Impact of Choice Set on Tobacco Consumption

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Abstract

This paper estimates the impact of a change in product choice set on tobacco consumption. We exploit product discontinuation in the tobacco market due to an unforeseen factory shutdown caused by a devastating earthquake. Using national representative scanner data from Japan, we find that taking one or more options from one's tobacco choice set did not reduce the total number of cigarettes, but it reduced the total tar and nicotine purchased in each month by approximately 20 percentage points. Consumers shifted to lower-tar (nicotine) cigarettes after the supply shock, and such an impact persisted in the long term.

Key Words: Choice Set; Tobacco Purchases; Supply Shocks; Earthquake

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1 Introduction

Smoking is widely known to be harmful to health, but it is also difficult to quit. To reduce harm or ease the financial effect of smoking, smokers strategically reduce the number of cigarettes smoked per day and expect to move towards quitting gradually (McNeill, 2004). However, smokers may switch to cigarettes with higher tar and nicotine to compensate for the reduction in consumption. This compensation can eliminate some of the health benefits of reducing cigarette consumption (Evans and Farrelly, 1998; Farrelly et al., 2004). Hence, reducing the harm of smoking not only depends on the consumption of tobacco products but also on the type of tobacco products that smokers choose. Usually, smokers develop a set of favorite products that they purchase every day. Such a set of choices is not fixed over time and can be influenced by price, income, individual preferences, and tastes. While the tobacco products in the set look similar, they contain various amounts of tar and nicotine and therefore pose heterogeneous health risks (Harris et al., 2004). Smokers may be aware of the risks associated with these two substances and rationally adjust their consumption and choices within the confines of addiction (Becker and Murphy, 1988). Ignoring product heterogeneity could lead to biased estimates of the demand and welfare changes (Bajari and Benkard, 2005; Ackerberg and Rysman, 2005).

Choice set is ubiquitous plays a significant role in consumption and other economic behavior. Identifying choice sets in marketing helps us target consumers and segmentation (Draganska and Klapper, 2011). In political field, the structure of the choice set has significantly influenced the strategy selection of national security decision-makers (Mintz et al., 1997). In the health care market, enhanced consumer choice for public services is central to improving quality care (Gaynor et al., 2016). Indeed, a good understanding of consumer choice sets could underpin effective policies. Thus, there is a need to probe into smokers' choices, in

addition to the number of cigarettes smoked, when we discuss smoking behavior and tobacco control policy. However, it is difficult to draw a causal connection between the choice set and consumption. On the one hand, the choice set is highly endogenous, because it is correlated with a complex system of individual, social, and environmental factors. On the other hand, the development of a choice set usually takes a long time. Most data do not allow us to identify subtle changes in consumer choice sets.

In this study, we designed an observational study that enables the estimation of causal effects of choice sets on tobacco consumption by leveraging the impact of a sudden shutdown of tobacco factories due to a natural disaster – the 2011 Great East Japan Earthquake. On March 11, 2011, an M9-class earthquake hit four major factories of Japan Tobacco Inc. (JT), the third-largest tobacco manufacturer in the world. While JT's factories in other areas of the country were intact, JT was not capable of maintaining the full capacity of production. Unable to continue the supply of all products, JT decided to permanently terminate certain products produced in the earthquake-stricken area. This unforeseen decision soon affected the availability of these discontinued products in the market across the country. Smokers who regularly purchase these discontinued products were severely affected and had to consider changing their purchasing patterns. How did they react to this product discontinuation? Did they stop smoking or reduce tobacco consumption? Or did they search for similar alternatives and keep the consumption as before?

To answer these questions, we applied a difference-in-differences approach, in which we compare tobacco purchases of affected smokers before and after the product discontinuation. The analysis used large-scale, nationally representative consumer scanner data in Japan from January 2010 to December 2014, which includes 16,533 smokers in a total of 75,817 participants. Our empirical analyses yield three major findings. First, we show that when one or more favorite products

are taken away from one's choice set, consumers switch to products that are lower in tar and nicotine while keeping the number of cigarettes consumed as before. Second, the discontinued products were relatively high in tar and nicotine than average. After the product discontinuation, affected tobacco consumers did not appear to search for new alternative tobacco products to compensate, and they remained consuming cigarettes that are lower in tar or nicotine from a smaller choice set. Third, tobacco consumption, in terms of tar and nicotine volume, did not decrease in the short term but continued to decline significantly in the long term.

These findings contrast starkly with the conventional literature discussing taxation as a tool to reduce tobacco consumption. Previous studies suggest that addictive consumers reduce the number of cigarettes in response to price increases but switch to high-nicotine products to maintain the desired level of nicotine intake (Adda and Cornaglia, 2006; Cotti et al., 2016). However, such compensating behavior does not exist when a smoker is facing a shrunken choice set. Previous studies also suggest that tobacco consumption will decrease with tax increases. Yet such a positive effect can only last for a while and consumption gradually returns to pre-tax levels (Callison and Kaestner, 2014). In contrast, the impact of a shrunken choice set on reducing tobacco consumption can be sustained in the long run.

Although removing some choices of consumers could also reduce tobacco consumption, it is not sensible to advance that affecting consumer choice set could lead to a better outcome than taxation. After all, our study and taxation literature are based on different mechanisms. Taxation affects tobacco consumption through the affordability of consumers, whereas the choice set affects tobacco consumption through the availability of products. Tax increases have been considered as the most effective way to control smoking prevalence (World Health Organization, 2015). However, this policy may not be as efficient as other control policies.

For example, smoke-free public areas could reduce tobacco consumption by 20%. Achieving the same effect requires a 40% increase in tobacco prices on markets such as Japan where the price elasticity of tobacco is -0.5 (Wan, 2006). Our study provides a new angle for decision-makers to develop tobacco control policy. Health interventions using consumer choice sets are not new. For example, soda bans in school have shown positive effects on reducing consumption (Terry-McElrath et al., 2015). Regarding tobacco control, product bans on flavored cigarettes have significantly reduced adolescent tobacco use (Courtemanche et al., 2017). To date, e-cigarettes have also been banned in several countries. However, there is little evidence showing the effectiveness of such product bans on a full range of products. Our discussions on the choice set implicitly provide evidence for the causal impact of product bans on tobacco control.

The rest of the paper proceeds as follows. Section 2 describes the background of the study. Sections 3 and 4 describes the data and empirical strategies. Section 5 and 6 describe the estimation results and discuss the mechanism, and Section 7 concludes.

2 Tobacco Market in Japan

Since 1970, Japan has been ranked among the top-10 cigarette-consuming countries in the world (Hoffman et al., 2019). The sales volume exceeded 3,000 trillion cigarettes until it gradually declined after 2000 to reach 1,300 trillion cigarettes in 2018 (Tobacco Institute of Japan 2019). The sales revenues remained stable at around 40,000 trillion Japanese Yen. The leading player in the domestic market is Japan Tobacco Inc.(JT), which is the third-largest tobacco company in the world and controls over 60% of the domestic sales (Japan Tobacco, 2018). It was a state-owned monopoly until it was privatized in 1985, with the government owning 67%. This share declined to a half in 2004 and then to one-third in 2016 (MacKenzie et al., 2017). Tobacco contributes 2 trillion yen annually to the

government in taxes and dividends. The government maintains control over the manufacture, distribution, and pricing of all tobacco products. There is a wide variety of cigarettes on the market, from ultra-low tar (1 mg per stick) to high tar cigarettes (up to 42 mg per stick). Despite product variations, product prices are almost uniform, and there is no price discrimination across regions (see Figure 1). Tobacco manufacturers are not allowed to raise product prices in addition to tax increases by the government. Recent tax increases occurred in 2010 and 2014. Stockpiling and increased consumptions were triggered before tax hikes. After a period of adjustment, tobacco consumption gradually returned to the pre-tax level (see Figure 2). Other than tax increases, cigarette prices were fixed even when the market faced a short supply.[1]

[Insert Figures 1 and 2 Here]

Unlike tax increases, supply shocks could affect tobacco consumption in the longer term. Back in 2011, there was a supply shock of cigarettes due to a devastating earthquake. On March 11, 2011, the Great East Japan earthquake and tsunami hit two cigarette manufacturing factories of JT and another two production-related plants that produce semi-products and filters. With the shutdown of these factories and blackouts, JT's remaining four factories had only 70% of the normal capacity. A stable supply of all products became difficult. Two weeks after the earthquake, JT announced that it would temporarily withhold shipments between March 30 and April 10 to increase production and inventories of 25 key products, which accounted for about 65% of its total sales (Japan Tobacco, 2011). Starting April 11, JT gradually resumed supply of key products. Until May 11, two months after the earthquake, JT committed to resuming the supply of 73 products by early August, but at the same time decided to end the supply of 23 products that had a low market share before the earthquake. These permanently discontinued products had, on average, higher levels of tar and nicotine content (0.27

[1]Black-marketing of tobacco was not reported.

mg and 1.33 mg, respectively) than other surviving JT products and imported products Table A1 in the Appendix). Despite a small market share, these permanently discontinued products have significantly affected the choices available to some smokers. Their choice sets shrank immediately. This supply shock was unexpected, so consumers could not stockpile the products before the earthquake as they did before tax increases.

3 Data

We used nationally representative consumer scanner data, called SCI (Nationwide Consumer Panel Survey), in Japan from April 2010 to December 2014. SCI is analogous to other leading market research databases such as Nielsen Homescan and Kantar WorldPanel. The INTAGE Group collected the data from January 2010. The company recruited participants through web banners and job search websites, and the participants received reward points as a return on participation from a website of the INTAGE Group (https://www.cue-monitor.jp/), and those reward points can be exchanged for cash and various gift cards. Based on the population census, the sampling procedure was a quota sampling technique, so the final sample had the same proportions of individuals as the entire population in terms of sex, marital status, and age.

The data company conducted the baseline survey in April 2010 and covered 21,607 individuals from 11 standard regions from north to south (Hokkaido, Tohoku, Kanto, Keihin, Keihanshin, Tokai, Hokuriku, Chugoku, Shikoku, Kyushu, and Okinawa). In the follow-up surveys, they recruited additional individuals in the same way as the baseline survey. The sample size reached 55,790 individuals in 2014. Participants continued to stay in the panel as long as they complied with the reporting rules set by the INTAGE Group, who regularly monitored the quality of the submitted data. Those who withdrew or failed to meet the reporting criteria were replaced by individuals with the same sex, marital status, age, and

residential area.

After each purchase, participants used mobile devices to scan the barcodes on products and entered the date of purchase and receipt information (including unit price, number of items purchased, the total amount paid, and store name) on the survey website. Using the scanned barcodes, the INTAGE Group collected product attributes, such as brand, package size, manufacturer, tar and nicotine content, flavor, and cigarette size. The information on the tar and nicotine content of cigarettes was in line with the International Organization for Standardization testing procedures. Heated, cut, and smokeless tobacco (2% of the sample) were excluded from the analysis because of missing tar and nicotine information.

Pooling all participants in the survey between April 2010 and December 2014, we obtained a final sample of 75,817 consumers who either purchased or did not purchase cigarettes. The average length of participation in the survey was 30.8 months (1 to 57 months). Among these consumers, 16,533 purchased at least one pack of cigarettes between January 2010 and December 2014. Table 1 shows summary statistics for monthly tobacco purchases and socioeconomic status (SES) of cigarette purchasers. We used the number of cigarettes to measure purchase volume. However, this general index assumes cigarettes to be homogeneous and does not capture differences in tar and nicotine content. To assess tobacco use, the amount of tar and nicotine rather than the number of cigarettes smoked has real importance. Tar is responsible for the increased health risks of smoking, whereas nicotine causes addiction. Therefore, we also used the total amounts of tar and nicotine in purchased products to quantify purchase volume.

[Insert Table 1 Here]

The sample comprises 542,582 observations for total monthly purchases from 16,533 cigarette purchasers. In one month, a typical (median) consumer purchased 20 cigarettes, whereas some did not have a purchase, and some purchased 20,000 cigarettes. The average total tar and nicotine in purchased cigarettes were 1,311.61

mg and 108.84 mg, respectively. The SES of cigarette purchasers included age, sex, family size, education (secondary or lower as reference, with junior college or equivalent, and higher education as categories), household income (less than 4 million yen as reference, with categories of 4-5.49 million, 5.5-6.99 million, 7-8.99 million, 9 million and higher), and occupation (drivers and construction workers as blue-collar workers, with office workers as white-collar workers, students, unemployed, and others other than unemployed as categories).

Cigarette purchasers were equally distributed between males and females with an average age of around 44. Nearly two-thirds of purchasers were married, and the average household size was around three people. Purchasers with secondary or lower education had the highest proportion (41%), followed by highly educated purchasers (35%) and those with junior college or equivalent (24%). Almost half of the purchasers had an annual family income lower than 5.5 million yen. Employed purchasers comprised 75% of the purchasers and 65% of them were white-collar workers. Blue-collar workers, students, unemployed and others occupied another 35% of the purchasers.

Table 1 further shows the differences between consumers whose tobacco choice set was affected and those whose choice set was not. Purchasers were affected if they bought discontinued products at all before the earthquake. In the sample, 664 purchasers (4%) were affected. As of August 2011, discontinued products became out of stock, although there have been sporadic purchases since then (Figure 3). Even though the product discontinuation was accidental, unaffected purchasers on average bought fewer cigarettes and less tar and nicotine in cigarettes.

[Insert Figure 3 Here]

Figure 4 provides time trends in purchase volume for both groups. The two groups had a similar trend, and the affected group had a higher purchase volume across all time periods. Regarding the SES, affected purchasers were more likely to be older, male, married, and employed. Affected purchasers with higher educa-

tion were 7% higher than their non-affected counterparts. In terms of household income, affected purchasers were more likely to be from middle to high-income families (5.5 million and over). Despite a difference of 1%, the household incomes of the two groups are close to each other.

[Insert Figure 4 Here]

4 Empirical Strategy

We used a difference-in-differences (DID) approach to estimate the impact of the change in the choice set due to product discontinuation on tobacco consumption. The regression takes the following format:

$$Volume_{it} = \beta_0 + \beta_1 Treat_i + \beta_2 Post_t + \beta_3 Treat_i \times Post_t + X_{it}\theta + \eta_i + \lambda_t + \varepsilon_{it} \quad (1)$$

where indices i and t represents individual and month. $Volume_{it}$ is the total number of cigarettes or the amount of tar (nicotine) purchased. $Treat_i$ is a dummy variable indicating if individuals were affected by the production discontinuation or not. The key to defining affected (treatment group) and unaffected (control group) individuals is whether the individual had purchased discontinued products before the earthquake. $Post_{it}$ is a dummy variable that equals one if the discontinued products were out of stock and zeroes otherwise. The impact of product discontinuation on purchases is explained by the coefficient (β_3) of the interaction between treatment and post-shock. X_{it} represents a vector of individual characteristics, including age, gender, education, household income, and residential region.η_i and λ_t are individual and time fixed effect. The standard error is clustered at the individual level in all estimations.

Note that consumers' choices might not be random, although the earthquake was an exogenous shock. JT's decision to discontinue certain products may be correlated with product characteristics alongside the factory shutdown, and the

discontinued items might have been preferred by smokers with certain characteristics. To address possible selection bias, we combine propensity scoring matching (PSM) with DID estimations. The sample includes individuals from the treated and control groups before the earthquake from April 2010 to February 2011. The propensity score of being affected by the product discontinuation is estimated by the following probit regression.

$$PS_i = Pr(D_i = 1|x_i) = \Phi(x_i'\gamma + \epsilon_i) \tag{2}$$

where $\Phi(\cdot)$ is a standard normal cumulative distribution function. x_i is a vector of individual characteristics as in Eq.(1). Based on the pre-earthquake data, we applied kernel matching (Heckman et al., 1998) to select individuals with a similar probability of being affected by the supply shock. The choice of the bandwidth is based on the rule-of-thumb bandwidth for Epanechnikov kernels (Silverman, 1986). Other matching methods such as nearest neighbor (NN) matching (Rubin, 1973) and caliper matching (Rosenbaum and Rubin, 1985) are also used to check the robustness of estimates. Nearest neighbor matching is performed without replacement. For caliper matching, the tolerance level on the maximum propensity score distance was calibrated at 0.01 standard deviation. After matching, individuals in the two groups should not exhibit statistically significant differences in the means of the characteristics. We then create a sample of matched individuals in treated and control groups and perform DID estimation specified in Eq.(1).

An important assumption of our DID identification strategy is the parallel trend, which requires the trends in outcomes without the treatment would have been the same in both the treatment and the control groups. We test this assumption by estimating a slightly modified version of Eq.(1). The interaction term $Treat_i \times Post_t$ is replaced by the sum of interaction terms between treatment and all the month dummies ($\sum Treat_i \times Month_t$). The coefficients of the

interaction terms explain the validity of the parallel trend assumption. Figure B.1 in the Appendix plots the estimated monthly effects of production discontinuation on the total amount of tar purchased. The points and spikes represent the magnitudes of point estimates and 95% confidence intervals, respectively. The estimates are significant at the 5% level if the confidence intervals do not cross zero. Without matching, there is a significant pre-trend before August 2011. Considering the differences between the treatment and control groups, we conduct matching and use paired samples to test the parallel trend assumption. Now, we observe no significant pre-trend before August 2011.

5 Results

This section discusses the impact of a changing choice set on cigarette purchases. We have considered the relevance of product discontinuation, geographical variation, and short- and long-term changes in purchases.

5.1 Baseline Estimation

In the baseline estimation, we define treated individuals as those who purchased permanently discontinued products before the earthquake. The treated group comprises 664 cigarette purchasers, accounting for 4% of the full sample. The purchase or consumption is usually measured by the number of cigarettes. But the number does not fully reflect potential health risks associated with tar and nicotine content in cigarettes. Given this, we also calculated the total amount of tar and nicotine contained in products to measure purchases.

Table 2 presents the baseline estimation results of Eq.(1). All columns have controlled for individual characteristics (age, sex, marital status, education level, household income, and residential region) as well as month fixed effects. Cigarette purchases in the odd-numbered columns are in logarithmic scale. In panel A, a matched sample generated by kernel matching is used for estimation. The matched

sample comprises 3,962 individuals, of which 520 were treated. In column (1), the estimated coefficient is -18.6, which is statistically significant at the 5% level. This finding suggests that, with the advent of product discontinuation, cigarette purchases of affected individuals have reduced by 18.6 sticks. The estimated coefficient in column (2) illustrates the percentage change in purchases of the treated group after product discontinuation. The reduction in cigarette purchases was 16%. The remaining columns report changes in total tar and nicotine in cigarettes purchased. Total tar and nicotine were reduced by 176.8 mg (or 23%) and 13.2 mg (or 17%) per month, respectively. Such reduction is approximately equivalent to a 20-cigarette pack containing 8 mg of tar or 0.6 mg of nicotine per stick. In panel B, a 1:1 NN matching produced a smaller matched sample of 474 treated individuals. In panel C, the matched sample includes 520 treated individuals, which was obtained by matching one treated unit to the four nearest control units. In panel D, caliper matching yielded a matched sample of 519 treated individuals. The results in the last three panels are consistent. Both the number of cigarettes and the total tar and nicotine purchased have decreased. Overall, as a product in the choice set diminished, smokers appeared to consider reducing their cigarette consumption.

[Insert Table 2 Here]

5.2 Relevance of Product Discontinuation

A tobacco brand usually has multiple sub-brands targeting different consumers. Over time, a consumer will develop loyalty to a product. A consumer's choice set may include various products, but his or her preferences for each may vary. The disappearance of one choice in a choice set does not necessarily affect consumption patterns. Only the discontinuation of essential products in the set may impose a real impact on purchasing behavior. Therefore, we further examine the impact of a changing choice set by redefining the treated group. The importance of a product

in the choice set is measured by purchase frequency. In the following analysis, individuals are assigned to treatment group if their most frequently purchased products were discontinued. We consider two ways to define a product by: 1) tar/nicotine content; and 2) brand name. Some consumers may be less concerned about the brand name and more about the risks associated with tar and nicotine content in a cigarette, while others may be loyal to a brand and choose products regardless of tar or nicotine content.

We first estimate the changes in purchases when the tar/nicotine content of the discontinued items had been most preferred. According to the new definition, the treated group now has 347 individuals. We re-estimate Eq. (1), and Table 3 presents the results. Compared to the baseline estimates in Table 2, we find no significant decrease in the total number of cigarettes for the treated individuals as the most preferred products became unavailable on the market. In contrast, the total tar in purchased cigarettes has decreased by 145.8 mg per month after the discontinuation. However, such change explained in percentages is not significant. Similarly, we only observe a 13% decrease in the total nicotine after the product discontinuation.

We then estimate the impact of discontinuation when the most preferred brand (and not tar/nicotine level) was discontinued. The sample size of treated individuals further reduces to 166. In panel B of Table 3, the number of cigarettes in a month continues to show no significant changes, whereas the total tar and nicotine purchased in a month experienced considerable decreases after the discontinuation. The reductions are statistically significant in both absolute value and percentage. Production discontinuation reduced 325.8 mg (35%) in tar and 23.7 mg (25%) in nicotine purchased in a month, which was much larger than the baseline results. Overall, the impact of product discontinuation on the number of cigarettes purchased depends on how we define treatment. However, no matter how the treatment is defined, the total tar in cigarettes continues to decline after

product discontinuation.

[Insert Table 3 Here]

5.3 Geographical Variation

The earthquake mainly hit the Tohoku region, where the smoking prevalence has been high. Notably, the smoking rates in Fukushima, Iwate, and Miyagi – the three prefectures severely affected by the earthquake – have consistently ranked among the top 10 in the country, with smoking rates of around 38% in 2013 (Ministry of Health, Labor and Welfare, 2013). Product discontinuation due to the earthquake may have a greater impact on consumers living in prefectures with high smoking rates. To test the geographic variation in purchase changes, we included a dummy variable representing six prefectures in Tohoku (Iwate, Fukushima, Akita, Aomori, Yamagata, Miyagi) and estimated the effect of the choice set on purchasing behavior using the following regression.

$$\begin{aligned} Volume_{it} = \alpha_0 + \alpha_1 Treat_i \times Post_t + \beta_2 Post_t \times Tohoku_i \\ + \beta_3 Treat_i \times Post_t \times Tohoku_i + X_{it}\theta + \eta_i + \lambda_t + \varepsilon_{it} \end{aligned} \tag{3}$$

The coefficient α_3 explains the heterogeneous effect of product discontinuation on cigarette purchases across regions. To eliminate the impact of relocation on purchases, we excluded consumers who changed residential areas. These consumers accounted for 2% of the sample (328 out of 16,533).

The estimation results are shown in Table 4. We have controlled for individual fixed effect and month fixed effect in all columns. In column (3), the negative estimate of $Treat \times post$ suggests a significant decrease in total tar after product discontinuation in all regions. Combing the positive estimate of $Treat \times post \times Tohoku$, we find that the extent of reduction, however, varies across regions. Product discontinuation has a greater impact on consumers liv-

ing in other regions. For consumers living in the Tohoku region, the total tar in cigarettes has declined less than consumers living in other regions with low smoking rates.

[Insert Table 4 Here]

5.4 Short- and long-term effects

Our analyses thus far examined the average changes in cigarette purchases after the supply shock associated with product discontinuation in the 40 months between August 2011 and December 2014. We then examined how purchasing behavior changes across different periods. Consumers facing supply shocks may gradually adjust the number of cigarettes purchased each month, search for alternatives, or even consider stopping consumption. We conduct the same estimation for different time spans to explore the short- and long-term effects of product discontinuation. As above, consumers were classified as treated if their most frequently purchased products were discontinued. Table 5 shows the changes in purchases until 6, 12, 24, and 36 months after the products were out-of-stock in August 2011.

Until February 2012 – six months after the discontinued products became unavailable, we did not observe a significant change in purchases measured by the number of cigarettes and total tar and nicotine. In the first six months, consumers appeared to search for alternatives, and the new choice set does not seem to be formed within the short term. We found a significant reduction of purchases when we expanded the post-treatment period until 24 and 36 months after August 2011. The average reduction in total tar purchased was 132.8 – 139 mg. The number of cigarettes purchased did not change significantly, however. As demonstrated above, the purchasing pattern might not change immediately, but it can exhibit a long-term adjustment. Consumers switched to low-tar type cigarettes without changing the number of cigarettes purchased.

[Insert Table 5 Here]

6 Mechanisms

We have examined the causal effect of a change in the choice set on tobacco purchases. The total tar purchased each month showed a decreasing and long-term trend after product discontinuation. Several factors such as income, education attainment, and attitudes toward risks could drive consumers to alter purchasing patterns (Perelman et al., 2017; Brown et al., 2018; Bratti and Miranda, 2010; Cutler and Glaeser, 2005; Hanaoka et al., 2018). The availability of substitutes and loyalty to a product also could contribute to changes in the purchasing pattern (Dawes, 2014). In the following subsections, we will discuss possible factors that may influence purchasing patterns.

6.1 Socioeconomic Disparities

Since income is positively associated with smoking behavior (Perelman et al., 2017), a reduction in consumption could be due to job losses and a decrease in income.

Cigarette smoking is usually among people of low socioeconomic status. Income is one of the factors that positively associated with smoking behavior (Perelman et al., 2017). Job losses or a decrease in income may force smokers to reduce tobacco consumption. It follows that the decrease in cigarette consumption may be due to unemployment or reduced income caused by the earthquake. Meanwhile, existing literature suggests that wealthy people are more likely to quit smoking because of their strong commitments to quit (Reid et al., 2010). It is natural to ask the role of income in tobacco consumption. To answer this question, we explored the differential impact of choice set across different household income groups.

First, we checked the data to see how many people lost their jobs or income after the earthquake. We find that over 90% of consumers had consistent income during all survey periods. Consumers whose income had been decreased consti-

tuted less than 5% of the sample (See Figure B.3). In this context, job losses due to the earthquake can hardly be a factor driving reductions in cigarette consumption. Next, excluding consumers with changing incomes, we estimated changes in consumption across income groups using Eq.(1). Table 6 reports the results. The low-income group (less than 4 million yen) did not have systematic changes in consumption before and after the product continuation. Surprisingly, cigarette purchases in the middle-to-high income class (7-899 million yen) have decreased significantly. Consumers in this group purchased 52 fewer cigarettes per month, and the total amount of tar was reduced by 55 percentage points. This result supports the finding of Reid et al. (2010).

Except for income, changes in cigarette consumption can be explained by education attainment. While income and education attainment are closely related, the education gradient largely explains disparities in smoking (Cutler and Glaeser, 2005). Higher educated individuals are more likely to quit smoking and have a lower level of smoking intensity (Bratti and Miranda, 2010). They can also reduce cigarette consumption more than those with other education levels. We now looked at the differential impact of choice set on tobacco consumption by educational groups. This estimation also used the specification in Eq.(1), and individual- and time-fixed effects were controlled. The results, reported in Panel B of Table 6, show that consumers of all educational levels did not significantly change their cigarette purchases after product discontinuation. Educational levels might not be a reason that affects tobacco consumption.

[Insert Table 6 Here]

6.2 Changes in the Choice Set

The purchase volume does not fully reflect the purchasing patterns. Instead, the choice in the set is the key to answering changes in purchasing patterns. Variations in the choice set can be measured by median, maximum, the most frequently

purchased tar type, and the size of a choice set. The tar content in each cigarette suggests whether an individual is a high-, medium- or low-tar smoker. The size of the choice set reflects the preference for product diversity (Andrews and Srinivasan, 1995; Salisbury and Feinberg, 2012). In our sample, while individuals had a broad choice over products, there was not much variability in the type of tar chosen. About 81% of monthly purchases were concentrated on one type of tar. Based on Eq.(1), we quantify the impact of product discontinuation on the choice set.

Table 7 shows that the tar content per cigarette has decreased in the post-treatment period. The decrease in the median or most frequently purchased tar type was 0.31—0.33 mg. For heavy smokers (who smoke 25 or more cigarettes a day) (Wilson et al., 1992), the monthly reduction amounted to 247.5 mg. The maximum tar of each cigarette also was reduced by 0.55 mg. In addition to the tar type, affected consumers had a lower preference for choice diversity. The results suggest that consumers switched to lower-tar cigarettes, and they were less likely to search for alternatives or to try new options if their choice set shrank because of product unavailability. This switch did not change the purchasing volume of cigarettes.

Such a phenomenon may be explained by the theory of choice set formation in economics and marketing research. On the one hand, consumers may be variety-seeking and enjoy the satisfaction from a diversity choice set (Simonson, 1990; Salisbury and Feinberg, 2012). On the other hand, there are behavioral economic studies examining a choice-set dependent utility in the context of self-control (Gul and Pesendorfer , 2004; Guindon et al., 2018). Studies show that when consumers suffer from self-control problems, they may prefer a smaller choice set with fewer tempting goods. Therefore, if smokers want to reduce addiction and are aware of their self-control problem, they may not compensate and reduce consumption when a product that is high in nicotine is taken away from their choice set. Our empirical evidence supports the latter.

[Insert Table 7 Here]

6.3 Product Switching

Besides product choice, we investigated how consumers searched for alternatives when their preferred items were discontinued. Figure 5 illustrates switching patterns for consumers whose preferred items were discontinued. There are four switching patterns: no search for substitutes, vertical searching, horizontal searching, and two-dimensional searching. Each brand has a variety of products with different levels of tar and nicotine. Consumers switch vertically if they choose a different product within a brand. They switch horizontally if they choose products with the same tar content but from a different brand or switch to different brands with different tar and nicotine content.

[Insert Figure 5 Here]

To identify the direction of switching, we used all the transaction records of 4,879 smokers from April 2010 to February 2011 and constructed a baseline choice set for each consumer. Among the affected consumers, about 65–80% of transactions did not have new alternatives in the choice set, whereas vertical, horizontal, and two-dimensional searching had only a small portion of the transactions (Figure B.4). This implies that the reduction in purchases of tar is largely driven by a shift from discontinued item to a lower-tar item within the existing choice set.

To formally examine the switching behavior over time, we used data from April 2011 and onward and ran a probit regression to estimate the probability of switching using the following form:

$$\begin{aligned} &Prob(Y_{it} = 1 | Treat_i, Month_t, X_{it}) \\ &= F(\alpha_0 + \alpha_1 Month_t + \alpha_2 Treat_i + \alpha_3 Month_t \times Treat_i + X_{it}\Gamma) \end{aligned} \tag{4}$$

Y_{it} is the binary variable indicating if the consumer has searched for alternatives. Searching can be vertical, horizontal, or two dimensional. The sign of α_3 indicates

whether there is an increase or decrease in the predicted probability of searching. Figure 6 visualizes the estimated α_3. The probability of searching increases during the period between September 2011 and May 2012 – starting the fourth month after JT announced the termination of its products in May 2011. This assumed that an adjustment of the choice set, if any, would occur in the first year, but after that, the consumers would select items from their established choice set.

[Insert Figure 6 Here]

7 Conclusion

This paper offers evidence on how changes in the choice sets of consumers in the Japanese tobacco market influenced consumption. We exploited the discontinuation of some tobacco products because of factory shutdowns after the great earthquake hit the Tohoku region of Japan. We found that the supply shock had a significant effect on the size of the choice set, and therefore, cigarette purchases. In the case of tobacco, consumers did not exhibit preference over variety – they did not compensate for the loss of preferred items by adding alternatives, similar items to their shopping bags. Instead, they purchased items that were lower in tar and nicotine from their existing choice set. We did not find diversification effect as suggested by previous studies (Andrews and Srinivasan, 1995; Salisbury and Feinberg, 2012). A shrunken choice set driven by product discontinuation could encourage consumers to reduce tobacco purchases, particularly in terms of total tar purchased. The discontinued items were relatively high in tar and nicotine in the market, so they were more tempting for certain consumers. In general, switching to lower-tar cigarettes while purchasing the same number of cigarettes suggests that tobacco purchasers had "healthier" purchasing or consumption patterns after the shock.

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Figures

Figure 1: Distribution of tar per cigarette and price per pack

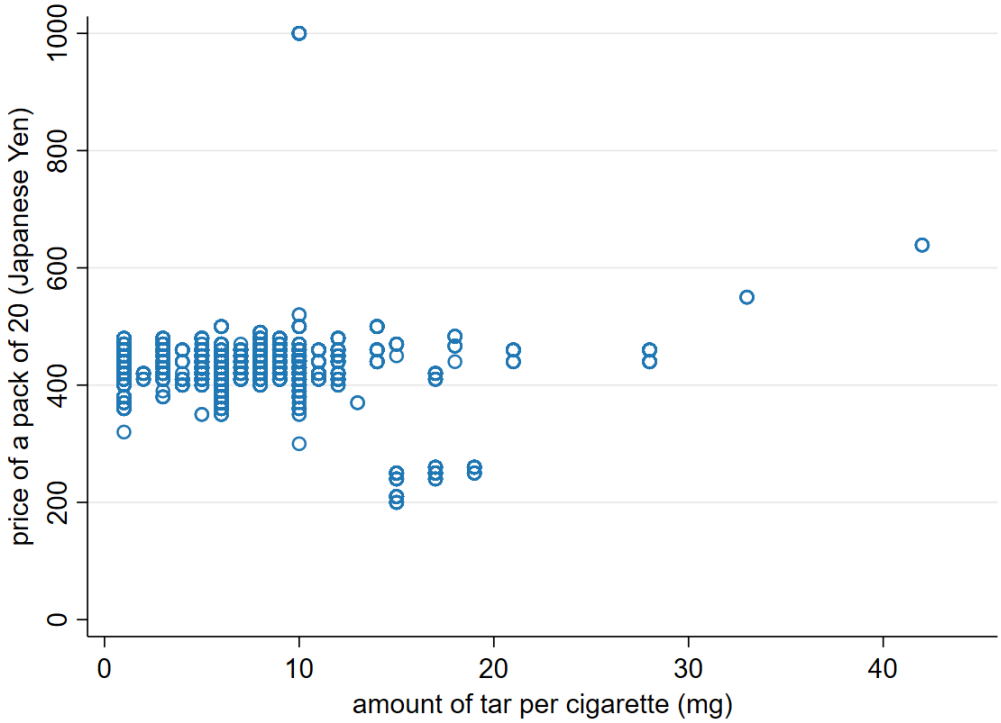
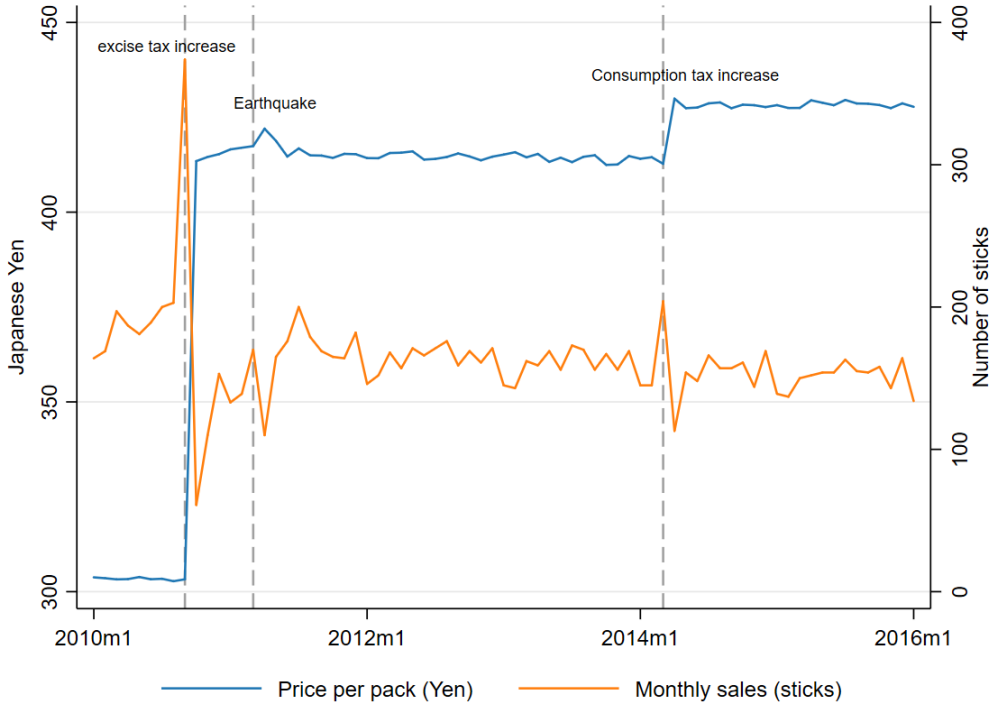


Figure 2: Tobacco sales and price over time



Source: Tobacco Institute of Japan. Note: The price per pack is calculated as the monthly sales revenue divided by the number of sticks sold. From October 2010, the excise tax on tobacco increased by about 40%. Cigarette price increased again as the consumption tax increased to 8% from April 2014.

Figure 3: The stock of discontinued products over time

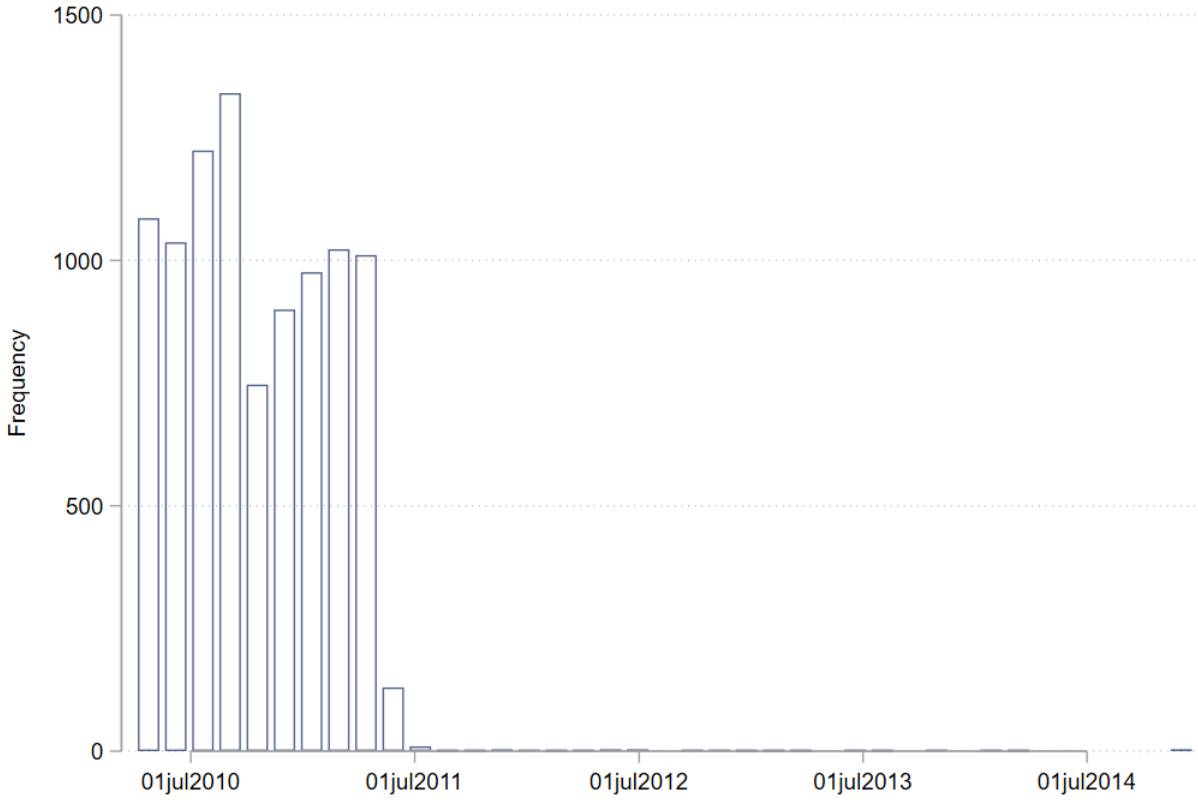


Figure 4: Cigarette purchases by groups: affected vs. non-affected groups

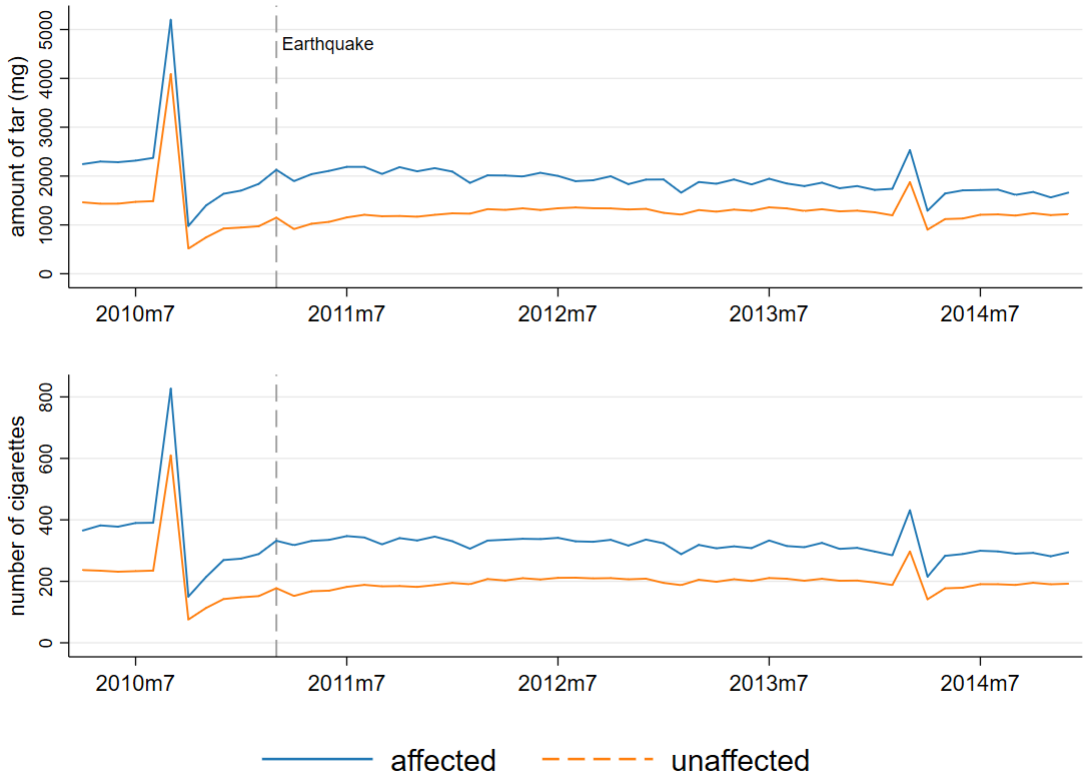
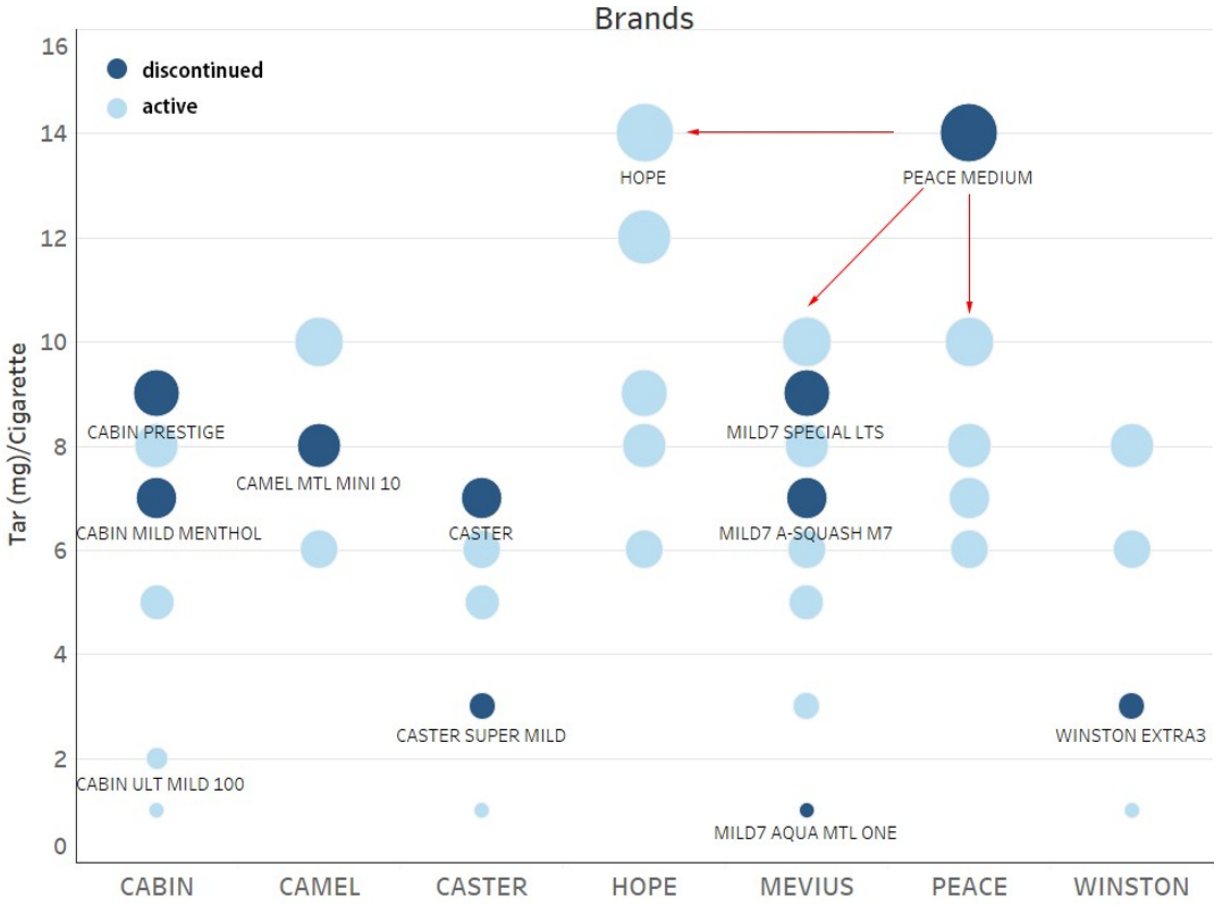


Figure 5: Patterns of Product Switching



NOTE: This figure only shows 7 brands of JT products. JT has changed the Mild Seven brand name to Mevius since August 8, 2012.

Figure 6: Probabilities of Product Switching

Tables

Table 1: Summary of Statics of Tobacco Purchasers

	Full Sample				Subgroup Means		
Variables	Mean	SD	Min.	Max.	Unaffected	Affected	Mean Difference
Number of cigarettes	206.74	334.5	0	20,000	199.7	326.6	-126.94***
Total amount of tar (mg)	1311.61	2900.4	0	273,000	1273	1969	-696.52***
Total amount of nicotine (mg)	108.84	234.9	0	24,700	105.5	165.4	-59.88***
Tar per cigarette (mg)	6.19	4.89	1	42	6.23	5.79	0.45***
Nicotine per cigarette (mg)	0.52	4.89	0.1	2.3	0.52	0.49	0.03***
Age	43.94	11.6	16	73	43.7	48.08	-4.39***
Male	0.5	0.5	0	1	0.49	0.68	-0.19***
Married	0.68	0.47	0	1	0.68	0.64	0.04***
Family size	2.98	1.33	1	6	2.98	2.87	0.11***
Education							
Secondary school or lower	0.41	0.49	0	1	0.41	0.39	0.02***
Junior college or equivalent	0.24	0.43	0	1	0.25	0.2	0.04***
Higher education	0.35	0.48	0	1	0.34	0.41	-0.07***
Family Income							
Less than 4 million	0.3	0.46	0	1	0.3	0.29	0.01***
4-5.49 million	0.21	0.41	0	1	0.21	0.21	0.00
5.5-6.99 million	0.17	0.38	0	1	0.17	0.18	-0.01***
7-8.99 million	0.15	0.36	0	1	0.15	0.14	0.02***
9 million and higher	0.16	0.37	0	1	0.16	0.18	-0.01***
Employed	0.75	0.43	0	1	0.75	0.79	-0.04***
Occupation Type							
Blue-collar	0.12	0.32	0	1	0.12	0.14	-0.02***
White-collar	0.65	0.48	0	1	0.65	0.67	-0.02***
Student/unemployed/others	0.24	0.42	0	1	0.24	0.2	0.04***

Note: *, **, and *** denote significance at the 10%, 5%, and % levels, respectively.

Table 2: The Impact of Production Discontinuation on Purchase Volume: Baseline

	# Sticks	Log (1+sticks)	Total tar	Log (1+tar)	Total nicotine	Log(1+nicotine)
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. Kernel matching						
$Treat \times Post$	-18.6**	-0.16**	-176.8**	-0.23**	-13.2**	-0.17***
	(9.11)	(0.078)	(76.6)	(0.097)	(6.27)	(0.067)
Observations	188,481	188,481	188,481	188,481	188,481	188481
R^2	0.11	0.078	0.067	0.075	0.069	0.079
Panel B. 1:1 NN matching						
$Treat \times Post$	-35.9**	-0.17	-244.6**	-0.21	-19.3**	-0.16
	(15.2)	(0.12)	(117.0)	(0.16)	(9.82)	(0.11)
Observations	46,836	46,836	46,836	46,836	46,836	46,836
R^2	0.13	0.096	0.096	0.092	0.096	0.098
Panel C. 4-NN matching						
$Treat \times Post$	-22.0*	-0.084	-214.6**	-0.12	-16.2**	-0.089
	(12.0)	(0.094)	(98.1)	(0.12)	(8.14)	(0.080)
Observations	95,831	95,831	95,831	95,831	95,831	95,831
R^2	0.13	0.090	0.093	0.086	0.094	0.091
Panel D. Caliper matching						
$Treat \times Post$	-18.8**	-0.17**	-181.1**	-0.24**	-13.5**	-0.17***
	(9.12)	(0.078)	(76.4)	(0.097)	(6.25)	(0.067)
Observations	188,563	188,563	188,563	188,563	188,563	188563
R^2	0.11	0.078	0.067	0.075	0.069	0.080
Individual characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Month fixed effect	Yes	Yes	Yes	Yes	Yes	Yes

Note: Standard errors shown in parentheses are clustered at the individual level.
*, **, and *** denote significance at the 10%, 5%, and % levels, respectively.

Table 3: Re-defining the Treated Group

	# Sticks	Log (1+sticks)	Total tar	Log (1+tar)	Total nicotine	Log(1+nicotine)
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. most frequently purchased products (tar per stick) were discontinued						
$Treat \times Post$	-4.07	-0.093	-145.8*	-0.18	-9.11	-0.13*
	(10.5)	(0.100)	(82.7)	(0.12)	(6.52)	(0.077)
Individual characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Observations	187,754	187,754	187,754	187,754	187,754	187,754
R^2	0.018	0.049	0.011	0.049	0.011	0.046
Panel B. most frequently purchased products (brand) were discontinued						
$Treat \times Post$	-20.9	-0.22	-325.8**	-0.35*	-23.7**	-0.25**
	(17.1)	(0.15)	(137.9)	(0.18)	(11.2)	(0.12)
Individual characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Month fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Observations	25,484	25,484	25,484	25,484	25,484	25,484
R^2	0.015	0.052	0.012	0.050	0.012	0.047

Note: Standard errors shown in parentheses are clustered at the individual level.
*, **, and *** denote significance at the 10%, 5%, and % levels, respectively.

Table 4: Geographical Variations

	# Sticks	Log (1+sticks)	Total tar	Log (1+tar)	Total nicotine	Log(1+nicotine)
	(1)	(2)	(3)	(4)	(5)	(6)
$treat \times post$	-2.59	-0.076	-182.1**	-0.18	-11.3	-0.14*
	(10.9)	(0.11)	(90.7)	(0.12)	(7.13)	(0.082)
$post \times northeast$	-6.02	0.051	-164.4*	0.021	-12.9	-0.019
	(15.3)	(0.14)	(96.6)	(0.17)	(7.97)	(0.11)
$treat \times post \times northeast$	31.2	0.014	627.6***	0.18	43.0***	0.22
	(36.0)	(0.41)	(174.9)	(0.44)	(14.0)	(0.29)
Observations	180,292	180,292	180,292	180,292	180,292	180,292
R^2	0.10	0.085	0.059	0.081	0.061	0.084

Note: Standard errors shown in parentheses are clustered at the individual level.
*, **, and *** denote significance at the 10%, 5%, and % levels, respectively.

Table 5: Short- and Long-term Effect

	# Sticks (1)	Log (1+sticks) (2)	Total tar (3)	Log (1+tar) (4)	Total nicotine (5)	Log(1+nicotine) (6)
Panel A. 6 months after out-of-stock (Feburary 2012)						
$Treat \times Post$	-2.52	-0.11	-54.0	-0.18*	-2.87	-0.13*
	(9.11)	(0.088)	(74.9)	(0.11)	(6.16)	(0.071)
Observations	77,928	77,928	77,928	77,928	77,928	77,928
R^2	0.0076	0.0036	0.0056	0.0038	0.0057	0.0038
Panel B. 12 months after out-of-stock (August 2012)						
$Treat \times Post$	-0.72	-0.096	-79.5	-0.17	-4.91	-0.13*
	(9.61)	(0.088)	(74.1)	(0.11)	(6.08)	(0.070)
Observations	99,629	99,629	99,629	99,629	99,629	99,629
R^2	0.0078	0.0098	0.0059	0.011	0.0060	0.010
Panel C. 24 months after out-of-stock (August 2013)						
$Treat \times Post$	-0.41	-0.092	-132.8*	-0.17	-8.62	-0.13*
	(9.86)	(0.095)	(77.6)	(0.11)	(6.20)	(0.074)
Observations	139,723	139,723	139,723	139,723	139,723	139,723
R^2	0.011	0.024	0.0085	0.024	0.0082	0.022
Panel D. 36 months after out-of-stock (August 2014)						
$Treat \times Post$	-3.00	-0.090	-139.0*	-0.17	-8.72	-0.13*
	(10.3)	(0.098)	(81.6)	(0.11)	(6.45)	(0.075)
Observations	176,297	176,297	176,297	176,297	176,297	176,297
R^2	0.015	0.043	0.0098	0.042	0.0095	0.040

Note: Standard errors shown in parentheses are clustered at the individual level.
*, **, and *** denote significance at the 10%, 5%, and % levels, respectively.

Table 6: Cigarette Purchases by SES Groups

	# Sticks	Log (1+sticks)	Total tar	Log (1+tar)	Total nicotine	Log(1+nicotine)
	(1)	(2)	(3)	(4)	(5)	(6)
A. Household Income Group						
less than 4 million	8.71	0.052	143.6	0.064	13.0	0.048
	(23.9)	(0.21)	(134.0)	(0.26)	(11.6)	(0.17)
4-5.49 million	13.2	-0.14	-108.8	-0.29	-5.42	-0.20
	(20.5)	(0.20)	(116.8)	(0.23)	(8.74)	(0.15)
5.5-6.99 million	-12.7	-0.069	-470.2	-0.11	-32.9	-0.086
	(26.4)	(0.18)	(334.7)	(0.21)	(25.1)	(0.14)
7-8.99 million	-52.0**	-0.39	-366.4**	-0.55*	-28.4**	-0.41**
	(22.3)	(0.25)	(169.1)	(0.29)	(13.4)	(0.19)
9 million and higher	6.37	0.15	28.8	0.14	2.85	0.081
	(25.5)	(0.26)	(178.7)	(0.30)	(14.9)	(0.19)
B. Educational Group						
Secondary school or lower	-4.06	-0.17	-116.0	-0.30	-6.17	-0.21*
	(19.8)	(0.16)	(141.0)	(0.19)	(11.4)	(0.13)
Junior college or equivalent	-32.6	-0.20	-190.5	-0.22	-11.6	-0.18
	(22.1)	(0.23)	(127.0)	(0.27)	(9.97)	(0.18)
Higher education	10.3	0.051	-126.8	-0.0039	-8.60	-0.013
	(13.5)	(0.15)	(138.7)	(0.17)	(10.7)	(0.11)

Note: Standard errors shown in parentheses are clustered at the individual level.

*, **, and *** denote significance at the 10%, 5%, and % levels, respectively.

Table 7: Changes in the Choice set

	median tar	max tar	most frequently purchased tar	size of choice set
	(1)	(2)	(3)	(4)
$Treat \times Post$	-0.33**	-0.53***	-0.31**	-0.089***
	(0.13)	(0.14)	(0.13)	(0.034)
Individual characteristics	Yes	Yes	Yes	Yes
Month fixed effect	Yes	Yes	Yes	Yes
Observations	18,7791	18,7791	18,7791	18,7791
R^2	0.022	0.032	0.021	0.048

Note: Standard errors shown in parentheses are clustered at the individual level.
*, **, and *** denote significance at the 10%, 5%, and % levels, respectively.

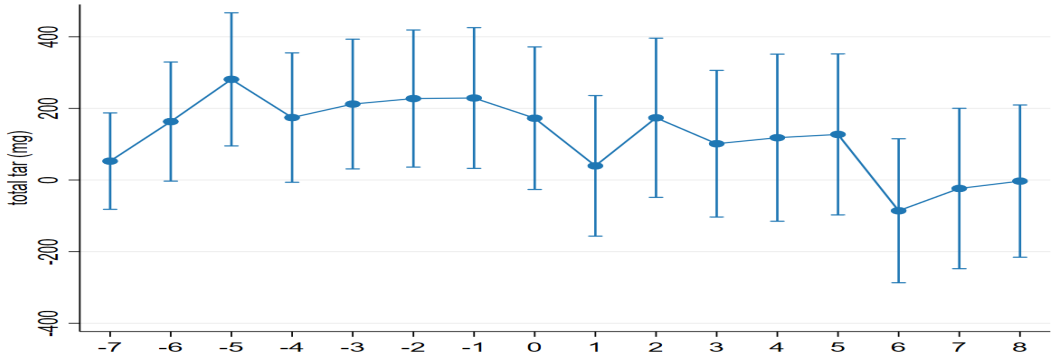
Appendix

A Tables

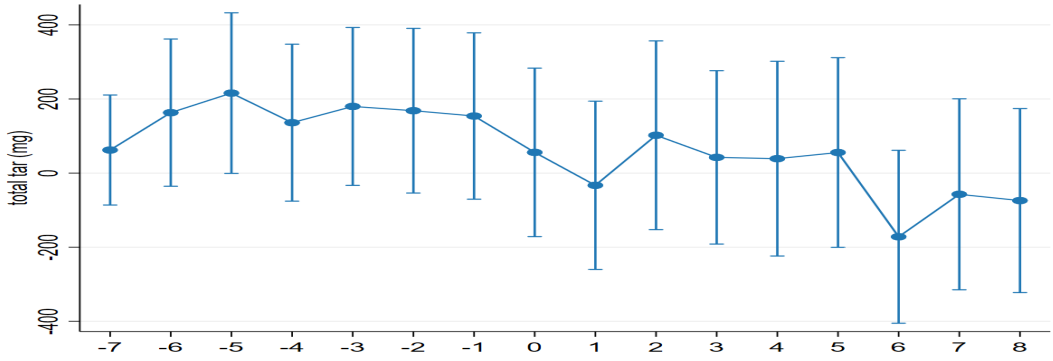
Table A1: Distribution of Tar and Nicotine of Cigarettes

		mean	median	min	max
JT-discontinued	tar (mg/cigarette)	7.25	7	1	17
	nicotine (mg/cigarette)	0.595	0.6	0.1	1.2
JT-nondiscontinued	tar (mg/cigarette)	6.98	6	1	28
	nicotine (mg/cigarette)	0.597	0.5	0.1	2.3
Imported	tar (mg/cigarette)	5.923497	6	1	33
	nicotine (mg/cigarette)	0.493989	0.5	0.1	1.7

B Figures



(a) Before matching



(b) After matching

Figure B.1: Testing for Parallel Assumption

Figure B.2: The quality of matching

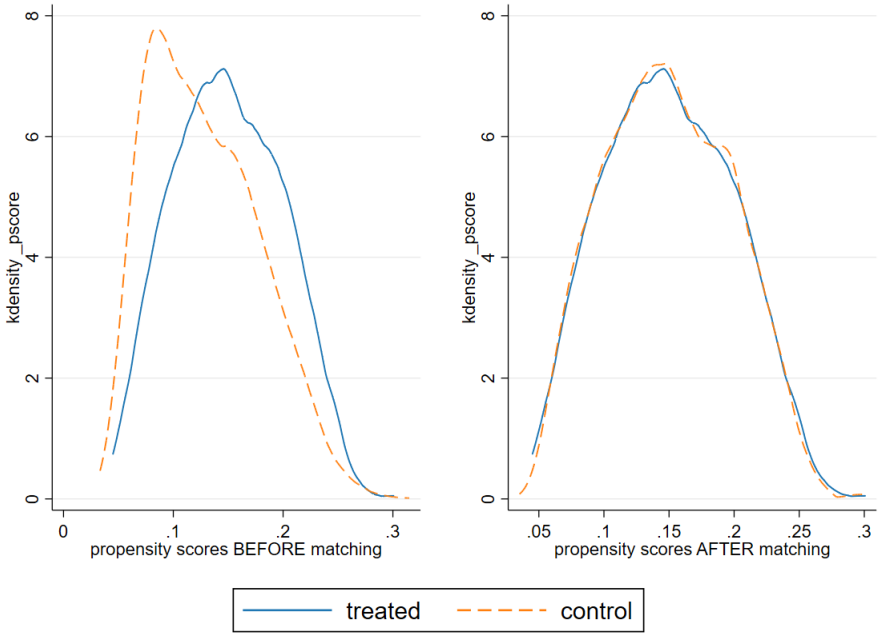


Figure B.3: Percentages of Income Changes

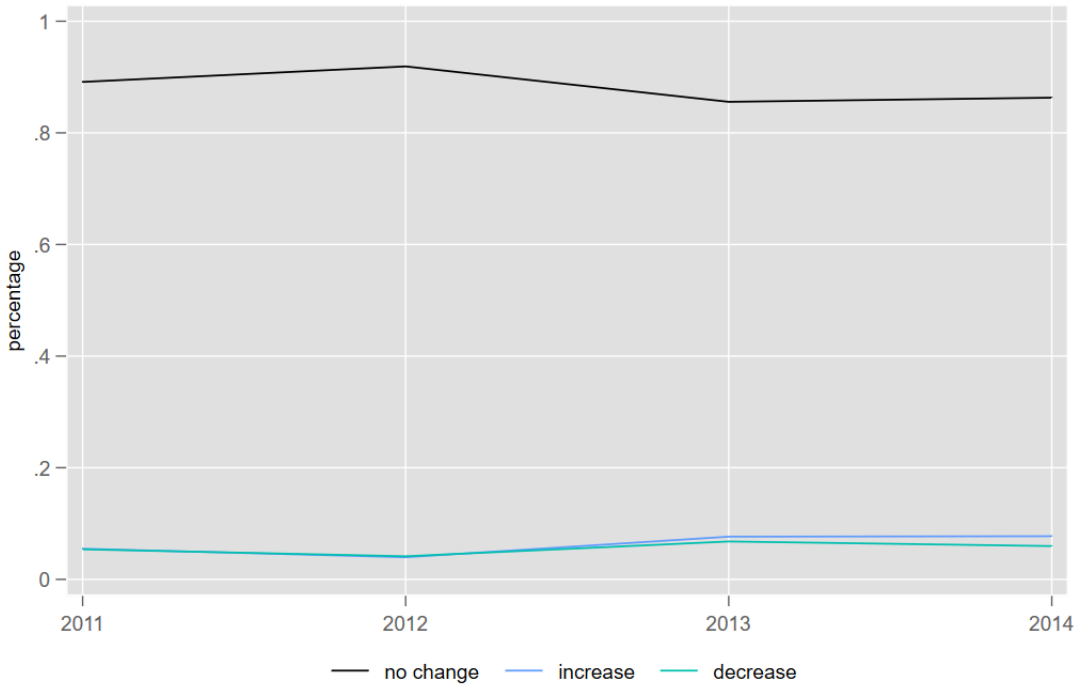


Figure B.4: Patterns of Product Switching