HIAS-E-108

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August, 2021

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Does Restricting the Availability of Cigarettes Reduce Smoking?*

Ryota Nakamura† and Ying Yao‡

Draft Version: August 30, 2021

Abstract

This paper estimates the causal effects of restricting cigarette availability on purchasing patterns. We design a research strategy that enables the estimation by leveraging the impact of an unforeseen discontinuation of products because of the 2011 Great East Japan Earthquake. We analyze nationally representative home scanner data in Japan and find that making certain products unavailable leads smokers to switch to products with less tar and nicotine and purchase 32 percent fewer cigarettes per month. As a result, the total amount of tar and nicotine in purchased cigarettes has decreased by 43 and 30 percentage points, respectively. Such effects persist over the years.

Keywords: Tobacco consumption; Supply restriction; Product availability; Natural experiment; Japan

JEL Classification: D12, I12, I18

*This work is supported by JSPS KAKENHI Grant Number JP19K13717 and Health and Labour Sciences Research Grant Number 20FA1022. The views expressed in this article are those of the authors and do not necessarily reflect those of the funders.

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1 Introduction

Smoking is a major public health concern that kills millions of people every year. Governments in many countries have strived to constrain smoking and other risky behaviors by restricting access to unhealthful products. The strategies involve partial bans on products under specific conditions, e.g., minimum age restrictions on purchases (Cook and Moore, 2001; DiNardo and Lemieux, 2001; Abouk and Adams, 2017), banning smoking in public places and workplaces (Evans et al., 1999; Farrelly et al., 1999; Wakefield et al., 2000), and restricting hours on sales (Bernheim et al., 2016). Outright bans on a product are among the most aggressive and rare classes of regulatory interventions, and their impact on health behavior is largely unknown (Miron and Zwiebel, 1991; Cawley and Ruhm, 2011). In this study, we demonstrate how restricting the availability of certain tobacco products affects smokers' choice and consumption of tobacco. We show that such an intervention can achieve a sustainable reduction in smoking.

Endogenous consumer choices present major challenges to causal inferences between restricting product availability and consumption. Choices or preferences of tobacco are typically formed over time and associated with a complex system of individual, social, and financial factors. Methodologically, a randomized control trial that restricts access to certain marketed products is impractical to implement. In this study, we present a unique observational research design that exploits an unforeseen discontinuation of tobacco products because of factory shutdowns after a large natural disaster—the 2011 Great East Japan Earthquake. The unplanned product discontinuation prompted changes in the purchasing patterns of tobacco by smokers who consumed these products. To quantify the impacts of the product discontinuation on tobacco choice and consumption, we use large-scale, nationally representative home scanner data from Japan, which cover the daily grocery transactions of 75,817 consumers from April 2010 to December 2014. We focus on a sample of 16,533 cigarette purchasers. We apply a difference-in-differences (DID) approach that compares tobacco purchases of the affected smokers before and after the stockout of the discontinued tobacco products with smokers who were unaffected by the discontinuation. In particular, we investigate the dynamic process of choice adjustment

and the corresponding consequences for product choice and the total consumption of the substances.

Our empirical analysis provides three main findings. First, affected consumers switched to products with less tar and nicotine following the stockout of discontinued products. As a result, the tar and nicotine levels in a cigarette decreased by 12 and 3 percentage points, respectively. The range of product choices also changed significantly, with the upper and lower bounds of the selected products shifting toward lower-tar products. Second, although affected consumers searched for new alternatives, they ended up choosing products from the remaining familiar options. Their new regular choices stabilized after a short adjustment period. Third, monthly cigarette consumption exhibited a sustained decline following the stockout. The number of cigarettes purchased decreased by approximately 30 cigarettes or 32 percentage points. In addition, because of product switching, the total tar and nicotine in purchased cigarettes fell by 278 mg (or 43 percentage points) and 23 mg (or 30 percentage points), respectively.

We also speculate on several pathways that may influence cigarette consumption after product discontinuation. First, we investigate the idea that the discontinuation of a consumer's most preferred products could have a tangible impact on their behavioral change. We find that affected consumers shifted to products with less tar and nicotine regardless of whether the discontinued products were among the most purchased. Second, the level of addiction may reflect the difficulty of reducing cigarette consumption. It turns out that heavy and light smokers made similar product switches and reduced cigarette consumption. Third, as contributors to disparities in smoking, educational attainment and income may explain part of the behavioral change concerning cigarette purchases. However, our results show that the reduction in purchases is evident among all education and income groups. Fourth, we evaluate the assumption that behavioral change may vary by residence, as consumer exposure to the earthquake and subsequent supply shocks differed. We find that the stockout of discontinued products uniformly affected consumers across the country. Consumers in earthquake-stricken areas displayed the same behavioral changes in terms of cigarette purchases as those in other areas.

This paper adds to the broader literature on the economics of preventing smoking and the use of other undesirable substances. Prior studies have examined the impact of supply restrictions on alcohol consumption and related health outcomes (Miron and Zwiebel, 1991; Jacks et al., 2021), methamphetamine supply and use (Dobkin and Nicosia, 2009), sales of flavored cigarettes and e-cigarettes (Abouk and Adams, 2017; Courtemanche et al., 2017). Our contribution to the literature is four-fold. First, we investigate a supply restriction of some (not all) products in the tobacco market. Rather than treating products as homogenous, we use detailed product information to extensively analyze the substitution of and the switch between products. Furthermore, by exploiting five years of daily observations of cigarette purchases, we demonstrate how the choice and consumption of tobacco products have adjusted over time following the supply restriction.

Second, we estimate the effect of supply restrictions in the context of limited supply and not price increases. In previous studies on supply restrictions, price played a crucial role in the change in consumption as supply restrictions translate to rising demands and thus an increase in prices (Dobkin and Nicosia, 2009). In our case, strict regulation by the government kept tobacco prices fixed, even when cigarettes were in short supply. This unique environment precludes the bias in policy effects associated with the price elasticity of the demand for tobacco.

Third, we adopt a research design that minimizes biases because of "policy endogeneity" — the timing of the product restriction determined partially by the prevalence of smoking and/or relevant health outcomes (Cawley and Ruhm, 2011). In our case, the supply restriction was not determined by the regulator; it was tied entirely to an unforeseen plant shutdown caused by a devastating earthquake.

Finally, in terms of policy implications, we find a persistent effect of supply restrictions on reducing smoking across the population, which is barely documented in real-world evidence (Hollands et al., 2019). Prior research suggests that this long-term effect exists only in specific populations (Terry-McElrath et al., 2015), is attenuated by the presence of alternatives (Courtemanche et al., 2017), or is temporary (Dobkin and Nicosia, 2009).

From a policy perspective, this paper also adds to the recent debate on major tobacco

control policies. The use of affordability policies such as price increases or taxation is common in reducing tobacco use and smoking rates. However, policy effects are often temporary and induce compensatory behavior. Smokers often gradually return to pre-tax consumption levels after tax hikes. Moreover, they tend to switch to cigarettes with more tar and nicotine as they reduce the number of cigarettes they consume, which greatly offset the health effects of tax increases (Evans and Farrelly, 1998; Farrelly et al., 2004; Adda and Cornaglia, 2006; Cotti et al., 2016). In contrast to tax increases, imposing supply restrictions can alter health behavior in the long term without triggering compensatory behavior. Our findings provide evidence and insights for the implementation of similar policies to control tobacco use.

The rest of the paper proceeds as follows. Section 2 outlines the context of the research design, while Sections 3 and 4 describe the data and empirical strategies, respectively. In Section 5, we present the impact of product discontinuation on cigarette purchases. The potential drivers resulting in behavioral change are discussed in Section 6. We then conclude the work in Section 7.

2 Background

2.1 Tobacco Market in Japan

Japan is one of the 10 countries with the greatest cigarette consumption (Hoffman et al., 2019). Although sales have fallen in recent years because of declining smoking rates, tobacco contributes 2 trillion yen annually in taxes (about 1.6 percent of the national tax revenue in 2019) and dividends to the Japanese government. Japan Tobacco (JT) is the only tobacco manufacturer in Japan, controlling over 60 percent of the domestic sales in Japan (Japan Tobacco, 2018). It was a state-owned monopoly, with the Ministry of Finance owning 67 percent of the company, until its privatization in 1985. While its ownership share continues to decline,[1] the Ministry of Finance remains the primary stakeholder, and it controls tobacco manufacturing, distribution, and pricing. By law, tobacco companies and retailers must obtain licenses from the Ministry, and they cannot

[1]This share declined to 50 percent in 2004 and then to 33 percent in 2016 (MacKenzie et al., 2017).

change their product prices without permission. In the past decades, tobacco prices have changed only in response to changes to the tobacco excise tax or the consumption tax.[2] As a result, cigarette prices are nearly identical across products, and there is no price discrimination across regions (Figure B.1(a) in the Appendix). Furthermore, these prices remained fixed even when the market faced a short supply after the earthquake in 2011. In addition, there is no known black market for tobacco in Japan.

Despite the small price gap between products, products are excessively diversified, from ultra-low-tar (1 mg per cigarette) to high-tar cigarettes (up to 42 mg per cigarette). The nicotine content in cigarettes increases with the tar content (Figure B.1(b)). The typical products in the market are gradually shifting from high-tar to low-tar products. The weighted average of tar (nicotine) in a cigarette has decreased from 9.5 (0.78) mg in 1994 to 6.8 (0.56) mg in 2019 (Figure B.1(c)). Among the 100 best-selling products, 1mg-tar cigarettes have the highest market share at about 24 percentage points. The runners-up are cigarettes with 8 mg and 6 mg of tar, together making up approximately 27 percent of the market. In the following ranking, cigarettes with a tar content of 14 mg and 3 mg together account for a total of 16 percent of the market (Figure B.1(d)).

2.2 JT Products and Supply

As of 2020, JT had 11 major brands, nearly half the number it had in 2011. Products range from low to high tar (nicotine) content in each brand, and they each target different market segments (See Figure B.2 in the Appendix). JT only occasionally discontinues products, and the product lineup has not changed significantly. It has only increased from 96 in 2011 to 102 in 2020. Some of those terminated were long-established products, while others were on the market for just a brief period. Since 2000, JT has removed an average of four products from its catalog each year. Notably, JT discontinued 23 products in 2011, when the earthquake occurred. Following this event, JT rarely discontinued products. Since 2016, JT has resumed discontinuing products, with up to eight discontinued products per year (see Figure 1).

[2]Recent tax hikes occurred in April 2010 and December 2014. The first one was the excise tax increase in October 2010. The second one was the consumption tax, which rose from 5 percent to 8 percent in April 2014.

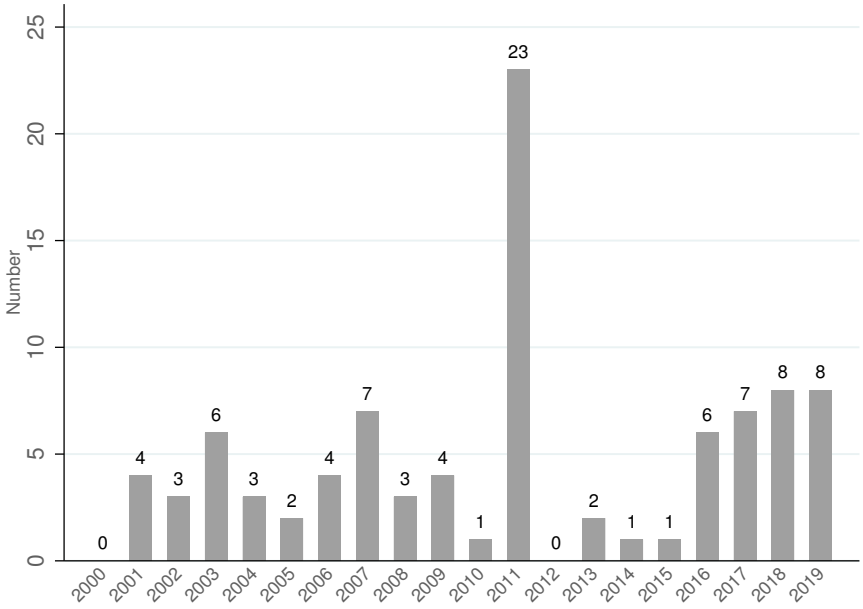


Figure 1: The number of discontinued JT products

Notes: This chart shows product discontinuations from 2000-2019 for the 23 brands listed on JT's press release on May 11, 2011. See https://www.jt.com/media/news/2011/pdf/20110325_02.pdf for details.

Product discontinuations are usually planned, with the exception being those associated with the Great East Japan Earthquake in 2011. The earthquake and subsequent tsunami caused JT to lose 30 percent of its production capacity as two JT cigarette manufacturing plants and another two factories producing semi-finished products and filters were shut down. Unable to consistently supply all of its products, JT announced that it would temporarily suspend shipments from March 30 to April 10 to increase the production and inventory of 25 key products, which account for approximately 65 percent of its total sales (Japan Tobacco, 2011). As a result, JT cigarettes were in extremely short supply on the market, causing panic among smokers. Starting on April 11, JT gradually restored the supply of key products. On May 11, two months after the earthquake, JT committed to resuming the supply of 73 products by early August. However, it eventually discontinued 23 products that possessed low market shares before the earthquake and whose sales were expected to decline at an accelerated rate over the next few years (Japan Tobacco, 2011).

These discontinued products were sold nationwide, except for two geographically re-

stricted products. They had been on the market for various lengths of time; nearly half of them had a product history of more than 10 years. Despite the gap in market share, discontinued products, key products, and other JT products were very similar in average tar and nicotine content, containing around 7.5 mg per cigarette. The typical (median) price of a 20-cigarette pack was identical for three types of products. In terms of average price, the discontinued products were slightly higher than the key and other surviving products by about 10–20 yen per pack (see Table 1).

Table 1: Attributes of JT products (as of May 2011)

	Attribute	Mean	SD	Median	Min.	Max.
Discontinued products ($n = 23$)	Tar per cigarette (mg)	7.3	4.4	7	1	17
	Nicotine per cigarette (mg)	0.6	0.3	0.6	0.1	1.2
	Year of release	1997	12	2000	1970	2010
	Price per pack (20 cigarettes)	424.3	19.5	410	390	470
Key products ($n = 25$)	Tar per cigarette (mg)	7.7	5.7	8	1	19
	Nicotine per cigarette (mg)	0.6	0.4	0.6	0.1	1.4
	Year of release	1991	16	1996	1957	2011
	Price per pack (20 cigarettes)	402.8	49	410	240	440
Other JT products§ ($n = 46$)	Tar per cigarette (mg)	7.5	6.9	6	1	28
	Nicotine per cigarette (mg)	0.5	7	0.5	0.1	2.3
	Year of release	1994	22	2003	1906	2011
	Price per pack (20 cigarettes)	412.9	62.9	410	200	600

Notes: The product list is extracted from JT's press release in May 2011 (See https://www.jt.com/media/news/2011/pdf/20110512_10.pdf for details). §Two smokeless products (Zerosytle) are excluded because information about tar and nicotine is not available.

3 Data and Stylized Facts

3.1 Data

We use nationally representative consumer scanner data from the SCI® Nationwide Consumer Panel Survey of Japan from April 2010 to December 2014. SCI® is analogous to other leading home scanner databases, such as Nielsen Homescan and Kantar WorldPanel. The Intage Group began recruiting participants in December 2009 through web banners and job search websites. In return for participation, the participants received reward points from a website belonging to the Intage Group (https://www.cue-monitor.jp/), which could be exchanged for cash and various gift cards. The data collection is based

on the population census. The sampling procedure uses a quota technique that draws a sample of individuals with the same proportions of individuals as the entire population regarding demographic characteristics such as sex, marital status, and age.

The baseline survey was conducted in April 2010, and it covered 21,607 individuals from 11 regions from northern to southern Japan (Hokkaido, Tohoku, North Kanto, South Kanto, Hokuriku, Tokai, Kinki, Chugoku, Shikoku, Kyushu, and Okinawa).[3] In the follow-up surveys, the data company recruited additional individuals in the same manner as the baseline survey. As a result, the sample size comprised 55,790 individuals in 2014. Participants remain in the panel if they comply with the reporting rules set by the Intage Group, which regularly monitors the quality of the submitted data. New participants with the same sex, marital status, age, and residential area were sought to replace those who withdrew or failed to meet the reporting criteria.

After each purchase, participants are required to use a mobile device to scan the barcodes on products and enter 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 collection of information on cigarettes' tar and nicotine content aligns with the testing procedure of the International Organization for Standardization. We find that three discontinued products are not included in the dataset. We also choose to exclude heated, cut, and smokeless tobacco (2 percent of the sample) from the dataset because of a lack of tar and nicotine information.

3.2 Cigarette Purchasers and Their Characteristics

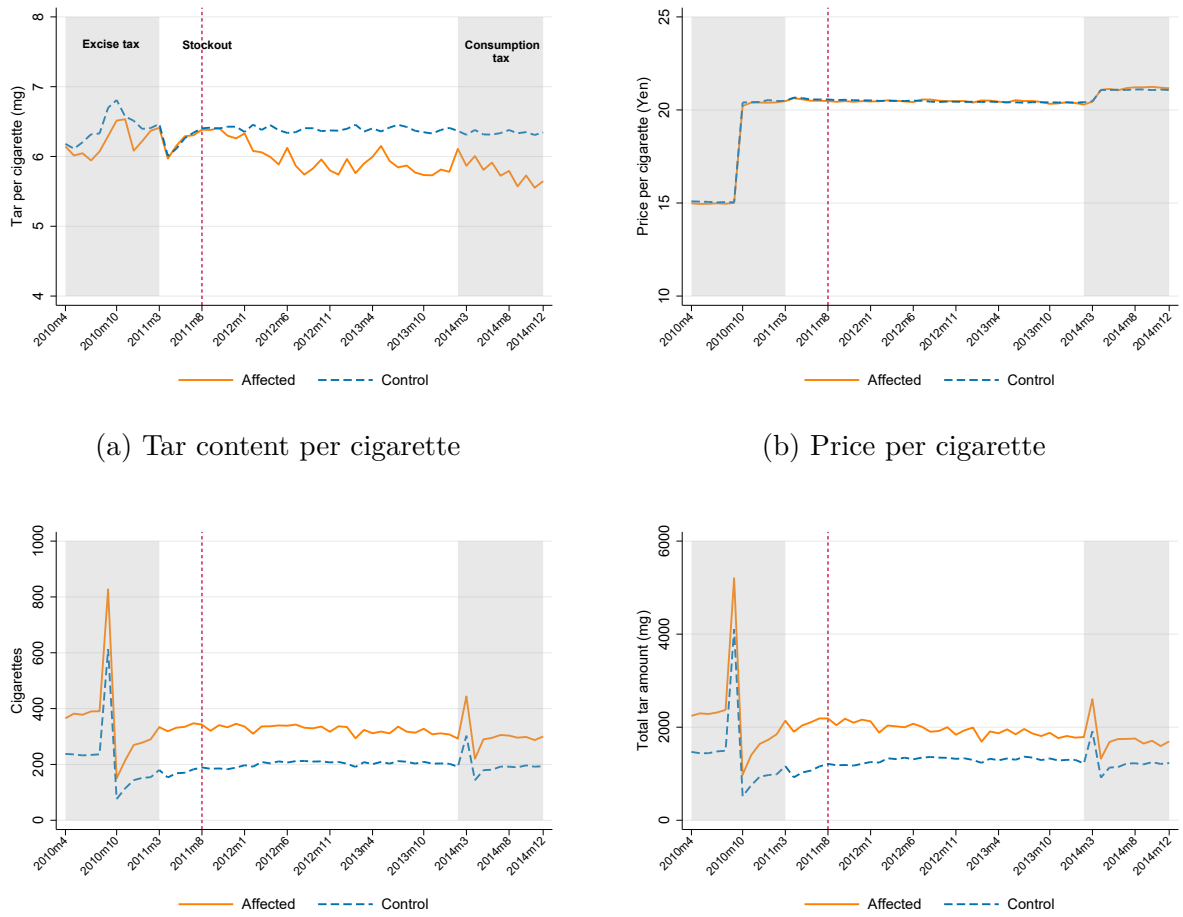
By pooling all participants in the survey between April 2010 and December 2014, we obtain a final sample of 75,817 consumers. Among these consumers, 16,533 purchased at least one pack of cigarettes during the survey period. The average length of their participation in the survey was 32.8 months (ranging from 1 to 57 months).

[3]The definitions of regions follow the classification of the Organization for Economic Cooperation and Development (OECD).

The cigarette purchasers vary in age, sex, family size, education, household income, and occupation (see Table A1 in the Appendix). Male and female consumers are almost equally distributed, with an average age of approximately 44. Nearly two-thirds of consumers are married, and the average household size is around three people. Purchasers with secondary education or lower represent the largest proportion (41 percent), followed by highly educated purchasers (35 percent) and those with a junior college education or equivalent (24 percent). Nearly half of the purchasers have an annual household income of less than 5.5 million yen, approximately equal to the national average annual income (Ministry of Health, Labor and Welfare, 2009). Employed consumers comprise 75 percent of the purchasers, of which 65 percent are white-collar workers. Blue-collar workers, students, unemployed, and others groups constitute another 35 percent of the purchasers.

We aggregate monthly transactions for each cigarette purchaser and identify that 664 of them bought discontinued products before the discontinuation notice was issued in May 2011. These affected consumers tended to be older, male, married, better educated, and employed, and they purchased more cigarettes than those who did not purchase the discontinued products. We present the purchasing trends of these two groups in Figure 2.

The two groups have not differed in their preferences for tar content, except for the periods after product discontinuation. The split in preferences between the two groups was evident a few months after the discontinuation notice. Affected consumers shifted to low-tar cigarettes, while unaffected consumers had stable preferences over time (Figure 2(a)). Despite the divergence in preferences, the price each group paid for a cigarette overlapped, reflecting the price homogeneity of tobacco products in Japan (Figure 2(b)). Unlike product preferences, the gap in purchase volume between the two groups has persisted (Figure 2(c) and 2(d)). This gap varied with consumer response to supply shocks, such as tax hikes and product discontinuations. Before the tax increases, both groups showed signs of pre-tax stockpiling, with consumption gradually returning to pre-tax levels after a brief post-tax slump. In contrast, the consumption of affected consumers slowly declined when their previously purchased products became unavailable, whereas the consumption of unaffected consumers remained stable.



(a) Tar content per cigarette

(b) Price per cigarette

(c) Number of cigarettes

(d) Total amount of tar

Figure 2: Cigarette purchases over time

Notes: The two shaded areas represent a few months before and after the two tax increases. The dotted lines represent the month when discontinued products became out-of-stock.

4 Empirical Strategy

We apply a DID approach to estimate the effect of product discontinuation on tobacco consumption. The regression takes the following format:

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

where indices i and t represent the individual and month, respectively, and Y_{it} represents consumer product choices or purchase volume. In addition, $Treat_i$ is a dummy variable that indicates whether individual i had purchased discontinued products before the discontinuation notice (May 2011). Moreover, $Post_t$ is a dummy variable that is equal to

1 if the discontinued products were out of stock, and it is 0 otherwise. The transaction data suggest that the stockout of discontinued products occurred in August 2011, although sporadic purchases have occurred since then (see Figure B.3 in the Appendix). We, therefore, designate September 2011 as the beginning of the post-stockout period. The coefficient (β_3) captures the treatment effect of product discontinuation on consumer choices. The control variables include a series of individual characteristics, including age, gender, education, household income, family size, and the prefecture of residence. Finally, the fixed effects of the individual (η_i) and month (λ_t) are considered.

The validity of the DID analysis requires that 1) the allocation of the treatment is not determined by smoking behavior, 2) in the absence of product discontinuation, the purchase choices of treated and comparison consumers would follow the same trend, and 3) the composition of the treatment and comparison groups are stable. The remainder of this section tests these assumptions and provides evidence that supports our use of this research strategy.

4.1 Assignment of Treatment

For our DID approach to be valid, smokers' behavior should not determine product discontinuation. Product discontinuation is ubiquitous in firm behavior. Firms, including JT, often make strategic decisions about the timing and range of product discontinuation. Such decisions raise concerns about "policy endogeneity" (Cawley and Ruhm, 2011), i.e., whether our treatment assignment is affected by consumer behavior. The process of selecting products to discontinue may not be random, especially when JT was faced with limited production capacity. We, however, argue that the individual smokers' behaviors did not influence JT's decision in this case.

In terms of the timing of the discontinuation, it is unlikely that JT's product rationalization shortly after the earthquake was planned. In contrast to a planned discontinuation, JT's post-earthquake decision was driven by an unforeseen shortage of production capacity that made it impossible to sustain their original lineup of products. As shown in Figure 1, the number of products discontinued as a result of planning had been small

before 2011 — typically around four per year. The significantly higher number of discontinued products in 2011 reflects the unintended consequences of supply disruptions.

JT has publicly announced that market share — measured by aggregate sales — determines product rationalization, especially with regard to product range. This criterion meets the main interest of the majority stakeholder — the Ministry of Finance. Since the tax per cigarette in Japan is fixed across products, product prioritization using aggregate sales rules can maximize tax revenue. Admittedly, we cannot rule out the possibility that JT chose to fine-tune the product range based on its prediction of consumer responses. However, the fact that JT used aggregate sales as the criterion to discontinue products implies that the behavior of individual smokers was unlikely to play a crucial role in determining the range of products to be discontinued.

Furthermore, the behavior of individual smokers can hardly respond to aggregate sales. Our data confirm that a high market share does not guarantee more individual purchases. For example, for some treated consumers, the discontinued products—despite their low market share—accounted for all of their purchases. The discontinued products, on average, accounted for 24 percent of purchases by treated consumers, which was higher than some other JT products (see Table A2 in the Appendix).

4.2 Common Trends in Cigarette Purchases

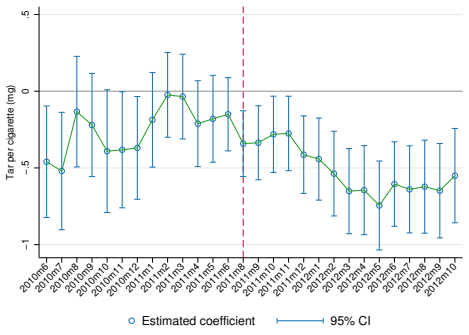
We perform an event study analysis to examine whether the trends in outcomes are the same in the treatment group and control group in the absence of treatment exposure. The regression uses a slightly modified version of equation (1):

$$Y_{it} = \beta_0 + \sum_{j=-15}^{15} \delta_j D_{i,t-j} + \theta Control_{it} + \eta_i + \lambda_t + \varepsilon_{it} \tag{2}$$

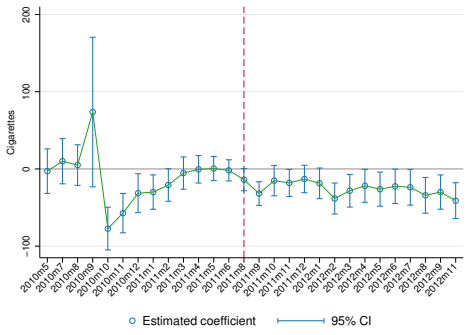
We normalize the timing of the stockout (August 2011) to period 0 and set the analysis period to 15 months before ($-15 < j < 0$) and after ($0 \leq j \leq 15$) the stockout. The dummy variable $D_{it} = \mathbb{1}[Treat_i = t]$ takes the value 1 in the month of stockout and zero otherwise. The estimated coefficient for δ_j represents the effects of supply shock on the treated consumers at month j. The indicator $D_{i,t-1}$ is omitted to reflect the baseline

difference between consumers when the stockout occurred and when they did not occur. We expect $\delta_j = 0$ for $-15 < j < 0$ if pre-existing trends in the outcome are absent.

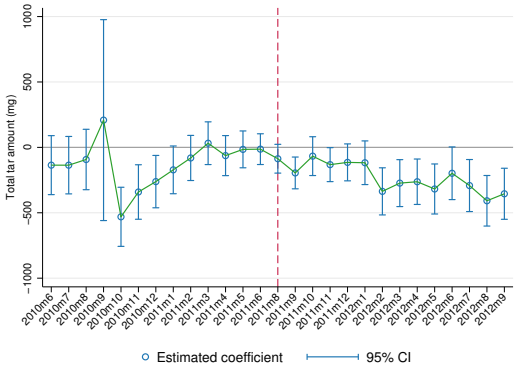
Figure 3 presents the event study graphs of the impact of product discontinuation on product choices, cigarettes purchased, and total amount of tar (nicotine) in purchased products. The product choice is indicated by the cigarette's tar (nicotine) content, which is obtained by dividing the total amount of tar (nicotine) by the total number of cigarettes. Here we only visualize the results for tar because, as shown in Figure B.1(b), tar and nicotine content in a cigarette are positively correlated. A vertical dashed line indicates the month of the stockout in all subfigures. These figures suggest that there are no systematic differences in pre-existing trends except for the period between October 2010 and February 2011. The excise tax increase in October 2010 may explain the sharp decline in purchases. To eliminate the interference of the two tax hikes, we restrict the analysis to periods between March 2011 and February 2014.



(a) Product choice



(b) Number of cigarettes



(c) Total tar in purchased cigarettes

Figure 3: Event-study analysis of cigarette consumption

Notes: The dashed line represents the month in which stockout occurred. The circles and spikes represent the estimated coefficients and 95% confidence intervals, respectively.

4.3 Comparability between Affected and Comparison Groups

Another challenge to the analysis is compositional changes in consumer characteristics, which may be associated with changes in treatment exposure. As illustrated in Table A1 of the Appendix, the affected and comparison consumers have different socioeconomic characteristics. Despite these differences, the identification strategy is valid as long as the distribution of these covariates is stable over time. The design of the survey stated that the composition and distribution of the survey participants were stable. Furthermore, a comparison of the means between the two groups over the study periods confirms that compositional changes are unlikely to exist (Table A3 in the Appendix).

Given the group differentials and potential bias because of confounding, we also incorporate propensity scores into our DID estimations. We restrict transactions to the pre-earthquake period from April 2010 to February 2011 and obtain a sample of consumers in the treated and control groups. A logit regression estimates the propensity score of an individual being affected by the product discontinuation. The control variables include individual characteristics and monthly purchase intensity, i.e., the average number of cigarettes and average tar (nicotine) content per cigarette in purchased products. We apply the kernel matching method (Heckman et al., 1998) to select baseline individuals with a similar probability of being affected by the stockout. The choice of bandwidth in kernel matching is based on the rule-of-thumb bandwidth for Epanechnikov kernels (Silverman, 1986). The diagnostic test after matching suggests a balance between the treated and control groups. Individuals in the two groups do not exhibit statistically significant differences in the means of the covariates (Figure B.4 in the Appendix). The DID estimation is then performed using the sample of matched consumers. Additional tests using matched samples confirmed the absence of pre-existing trends in pre-stockout periods from March 2011 to August 2011 (Figure B.5 in the Appendix).

5 Results

5.1 Consumer Choices

Like other consumers, smokers often develop a set of product choices based on their past purchases. This set of choices includes multiple products with varying tar (nicotine) content. Consumer preferences for each item in the set may vary. For some consumers, the loss of one option in the set may not affect their purchasing decisions; they can continue to select items from their remaining choices. Others may search for new alternatives to replace the lost item(s). Either pattern will drive a shift in choices, either to products with the same or different tar (nicotine) content.

To identify changes in consumer choices, we compare the tar (nicotine) content per cigarette before and after the stockout. Dependent variables, such as average, maximum, and minimum tar (nicotine) per cigarette, are constructed based on monthly transactions. The average indicator is a weighted index representing the tar (nicotine) content of the consumer's most purchased products.[4] We present the results in Table 2. The estimates of different methods in column 1 show that the tar content per cigarette decreased by 12 percentage points after the stockout, while the reduction in nicotine content per cigarette (column 2) was 3 percentage points. In addition to the average content per cigarette, the upper bounds of tar and nicotine content per cigarette (columns 3 and 4) dropped by 16 and 4 percentage points, respectively. Reductions in the lower bounds of tar and nicotine content per cigarette (columns 5 and 6) are not as pronounced as the upper bounds, at approximately 7 and 1.1 percentage points, respectively.

[4]The data also show that the two indicators coincide with each other.

Table 2: Changes in product choices

	Substance per cigarette		Upper bounds		Lower bounds	
	Tar	Nicotine	Tar	Nicotine	Tar	Nicotine
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. DID						
$Treat \times Post$	-0.12***	-0.026***	-0.16***	-0.044***	-0.058***	-0.0077
	(0.020)	(0.0050)	(0.022)	(0.0058)	(0.020)	(0.0049)
Post	-1.35***	-0.30***	-1.41***	-0.32***	-1.24***	-0.27***
	(0.074)	(0.018)	(0.078)	(0.020)	(0.069)	(0.017)
Observations	366,865	366,865	366,865	366,865	366,865	366,865
Mean of Dep. Var.	3.34	0.28	3.64	0.30	3.06	0.26
SD of Dep. Var.	4.64	0.37	4.99	0.40	4.42	0.36
Panel B. PSM-DID						
$Treat \times Post$	-0.12***	-0.027***	-0.16***	-0.044***	-0.069***	-0.011**
	(0.021)	(0.0052)	(0.023)	(0.0060)	(0.020)	(0.0050)
Post	-1.65***	-0.36***	-1.77***	-0.41***	-1.45***	-0.30***
	(0.18)	(0.045)	(0.20)	(0.053)	(0.17)	(0.041)
Observations	193,385	193,385	193,385	193,385	193,385	193,385
Mean of Dep. Var.	3.77	0.32	4.28	0.36	3.35	0.28
SD of Dep. Var.	4.68	0.38	5.21	0.42	4.39	0.36

Notes: Mean and SD of dependent variables reported are in levels. Dependent variables in the regressions are in logarithmic scale. The matched sample for difference-in-differences estimation is generated by the kernel matching method. All columns are controlled for individual characteristics (age, sex, marital status, education level, household income, family size, and prefecture of residence) as well as month fixed effects. Standard errors shown in parentheses are clustered at the individual level. *, **, and *** denote significance at 10%, 5%, and 1%, respectively.

5.2 Choice Adjustments

The average treatment effect described above does not reveal the timing of the shift in choices nor the formation of a new purchasing pattern. Therefore, we conduct a series of event study analyses to explore the dynamics of changing consumer choices. As in equation (2), we normalize the timing of the stockout to period 0 and set the analysis period to 5 months before and 15 months after the stockout. Figure 4 summarizes the point estimates and confidence intervals of the regressions.

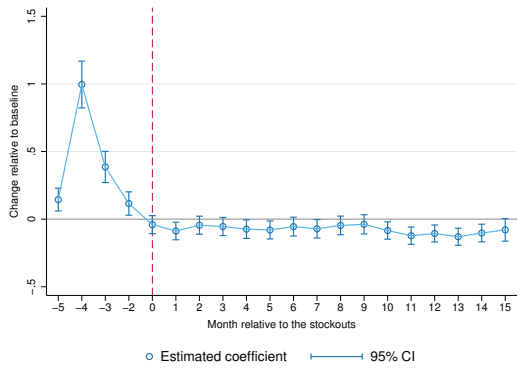
We first examine product search behavior. While consumer choices are relatively stable, they occasionally make taste discoveries. For example, if the consumer purchases a product that is different from all of their previously purchased items, we would consider this be be a new search. We propose that such discoveries are likely to be frequent when some products are temporarily or permanently unavailable. Figure 4(a) shows that product searching was prominent when JT's entire product line was in short supply

immediately following the earthquake ($t = -4$). As the supply of products resumed, the number of searches plummeted and remained low for 15 months after the stockout.

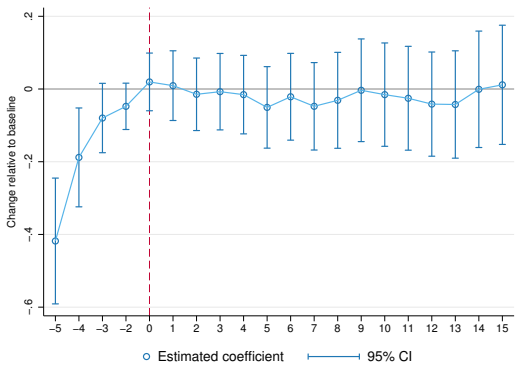
In addition to the number of searches, we examine the tar levels of the products searched to explore the composition of the consumer consideration set, which considers all previously purchased items. This set is continuously updated as new options are explored. We compare the realized choices of each month with the items in this updated set to identify new searches. Variations in the tar levels of the consideration set are used to determine the direction of a search. Given that multiple products are being searched, we extract the average, upper, and lower bounds of the tar content in a cigarette to examine their changes following the stockout. Figures 4(b)–4(d) demonstrate that the new searches do not change the composition of the consideration set. The tar content of newly searched items may be higher or lower than the existing items, making the change in the average tar level of the consideration set negligible.

How likely are these newly searched products to enter consumers' consideration and become regular choices? We first aggregate these newly searched products and then compare them with the realized choices in the next period to verify that consumers have selected them. As shown in Figure 4(e), the affected consumers were less likely to choose newly searched products in periods following the stockout. In other words, these consumers tend to choose familiar and frequently purchased products, even if the range of purchase options is narrowed.

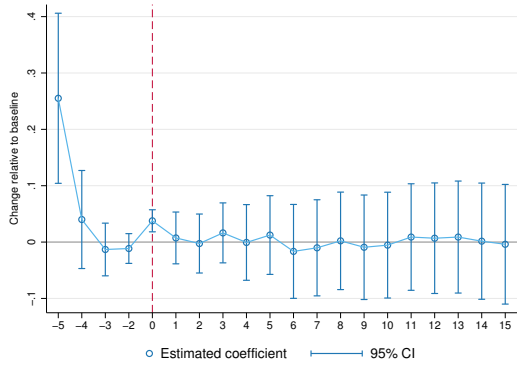
Recall that affected consumers switched to low-tar products after the stockout. Yet we have not explored when these consumers stabilized their new regular choices. We visualize changes in the most purchased products in Figure 4(f), which represent consumers' typical or regular choices. Although consumers started product searches shortly after the earthquake, new regular choices did not form immediately, and in the first three months following the earthquake, the direction of product searches varied across consumers. As a result, the new typical choices did not stabilize until August 2011. Since then, affected consumers have continued to choose lower-tar products, with typical choices stabilizing over time.



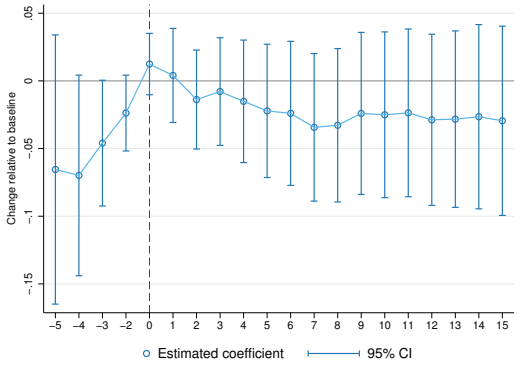
(a) Number of newly searched products



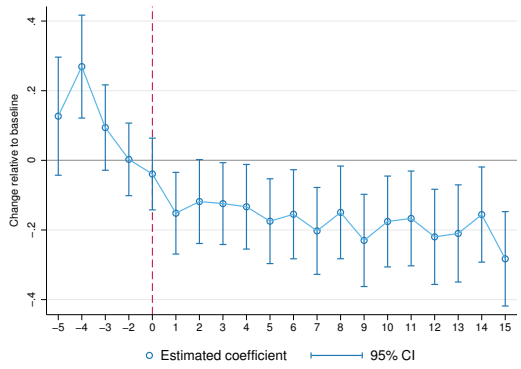
(b) Upper (tar) bounds of consideration set



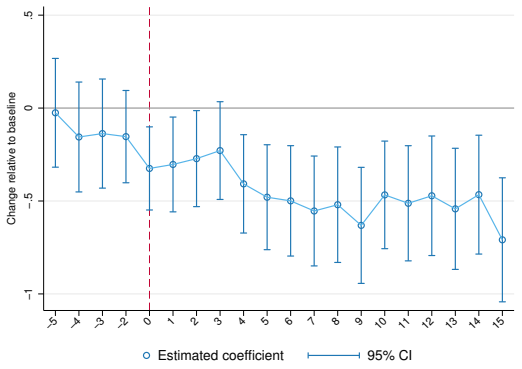
(c) Lower (tar) bounds of consideration set



(d) Average tar level of consideration set



(e) Probability of choosing newly searched products



(f) Most-purchased product type (tar)

Figure 4: Event-study analysis of cigarette consumption

Notes: The dashed line represents the month in which stockouts occurred. The circles and spikes represent the estimated coefficients and 95% confidence intervals, respectively.

5.3 Cigarette Consumption

Next, we estimate the change in consumption using equation (1). The number of cigarettes and the amount of tar (nicotine) purchased are used to measure consumption. The regressions are controlled for individual characteristics (i.e., age, sex, marital status, education level, household income, family size, and prefecture of residence) and month fixed effects. These results are reported in Table 3. Cigarette purchases presented in the first three columns are in levels, whereas the numbers presented in the last three columns are in the logarithmic scale. In panel A, column 1 shows that affected consumers purchased approximately 30 fewer cigarettes per month after the stockout of discontinued products, a decrease of about 32 percentage points (as shown in column 4). Similarly, the total tar and nicotine in purchased cigarettes reduced by about 278 mg (or 43 percentage points) and 23 mg (or 30 percentage points), respectively. This reduction is equivalent to a 20-cigarette pack containing 14 mg of tar or 1 mg of nicotine per cigarette.

We further subdivide the study period into several segments and quantify the short-term and long-term changes in purchases. The time intervals are categorized into periods between the start of the analysis period and the 6th, 12th, 18th, and 24th months after the stockout of discontinued products. Table A4 in the Appendix presents the results for those intervals. In the 6th month following the stockout (February 2012), we observe that affected consumers significantly cut their total purchases. They, on average, purchased 26 (or 26 percent) fewer cigarettes per month; this number continues to decrease if the analysis period is extended. By the 24th month after the stockout, affected consumers purchased an average of 32 (or 34 percent) fewer cigarettes per month. The total purchased tar and nicotine exhibit similar trends. In the first six months of the stockout, the total tar and nicotine declined by 167 mg (or 34 percentage points) and 15 mg (or 23 percentage points), respectively. Further reductions in both indicators are observed if the study period is extended by another six months. As of the 24th month after the stockout, the reductions in total tar and nicotine purchased reached 264 and 22 mg, respectively.

Table 3: Changes in the purchase volume

	Levels			Logarithmic scales		
	Number of cigarettes (1)	Total tar (2)	Total nicotine (3)	Number of cigarettes (4)	Total tar (5)	Total nicotine (6)
Panel A. DID						
Treat × *Post*	-30.1***	-275.0***	-22.5***	-0.32***	-0.43***	-0.30***
	(7.28)	(57.6)	(4.77)	(0.062)	(0.076)	(0.052)
Post	-288.7***	-1964.7***	-159.8***	-4.25***	-5.36***	-3.49***
	(22.8)	(226.8)	(18.2)	(0.21)	(0.27)	(0.18)
Observations	366,865	366,865	366,865	366,865	366,865	366,865
Mean of Dep. Var.	207.5	1316.0	109.0	2.99	3.76	2.46
SD of Dep. Var.	305.9	2666.8	214.1	2.86	3.62	2.48
Panel B. PSM-DID						
Treat × *Post*	-30.4***	-278.3***	-22.7***	-0.32***	-0.43***	-0.30***
	(7.29)	(57.7)	(4.78)	(0.062)	(0.076)	(0.052)
Post	-286.9***	-1721.6***	-142.6***	-4.08***	-5.06***	-3.27***
	(34.3)	(303.4)	(25.4)	(0.30)	(0.37)	(0.25)
Observations	193,395	193,395	193,395	193,395	193,395	193,395
Mean of Dep. Var.	193.8	1200.2	99.8	2.76	3.45	2.26
SD of Dep. Var.	303.5	2565.9	206.8	2.87	3.62	2.47

Notes: All columns are controlled for individual characteristics (age, sex, marital status, education level, household income, family size, and prefecture of residence) as well as month fixed effects. Standard errors shown in parentheses are clustered at the individual level. *, **, and *** denote significance at 10%, 5%, and 1%, respectively.

Overall, product discontinuations have driven the affected consumers to shift products and purchase fewer cigarettes. Such behavioral change is sustained in the long term. Our results contrast with prior studies which find that the shift to low-tar (nicotine) cigarettes can trigger compensatory behavior. In those studies, consumers purchase additional low-tar (nicotine) cigarettes to maintain the same level of nicotine demand as before (Evans and Farrelly, 1998; Farrelly et al., 1999; Adda and Cornaglia, 2006; Cotti et al., 2016). The compensatory behavior found in those studies was in the context of tax increases, where consumers still had access to preferred products, although at a higher cost. However, such compensatory behavior does not exist in our case because of the complete restriction of the consumer's access to products. That is, the inaccessibility of products leads consumers to focus on familiar products with less tar (nicotine) and reduce cigarette consumption.

6 Discussion

Several factors that may contribute to the continued declines in cigarette purchases.

6.1 Product Relevance

As previously mentioned, consumers have different preferences for each product they purchase. Therefore, the disappearance of a previously purchased item might not affect purchasing patterns. However, losing regularly purchased products may have a tangible impact on purchases. We, therefore, re-define the treatment group by excluding consumers who occasionally purchase one or two packs of discontinued products. Under this new definition, the number of affected consumers drops to 314. The results in Panel A of Table 4 show that affected consumers consistently switch to lower-tar (nicotine) cigarettes after product discontinuation. The tar and nicotine levels in an average cigarette declined by 9.4 and 2 percentage points, respectively. In addition, the number of cigarettes purchased per month decreased by 17 percentage points, and the total amount of tar and nicotine consumed fell by 27 and 19 percentage points, respectively.

Furthermore, we re-define the treatment group to consumers whose most purchased product was discontinued. We note that some consumers purchased the same quantity of multiple products, indicating substitutability between the products. As an extreme approach, we further restrict the treated consumers to those whose most purchased product was not available. Under these conditions, the number of affected consumers declines to 158. Panel B of Table 4 shows that affected consumers consistently switched to "lighter" products, where tar and nicotine levels in a cigarette were lowered by 7.5 and 1.8 percentage points, respectively. There was not a significant decrease in total consumption.

Combining the results in Section 5, we find that the unavailability of products triggers a sustained shift in choices to low-tar (nicotine) products, regardless of how we define the treatment group.

Table 4: Treatment group re-defined

	Tar per cig.	Nicotine per cig.	# Cigarettes	Total tar	Total nicotine
	(1)	(2)	(3)	(4)	(5)
A. Exclude occasional purchases					
$Treat \times Post$	-0.094***	-0.020***	-0.17*	-0.27**	-0.19**
	(0.029)	(0.0072)	(0.096)	(0.12)	(0.079)
Post	-2.04***	-0.46***	-6.67***	-8.36***	-5.53***
	(0.29)	(0.072)	(0.84)	(1.07)	(0.76)
N (treated consumers)	314	314	314	314	314
Observations	189,821	189,821	189,821	189,821	189,821
Mean of Dep. Var.	3.66	0.31	271.9	1632.5	137.3
SD of Dep. Var.	4.60	0.38	337.5	2898.7	238.7
B. Most purchased product was discontinued					
$Treat \times Post$	-0.075*	-0.018*	0.0044	-0.095	-0.066
	(0.040)	(0.0092)	(0.13)	(0.15)	(0.099)
Post	-1.99***	-0.44***	-6.30***	-7.94***	-5.14***
	(0.38)	(0.094)	(1.00)	(1.33)	(0.93)
N (treated consumers)	158	158	158	158	158
Observations	176,263	176,263	176,263	176,263	176,263
Mean of Dep. Var.	3.33	0.28	247.2	1530.4	129.2
SD of Dep. Var.	4.64	0.38	339.1	3039.7	252.5

Notes: Mean and SD of dependent variables reported are in levels. Dependent variables in the regressions are in logarithmic scale. The matched sample for difference-in-differences estimation is generated by the kernel matching method. All columns are controlled for individual characteristics (age, sex, marital status, education level, household income, family size, and prefecture of residence) as well as month fixed effects. Standard errors shown in parentheses are clustered at the individual level. *, **, and *** denote significance at 10%, 5%, and 1%, respectively.

6.2 Purchase Intensity

The addictive nature of nicotine makes it difficult to quit smoking. Given the degree of nicotine dependence, heavy or frequent smokers may not exhibit a strong inclination to reduce consumption compared to light or occasional smokers.

We examine the behavioral change of different types of smokers using purchase volume as a proxy for addiction. We classify smokers as heavy (frequent) and light (occasional) smokers using a threshold of five cigarettes per day based on average pre-earthquake purchases. Table 5 presents the estimates for the changes in purchases for both types of smokers. The tar content of the products chosen by frequent and occasional smokers has been reduced by 5 and 8 percentage points, respectively. When taking product switching into account, the total amount of tar in cigarettes decreased by 20 and 24 percentage points in the two groups, respectively. The nicotine content in a cigarette and

the corresponding total amount showed similar downward trends.

We then evaluate the variations in consumption by including a dummy variable representing smoker types in equation (1) and the following estimate:

$$Y_{it} = \alpha_0 + \alpha_1 Post_t + \alpha_3 Frequent_i + \beta_1 Treat_i \times Post_t + \beta_2 Post_t \times Frequent_i + \gamma Treat_i \times Post_t \times Frequent_i + X_{it}\theta + \eta_i + \lambda_t + \varepsilon_{it} \quad (3)$$

The coefficient for the triple interaction term captures the difference in the impact of product discontinuation on both types of cigarette purchases. The estimates in the last two lines of Table 5 show that there were no significant differences in product choices and purchase volume in the two groups after product discontinuation, although the degree of declines varied.

Table 5: Frequent vs occasional purchasers

	Tar per cig.	Nicotine per cig.	# Cigarettes	Total tar	Total nicotine
	(1)	(2)	(3)	(4)	(5)
Frequent	-0.063**	-0.014**	-0.17**	-0.24**	-0.18**
($n = 416$)	(0.028)	(0.0069)	(0.084)	(0.10)	(0.073)
Occasional	-0.058*	-0.014*	-0.085	-0.14	-0.082
($n = 248$)	(0.032)	(0.0078)	(0.094)	(0.11)	(0.073)
Diff. in Means	-0.0082	-0.00050	-0.097	-0.11	-0.11
	(0.042)	(0.010)	(0.13)	(0.16)	(0.10)

Notes: All the dependent variables are in logarithmic scale. The matched sample for difference-in-differences estimation is generated by the kernel matching method. All columns are controlled for individual characteristics (age, sex, marital status, education level, household income, family size, and prefecture of residence) as well as month fixed effects. Standard errors shown in parentheses are clustered at the individual level. *, **, and *** denote significance at 10%, 5%, and 1%, respectively.

6.3 Socioeconomic Disparities

Smoking is associated with the socioeconomic status (SES) of adults, and it is particularly prevalent among people of low SES. The disparities in smoking are largely explained by the education gradient (Cutler and Glaeser, 2005). Highly educated individuals tend to smoke less and quit more often (Bratti and Miranda, 2010). Hence, changes in cigarette purchases can be attributable to well-educated consumers. Here, we test the heterogeneous effect of product discontinuation on purchases based on educational groups.

Columns 1–3 in Table 6 show that consumers in all education groups shifted to lower-tar and nicotine products, purchasing 26–33 percent fewer cigarettes, and consuming 37–56 percent less total tar, and 24–39 percent less total nicotine.

Table 6: Cigarette purchases by SES groups

	Education groups			Income groups		
	Secondary or lower	Junior college	High education	Low income	Middle income	High income
	(1)	(2)	(3)	(4)	(5)	(6)
Tar per cig.	-0.13***	-0.12***	-0.11***	-0.036	-0.16***	-0.10***
	(0.033)	(0.043)	(0.034)	(0.044)	(0.041)	(0.036)
Nicotine per cig.	-0.029***	-0.023**	-0.027***	-0.0079	-0.040***	-0.026***
	(0.0080)	(0.011)	(0.0084)	(0.011)	(0.0099)	(0.0090)
# Cigarettes	-0.33***	-0.46***	-0.26**	-0.19	-0.40***	-0.37***
	(0.099)	(0.12)	(0.11)	(0.13)	(0.12)	(0.12)
Total tar	-0.46***	-0.56***	-0.37***	-0.21	-0.57***	-0.46***
	(0.12)	(0.15)	(0.13)	(0.16)	(0.15)	(0.14)
Total nicotine	-0.32***	-0.39***	-0.24***	-0.14	-0.41***	-0.31***
	(0.086)	(0.10)	(0.087)	(0.11)	(0.10)	(0.092)

Notes: All the dependent variables are in logarithmic scale. The difference-in-differences estimation in this table uses a matched sample generated by the kernel matching method. All columns are controlled for individual characteristics (age, sex, marital status, education level, household income, family size, and prefecture of residence) as well as month fixed effects. Standard errors shown in parentheses are clustered at the individual level. *, **, and *** denote significance at the 10%, 5%, and 1%, respectively.

In addition to education, income is another driver for smoking disparities. Low-income households tend to reduce their cigarette consumption when experiencing financial pressure because most of their income is spent on necessities. To evaluate the role of income in cigarette purchases, we first investigate the data of the unemployed or those who experienced wage reductions after the earthquake. The data show that over 95 percent of consumers had consistent levels of income during the survey periods. Consumers who experienced income reductions constitute less than 0.25 percent of the sample (see Figure B.6 in the Appendix). Thus, unemployment or reduced income because of the earthquake cannot be considered a sufficient reason for reduced cigarette purchases.

We then exclude consumers with fluctuating incomes and re-estimate the changes

in cigarette purchases across income groups. As presented in columns 4–6 of Table 6, consumers in all income groups exhibit varying degrees of reduction in the number of cigarettes or tar (nicotine) content. Remarkably, the middle-income group (4–6.99 million yen) and the high-income group (7 million yen and above) exhibited substantial reductions in the quantity purchased and the tar (nicotine) in cigarettes. Affected consumers in these two groups purchased 40 percent fewer cigarettes, and the total amount of tar and nicotine in purchased cigarettes declined by 46–57 percentage points.

6.4 Geographical Variations

Previous research shows that people in earthquake-stricken areas become more risk-tolerant and tend to engage in more risky behaviors than people in other areas (Hanaoka et al., 2018). Therefore, we consider that smokers in the Tohoku region—the epicenter of the earthquake— might not have reduced their purchases compared to smokers in the other areas.

We first examine the geographic distribution of the affected consumers, which is nationwide. About one-third of them are in South Kanto, and 15 percent are in Kinki. This is followed by Tokai, Kyushu, and Tohoku, each accounting for about 10 percent (see Figure B.7 in the Appendix). Hence, product discontinuation is unlikely to affect only consumers in the Tohoku region.

We now test the behavioral change in different regions and compare geographical variations. Similar to Subsection 6.2, we include an triple interaction term $Treat_i \times Post_t \times Tohoku_i$ in equation (1), where $Tohoku_i$ is a dummy variable representing the six prefectures in Tohoku (Akita, Aomori, Fukushima, Iwate, Miyagi, and Yamagata). In addition, we exclude consumers who changed residential areas during each survey period to eliminate the influence of relocation on purchases. These consumers account for 2 percent of the sample (328 out of 16,533). The estimates in column 3 of Table 7 suggest that consumers in the Tohoku region did not reduce their purchases any more than those in other regions. Thus, product discontinuation had an equal effect on affected consumers nationwide.

We note that the South Kanto region, where cities like Tokyo and Yokohama are located, has a high proportion of affected consumers. Therefore, we further compare consumers' purchases in South Kanto with those of consumers in other regions. The results in column 6 confirm that there are no regional differences exist with respect to the effect of product discontinuation on consumer purchases.

Table 7: Geographical variations

	Tohoku vs. other regions			South Kanto vs. other regions		
Dependent variable	Tohoku (1)	Other Regions (2)	Diff. in Means (3)	South Kanto (4)	Other Regions (5)	Diff. in Means (6)
Tar per cig.	-0.100*	-0.11***	0.018	-0.12***	-0.11***	-0.0062
	(0.056)	(0.022)	(0.062)	(0.039)	(0.025)	(0.047)
Nicotine per cig.	-0.013	-0.026***	0.014	-0.028***	-0.023***	-0.0047
	(0.013)	(0.0056)	(0.014)	(0.0096)	(0.0062)	(0.011)
# Cigarettes	-0.53**	-0.29***	-0.23	-0.28**	-0.33***	0.043
	(0.21)	(0.067)	(0.23)	(0.13)	(0.074)	(0.15)
Total tar	-0.58**	-0.40***	-0.16	-0.39**	-0.43***	0.037
	(0.25)	(0.083)	(0.27)	(0.15)	(0.092)	(0.18)
Total nicotine	-0.36**	-0.28***	-0.063	-0.26**	-0.30***	0.035
	(0.17)	(0.057)	(0.18)	(0.10)	(0.063)	(0.12)

Notes: All columns are controlled for individual characteristics (age, sex, marital status, education level, household income, family size, and prefecture of residence)as well as month fixed effects. Standard errors shown in parentheses are clustered at the individual level. *, **, and *** denote significance at the 10%, 5%, and 1%, respectively.

7 Conclusion

Using a natural experiment, we exploit this opportunity to investigate the effect of product discontinuation on tobacco consumption. This study predicts that restricting product availability can constrain addictive behavior in the long term. The removal of certain products does not trigger compensatory behavior in consumers for lost choices to maintain their addiction level; instead, it leads smokers to choose "lighter" products from a restricted set of regular choices. The new choices can stabilize after a brief period of choice discovery and adjustment. As product preferences shifted, tobacco consumption exhibited an equivalent decline, not only in terms of the number of cigarettes but also in

the total amount of tar (nicotine) purchased. Such behavioral change is evident regardless of the consumer's level of addiction, education, income, or area of residence.

When faced with a restriction in the supply of a familiar cigarette, finding alternatives with similar attributes outside of a familiar product range can make decision-making difficult. Information overload can confuse consumers and may delay their choices or cause them not to choose at all (Dhar, 1997; Chernev, 2003). The shift to low-tar (nicotine) products and reduced cigarette consumption may be attributable to growing health concerns. Smokers often perceive such cigarettes as a safer alternative to high-tar, full-flavor cigarettes; however, low-tar (nicotine) cigarettes are equally harmful to health (Cohen, 1996). Thus, instead of quitting immediately, smokers switch to "lighter" cigarettes to cope with nicotine cravings, believing that this will reduce health risks. Furthermore, smokers may prefer to exclude "stronger" or tempting products as a commitment to reducing tobacco consumption (Gul and Pesendorfer, 2004).

Our study, therefore, points to some avenues for future research. For example, the mechanism of the observed sustained behavioral change is yet to be explored. In additinon, consumer preferences and choices under consideration are built upon historical purchases. Further investigation of consumers' choice sets or consideration sets is needed to explain the drivers behind consumers' reactions to the loss of regular choices. Moreover, our estimates imply that consumers are likely to use product discontinuation as a commitment device to reduce cigarette consumption. Laboratory or field experiments like those conducted by Toussaert (2018, 2019) are needed to evaluate consumers' intent to reduce smoking or their use of commitment devices.

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Appendix

A Tables

Table A1: Descriptive statics of cigarette purchasers

	Full Sample				Subgroup Means		
Variables	Mean	SD	Min	Max	Unaffected	Affected	Diff. in Means
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***
Household income							
<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	0.16	0.37	0	1	0.16	0.18	-0.01***
Occupation							
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***

Notes: The table uses a pooled sample of consumers from 2010 to 2014. *, **, and *** denote significance at the 10%, 5%, and 1%, respectively.

Table A2: Composition of cigarette purchases

	Key products	Other JT products	JT discontinued	Non-JT products
Treated group	0.30	0.20	0.24	0.25
	[0.39]	[0.33]	[0.37]	[0.37]
Comparison group	0.34	0.21	–	0.45
	[0.45]	[0.38]	–	[0.47]

Notes: The table shows the percentage of key products, other JT products, discontinued products, and non-JT products in total consumer purchases before the earthquake. Standard deviations are shown in brackets.

Table A3: Descriptive Statics of Cigarette Purchasers: by Years

	2010		2011		2012	
	Treated	Control	Treated	Control	Treated	Control
Age	43.15	45.48	43.68	46.81	42.81	48.08
Male	0.58	0.71	0.48	0.69	0.52	0.71
Married	0.64	0.61	0.68	0.63	0.67	0.63
Education						
Secondary school or lower	0.42	0.40	0.43	0.40	0.43	0.40
Junior college or equivalent	0.22	0.19	0.24	0.20	0.24	0.20
Higher education	0.36	0.41	0.32	0.4	0.33	0.40
Household income						
<4 million	0.30	0.29	0.30	0.29	0.32	0.30
4-5.49 million	0.21	0.22	0.21	0.22	0.20	0.21
5.5-6.99 million	0.15	0.17	0.17	0.18	0.17	0.19
7-8.99 million	0.16	0.14	0.15	0.14	0.15	0.13
≥9 million and higher	0.18	0.19	0.17	0.18	0.16	0.17
Occupation						
Blue-collar	0.13	0.13	0.11	0.13	0.13	0.15
White-collar	0.65	0.68	0.66	0.68	0.65	0.68
Student/unemployed/others	0.22	0.20	0.23	0.19	0.22	0.16

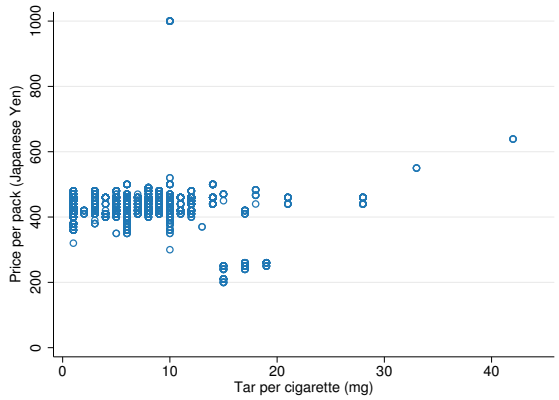
Notes: The table reports the means of the variables by treatment and control groups.

Table A4: Short- and Long-term effect

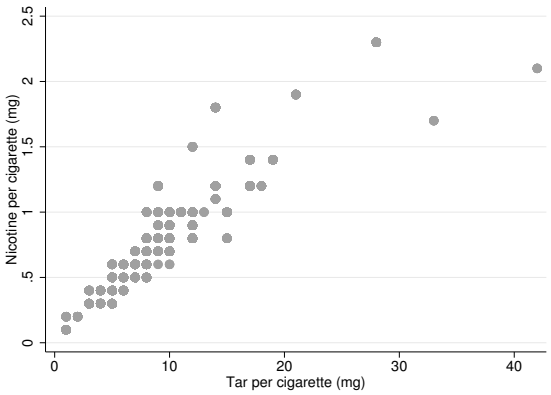
	Levels			Logarithmic scales		
	# Cigarettes	Total tar	Total nicotine	# Cigarettes	Total tar	Total nicotine
	(1)	(2)	(3)	(4)	(5)	(6)
A. Until the 6th month after stockouts (Feb 2012)						
$Treat \times Post$	-25.9***	-166.8***	-14.5***	-0.26***	-0.34***	-0.23***
	(6.02)	(46.3)	(3.80)	(0.051)	(0.064)	(0.043)
Post	-86.2**	-887.9**	-69.5**	-0.55*	-0.68**	-0.49**
	(39.4)	(384.1)	(30.9)	(0.28)	(0.32)	(0.22)
Observations	74,294	74,294	74,294	74,294	74,294	74,294
B. Until the 12th month after stockouts (Aug 2012)						
$Treat \times Post$	-25.7***	-207.9***	-17.6***	-0.27***	-0.36***	-0.25***
	(6.61)	(51.7)	(4.25)	(0.053)	(0.066)	(0.045)
Post	-166.8***	-1454.8***	-115.5***	-2.30***	-2.94***	-1.96***
	(30.2)	(362.0)	(28.6)	(0.22)	(0.30)	(0.21)
Observations	109,810	109,810	109,810	109,810	109,810	109,810
C. Until the 18th month after stockouts (Feb 2013)						
$Treat \times Post$	-27.3***	-237.4***	-20.0***	-0.30***	-0.41***	-0.28***
	(6.84)	(54.5)	(4.48)	(0.057)	(0.071)	(0.048)
Post	-329.9***	-2535.7***	-202.0***	-4.10***	-5.12***	-3.43***
	(46.5)	(546.4)	(42.9)	(0.43)	(0.60)	(0.41)
Observations	143,555	143,555	143,555	143,555	143,555	143,555
D. Until the 24th month after stockouts (Aug 2013)						
$Treat \times Post$	-31.6***	-264.3***	-21.9***	-0.34***	-0.45***	-0.31***
	(7.19)	(57.3)	(4.74)	(0.060)	(0.074)	(0.051)
Post	-426.8***	-2749.1***	-222.3***	-5.16***	-6.32***	-4.18***
	(66.6)	(505.3)	(41.0)	(0.38)	(0.50)	(0.36)
Observations	175,570	175,570	175,570	175,570	175,570	175,570

Notes: The difference-in-differences estimation in this table uses a matched sample generated by the kernel matching method. All columns are controlled for individual characteristics (age, sex, marital status, education level, household income, family size, and prefecture of residence) as well as month fixed effects. Standard errors shown in parentheses are clustered at the individual level. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

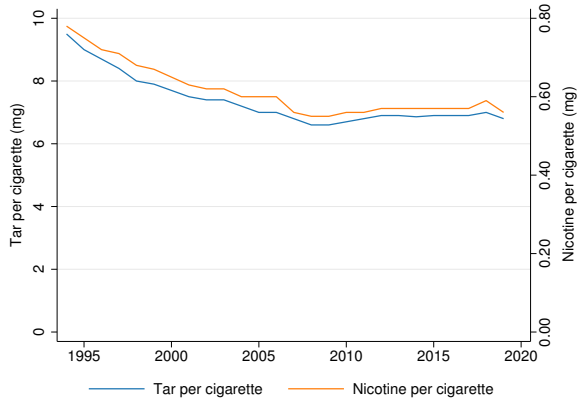
B Figures



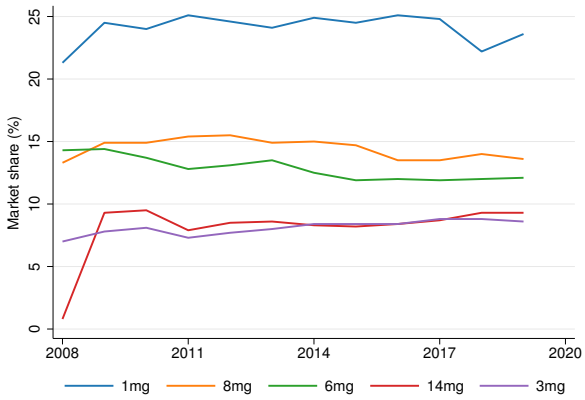
(a) Tar content per cigarette and price per pack



(b) Correlation between tar and nicotine



(c) Weighted average of tar (nicotine)



(d) Market share by tar type

Figure B.1: Tobacco market in Japan

Notes: The price per pack in (a) represents the price after the consumption tax increase of April 2014. Subfigures (b)–(d) were generated using data from the Tobacco Institute of Japan (see https://www.tioj.or.jp/data/index.html). The price per pack is calculated as the monthly sales revenue divided by the number of cigarettes sold.

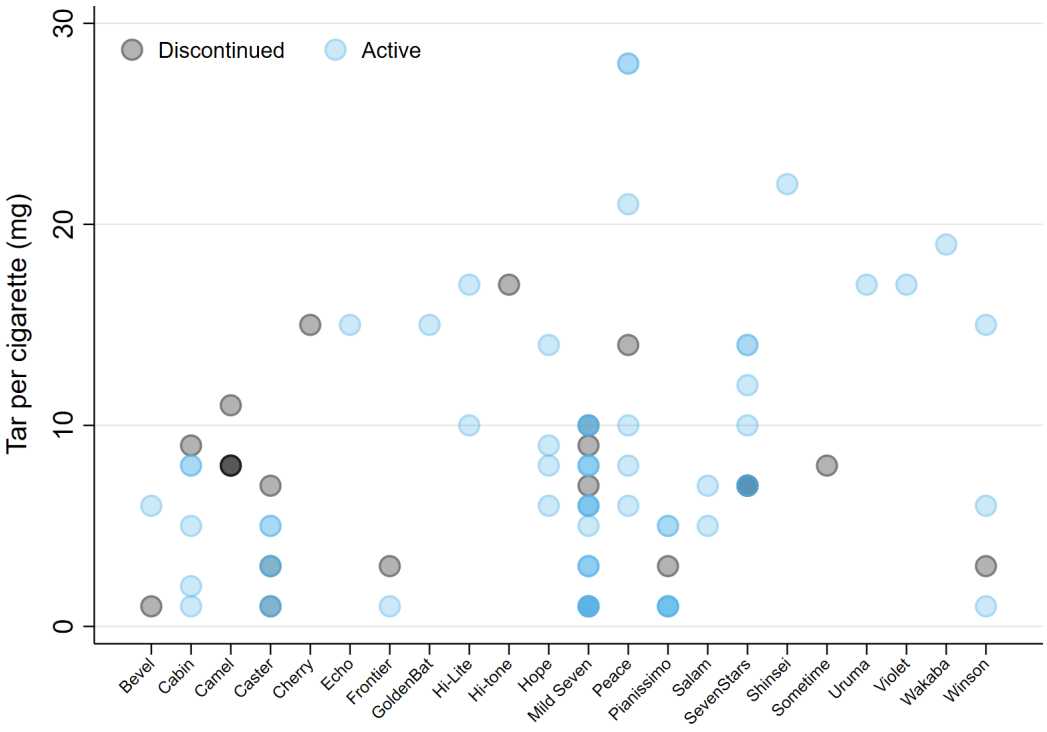


Figure B.2: Tar distribution of JT products

Notes: The data come from a JT press release in May 2011. The figure shows 94 products of 22 brands, of which two products from a brand (Zerostyle) are excluded due to lack of tar and nicotine information. See https://www.jt.com/media/news/2011/pdf/20110512_10.pdf for details.

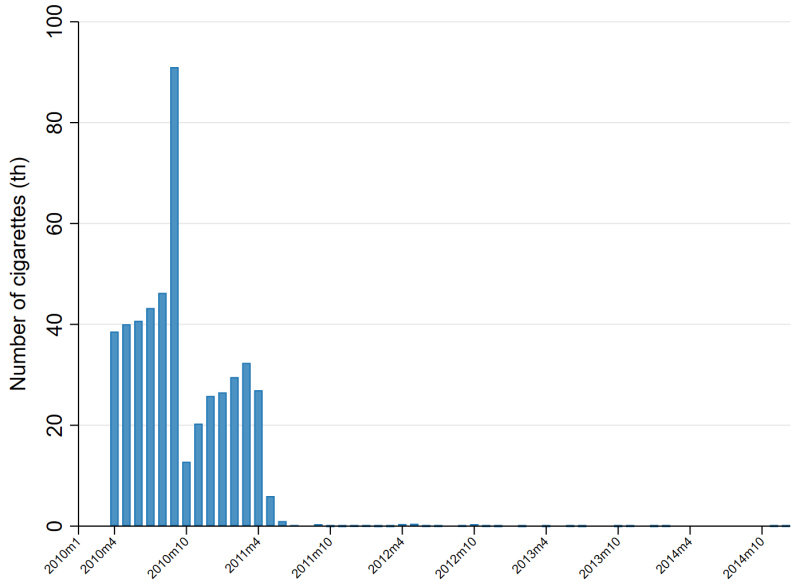


Figure B.3: Purchases of discontinued products over time

Notes: This figure shows the total monthly purchases of discontinued products. The first zero purchase occurred in August 2011.

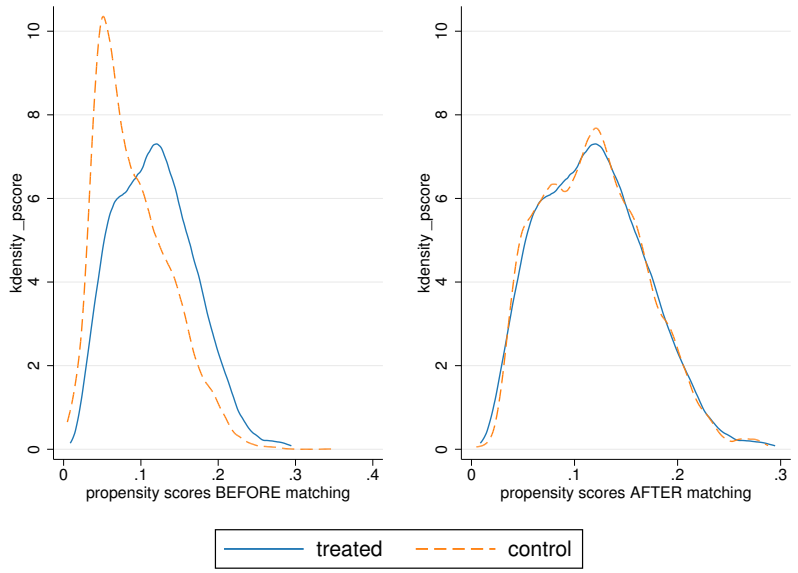
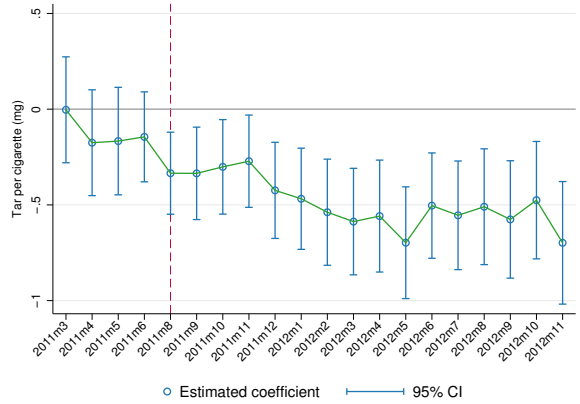
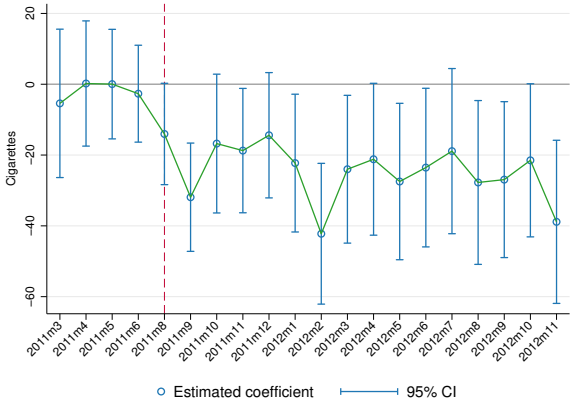


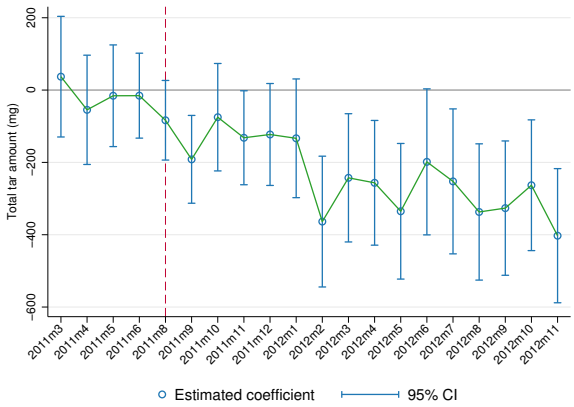
Figure B.4: Diagnostic test for propensity score matching



(a) Product choice



(b) Number of cigarettes



(c) Total tar in purchased cigarettes

Figure B.5: Common trends in cigarette consumption using matched sample

Notes: The dashed line represents the month in which stockout occurred. The circles and spikes represent the estimated coefficients and 95% confidence intervals, respectively.

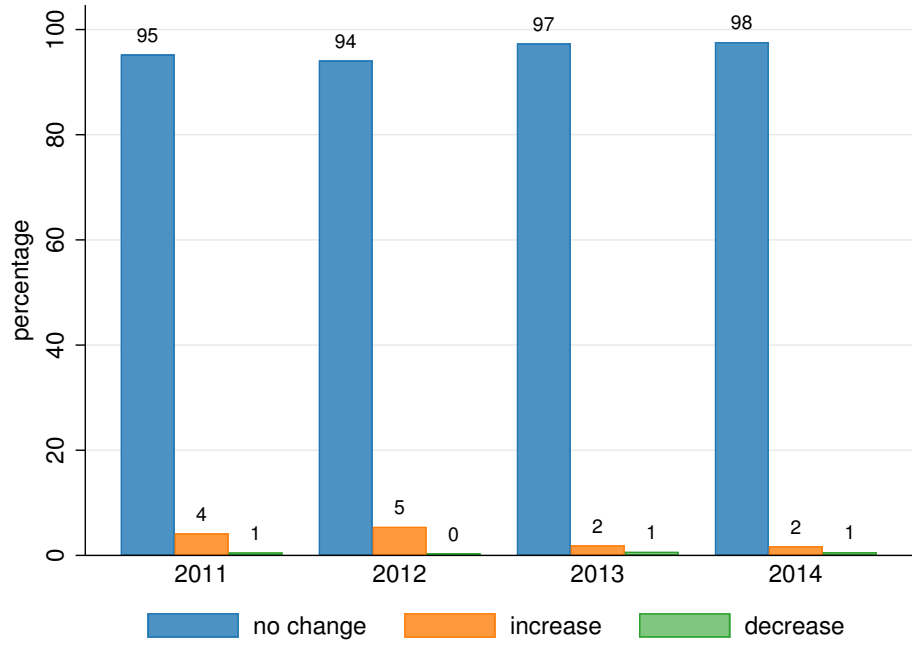


Figure B.6: Distribution of changes in household income by year

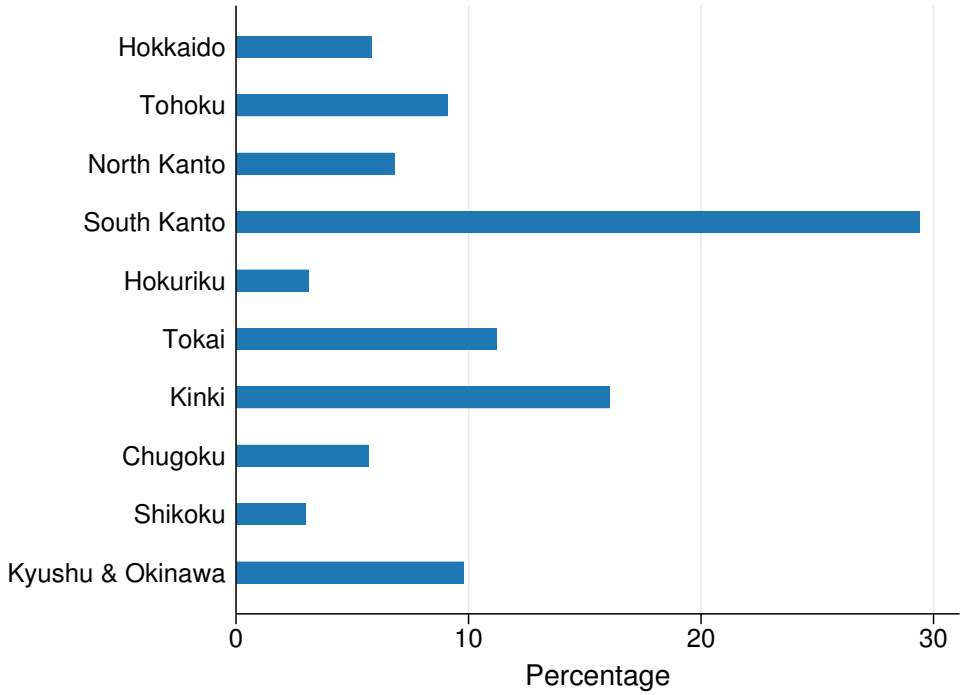


Figure B.7: Geographical distribution of affected consumers

Notes: The regions are displayed from north to south of Japan.