observations is quite small are omitted when estimating the logit model. Columns (1) and (2) report the marginal effects of a one unit change in the number of products sold on the probability of price change around the mean of $X_{i,r}$. Columns (3) and (4) report estimates of the coefficient on the number of products sold.

logit model:

$$Pr(I^3_{i,r} = 1, 0 | X_{i,r} = x) = \Phi(\beta' X_{i,r}), \tag{3}$$

where $I^3_{i,r}$ denotes an indicator variable that takes 1 if the price change for item i sold at retailer r differs from a 3 percentage-point increase and 0 otherwise. $X_{i,r}$ is a vector of explanatory variables that include the log of the number of products sold by manufacturer m that produces product i, $\log_{10} N_m$, as well as dummy variables for product categories and retailers. In addition, I estimate the following equation using ordinary least squares:

$$Size^3_{i,r} = \gamma' X_{i,r} + \epsilon^3_{i,r}, \tag{4}$$

where $Size^3_{i,r}$ denotes the size of the price change for item i sold at retailer r, given that the price change differs from a 3 percentage-point increase. $X_{i,r}$ include the same set of explanatory variables. These equations are estimated based on observations for April 2013 and April 2014.

The hypothesis that firms face information rigidity when adjusting prices implies that manufacturers selling more products were more likely to update information on the optimal price. This means that these manufacturers were more likely to adjust tax-excluded prices, so that in April 2014 they changed tax-included prices by an amount that differed from the 3 percentage point tax hike. On the other hand, in April 2013, manufacturers had no reason to increase tax-included prices by 3 percentage-point in the absence of the tax hike, so that such a pattern should not be observed. For the size of price changes, the prediction is common across both years, because manufacturers selling more products are more likely to change tax-included prices by smaller amounts.

The estimation results are shown in Table 5. They indicate that for April 2014 a positive correlation between the number of products a manufacturer sells and the probability of price changes can be observed. On the other hand, for April 2013, the correlation was slightly negative. This result suggests that manufacturers selling more products were more likely to adjust tax-included prices by an amount that differed from the 3 percentage point tax hike in April 2014, while this relationship cannot be observed for a year earlier. This is consistent with the hypothesis that firms faced information rigidity even though they incurred menu costs in April 2014.

These results are consistent with the findings of previous studies such as Zbaracki et al. (2004) and Pasten and Schoenle (2016), in that my result and the findings of these studies both suggest that firms face substantial information frictions when adjusting prices. That said, the results in this paper are not directly comparable to those in previous studies, because this paper analyzed the effect of information frictions on the price-setting behavior of firms that incurred menu costs, which has not been examined in previous studies.

5 Robustness

To check the robustness of the results, I conduct three additional analyses. First, I use a longer window length to construct the regular price. Second, I examine the potential effect of

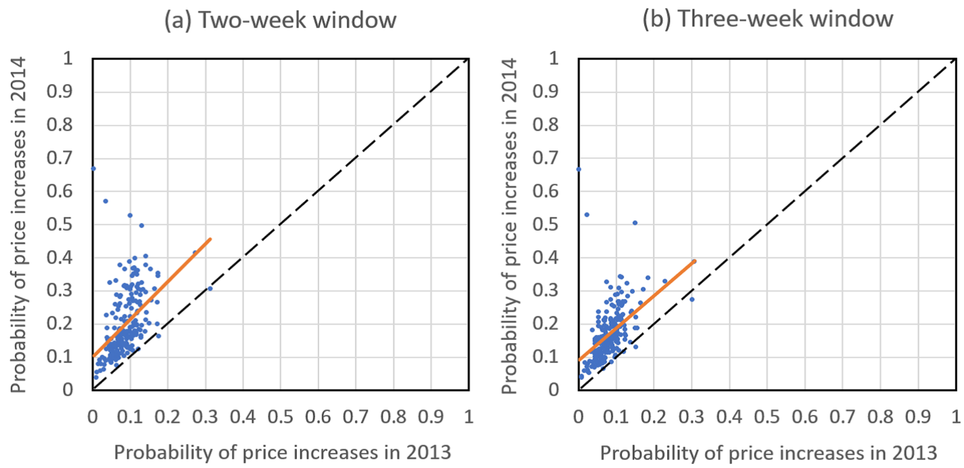

Figure 5: Probability of price increases using the longer window length

Notes: The probability of price increases is essentially calculated in the same way as in Figure 2(b). The only modification is that I use a 2- and a 3-week window to construct the regular price. The orange line denotes the OLS fitted line, while the black dashed line denotes the 45 degree line.

price points on firms' price-setting behavior. Third, I define price changes in relative terms instead of absolute terms. The main results are robust to all of these modifications.

5.1 Changing the Window Length

First, I examine whether the window length used to construct the regular price affects the main results. In the baseline analysis, I define the regular price as the modal price of the last week of March and the first week of April to focus on the effect of the tax hike. This is similar to the definition of the regular price adopted by Abe and Tonogi (2010), who use the weekly modal price as the regular price. However, other definitions have been used in previous studies to observe firms' price-setting behavior. For example, Eichenbaum, Jaimovich, and Rebelo (2011) define the reference price as the quarterly modal price. Based on these different definitions, Sudo, Ueda, and Watanabe (2014) point out that using a shorter window length leads to an increase in the measured frequency of price changes.

To check whether the baseline result is affected by the window length, I calculate the

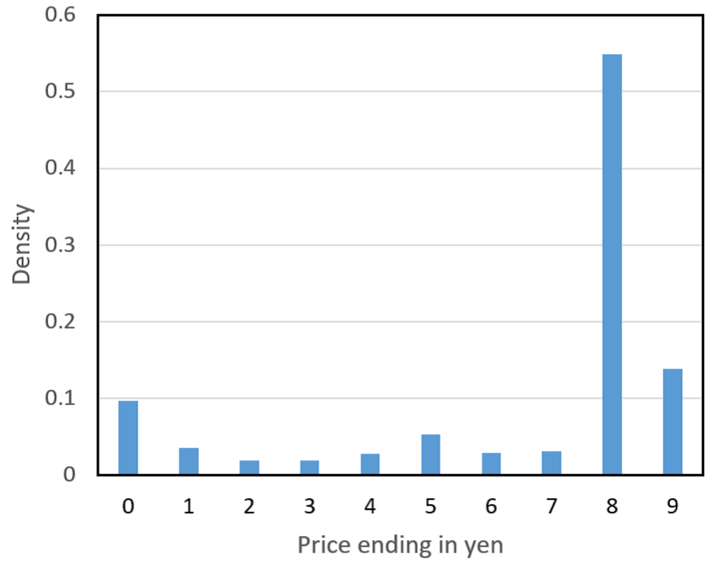

Figure 6: Distribution of the last digit of prices in March 2014

Notes: The figure shows the frequency of the last digit of tax-included prices in March 2014.

probability of price increases using longer window lengths. Specifically, I use a 2- and a 3-week window length, and the results are shown in Figures 5(a) and 5(b), respectively. The results are comparable to those in Figure 2(b), meaning that using a longer window length does not affect the finding that the probability of price increases rose in April 2014.[19]

5.2 Price Points

Second, I check whether the main result is affected by the existence of so-called "price points." A number of studies, such as Kashyap (1995) and Levy et al. (2011), have noted that firms tend to set prices at particular levels that they believe maximizes the turnover.[20] This means that in the wake of the tax hike, firms may have adjusted prices by smaller amounts more intensively than in the preceding year, which may lead to biases in the measurement of the

[19] I do not use the modal price of the quarter before and after the tax hike as the regular price, because applying such a longer window might fail to pick up the effect of the tax hike.

[20] More formally, a price point represents a price where the marginal revenue curve is discontinuous, so that firms hesitate to exceed this. See Kashyap (1995).

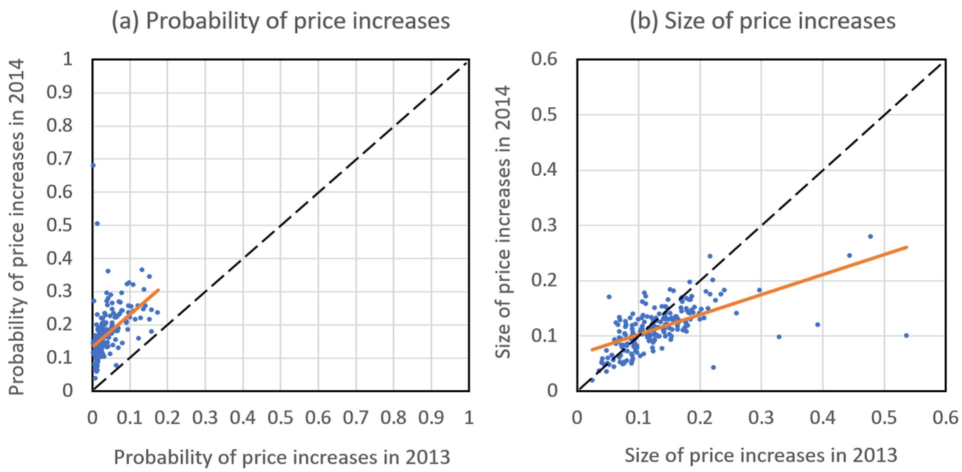

Figure 7: Probability and size of price increases excluding price points

Notes: The probability and size of price increases are essentially calculated in the same way as in Figures 2(b) and 3(b). The only modification is that I exclude price increases for items for which the price ended in "8" in both April 2013 and April 2014. The orange line denotes the OLS fitted line, while the black dashed line denotes the 45 degree line.

probability and the size of price changes.

To examine the effect of price points on firms' price-setting behavior, Figure 6 plots the distribution of the last digit of prices in March 2014. The figure indicates that "8" is the most frequent number in which prices end in the scanner data for Japan used in this study.[21] Taking this finding into account, it seems possible that some firms reset tax-included prices after the tax hike so that they end with "8."[22] To examine whether this kind of price-setting behavior affects the main findings in Section 3, Figures 7(a) and (b) plot the probability and size of price increases for items for which the price in April ended numbers other than "8." The figures indicate that the probability of price increases rose in April 2014, while the size of price increases declined, suggesting that the role of price points in firms' price-setting appears to have been limited.

[21] Levy et al. (2011) in their study using scanner data for the U.S. find that the most frequent number in which prices end is "9."

[22] Another possibility is that after the tax hike, firms were reluctant to change prices that had already been set at price points. This means that the probability of price changes is biased downward while the size of price changes is biased upward, so that the results are conservative.

Table 6: Impact of economies of scope on the probability and size of price changes defined in relative terms

	Frequency		Size	
	2013	2014	2013	2014
	(1)	(2)	(3)	(4)
A: Price adjustment				
$\log_{10} N_m$	0.0169	-0.0007	-0.0047	0.0020
	(0.0006)	(0.0001)	(0.0004)	(0.0001)
R^2	0.07	0.20	0.11	0.04
Observations	1,845,880	2,105,422	458,536	2,021,007
B: Information updating				
$\log_{10} N_m$	-0.0008	0.0488	-0.0048	-0.0035
	(0.0003)	(0.0007)	(0.0004)	(0.0003)
R^2	0.07	0.09	0.11	0.10
Observations	456,542	2,021,007	450,271	856,154

Notes: Standard errors in parentheses. Categories and retailers for which the number of observations is quite small are omitted when estimating the logit model. Columns (1) and (2) report the marginal effects of a one unit change in the number of products sold on the probability of price change around the mean of $X_{i,r}$. Columns (3) and (4) report estimates of the coefficient on the number of products sold.

5.3 Price Changes Defined in Relative Terms

Third, I examine whether changing the definition of price changes affects the main result. Specifically, I define price changes in relative terms instead of absolute terms. So far, a price is regarded to have changed when the regular price in April differs from that in March by *more than* 1 yen. However, this could potentially result in downward biases in the probability of price change for low-priced items. As an example, consider an item which was priced at 20 yen in March. If the price of this item was raised by 1 yen in April, this would be equivalent to a price increase of 5 percent, which is quite substantial. However, when price changes are identified in absolute terms—i.e., that they need to exceed 1 yen—this would not be regarded as a price change.

Therefore, to address this issue, I identify (tax-included) price changes in terms of whether the percentage change of the regular price in April was more than plus or minus 0.5 percent. Similarly, I identify (tax-excluded) prices change in terms of whether the percentage change of the regular price in April was more than 3.5 percent or less than 2.5 percent. Based on these definitions, I estimate the same equations (1)-(4). The results are shown in Table 6 and are very similar to the baseline results in Tables 3 and 5. Specifically, the link between the number of products sold and the probability and size of price changes in April 2014 was weaker than in April 2013 in the case of tax-included prices, while in the case of tax-excluded prices the link between the number of products sold and the probability and size of price changes remained essentially unchanged.

6 Concluding Remarks

This paper examined firms' price-setting behavior in response to Japan's consumption tax hike in April 2014. The main findings of the paper can be summarized as follows. First, a sizable fraction of tax-excluded prices remained unchanged after the tax hike. Second, the probability of (tax-excluded) price changes increased after the tax hike, while the size of price changes decreased. These findings cannot be explained by saying that *either* tax-included *or* tax-excluded prices are sticky. This paper therefore argued that *both* tax-included *and* tax-excluded prices are sticky. Specifically, this paper argued that tax-included prices are sticky due to menu costs, while tax-excluded prices are sticky due to information rigidity. To support this argument, the price-setting behavior of multi-product firms was examined.

The results obtained in this paper provide two policy implications. First, they suggest that Feldstein's (2002) proposal to use a consumption tax hike to generate inflation should be effective, although the feed-through of such a tax hike would likely only be partial. The analysis using Japan's consumption tax hike in 2014 showed that although most prices were raised by an amount equal to or greater than the tax hike, not all prices were raised, implying that tax-included prices are sticky, likely due to menu costs. Given that firms face menu costs when changing tax-included prices, the size of the tax hike needs to be large enough for firms to incur menu costs. However, Feldstein's proposal is to increase the consumption tax rate by 1 percentage point per quarter, which is smaller than the 3 percentage-point increase in Japan, meaning that the feed-through may be smaller.

Second, this paper showed that both tax-included and -excluded prices are sticky. Previous studies, such as Schmitt-Grohe and Uribe (2012), point out that the inflation target adopted by central banks depends on what kind of prices are sticky. Specifically, they consider which of quality-adjusted and nonquality-adjusted prices should be targeted, and conclude that prices that are sticky should be kept constant to avoid inefficient price dispersions. Taking their discussion into account, Japan's experience suggests that central banks should pay attention to both tax-included and -excluded prices.

References

[1] Abe, Naohito and Akiyuki Tonogi, 2010, "Micro and Macro Price Dynamics in Daily Data," *Journal of Monetary Economics*, 57(6), 716-728.

[2] Alvarez, Fernando E. and Francesco Lippi, 2014, "Price Setting with Menu Cost for Multiproduct Firms," *Econometrica*, 82(1), 89-135.

[3] Alvarez, Fernando E., Francesco Lippi, and Luigi Paciello, 2011, "Optimal Price Setting with Observation and Menu Costs," *Quarterly Journal of Economics*, 126(4), 1909-1960.

[4] Benedek, Dora, Ruud De Mooji, Michael Keen, and Philippe Wingender, 2015, "Estimating VAT Pass Through," *IMF Working Paper*, WP/15/214.

[5] Bhattarai, Saroj and Raphael Schoenle, 2014, "Multiproduct Firms and Price-Setting: Theory and Evidence from U.S. Producer Prices," *Journal of Monetary Economics*, 66, 178-192.

[6] Caballero, Ricardo J. and Eduardo M.R.A. Engel, 2007, "Price Stickiness in Ss Models: New Interpretations of Old Results," *Journal of Monetary Economics*, 54, 100-121.

[7] Calvo, Guillermo A., 1983, "Staggered Prices in a Utility-Maximizing Framework," *Journal of Monetary Economics*, 12(3), 383-398.

[8] Carbonnier, Clement, 2007, "Who Pays Sales Taxes? Evidence from French VAT Reforms, 1987-1999," *Journal of Public Economics*, 91, 1219-1229.

[9] Coibion, Olivier and Yuriy Gorodnichenko, 2015, "Information Rigidity and the Expectations Formation Process: A Simple Framework and New Facts," *American Economic Review*, 105(8), 2644-2678.

[10] Correia, Isabel, Emmanuel Farhi, Juan Pablo Nicolini, and Pedro Teles, 2013, "Unconventional Fiscal Policy at the Zero Bound," *American Economic Review*, 103(4), 1172-1211.

[11] Dutta, Shantanu, Mark Bergen, Daniel Levy, and Robert Venable, 1999, "Menu Costs, Posted Prices, and Multiproduct Retailers," *Journal of Money, Credit and Banking*, 31(4), 683-703.

[12] Eggertsson, Gauti B. and Michael Woodford, 2006, "Optimal Monetary and Fiscal Policy in a Liquidity Trap," in Richard H. Clarida, Jeffrey Frankel, Francesco Giavazzi, and Kenneth D. West (eds.),*NBER International Seminar on Macroeconomics 2004*, 75-144.

[13] Eichenbaum, Martin, Nir Jaimovich, and Sergio Rebelo, 2011, "Reference Prices, Costs, and Nominal Rigidities," *American Economic Review*, 101(1), 234-262.

[14] Feldstein, Martin, 2002, “Commentary: Is There a Role for Discretionary Fiscal Policy?” in *Rethinking Stabilization Policy*, Kansas City: Federal Reserve Bank of Kansas City.

[15] Gagnon, Etienne, David Lopez-Salido, and Nicolas Vincent, 2012, “Individual Price Adjustment along the Extensive Margin,” in Daron Acemoglu, Jonathan Parker, and Michael Woodford (eds.),*NBER Macroeconomics Annual 2012*, 27, 235-281.

[16] Hobijn, Bart, Federico Ravenna, and Andrea Tambalotti, 2006, “Menu Costs at Work: Restaurant Prices and the Introduction of the Euro,” *Quarterly Journal of Economics*, 121(3), 1103-1131.

[17] Karadi, Peter and Adam Reiff, 2018, “Menu Costs, Aggregate Fluctuations, and Large Shocks,” *American Economic Journal: Macroeconomics*, forthcoming.

[18] Kashyap, Anil K., 1995, “Sticky Prices: New Evidence from Retail Catalogs,” *Quarterly Journal of Economics*, 110(1), 245-274.

[19] Lach, Saul and Daniel Tsiddon, 1996, “Staggering and Synchronization in Price-Setting: Evidence from Multiproduct Firms,” *American Economic Review*, 86(5), 1175-1196.

[20] Lach, Saul and Daniel Tsiddon, 2007, “Small Price Changes and Menu Costs,” *Managerial and Decision Economics*, 28(7), 649-656.

[21] Levy, Daniel, Mark Bergen, Shantanu Dutta, and Robert Venable, 1997, “The Magnitude of Menu Costs: Direct Evidence from Large U.S. Supermarket Chains,” *Quarterly Journal of Economics*, 112(3), 791-825.

[22] Levy, Daniel, Dongwon Lee, Haipeng (Allen) Chen, Robert J. Kauffman, and Mark Bergen, 2011, “Price Points and Price Rigidity,” *Review of Economics and Statistics*, 93(4), 1417-1431.

[23] Mankiw, N. Gregory and Ricardo Reis, 2002, "Sticky Information versus Sticky Prices: A Proposal to Replace the New Keynesian Phillips Curve," *Quarterly Journal of Economics*, 117(4), 1295-1328.

[24] Midrigan, Virgiliu, 2011, "Menu Costs, Multiproduct Firms, and Aggregate Fluctuations," *Econometrica*, 79(4), 1139-1180.

[25] Pasten, Ernesto and Raphael Schoenle, 2016, "Rational Inattention, Multi-Product Firms, and the Non-Neutrality of Money," *Journal of Monetary Economics*, 80(C), 1-16.

[26] Schmitt-Grohe, Stephanie and Martin Uribe, 2012, "On Quality Bias and Inflation Targets," *Journal of Monetary Economics*, 59, 393-400.

[27] Sudo, Nao, Kozo Ueda, and Kota Watanabe, 2014, "Micro Price Dynamics during Japan's Lost Decades," *Asian Economic Policy Review*, 9(1), 44-64.

[28] Woodford, Michael, 2003, "Imperfect Common Knowledge and the Effects of Monetary Policy," in Philippe Aghion, Roman Frydman, Joseph Stiglitz, and Michael Woodford (eds.),*Knowledge, Information, and Expectations in Modern Macroeconomics*, 25-58. Princeton: Princeton University Press.

[29] Woodford, Michael, 2009, "Information-Constrained State-Dependent Pricing," *Journal of Monetary Economics*, 56(S), 100-124.

[30] Zbaracki, Mark J., Mark Ritson, Daniel Levy, Shantanu Dutta, and Mark Bergen, 2004, "Managerial and Customer Costs of Price Adjustment: Direct Evidence from Industrial Markets," *Review of Economics and Statistics*, 86(2), 514-533.