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The educational gap in tar and nicotine content in purchases of cigarettes: An observational study using large-scale representative survey data from Japan☆

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ABSTRACT

The intensity of tobacco use is commonly measured by the number of cigarettes, which is inaccurate because it masks the heterogeneity and substances contained in tobacco. Unlike existing studies, this study adopted the tar and nicotine content of purchased cigarettes as proxies for smoking intensity and elicited socioeconomic disparities from the participants regarding tobacco use. Using a nationally representative consumer panel survey of Japan from 2010 to 2014, we found that socioeconomic disparities in smoking are more pronounced when tar and nicotine content in cigarettes is considered. University graduates purchased 26% fewer cigarettes, and 40% less tar or nicotine than their secondary school-educated counterparts. Low education groups purchased more tar-rich cigarettes, which cost less than low-tar cigarettes. The public health recommendations for reducing socioeconomic health inequalities might be understated because they are drawn from evidence based on the number of cigarettes smoked.

1. Introduction

Cigarette smoking is a major risk factor for early death and disability (GBD 2015 Tobacco Collaborators, 2017; Niessen et al., 2018; Nugent et al., 2018; World Health Organization, 2017). It also significantly contributes to health inequalities, where smoking prevalence is disproportionally high among the poor and less educated people (Pampel and Denney, 2011). Educational attainment largely explains such disparities (Cutler and Glaeser, 2005). Higher educated people may smoke less because they have better knowledge of health risks (Cutler and Lleras-Muney, 2010). For instance, the proportion of moderately educated smokers (i.e., smokers with upper secondary or post-secondary non-tertiary education) in the European Union was 21.8% in 2014, which is 9.4% higher than people who completed tertiary education (Statistical Office of the European Communities, 2016). In the USA, smoking prevalence in 2016 was the highest among those with upper secondary education certificate (41.4%) and lowest among those with a graduate degree (4.5%) (Jamal et al., 2018). In Japan, the proportion of smokers with low levels of education reached 20% and has remained stable among smokers with secondary education or lower since 2013 (Ministry of Health, 2016).

Discussions on socioeconomic inequality in smoking are well documented (Fagan, 2016; Golden et al., 2016; MacLean et al., 2016; Ng et al., 2014; Tauras, 2006; Verguet et al., 2015; World Health Organization, 2014). However, earlier studies usually use the number of cigarettes smoked to quantify disparities, which assumes cigarettes to be homogenous 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.

Studies examining tar and nicotine levels in cigarettes offer key implications for public health policy. For example, Adda and Cornaglia (2006) and Cotti et al. (2016) used data from the USA and argued that the number of cigarettes smoked does not indicate tar and nicotine intake because individuals could choose tar- or nicotine-intensive products but smoke fewer cigarettes. Ignoring nicotine and tar intake may underestimate the harmfulness of smoking and the related socioeconomic inequalities. This paper aims to highlight disparities based on nicotine and tar intake, which is rarely discussed in the literature.

It is well recognized that cigarettes are differentiated by tar and nicotine content (Gray and Boyle, 2002). Thus, it is natural to use the

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amount of substances purchased or potentially inhaled to identify the harmfulness of smoking. Our research assesses the Japanese cigarette market to elaborate on the socioeconomic disparities in tar and nicotine content in cigarette purchases. As in other markets, the tar content per cigarette in Japan varies widely, ranging from ultra-low at 1 mg to extremely high at 42 mg. The nicotine content increases proportionally with the tar content (Appendix Fig. A1). Although the average tar content in each cigarette has continued to fall from 9.5 mg in 1994 to 6.9 mg in 2016, products with > 10 mg of tar per cigarette have gained popularity and are ranked among the top five on the market (Tobacco Institute of Japan, 2017). Unlike the USA, Australia, and the UK (Breton et al., 2018; Nargis et al., 2014; Scollo et al., 2015), the price gap between different cigarette brands is small due to government regulation. Interestingly, the price per milligram of tar is higher for products that are low in tar (Appendix Fig. A2).

We used large-scale nationally representative consumer survey data from Japan and investigated cigarette purchase behavior across different education groups. For the first time in the relevant literature, we measured the tar and nicotine content in cigarettes purchased to estimate the educational gradient in cigarette purchasing. More specifically, we examine 1) the relative size of the educational gradient in the purchase volume measured by the amount of tar and nicotine content and the number of cigarettes purchased and 2) the primary factors (e.g., product attributes or price) associated with the differences in the gradients.

2. Methods

2.1. Sample

We used nationally representative consumer survey 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 and recruited participants through web banners and job search websites. Participants received reward points as a return on participation from a website of the INTAGE Group (https://www.cue-monitor.jp/), and the reward points can be exchanged for cash and various gift cards. Based on the population census, the sampling procedure employed a quota sampling technique, wherein the final sample has the same proportions of individuals as the entire population concerning sex, marital status, and age (Appendix Table A1). They conducted the baseline survey in April 2010 and covered 21,607 individuals from 11 standard regions (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, and 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. Participants scanned the barcode of products using a mobile device and entered the date of purchase and receipt information (including unit price, number of items purchased, total amount paid, and store name) on the survey website after each purchase. 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. Among these consumers, 16,533 purchased at least one pack of cigarettes in 2010–2014.

Using the scanned barcode, 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) was excluded from the analysis because of missing tar and nicotine information.

2.2. Variables and measurement issues

2.2.1. Purchase volume

We used the number of cigarettes purchased and the total amounts of tar and nicotine in purchased products to measure purchase volume. The number of purchased cigarettes has been widely used in existing studies (MacLean et al., 2016; Ng et al., 2014; Tauras, 2006), while the tar and nicotine amounts implicitly explain tar and nicotine intake. Although tar and nicotine yields do not reveal intake, evidence has shown that a high urinary nicotine metabolite concentration corresponds to high nicotine yields (Ueda et al., 2002).

Overall purchases were relatively stable over time except for the two periods when the tobacco tax increased (Appendix Fig. A3); thus, we aggregated all transactions for each consumer. Because consumers had different participation periods in the survey, we further calculated the average volume of tobacco purchased per month.

2.2.2. Product choice

We measured consumer product choice by the intensity of tar and nicotine and the unit price of cigarettes. The intensity of tar and nicotine shows an individual's choice of cigarettes with different tar and nicotine content (total amount of tar (or nicotine) over the number of cigarettes purchased). Price could influence consumer choice. We computed the product price in two ways: price per cigarette and price per milligram of tar (or nicotine). We calculated the price per cigarette as the total spending on cigarettes over the number of cigarettes purchased. We expressed the price per milligram of tar (or nicotine) as the ratio of price per cigarette to the mean amount of tar (or nicotine) per cigarette.

2.2.3. Socioeconomic status

The socioeconomic status (SES) of participants include: age, sex, family size, education (secondary or lower as reference, junior college or equivalent, higher education), household income (< 4 million as reference, 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, office workers as white-collar workers, students, unemployed, and others other than unemployed).

2.3. Statistical analyses

We employed a two-part model (TPM) to investigate association between education levels and cigarette purchase. The TPM approach is commonly used in earlier studies (Chaloupka, 1991; Sari and Langenbrunner, 2001; Wasserman et al., 1991). The first part of the model uses a probit approach to estimate the probability of purchasing cigarettes. The second part of the model uses a log-linear regression analysis for predicting the purchase volume conditional on the individuals who made purchases. The regression analyses controlled for age, sex, marital status, education, occupation, income, and residential area. Some consumers who did not report household income (0.87% of the sample) were excluded from the regression analysis. To examine disparities in purchasing patterns across educational groups, we restricted the sample to consumers who purchased cigarettes during the survey period and used the ordinary least squares (OLS) method.

3. Results

3.1. Descriptive statistics

As indicated, participants were not eligible for the survey if they withdrew or failed to meet the reporting criteria. The average *length of* stay in the survey was 30.8 months (1 to 57 months). Table 1 presents statistics for the participants involved in the survey. Cigarette

Table 1
Characteristics of the survey participants.
Source: Authors' analysis of data for April 2010–December 2014 from the Japanese Home Scanner Data.

	Non-purchasers (n = 59,284)	Purchasers (n = 16,533)	p value
Age	40.76	42.86	< 0.001
Male	36.9%	50.4%	< 0.001
Married	66.4%	66.4%	0.94
Family size	3.01	2.97	< 0.001
Education			
Secondary school or lower	32.4%	42.1%	< 0.001
Junior college or equivalent	25.6%	24.2%	< 0.001
Higher education	42.0%	33.7%	< 0.001
Family income			
< 4 million	30.1%	32.2%	< 0.001
4–5.49 million	20.8%	21.2%	0.31
5.5–6.99 million	16.6%	16.7%	0.83
7–8.99 million	15.8%	15.0%	0.02
9 million and higher	16.7%	15.0%	< 0.001
Employment			
Employed	66.9%	75.5%	< 0.001
Occupation type			
Blue-collar	7.4%	12.5%	< 0.001
White-collar	61.5%	64.8%	< 0.001
Student/unemployed/ others	31.1%	22.7%	< 0.001
Residence area			
Chugoku	5.5%	5.7%	0.52
Hokkaido	3.9%	5.7%	< 0.001
Hokuriku	5.6%	5.5%	0.70
Kanto	5.9%	6.4%	0.010
Keihanshin	16.9%	14.5%	< 0.001
Keihin	29.8%	27.8%	< 0.001
Kyushu	9.9%	10.7%	< 0.001
Okinawa	0.9%	1.0%	0.06
Shikoku	3.0%	2.8%	0.12
Tohoku	6.4%	8.6%	< 0.001
Tokai	12.1%	11.2%	0.0013

Note: Of the 75,871 participants, 662 participants did not report household income.

purchasers and non-purchasers were unevenly distributed, accounting for 22% (n = 16,533) and 78% (n = 59,284) of the sample, respectively. Cigarette purchasers were more likely to be older and male and to have a smaller family. Of the purchasers, 42% had obtained only a secondary school diploma or lower, which was 10% higher than that of non-purchasers in the same low education group. The proportion of highly educated purchasers was 8% lower than the highly educated non-purchasers. Low-income individuals whose annual household income was < 4 million Japanese yen (JPY; average annual income in Japan) accounted for 32% of the purchasers. Individuals in paid employment constituted 75% of the purchasers. In most residential areas, purchasers and non-purchasers had similar proportions.

Table 2 reports descriptive statistics for volume and product choices. A typical (median) consumer purchased 176 cigarettes per month, which is equivalent to nine 20-cigarette packs. Variations in purchase volume across educational groups were apparent. Junior college graduates bought the fewest cigarettes, whereas secondary- and university-educated groups purchased a similar number of cigarettes. Some differences between the two groups were evident. Secondary school graduates purchased cigarettes with 1.2 times more tar compared to university graduates. Preferences for tar and nicotine did not reveal any differences between educational groups. In contrast, the price of a cigarette purchased by educational groups varied. While consumers from all groups paid a comparable price per cigarette (20.6 JPY each; equivalent to $0.2 USD), highly educated individuals purchased products that were higher in price per milligram of tar by 3.4–3.7 JPY.

3.2. Purchasing disparities

Buying intentions and purchase intensity varied across SES groups. Among SES factors, education level showed the most substantial difference (Appendix Table A3). The reference group for comparison was those attaining secondary education or lower. Table A3 reports the probability of being a tobacco purchaser and displays—given any purchases—how the volume of cigarettes purchased fluctuated as educational attainment changed from lower to higher levels. Fig. 1 visualizes the magnitude of educational gradients in tobacco purchasing.

Compared with the secondary education group, the probability of purchasing among junior college and university graduates was 6% and 11% lower, respectively. University graduates purchased 26% fewer cigarettes and 40% less tar or nicotine than their secondary school-educated counterparts. Our results suggest that the decrease in purchases measured by tar or nicotine content was about 1.5 times that measured by the number of cigarettes.

Aside from educational levels, other SES factors were also associated with cigarette purchasing behavior. Male participants purchased more cigarettes and a higher volume of tar and nicotine than female participants. Moreover, purchase volume changed by age. Consumers purchased more when younger but less as they aged. Consumers married with a large family bought fewer cigarettes and a lower amount of tar and nicotine. Moreover, high-income groups (≥9 million JPY) bought more cigarettes, but the products contained less tar and nicotine.

We conducted robustness checks to address a concern about the sample used. Given that some participants withdrew from the survey, it is difficult to identify the consistency of the purchases. We restricted the sample to those who remained in the survey from April 2010 to December 2014. Thus, we identified consumers who consistently made no cigarette purchases. The results reported in Appendix Table A4 confirm a negative gradient between educational attainment and cigarette purchasing. Estimates for educational gradients in purchasing showed a slight increase. For university graduates, purchases measured by tar or nicotine content were 33% lower than secondary school graduates. The decrease in purchases measured by tar for this group was 1.8 times that measured by the number of cigarettes, suggesting that our results are robust. Therefore, the effect of education on tar and nicotine intake remained substantial compared with an alternative measure based on the number of cigarettes.

3.3. Product choice disparities

We examined educational gradients in consumer product choices. Fig. 2 extracts the estimation results from Appendix Table A5.

We observed that higher educated consumers preferred low-tar cigarettes. Fig. 2(a) shows that the products chosen by university graduates contained less tar and nicotine—14.3% and 12.7% lower, respectively—than those chosen by their secondary school-educated counterparts. Second, product choices were not affected by the price of cigarettes but by the price of tar content. Tar-rich cigarettes cost less than low-tar cigarettes. Fig. 2(b) indicates that, compared with secondary school graduates, university graduates preferred expensive but lower-tar cigarettes. Besides the educational gradient, other SES groups had different purchasing patterns. Purchasing choices varied by sex, age, and family income. Men were more likely to choose high tar but cheaper cigarettes and changed product types more often. Middle- to high-income households preferred low-tar and expensive cigarettes.

Table 2
Tobacco purchases (median) by education group.
Source: Authors' analysis of data for April 2010–December 2014 from the Japanese Home Scanner Data.

	All (n = 16,533)	Secondary or lower (n = 6961)	Junior college or equivalent (n = 4003)	Higher education (n = 5569)
Total cigarettes/month	176	192	140	185
Total tar (mg)/month	630.0	741.8	501.7	612.9
Total nicotine (mg)/month	55.8	65.4	45.2	54.8
Choice of tar (mg)	6.0	6.0	6.0	5.7
Choice of nicotine (mg)	0.5	0.5	0.5	0.5
Price per cigarette (JPY)	20.6	20.6	20.6	20.6
Price per mg of tar (JPY)	3.5	3.4	3.6	3.7
Price per mg of nicotine (JPY)	41.3	40.2	42.1	43.1

Notes: The data show that consumers' purchases had large dispersion and skewed (Appendix Fig. A4 and Table A2). Purchase volume is measured by 1) number of cigarettes; 2) total amount of tar or nicotine contained in products purchased. Given that consumers have different participation period, we adjusted purchase volume by the length of stay in the survey, which forms monthly purchases. A consumer's preference over tar (nicotine) is the total amount of tar (nicotine) over a total number of cigarettes purchased. Product price is measured by: 1) price per cigarette; 2) price per milligram of tar (nicotine) content. Total spending on tobacco over the number of cigarettes purchased forms price per cigarette. Price per milligram of nicotine is a ratio of price per cigarette to the average amount of tar/nicotine per cigarette.

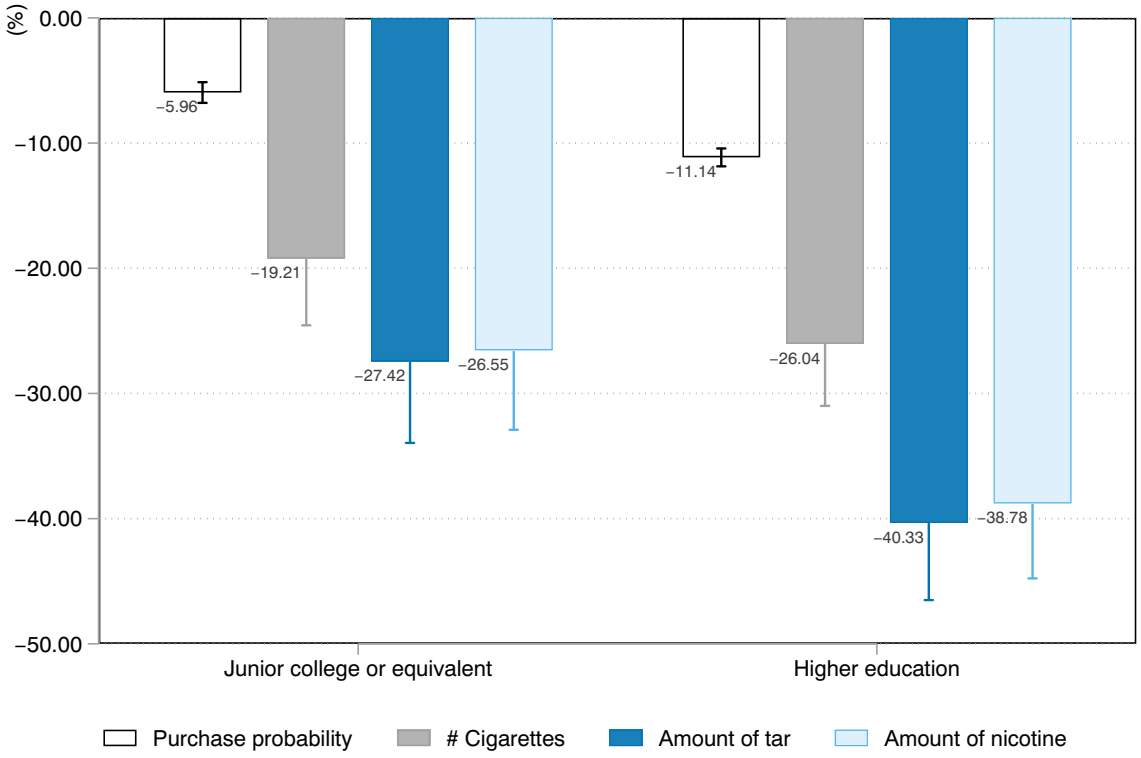

Fig. 1. Association between education and tobacco purchasing (reference group: secondary or lower education level).
Note: The results are computed using TPM regressions presented in Appendix Table A3. The analysis excludes 662 participants who did not report their household income. The reference group for education is those with secondary school or lower level of education. Ranges indicate 95% confidence intervals.
Source: Authors' analysis of data for April 2010 to December 2014 from the Japanese Home Scanner Data.

4. Discussion

Our results show that educational gradients in cigarette purchases measured by tar or nicotine content were about 1.5 times higher than those measured by the number of cigarettes. Moreover, the educational gradient is stronger than the income gradient. Income only accounts for a part of the education gradient in smoking (Cutler and Glaeser, 2005; Cutler and Lleras-Muney, 2010). Education is an important contributor and determinant of other socioeconomic characteristics, including income and wealth. Higher educated people earn more. Thereby, education affects their health and health behavior.

Similarly, our study shows that higher educated smokers tend to purchase lower-tar/nicotine products than lower educated smokers. This effect is much stronger than that obtained when we measure smoking by the number of cigarettes. A significant difference exists in the smoking cessation rate by education groups (Zhuang et al., 2015). Highly educated smokers have a higher smoking cessation and quit attempt rate than their lower educated counterparts. It is also likely that highly educated smokers may switch to lower-tar/nicotine content products when they are not successful at quitting. Due to the lack of specific data on this, we cannot provide more insight; therefore, this is an area that future research should explore.

Moreover, our finding provides interesting insight on how tobacco companies' potential pricing strategies differentially affect smoking and switching behaviors of smokers by education group. Tobacco companies may have specific pricing strategies for high tar/nicotine products that specifically target low SES people and younger (new smokers) individuals. A UK-based study stated that when faced with a tobacco tax

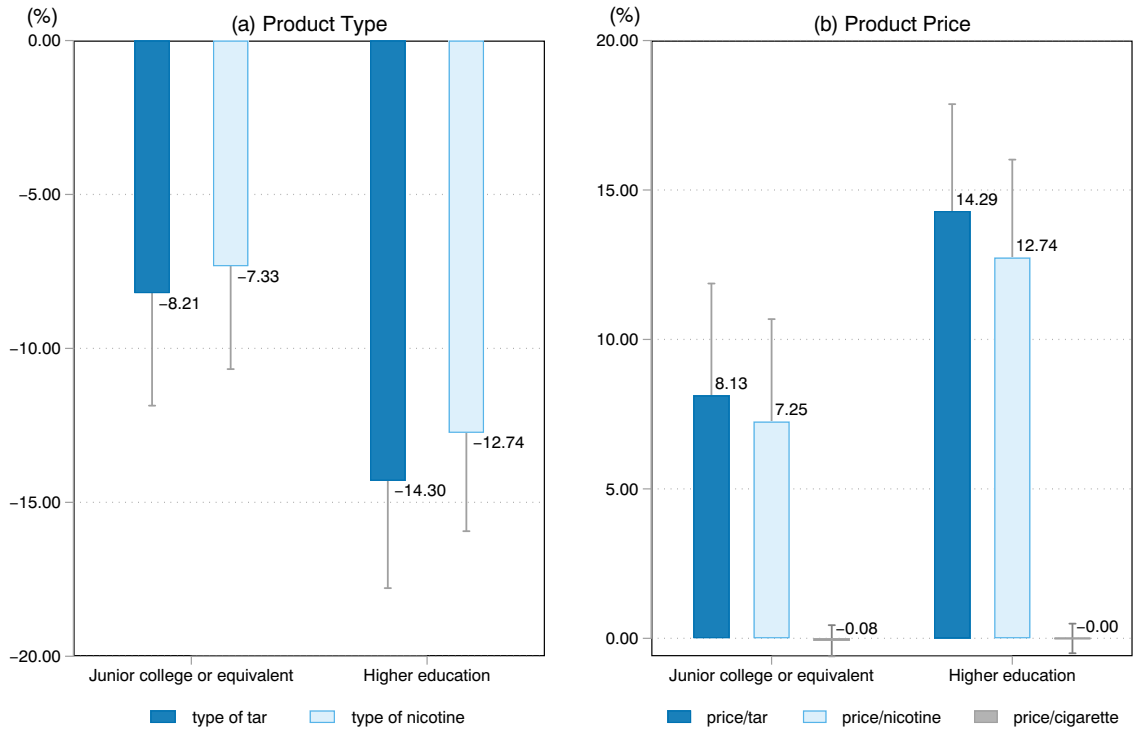

Fig. 2. Education gaps in preferences and product choice of tobacco (reference group: secondary or lower education level.
Note: The results are computed using OLS regressions as presented in Appendix Table A5. The analysis excludes 662 participants who did not report their household income. The product type chosen by a panelist is expressed as the total amount of tar (nicotine) over the total number of cigarettes purchased. Product price was measured as the price per cigarette and price per milligram of tar (nicotine) content. Total spending on tobacco over the number of cigarettes purchased was used as the price per cigarette. Price per milligram of tar (nicotine) is a ratio of price per cigarette to the mean amount of tar/nicotine per cigarette. The reference group is those with secondary school or lower level of education. Ranges indicate 95% confidence intervals.
Source: Authors' analysis of data for April 2010 to December 2014 from the Japanese Home Scanner Data.

increase, the tobacco industry increases prices over and beyond tax increases over time. However, when examined by price segments (i.e., premium, economy, mid, and ultra-low price (ULP)), the industry absorbs the tax increase and decreases the price for ULP products. With this pricing strategy, the ULP market share substantially increased over 3 years (Gilmore et al., 2013). A lower pricing strategy for higher tar/nicotine products will have significant public health consequences given that products with high nicotine content are more addictive and purchased more by people with lower SES. Limited research exists focusing on the tobacco industry pricing strategy. Future research focusing on this and its effect on smoking and switching behaviors could explain anti-smoking public policies and regulations for tobacco products.

This study provides guidance for tobacco-related research and control policies. First, to accurately measure the health risks of smoking, future researchers could emphasize the tar and nicotine content in cigarettes. While it is almost impossible for surveys to collect data on tar and nicotine intake, the surveys that gather tobacco brand information and the number of cigarettes smoked offer feasible alternatives to study the health implications of tobacco consumption. Similarly, modeling studies to predict the distributional effects of tobacco policies should consider the possibility that lower SES groups tend to choose higher tar and nicotine products than higher SES groups; otherwise, the health gains of reducing tobacco consumption by lower SES groups could be understated.

Second, tobacco control policies should strengthen supply-side regulation. The widely accepted WHO (2003) Framework Convention on Tobacco Control covers monitoring tobacco use, legislation mandating smoke-free environments, cessation programs, advertising bans, mass media campaigns, warning labels, and tobacco taxation. However, these are demand-side interventions. Supply-side regulations could also be effective tools against smoking. In 2018, the Food and Drug Administration (FDA) in the US issued a proposal to reduce the level of nicotine in combustible cigarettes to a minimally addictive or non-addictive level (FDA, 2018). Given the educational gradient indicated in our findings, this policy has the potential to influence people with a lower SES more and help reduce health inequities due to smoking. With the successful implementation of this policy in the US and other countries, tobacco products could become less or no longer addictive. It is likely that the policy helps addicted smokers (or daily smokers) in reducing nicotine and tar intake more. To have more comprehensive regulations in the production of tobacco products and nicotine content, public health policies should consider regulating the tar content of all cigarettes. Due to its association with several diseases, the toxicity of tar cannot be ignored (Lee, 2018).

Third, reducing SES inequalities in smoking is equally important as controlling smoking prevalence. Most tobacco control policies do not target low SES groups but the general population (Chaloupka and Warner, 2000; Saffer and Chaloupka, 2000; Sari, 2013; Spinney, 2007). It is not clear that tobacco control interventions (i.e., smoke-free environment and educational media campaigns) are effectively targeting low SES groups (Durkin et al., 2012; Hackshaw et al., 2010). While taxation is effective in reducing smoking, whether it has reduced educational disparities in smoking is still inconclusive (Hill et al., 2014). Therefore, future research is necessary to examine the effect of tobacco control interventions on reducing smoking inequalities among SES groups.

Some limitations exist in this study. First, we analyzed purchase volume, although purchasing and consumption are not equivalent. Thus, the purchased level of tar and nicotine does not necessarily correspond to actual intake (Ueda et al., 2002). More accurate measurements of tar and nicotine can be used in future research. Second, the

purchases were scanned and reported by the participants, rather than recorded as real-time transactions at the point of sale. Our analysis was based on aggregated purchases over the survey period and did not examine the dynamics of purchasing activities, such as brand loyalty, stockpiling, and brand switching. Despite these limitations, this paper is the first to investigate educational disparities in cigarette purchasing through tar/nicotine content. In particular, the study showed remarkable differences in product choices and the purchase volume of cigarettes across educational groups, which imply a socioeconomic heterogeneity in preferences over products with different levels of substances. In addition, the home scanner data are more objective and precise than survey data, and the data quality is not subject to participants' memories (Leicester, 2015).

5. Conclusions

We examined education level disparities in tobacco purchasing using scanner data from a Japanese sample. We quantified education gradients in terms of tar and nicotine intake. The results show that the educational gradients in tobacco purchases measured by tar or nicotine content were about 1.5 times larger than those measured by the number of cigarettes. Our estimates imply that earlier studies and policy recommendations focusing on the numbers of cigarettes purchased or consumed were likely to under- or overstate the health risks.

Declaration of competing interest

We have no conflict of interest to declare.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ypmed.2019.105828.

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