The Effects of The Tobacco Tax Increase on Public Health: The Empirical Analysis of the 2015's Tax Implementation in South Korea

By

KIM, Hanbin

THESIS

Submitted to

KDI School of Public Policy and Management

In Partial Fulfillment of the Requirements

For the Degree of

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Committee in charge:

Professor Baek, Ji Sun, Supervisor

Professor Shin, Jaeun

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ABSTRACT

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Korean government implemented a huge increase in tax on tobacco nationwide in 2015. Previous literature proved approximately 4% of smokers quit smoking because of about 114% of the increased price. Many other researchers who interested in public health studied about the relationship between smoking and health status. This study attempts to identify the empirical analysis of the tax effect on public health combining the previous ideas, which the adjusted smoking behavior by tax implementation improves public health. To estimates, this study utilizes KOWEPS raw data and difference-in-differences methods. As a result, this study suggests the potential possibility of the improvement of mental health. However, there are insignificant results and some limitations such as time limits of the data, thus, still there remains veiled scope for further research on this topic.

Keywords: tobacco tax, self-rated health, mental health, family relationship, secondhand smoking, South Korea

1 Introduction

Tobacco is one of the representative addictive goods; many researchers have dealt with smoking as a significant determinant of physical and psychological health. In particular, smoking has been considered a felon that burden enormous social cost to care for poor health. Because smoking is the main cause of cancers such as lung cancer, oral cancer, laryngopharyngeal cancer, and esophageal cancer, moreover, it causes coronary-artery disease, cerebrovascular disease, chronic lung disease, stomach ulcer, and so on (Lee et al., 2006; Lee et al., 2011). In practical, tobacco leads almost half of smokers to death, and about 8 million people died annually because of direct and secondhand smoking (World Health Organization [WHO], 2020). Lee et al. (2011) mentioned that smoking reduces life expectancy by about 20 years. Nonetheless, according to Morello et al. (2001), smoking is a preventable factor among fatal diseases that unto death.

Governments operate various anti-smoking campaigns and national tobacco control policies to alleviate social costs such as tax policy, which generally called Sin Tax. However, the effectiveness of the tobacco tax policy still controversial. One side asserts that the tobacco tax is plausible to restrain tobacco consumption, and the total welfare effect of the tax is positive (Park, 2016). On the other hand, the other side argues that the tax burden returned to the low-income level since the low-income level is the main consumer of tobacco (Kang et al., 2013; Kim et al., 2017). In practice, the Korean government increased taxes related to tobacco the first in 11 years since 2004; as a result, the price boosted about 114 percent in 2015. It was a substantial increase compared to the previous tax increase of about 44 percent. Kim and Jung (2020) proved this tax increase causes the behavioral change of smokers, and they reported that the response of the survey for willingness to quit smoking within six months increased a moment. However, the increase of willingness to quit smoking does not achieve the smoking cessation of next year.

Apart from all debates, all researchers agreed or have no objection that the tobacco tax's purpose is to improve public health by suppressing tobacco consumption. As discussed so far, some studies discovered the effect of smoking on individual health and whether the tax change can cause smokers' behavioral change. However, the field of studies that analyze whether the policy achieved its purpose seems to have remained as dimmed. In this study, I attempted to shed light on the dimming site by identifying health improvement after the tax increase. Thus, this study provides an overview of findings from the recent policy.

The rest of the paper follow the sequence. In the next part, the previous literature is summarized. The third part demonstrates the descriptive statistics of the samples. In part four, this paper illustrates the empirical methods to examine whether the tobacco tax implementation in 2015 affects health improvement. In the next part, the estimated results are provided. An extended discussion about the results is described with relevant literature in the following part. At last, the conclusion suggests further research based on the linkage between the estimated result and discussion.

2 Literature Review

In general, economic analysis has been treated individual health status about what factors sensitively effects on them. There were pieces of research that investigated how to measure individual health status. The efforts to develop the measurement are still up to now; nonetheless, previous researches support that self-rated health status is feasible to measure individual health status (Patrick & Bergner, 1990; Famer & Ferraro, 1997; Choi & Kim, 2018) since self-rated health status connotes overall individual health status (Kwon, 2011).

The main causal factors of self-rated health status have been identified as individual health behavior such as smoking and drinking status, eating habits, habitual exercise (Kim. J., 2016; Choi & Kim. H., 2018), particularly, there has been much support that the existence of

chronic disease is the principal factor of self-rated health status (Kwon 2011; Kim & Nam, 2019). Previous literature also added that demographic factors such as age, job, income level, education level, and marital status affect self-rated health status (Lee et al., 2006; Kwon 2011; Kim. J., 2016; Choi & Kim. H. Y., 2018; Kim. H. J. & Nam, 2019).

Meanwhile, smoking has been assessed as a crucial factor in public health among the factors of health (Lee et al., 2006). According to the literature, smoking causes negative effects on individual health by triggering various cancers and related diseases (Lee et al., 2006; Lee et al., 2011; Morello et al., 2001; WHO, 2020). Hence, this study expects that the correlation between smoking amount and self-rated health status may have an inverse relationship. However, there is the opposite result of this common sense. Kim (2004) reported that some subgroups of their sample had no significant difference in smoking amount between high self-rated health and low self-rated health. Also, Lee and his colleagues found that individuals who have better self-rated health smoked more than others in the elderly group (Lee et al., 2010). In the study of the following year, they commented about this context that the causality is not clear because related variables have been interacted to determine the smoking status and amount (Lee et al., 2011).

In addition, researchers interested in the relationship between smoking and physical health as well as mental health (Kim. J. M. et al., 2012; Kim. J. H., 2016; Kwon et al., 2016; Yun, 2018; Bin, 2020). Some of them reported that smoking is a noxious factor on psychological disorder such as stress, depression, suicidal idea (Kwon et al., 2016; Yun, 2018; Bin, 2020). Kwon, Kim Y. J., and Kim H. S. (2016) showed the risk of occurrence for stress, depression, and the suicidal idea was at least 1.66 times and up to 2.02 times higher than non-smoking groups in the group of smokers who smoke more than 20 per day. Bin (2020) supported previous research with his result that reported, even though it conditionally varies by the type of smoking, the risk of diagnosing depression, occurring depression, and stress was 2.87 times higher, 1.66

times higher, and 1.62 times higher in the smokers than in the non-smoking group.

Also, there is a growing interest in secondhand smoking that is commonly pointed out as a destructive factor of public health. The sidestream smoke, which is the smoke gushing out when someone smoking, have higher toxic chemical and carcinogen content than in the mainstream smoke (Kang et al., 2015). According to previous literature, secondhand smoking increases the risk of respiratory disease, metabolic syndrome, and restless sleep (Kwon et al., 2020). Kwon et al. (2020) reported that adolescents experienced depression of at least 27 percent and up to 41 percent due to secondhand. Other researchers also discovered that secondhand smoking negatively affects mental health (Kang et al., 2015; Jacob et al., 2020).

Hence, researchers actively study on smoking and family relationships due to the impact of smoking affects people around the smoker. However, the debate of causality between smoking and family relationships still present. Lee et al. (2010) announced that elderly smokers who satisfy family relationships have less amount of smoking. On the contrary, in their research of the following year, they expanded their sample to all ages and figured out the satisfaction of family relationships does not directly affect the smoking amount; however, there is an indirect effect on smoking amount through self-rated health status (Lee et al., 2011). On the contrary, other researches explore the opposite direction. In the research of Oh and Seo (2014), they found that smoking has an inverse relationship with life satisfaction; in other words, the higher the amount of smoking, the lower the satisfaction level with family relationships and life quality. By combining these results, it can be assumed that smoking and family relationships do not affect one side direction, but are interacted by each other. Thus, this study also attempts to identify the effects of adjusted smoking behavior on family relationships and the health status change of non-smokers by the discontinuity of secondhand smoking.

In Korea, the government implemented a massive tax increase policy on tobacco in 2015. Kim and Jung (2020) proved that there was an extraordinary number of cessation by militant

price rising of tobacco at the point of the implementation. Hence, whether the tobacco tax policy achieved the goal of improving public health is a worthwhile agenda. By combining the literature's discussion, this study pursues to identify whether adjusted smoking behavior by the tax policy caused actual health promotion. Also, to be a firm conclusion, this study applied additional analyses. The first sub-analysis attempt to discover the effects of smoking cessation in 2015 on health status after 2015. Additionally, whether the discontinuity of secondhand smoking affects the health status of the smoker's family is identified in the second sub-analysis. If significant positive effects after 2015 on any outcome variable, this study would confirm the tax policy improved public health and quality of life.

3 Data and Descriptive Statistics

3.1 Data Source

This study handles the raw data of the Korea Welfare Panel Study (KOWEPS), which has been generated by the Korea Institute for Health and Social Affairs (KIHASA) and Institute of Social Welfare of Seoul National University (SNU-ISW). KIHASA and SNU-ISW have tracked nearly seven thousand households to build KOWEPS data since 2006. The data includes demographic factors of each household and characteristics of a household member such as health status and welfare needs. Consequently, KOWEPS is plausible data to analyze whether the tobacco tax policy has achieved the purpose. In particular, the data has a chronic disease variable that has been known as the main factor of subjective health status (Kwon, 2011). Furthermore, there were many questionnaires to gather information on individual mental health status; this study can ascertain whether the tobacco tax policy could cover mental health care. All questionnaires about mental health are associated with neurotic behavior, self-recognition, and subjective feeling with interpersonal relationships. However, these surveys still subjective and indicate an only a narrow portion of mental health, so KOWEPS provides instruction to

evaluate overall mental health status by utilizing them. Consequently, this study generates the *CESD-11 scale* and *Rosenberg self-esteem scale* with these survey scores. According to KOWEPS instruction and Korea Disease Control and Prevention Agency (KDCA), the *CESD-11 scale* is representative of self-inspection to identify depression. The score suspects the extent of depression in three thresholds: 15, 21, and 25. In other words, if a person has *CESD-11 scale* over 25, it means the scale suggests visiting a psychiatrist to have an accurate diagnosis since maybe the person suffering in serious depression. In a similar context, a higher point in *Rosenberg self-esteem scale* indicates the person's self-esteem is healthier than the lower point.

This study uses the data comprised three years before and after 2015 to discover whether the tobacco tax increase has occurred health improvement after 2015. Also, the sample is cut out as a male aged over nineteen to minimize interruption. According to previous research about females and smoking, in Asian culture, female smokers seemed to be pressured to hide their smoking status since there is a social taboo (Mackay & Amos, 2003). Nam (2003) again discovered that this kind of cultural taboo had been detected in Korea. Similarly, there is a possibility of fabrication by an adolescent to hide their smoking status. A smoking adolescent is considered inappropriate in Korea since there is a law to punish the seller when they sell tobacco to adolescents.

The raw data provides the extent of expenditure at the household level. To control the expenditure level at the individual level, this study arranged household expenditure by the Organization for Economic Co-operation and Development (OECD) modified scale, which divides household expenditure by square root of the sum of the household member. By the many cases of adoption of this scale across abroad, it has been considered trustworthy (Martin, 2017). Kim and Jung (2020) also deal with the same data in the same manner.

There are additional analyses to state a solid conclusion of the policy effects. The first

analysis is to identify the health effect by year of smoking cessation after 2015. This sub-analysis treats the sample as same as the main analysis. Second, the analysis to identify the health effect by the cessation of secondhand smoking after 2015. This analysis drops a person who has the smoking experience to precisely estimate the effect of secondhand smoking discontinuity. Additionally, all individuals who lived alone without the household member are dropped since they may not be affected by secondhand smoking. This analysis also includes Females since all of the smokers in the main analysis is male. However, adolescents are excluded in the sample for the same reason above. Other control variables are the same as when analyzing the health effect of cessation of smoking.

3.2 Descriptive Statistics of the Sample

Table 1a and *Table 1b* illustrate the descriptive statistics for the outcome and control variables to analyze the effects of the tax policy on smoker's health status. The means and standard deviations for each analysis group are in the columns of *Table 1a*. The treatment group indicates a group of people who are a smoker in 2014. Most variables in *Table 1a* and *Table 1b* show up to 7 to 8 percent of differences in the distribution of demographic factors. It is hard to say that this difference causes serious damage to the analysis results since most of the serious factors have differences within 2 to 3 percent between the groups.

Table 2a describes outcome variables for the analysis of the effect of smoking cessation after 2015. From column (2) to (4), each column indicates that the treatment group of individuals who keep their non-smoking status from 2015. Column (5) indicates individuals who did not attempt to quit the smoke and still smoking after the implementation of the policy. The last column shows descriptive statistics of all non-smokers. The difference in composition for most variables between groups is very slight. A few control variables have a gap between the groups of more than 5 percent from between smokers and non-smokers, however, it is also hard to convict that is a critical matter since the descriptive statistics between smokers of 2014

Table 1a. Descriptive statistics of outcome variables for the main analysis

	All	Smokers in 2014	Non-smokers in 2014
Health related	Mean (SD)	Mean (SD)	Mean (SD)
Self-rated health status	2.44	2.31	2.51
	(0.93)	(0.89)	(0.95)
High rated score on health status (=1)	0.62	0.69	0.59
	(0.48)	(0.46)	(0.49)
Higher score on health status than last year (=1)	0.25	0.25	0.25
	(0.43)	(0.43)	(0.43)
CESD-11	13.89	14.07	13.80
	(4.19)	(4.39)	(4.07)
Suspicion of light depression (=1)	0.19	0.20	0.18
	(0.39)	(0.40)	(0.38)
Suspicion of hypostyptic depression (=1)	0.07	0.07	0.06
	(0.25)	(0.26)	(0.24)
Suspicion of serious depression (=1)	0.03	0.03	0.03
	(0.16)	(0.17)	(0.16)
Rosenburg self-esteem scale	30.76	30.57	30.87
	(4.01)	(4.12)	(3.94)
High rated score on family relationships (=1)	0.77	0.73	0.80
	(0.42)	(0.44)	(0.40)
High rated score on spouse relationships (=1)	0.87	0.86	0.87
	(0.34)	(0.34)	(0.33)
High rated score on child relationships (=1)	0.87	0.86	0.88
	(0.33)	(0.34)	(0.33)
High rated score on life satisfaction (=1)	0.87	0.86	0.88
	(0.33)	(0.35)	(0.32)
Number of observations	33,841	11,712	22,129

Note: The outcome variables that uses in supplement analysis are not included in this table, they are covered in appendix.

Table 1. Descriptive statistics of control variables for the main analysis

	All	Smokers in 2014	Non-Smokers in 2014
	Mean (SD)	Mean (SD)	Mean (SD)
Age	54.80 (17.22)	49.70 (14.75)	57.49 (17.81)
Married (=1)	0.53 (0.50)	0.43 (0.50)	0.59 (0.49)
Have chronic disease (=1)	0.74 (0.44)	0.68 (0.47)	0.77 (0.42)
Smoking in observation year (=1)	0.36 (0.48)	0.89 (0.31)	0.07 (0.26)
Expenditure level[a]			
Low expenditure level (~33rd percentile) (=1)	0.35 (0.48)	0.28 (0.45)	0.38 (0.48)
Middle expenditure level (~66th percentile) (=1)	0.33 (0.47)	0.38 (0.49)	0.31 (0.46)
High expenditure level (~100th percentile) (=1)	0.32 (0.47)	0.34 (0.47)	0.31 (0.46)
Job status		(0.12)	
White collar job (=1)	0.28 (0.45)	0.28 (0.45)	0.27 (0.45)
Blue collar job (=1)	0.31 (0.46)	0.41 (0.49)	0.26 (0.44)
Agroforestry & Fishery job (=1)	0.13 (0.33)	0.09 (0.28)	0.14 (0.35)
Unemployment (=1)	0.29 (0.45)	0.22 (0.42)	0.32 (0.47)
Generation[b]			
Teenage (=1)	0.08 (0.27)	0.07 (0.26)	0.08 (0.27)
Twenties (=1)	0.14 (0.35)	0.19 (0.39)	0.11 (0.32)
Thirties (=1)	0.20 (0.40)	0.27 (0.45)	0.16 (0.37)
Forties (=1)	0.17 (0.38)	0.20 (0.40)	0.16 (0.36)
Fifties (=1)	0.15 (0.36)	0.14 (0.34)	0.16 (0.37)
Sixties (=1)	0.18 (0.39)	0.10 (0.29)	0.23 (0.42)
Seventies or more (=1)	0.07 (0.26)	0.03 (0.16)	0.10 (0.30)
Number of observations	33,841	11,712	22,129

Note: To be short, the control variables for the *Age squared, Education level,* and *Residential area* are not included in this table. The appendix will cover them all.
aTo make individual expenditure levels, household expenditure data of KOWEPS is modified on OECD modified scale.
bTeenage only have nineteen years old since person under nineteen legally suppressed to buy cigarettes.

Table 2a. Descriptive statistics of outcome variables for the first sub-analysis

	For the Equation (2)					
	All	Individuals who ceased smoking in 2015 and keeping for 1 year	Individuals who ceased smoking in 2015 and keeping for 2 years	Individuals who ceased smoking in 2015 and keeping for 3 years	Individuals who kept their smoking from 2015	Non-Smokers in 2015
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Self-rated health status	2.44 (0.93)	2.33 (0.85)	2.27 (0.82)	2.26 (0.79)	2.32 (0.90)	2.51 (0.94)
High rated score on health status (=1)	0.62 (0.48)	0.66 (0.47)	0.70 (0.46)	0.70 (0.46)	0.69 (0.46)	0.58 (0.49)
Higher score on health status than last year (=1)	0.25 (0.43)	0.26 (0.44)	0.26 (0.44)	0.27 (0.44)	0.25 (0.43)	0.25 (0.43)
CESD-11 score	13.85 (4.13)	13.71 (3.95)	13.44 (3.59)	13.10 (2.88)	14.03 (4.36)	13.75 (4.00)
Suspicion of light depression (=1)	0.18 (0.39)	0.17 (0.37)	0.15 (0.36)	0.12 (0.33)	0.20 (0.40)	0.18 (0.38)
Suspicion of hypostyptic depression (=1)	0.07 (0.25)	0.05 (0.22)	0.04 (0.20)	0.02 (0.15)	0.07 (0.26)	0.06 (0.24)
Suspicion of serious depression (=1)	0.03 (0.16)	0.02 (0.15)	0.01 (0.12)	0.00 (0.07)	0.03 (0.17)	0.02 (0.15)
Rosenburg self-esteem scale	30.80 (3.98)	30.92 (3.69)	31.06 (3.63)	31.20 (3.50)	30.60 (4.14)	30.91 (3.89)
High rated score on family relationships (=1)	0.78 (0.42)	0.76 (0.43)	0.77 (0.42)	0.77 (0.42)	0.74 (0.44)	0.80 (0.40)
High rated score on spouse relationships (=1)	0.87 (0.34)	0.87 (0.33)	0.88 (0.32)	0.89 (0.32)	0.87 (0.34)	0.87 (0.33)
High rated score on child relationships (=1)	0.87 (0.34)	0.88 (0.33)	0.88 (0.33)	0.87 (0.33)	0.86 (0.34)	0.87 (0.33)
High rated score on life satisfaction (=1)	0.87 (0.34)	0.87 (0.34)	0.89 (0.31)	0.89 (0.32)	0.85 (0.36)	0.88 (0.32)
Number of observations	31,975	759	539	449	11,335	19,881

Note: The outcome variables that uses in supplement analysis are not included in this table, they are covered in appendix.

Table 2b. Descriptive statistics of control variables for analysis of the effect of cessation of smoking at 2015

	All	Individuals who ceased smoking in 2015 and keeping for 1 year	Individuals who ceased smoking in 2015 and keeping for 2 years	Individuals who ceased smoking in 2015 and keeping for 3 years	Individuals who kept their smoking from 2015	Non-Smokers in 2015
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Age	55.10 (17.01)	54.07 (16.80)	54.65 (16.57)	54.93 (16.82)	49.83 (14.72)	58.15 (17.49)
Married (=1)	0.54 (0.50)	0.48 (0.50)	0.49 (0.50)	0.49 (0.50)	0.44 (0.50)	0.60 (0.49)
Have chronic disease (=1)	0.75 (0.43)	0.69 (0.46)	0.72 (0.45)	0.71 (0.45)	0.69 (0.46)	0.79 (0.41)
Smoking in observation year (=1)	0.35 (0.48)	0.42 (0.49)	0.36 (0.48)	0.34 (0.47)	0.90 (0.30)	0.04 (0.19)
Expenditure level[a]						
Low expenditure level (~33rd percentile) (=1)	0.35 (0.48)	0.32 (0.47)	0.29 (0.46)	0.30 (0.46)	0.29 (0.45)	0.38 (0.49)
Middle expenditure level (~66th percentile) (=1)	0.33 (0.47)	0.36 (0.48)	0.37 (0.48)	0.37 (0.48)	0.38 (0.48)	0.31 (0.46)
High expenditure level (~100th percentile) (=1)	0.32 (0.47)	0.32 (0.47)	0.33 (0.47)	0.33 (0.47)	0.34 (0.47)	0.31 (0.46)
Job status						
White collar job (=1)	0.28 (0.45)	0.32 (0.47)	0.29 (0.45)	0.29 (0.46)	0.28 (0.45)	0.27 (0.44)
Blue collar job (=1)	0.31 (0.46)	0.32 (0.47)	0.35 (0.48)	0.36 (0.48)	0.40 (0.49)	0.26 (0.44)
Agroforestry & Fishery job (=1)	0.13 (0.33)	0.11 (0.32)	0.12 (0.33)	0.12 (0.32)	0.09 (0.29)	0.15 (0.36)
Unemployment (=1)	0.28 (0.45)	0.25 (0.43)	0.24 (0.43)	0.23 (0.42)	0.22 (0.41)	0.32 (0.47)
Generation[b]						
Teenage (=1)	0.07 (0.25)	0.07 (0.26)	0.06 (0.24)	0.06 (0.24)	0.07 (0.26)	0.07 (0.25)
Twenties (=1)	0.14 (0.35)	0.16 (0.37)	0.15 (0.36)	0.16 (0.37)	0.19 (0.39)	0.11 (0.31)
Thirties (=1)	0.20 (0.40)	0.18 (0.39)	0.19 (0.39)	0.17 (0.38)	0.28 (0.45)	0.15 (0.36)
Forties (=1)	0.18 (0.38)	0.22 (0.41)	0.22 (0.41)	0.22 (0.42)	0.20 (0.40)	0.16 (0.37)
Fifties (=1)	0.16 (0.36)	0.14 (0.35)	0.14 (0.35)	0.13 (0.33)	0.14 (0.34)	0.17 (0.38)
Sixties (=1)	0.19 (0.39)	0.15 (0.36)	0.16 (0.36)	0.17 (0.38)	0.10 (0.30)	0.24 (0.42)
Seventies or more (=1)	0.07 (0.26)	0.08 (0.27)	0.08 (0.27)	0.08 (0.28)	0.02 (0.15)	0.10 (0.30)
Number of observations	31,975	759	539	449	11,335	19,881

Note: To be short, the control variables for the Age squared, Education level, and Residential area are not included in this table. The appendix will cover them all.

aTo make individual expenditure levels, household expenditure data of KOWEPS is modified on OECD modified scale.

bTeenage only have nineteen years old since person under nineteen legally suppressed to buy cigarettes.

Table 3a. Descriptive statistics of outcome variables for the second sub-analysis

	All	Individuals who have any family member who keep smoking cessation from 2015	Individuals who have any family member who still smoking from 2015	Individuals who have family members who are a non-smoker
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Self-rated health status	2.63 (0.97)	2.43 (0.89)	2.37 (0.89)	2.70 (0.98)
High rated score on health status (=1)	0.53 (0.50)	0.63 (0.48)	0.66 (0.47)	0.50 (0.50)
Higher score on health Status than last year (=1)	0.25 (0.43)	0.25 (0.43)	0.24 (0.43)	0.25 (0.44)
CESD-11 score	14.75 (4.79)	14.20 (4.11)	14.10 (4.21)	14.94 (4.94)
Suspicion of light depression (=1)	0.26 (0.44)	0.22 (0.41)	0.21 (0.41)	0.27 (0.45)
Suspicion of hypostyptic depression (=1)	0.10 (0.30)	0.07 (0.25)	0.07 (0.25)	0.11 (0.31)
Suspicion of serious depression (=1)	0.04 (0.20)	0.02 (0.14)	0.03 (0.16)	0.05 (0.21)
Rosenburg self-esteem scale	30.43 (4.03)	30.70 (3.69)	31.02 (3.73)	30.27 (4.11)
High rated score on family relationships (=1)	0.78 (0.42)	0.78 (0.41)	0.82 (0.38)	0.78 (0.42)
High rated score on spouse relationships (=1)	0.86 (0.35)	0.85 (0.36)	0.89 (0.31)	0.87 (0.34)
High rated score on child relationships (=1)	0.87 (0.33)	0.90 (0.30)	0.94 (0.23)	0.87 (0.34)
High rated score on life satisfaction (=1)	0.87 (0.34)	0.95 (0.22)	0.77 (0.42)	0.86 (0.34)
Number of observations	65,495	1,989	12,714	50,792

Note: The outcome variables that uses in supplement analysis are not included in this table, they are covered in appendix.

Table 3b. Descriptive Statistics of control variables for analysis of the effect of cessation of secondhand smoking at 2015

	All	Individuals who have any family member who keep smoking cessation from 2015	Individuals who have any family member who still smoking from 2015	Individuals who have family members who are a non-smoker
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Age	57.00 (18.50)	50.83 (18.23)	48.78 (17.22)	59.30 (18.17)
Male (=1)	0.30 (0.46)	0.22 (0.42)	0.14 (0.35)	0.34 (0.47)
Married (=1)	0.64 (0.48)	0.70 (0.46)	0.72 (0.45)	0.62 (0.48)
Have chronic disease (=1)	0.60 (0.49)	0.52 (0.50)	0.46 (0.50)	0.64 (0.48)
Smoking in observation year (=1)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Expenditure level[a]				
Low expenditure level (~33rd percentile) (=1)	0.33 (0.47)	0.19 (0.39)	0.15 (0.35)	0.39 (0.49)
Middle expenditure level (~66th percentile) (=1)	0.33 (0.47)	0.37 (0.48)	0.41 (0.49)	0.31 (0.46)
High expenditure level (~100th percentile) (=1)	0.33 (0.47)	0.45 (0.50)	0.44 (0.50)	0.30 (0.46)
Job status				
White collar job (=1)	0.26 (0.44)	0.30 (0.46)	0.32 (0.47)	0.24 (0.43)
Blue collar job (=1)	0.17 (0.38)	0.18 (0.39)	0.18 (0.39)	0.17 (0.37)
Agroforestry & Fishery job (=1)	0.11 (0.31)	0.12 (0.32)	0.08 (0.27)	0.12 (0.32)
Unemployment (=1)	0.46 (0.50)	0.40 (0.49)	0.42 (0.49)	0.47 (0.50)
Generation[b]				
Teenage (=1)	0.09 (0.29)	0.16 (0.37)	0.15 (0.35)	0.08 (0.27)
Twenties (=1)	0.12 (0.32)	0.16 (0.36)	0.20 (0.40)	0.10 (0.30)
Thirties (=1)	0.15 (0.35)	0.13 (0.34)	0.18 (0.39)	0.14 (0.35)
Forties (=1)	0.15 (0.35)	0.20 (0.40)	0.18 (0.38)	0.14 (0.34)
Fifties (=1)	0.17 (0.37)	0.18 (0.38)	0.15 (0.36)	0.17 (0.37)
Sixties (=1)	0.23 (0.42)	0.13 (0.33)	0.10 (0.30)	0.26 (0.44)
Seventies or more (=1)	0.10 (0.30)	0.05 (0.21)	0.04 (0.19)	0.12 (0.32)
Number of observations	65,495	1,989	12,714	50,792

Note: To be short, the control variables for the *Age squared, Education level, Residential area,* and *Expenditure level* are not included in this table. The appendix will cover them all.

aTo make individual expenditure levels, household expenditure data of KOWEPS is modified on OECD modified scale.

bTeenage only have nineteen years old since person under nineteen legally suppressed to buy cigarettes.

Table 4. Descriptive statistics of treatment variables

	Main Analysis	Sub Analysis (1)	Sub Analysis (2)
	Mean (SD)	Mean (SD)	Mean (SD)
Smoking in year of 2014 (=1)	0.35 (0.48)		
Number of observation	33,841		
Smoking in observation year (=1)		0.35 (0.48)	0 (0)
Maintain cessation of smoking for 1 year from 2015 (=1)		0.02 (0.15)	
Maintain cessation of smoking for 2 year from 2015 (=1)		0.02 (0.13)	
Maintain cessation of smoking for 3 year from 2015 (=1)		0.01 (0.12)	
Number of observation		31,975	
Have family member who cease smoking at 2015 (=1)			0.03 (0.18)
Number of observation			65,495

who are in the column (2) to (5) are very close. In addition, the main interest of this study focused on the gap between smokers who ceased smoking in 2015, and smokers who kept smoking in 2015.

Table 3a and *Table 3b* demonstrate the outcome and control variables for the second sub-analysis for discovering the effect of secondhand smoking discontinuity. Same with the preceding table, *Table 3a* describes outcome variables related to the analysis of discontinuity of secondhand smoking with means and standard deviations. Demographic factors associated with the analysis are assembled in *Table 3b*. Some of them are omitted due to constrained space but appendix will cover them all. As shown as *Table 3a,* the difference in composition between groups of most outcome variables is less than 5 percent. *Table 3b* shows about 10 percent of the difference in means of *expenditure level*; in other words, smokers is common to find in a higher expenditure level group than a low expenditure level group in this sample. However, the main interest in this analysis model is difference between individuals who have any family member

who keep smoking cessation from 2015 and who have any family member who still smoking from 2015. The one of the supplementary outcome variable, *number of outpatient treatments in a year*, has a gap that the treatment group less visits the clinic to be treated than the control group. The differences in *expenditure level* and *outpatient treatment* variables between groups may be interpreted as the treatment group may be healthier or less dependent on outpatient treatment since they are richer than others.

Table 4 indicates how many individuals are involved in each interest dummy variable. According to *Table 4*, there were 11,844 smokers of 2014 among 33,841 observations in the main analysis. Only two to one percent of them ceased smoking and maintain their smoking status in the first additional analysis. In the secondary analysis, there were approximately 1,965 observations that encountered discontinuity of secondhand smoking among 65,495 observations.

4 Empirical Methods

The identical strategy of this study is the difference-in-differences (DiD) method that is the representative of quasi-experimental analysis. The treatment is implementing a tax increase for tobacco, and the datum point of treatment is 2015. The tax was implemented not on target but national-widely. All smokers in 2014 had pressure by the policy, and the policy set up a kind of barricade in front of potential smokers to restrict leap to be a smoker. However, each individual can be affected by the policy in their way or invulnerable from the policy. In other words, this study should assume that the policy effect is the same for each smoker. Also, it is unattainable to extract the potential smoker from the sample since the desire to be a smoker is invisible.

On the other hand, all smokers are categorized as intended-to-be-treated by the policy with the assumption that each smoker has the same effects from the policy. Thus, this study

arranges smokers in 2014 as the treatment group and arranges other non-smokers in 2014 as the control group. If any health status differences are discovered between the treatment and control group after 2015, the differences can be interpreted as the effect of the policy on public health.

In general, unobservable variables can be problematic when researchers using the ordinary least squares (OLS) to estimate outcome variables since they cannot be wholly controlled in the OLS model. Accordingly, this study embraces individual fixed effects to prevent bias from unobserved individual characteristics. This study intends to control time-invariant individual characteristics such as different threshold degree of smoking behavior by applying the individual fixed effects. Besides, this study includes year dummy variables to control for the time factor. All outcome variables in this study are binary, so the linear probability model (LPM) is applied. This study used robust standard errors clustered within an individual to resolve the heteroskedasticity of the LPM and the possibility of serial correlation. Even though this analysis used unbalanced panel data, the individual fixed effect model can adjust the bias from missing observation based on the assumption that omission might be occurred by time-invariant reason.

The main analysis to identify the health improvement effect of the tobacco tax policy is set up as below the equation with the fixed effects for the person *i* in period *t*:

(1) $y_{it} = \alpha_i + \tau_t + \delta(Smoke2014_{it} \times post15_t) + \gamma Smoke2014_{it} + \lambda post15_t + X_{it}\beta + \epsilon_{it}$

y_{it} demonstrates each outcome variable, including good health status that value one when individual self-rated health status is higher than the median in the Likert scale. Other outcome variables are as follows: the CESD-11 scale, suspicion of depression, a higher score than the median for satisfaction of relationship with family (=1). Besides, some supplementary variables are applied as outcome variables to make a stable conclusion. Individual fixed effects is served as α_i and τ_t captures year fixed effects.

X_{it} controls for demographic characteristics, including age, generation, final education

level, marital status, expenditure level, job status, and place of residence, as shown in *Table 1b*. Education level has five nominal variables: 'middle school graduates, or less', 'high school graduates', 'college graduates', 'university graduates', 'master and Ph.D. graduates'. Expenditure level consist of three nominal variables: low, middle, and high, it is calculated with the equivalent score by OECD, and each class has about 33 percent of observations. Job status is recorded with four nominal variables: 'blue collar', 'white collar', 'agroforestry or fishery', and 'unemployed'. Residential area is arranged with three nominal variables: 'metropolitan city including Seoul, the capital city', 'other cities', and 'rural'. Age-squared variable is added since this study supposes that age may affect health status in a quadratic way rather than linear. Also, all analyses add the dummy variable for the chronic disease since literature mentioned the presence of the chronic disease is the main factor of bad self-rated health status (Kwon, 2011; Kim. J. H., 2016; Kim & Nam, 2019). δ is the interest estimate of this study that captures the change of 2014's smoker group after the tax policy of 2015.

There are additional analyses to examine the results of the main analysis in the expanded condition: the first is an analysis of the effect of smoking cessation by the policy, and the second analysis attempt to identify the effect of the end of secondhand smoking. In the first sub-analysis, the smokers who ceased smoking in 2015 is treatment group. The equation of this model with the fixed effects for the person *i* in period *t* is:

$$(2)\ E(y_{it} \mid n \in \{1,2,3,4\}) = \alpha_i + \tau_t + \delta_n(CessationStatus_{nit} \times post15_t) + \gamma_n CessationStatus_{nit} + \lambda post15_t + X_{it}\beta + \epsilon_{it}$$

All outcome and control variables from the equation (1) are also employed in this model. As same with the equation (1), the fixed effect model captures unobserved time-invariant individual characteristics in α_i and controls unobserved time-invariant effects of years in τ_t. There are four dummy variables in $CessationStatus_{nit}$. Theoretically, the smokers who ceased the smoke in 2015 are the treatment group, however, this equation adds one more dummy

variable in $CessationStatus_{nit}$ to estimate an accurate coefficient. Thus, the treatment groups are included in $CessationStatus_{nit}$ for $n \in \{1,2,3\}$. And each n distinguish the year of cessation that marks each year of smoking cessation after 2015; in other words, it includes 1-year of cessation dummy, 2-year of cessation dummy, and 3-year of cessation dummy. The smokers who did not attempt to quit the smoke in 2015 are indicated as $CessationStatus_{4it}$ likewise. The control group consists of all non-smokers in 2014. Thus, δ_n reveals the effect of the implementing tobacco tax increase on all smokers in 2014, particularly $(\delta_n - \delta_4)$, for $n \in \{1,2,3\}$, will give a more precise coefficient of the effect of the tobacco tax policy on an individual who ceased the smoke in 2015 since δ_4 is the estimated coefficient of the policy effect on an individual who did not ceased the smoke in 2015. When the dummy variables of each smoking cessation year sequentially show significant estimates in δ_n, this study confirms the effect of smoking cessation by the tax implementation.

Another additional analysis examines the effect of the elimination of secondhand smoking on a family member. In this model, all individuals with smoking experience were dropped to secure the effect of secondhand smoking and eliminate the effect of direct smoking. This model deal with a non-smoker who has had a smoking family member as the treatment group. Other non-smokers are arranged in the control group. The equation for the person *i* in period *t* is:

$$(3)\ E(y_{it} \mid n \in \{1,2\}) = \alpha_i + \tau_t + \delta_n(FamilyQuit_{nit} \times post15_t) + \gamma_n FamilyQuit_{nit} + \lambda post15_t + X_{it}\beta + \epsilon_{it}$$

the outcome variable in this model is the same as the first model except for some supplementary outcome variables such as *Drink more glass of alcohol at the site than last year*, and *More frequency of drinking in the year than last year*. All control variables of other models are identically applied. This model also focused on estimate δ_n, however, there is $FamilyQuit_{nit}$ instead of $CessationStatus_{nit}$ in the second equation. δ_n indicates the effect of secondhand

smoking discontinuity by the tobacco tax implementation on individuals who had smoking family member in 2014. δ_1 indicates the effect of the policy implementation on individuals who experience discontinuity of secondhand smoking in 2015 and δ_2 focus on individuals who are still in the status of secondhand smoking even after the implementation of the policy. Thus, the third model interested in $(\delta_1 - \delta_2)$. To make precisely, this model also applied individual fixed effects in α_i and year fixed effects in τ_t. This study expects to confirm a significantly positive sign of $(\delta_1 - \delta_2)$, and some negative sign of $(\delta_1 - \delta_2)$ for some mental health-related variables, which is related with *CESD-11 score*, namely the significant impact of the policy.

5 Empirical Results

In this study, three analyses are applied to identify health status changes by the tobacco tax implementation after 2015. *Table 5* demonstrates the main analysis result, which explores health improvement within the smoker group by the tax implementation. The first sub-analysis to identify smokers' change by year of smoking cessation after the tax implementation is demonstrated in *Table 6*. The other sub-analysis to identify the effect of secondhand smoking discontinuity after the tax implementation illustrated the results in *Table 7*. Only interest variables are located in the vertical shaft in three tables. Even though control variables are not displayed, they are regressed in the calculation.

As reported in the literature review, some control variables show quite significant results on the outcome variables. Marital status has a negative sign of coefficient ($p < 0.1$) on good health status. However, a married person significantly better mental health status ($p < 0.01$). In the education level, mostly negative effects are shown in the higher education level on both health outcomes. Although there is no significant difference between job types, unemployment status is significantly hazardous on both health status ($p < 0.01$). The presence of chronic disease definitely captures the negative sign of the effects on both health status ($p < 0.01$), as

Table 5. Change of smoker's health by the tax implement after 2015

	Physical health related outcomes			*Family relationships*		
	High rated score on health status (=1)	Higher score on health Status than last year (=1)	Have Chronic Disease (=1)	High rated score on family relationships (=1)	High rated score on spouse relationships (=1)	High rated score on child relationships (=1)
Individual dummy who smoke at 2014 after 2015 (=1)	0.002	0.003	0.017*	0.004	-0.010	-0.002
	(0.009)	(0.009)	(0.009)	(0.009)	(0.008)	(0.007)
adj. R-sq	0.034	0.020	0.010	0.004	0.053	0.002
Year fixed effect	Y	Y	Y	Y	Y	Y
Individual fixed effect	Y	Y	Y	Y	Y	Y
	Mental health related outcomes					
	CESD-11 score	Suspicion of light depression (=1)	Suspicion of hypostyptic depression (=1)	Suspicion of serious depression (=1)	Rosenberg self-esteem scale	High rated score on life satisfaction (=1)
Individual dummy who smoke at 2014 after 2015 (=1)	0.143	0.013	0.007	0.004	-0.112	-0.095***
	(0.087)	(0.009)	(0.006)	(0.004)	(0.079)	(0.011)
adj. R-sq	0.010	0.007	0.004	0.001	0.008	0.291
Year fixed effect	Y	Y	Y	Y	Y	Y
Individual fixed effect	Y	Y	Y	Y	Y	Y
Number of observations	33,841					
Number of clusters	5,493					

Note: * p<0.1 ** p<0.05 *** p<0.01; robust standard error clustered within an individual is used. Standard errors in parentheses. The control variables used in as follows: *Marital status, Education level, Living Area, Chronic disease status, Age, Age squared, Household expenditure level.* These variables are not displayed in this table, nonetheless, they are regressed to control for all outcome variables. Some of outcome variables are omitted to save the space. The appendix will cover all outcome variables.

Table 6. Change of smokers by years of smoking cessation after the tax implement in 2015

	Physical health related outcomes					*Family relationships*
	High rated score on health status (=1)	Higher score on health Status than last year (=1)	Have chronic disease related to smoking (=1)	Drink more glass of alcohol at the table than last year (=1)	More frequency of drinking in the year than last year (=1)	High rated score on child relationships (=1)
Keep smoking cessation for 1 yr after 2015 (=1)	0.013	0.044	0.020	0.048*	0.030	0.006
	(0.031)	(0.031)	(0.013)	(0.028)	(0.025)	(0.031)
Keep smoking cessation for 2 yrs after 2015 (=1)	0.030	0.027	0.026*	0.057	0.027	0.062*
	(0.038)	(0.037)	(0.016)	(0.035)	(0.029)	(0.035)
Keep smoking cessation for 3 yrs after 2015 (=1)	0.014	-0.002	0.032*	0.060	0.056*	0.060
	(0.042)	(0.041)	(0.017)	(0.037)	(0.031)	(0.037)
Keep smoking from 2015 (=1)	0.005	-0.005	-0.001	0.001	-0.010	-0.107***
	(0.009)	(0.009)	(0.003)	(0.009)	(0.009)	(0.011)
adj. R-sq	0.035	0.020	0.830	0.011	0.014	0.287
Year fixed effect	Y	Y	Y	Y	Y	Y
Individual fixed effect	Y	Y	Y	Y	Y	Y
	Mental health related outcomes					
	CESD-11 score	Suspicion of light depression (=1)	Suspicion of hypostyptic depression (=1)	Suspicion of serious depression (=1)	Rosenberg self-esteem scale	High rated score on life satisfaction (=1)
Keep smoking cessation for 1 yr after 2015 (=1)	0.205	0.057**	0.028*	0.000	-0.190	-0.008
	(0.233)	(0.024)	(0.016)	(0.009)	(0.274)	(0.030)
Keep smoking cessation for 2 yrs after 2015 (=1)	0.021	0.038	0.025	0.005	-0.073	0.007
	(0.245)	(0.025)	(0.017)	(0.008)	(0.336)	(0.034)
Keep smoking cessation for 3 yrs after 2015 (=1)	-0.056	0.025	0.023	-0.002	-0.404	0.004
	(0.264)	(0.027)	(0.017)	(0.007)	(0.366)	(0.037)
Keep smoking from 2015 (=1)	0.088	0.002	0.003	0.004	-0.121	0.001
	(0.087)	(0.009)	(0.006)	(0.004)	(0.079)	(0.009)
adj. R-sq	0.010	0.007	0.004	0.001	0.008	0.004
Year fixed effect	Y	Y	Y	Y	Y	Y
Individual fixed effect	Y	Y	Y	Y	Y	Y
Number of observations	31,975					
Number of clusters	4,923					

Note: * p<0.1 ** p<0.05 *** p<0.01; robust standard error clustered within an individual is used. Standard errors in parentheses. The control variables used in as follows: *Marital status, Education level, Living Area, Chronic disease status, Age, Age squared, Household expenditure level.* These variables are not displayed in this table, nonetheless, they are regressed to control for all outcome variables. Some of outcome variables are omitted to save the space. The appendix will cover all outcome variables.

Table 7. Change of non-smoker by end of secondhand smoking after the tax implementation in 2015

	Physical health related outcomes		*Family relationships*		
	High rated score on health status (=1)	Higher score on health Status than last year (=1)	High rated score on family relationships (=1)	High rated score on spouse relationships (=1)	High rated score on child relationships (=1)
Have family member who ceased smoking at 2015 (=1)	-0.026	-0.019	-0.003	-0.031**	-0.007
	(0.018)	(0.016)	(0.017)	(0.015)	(0.012)
Have family member who still smoke from 2015 (=1)	-0.010	0.017**	-0.000	-0.028***	0.001
	(0.008)	(0.008)	(0.008)	(0.007)	(0.006)
adj. R-sq	0.029	0.016	0.004	0.072	0.002
Year fixed effect	Y	Y	Y	Y	Y
Individual fixed effect	Y	Y	Y	Y	Y

	Mental health related outcomes					
	CESD-11 score	Suspicion of light depression (=1)	Suspicion of hypostyptic depression (=1)	Suspicion of serious depression (=1)	Rosenberg self-esteem scale	High rated score on life satisfaction (=1)
Have family member who ceased smoking at 2015 (=1)	-0.055	-0.002	-0.013	0.006	-0.134	-0.038**
	(0.175)	(0.018)	(0.010)	(0.007)	(0.148)	(0.019)
Have family member who still smoke from 2015 (=1)	0.186**	0.011	0.009*	0.007**	-0.085	-0.007
	(0.080)	(0.008)	(0.005)	(0.003)	(0.066)	(0.009)
adj. R-sq	0.006	0.005	0.002	0.001	0.007	0.307
Year fixed effect	Y	Y	Y	Y	Y	Y
Individual fixed effect	Y	Y	Y	Y	Y	Y
Number of observations	65,494					
Number of clusters	12,018					

Note: * p<0.1 ** p<0.05 *** p<0.01; robust standard error clustered within an individual is used. Standard errors in parentheses. The control variables used in as follows: *Marital status, Education level, Living Area, Chronic disease status, Age, Age squared, Household expenditure level.* These variables are not displayed in this table, nonetheless, they are regressed to control for all outcome variables. Some of outcome variables are omitted to save the space. The appendix will cover all outcome variables.

most of the researchers mentioned before (Kwon 2011; Kim & Nam, 2019). There is a possibility that the affluent status of expenditure levels may increase accessibility to a hospital. Because the middle and the high expenditure group significantly have a higher number of outpatient treatment and hospitalization than the low expenditure group ($p < 0.01$). A higher level of expenditure has a significantly higher point on the *Rosenberg self-esteem scale*, at least 0.17 up to 0.22 points ($p < 0.01$).

5.1 Change of Smokers by the Tax Implementation after 2015

Unfortunately, *Table 5* presents no significant effect of tax implementation on the smoker's health status. The only significant result is the estimate onto *High rated score on life satisfaction*, however, the direction of the coefficient is different from the expectation. In addition, other mental related variables that are also insignificant have unexpected direction. These results are very unlike the expectation from the results of previous literature. On the other hand, although the significance of estimates for the *high rated score on health status* is worthless, the coefficient is positive. In the point of optimistic view, perhaps it connotes that a chance of a positive effect on health status of smokers by the tax implementation can be presented in other conditions.

5.2 Change of Smokers by the Year of Smoking Cessation after 2015

As similar to the above, *Table 6* illustrates no effects of each year of 2015's smoking cessation on the probability to choose a high score on self-rated health status after 2015. Even though this study applies the supplementary outcome variables, the coefficient onto variables are insignificant, hence, it needs to review related literature to account for the result. Although the slightly higher probability of suspicion of light depression ($p < 0.05$) and hypostyptic depression ($p < 0.1$) in the first year of smoking cessation, there is a continuously decreasing probability of suspicion of depression and point of CESD-11 scale. This flow connotes the possibility that the positive effect of smoking cessation on mental health may be discovered in

longer-term research. Furthermore, the difference between individuals who ceased smoking in 2015 and those who kept smoking after 2015 supports the expectation of this study based on the results of previous literature, which demonstrated negative effects on the physical health of the smoke (Lee et al., 2006; Lee et al., 2011; Morello et al., 2001; WHO, 2020).

There are a few additional significant results such as *Have chronic disease related to smoking* for two years of cessation and three years of cessation ($p < 0.1$), *Drink more glass of alcohol at the table than last year* for one year of cessation ($p < 0.1$), *More frequency of drinking in the year than last year* for three years of cessation ($p < 0.1$), *High rated score on child relationships* for two years of cessation ($p < 0.1$) and for those who kept the smoke ($p < 0.01$). Particularly, individuals who kept smokes after 2015 significantly have a negative estimate of the probability of choosing a lower level in the relationship with their child. It may support the results of Oh and Seo (2014), which suggested the smokes had negative effects on the good relationship with their family.

5.3 Change of Non-smoker by the End of Secondhand Smoking after 2015

The main results for the analysis of health-related change of non-smoker by the discontinuity of secondhand smoking are shown in *Table 7*. The interesting variable of this analysis has an insignificant coefficient at most of the outcome variables. In addition, the significant coefficient has an unexpected direction. As expected by the preceding studies, there is a significantly negative estimate of the relationship with their spouse for those who have a family member who still smokes from 2015 ($p < 0.01$), however, the same results appears for those who have a family member who ceased smoking at 2015 ($p < 0.05$). It may imply longer time or other conditions are necessary to have some positive change of family relationship by a discontinuity of secondhand smoking.

5.4 Supplementary Analysis

This study attempts supplementary analyses to make sure other results and to find some

other evidence. The first trial is *Probit* and *Logit* analysis, however, it is impossible to utilize since nearly half of the samples are dropped, and the t-statistics are too low in their results. The next, this study used other outcome variables associated with physical health: have a smoke-related chronic disease (=1), number of outpatient treatment per year, and number of hospitalization per year. However, all of them are insignificant in three analyses.

Meanwhile, various studies commonly argued there is a correlation between smoking and drinking (Choi et al., 2001; Kim et al., 2012; Oh & Seo, 2014; Kwon et al., 2016; Yun, 2018; Bin, 2020), however, the controversy about the causality is still contentious. According to Kim et al. (2012), smoking may help release mental pressure. Then there is a possibility of short-term stress accumulation caused by smoking cessation. It is necessary to identify whether the amount of alcohol consumed has increased as a reflection of the accumulation since increasing drinking amount may offset the effect of less smoking. In three analyses, some key variables have a slightly significant ($p < 0.1$) coefficient, however, it is hard to confirm clearly since the significant result is not consistent in all analyses.

6 Discussion and Limitation

6.1 Discussion

This study identifies the change of public health and life quality after a massive tax increase in 2015 with the KOWEPS data. The physical health-related data and the data about mental health and family relations are used as outcome variables. Individual socioeconomic characteristics are controlled to precisely estimate the results, and the fixed effect model catches time-invariant individual characteristics and the effect of years. Besides, this study applies three analyses model and attempt to supplementary analysis. However, most of the interest variables are illustrated as insignificant on the outcomes. Even though some of the significant results are shown, they have unexpected direction on the outcomes. Therefore, it is necessary to recall

previous studies to account for the results.

6.1.1 Physical Health Change and Smoking

Even the result of the analysis for individual health improvement was not significant with most of the key variables; it should be cautious about interpreting that adjusted smoking behavior by the tobacco tax implementation has no health-related improvement. Numerous researchers support that quite a lot of factors can affect self-rated health status. The research of Kim (2016) found that extent of the health status of the elderly was changed by time flow. According to Kim's idea (2016), this study's data period and methods may be insufficient to discover the improvement of health from the policy. Also, other previous literature reported the self-rated health status could be affected by an individual socio-economic level status (Kwon, 2011; Kim. J., 2016; Choi & Kim. H. Y., 2018; Kim. H. J. & Nam, 2019), and even social capital, which is the individual resource of social network and mutual link with others and organization (Kim, 2016). Besides, Kwon (2011) traced the track of self-rated health by life cycle and find out various matters of self-rated health, in addition, there is a remarkably unexpected factor such as voluntary work experience, which is more significant than smoking amount. Thus, this study may show that the change in smoking status has scarce or no effect on not actual health status but perceived health status.

6.1.2 Mental Health Change and Smoking

As similar to the physical health case, adjusted smoking behavior does not show significant results for mental health. The correlation between smoking and mental health was investigated in numerous research (Hemmingsson & Kriebel, 2003; Kim et al., 2012; Kwon et al., 2016; Yun, 2018; Bin, 2020). However, there is controversy about causality between them. For instance, one of the studies found that mental strain motivates smoking (Kim et al., 2012). Also, Yun (2018) suggests that smoking can be a method to deal with mental strain. On the other hand, Hemmingsson and Kriebel (2003) proved that smoking wrecked mental health,

leading the individuals to suicidal ideation. Park (2014) also provides that smoking status directly foment suicidal ideation.

Combining previous research results, perhaps the results of this study support that smoking has unidentified mutual causality with mental strain rather than significant effects on mental health by changing its status. In the optimistic view, when the years of smoking cessation are going on, estimates of the *CESD-11 scale* sequentially decrease, and estimates of the *high rated score on life satisfaction* sequentially increase. Thus, the mental release by the treatment may be discovered when the period of investigation can be longer than three years.

6.1.3 Change of Family Relationships Satisfaction

The causality between smoking and family relationship satisfaction is uncertain in the previous researches. Lee et al. (2010) said family relationships affect the smoking amount of a family member. In their investigation, the ones who have higher satisfaction with family relationships tend to less smoke and tend to pursue health promotional behavior (Lee et al., 2010). However, in the study with an extended sample in the following year, the amount of smoking did not vary depending on family relationships (Lee et al., 2011). Contrary to last year's results, Lee et al. (2011) reported that smoking among family members affects family relationships. They also comment that there is the possibility that individual characteristics may have larger effects on one’s smoking status than one’s family-related factors (Lee et al., 2011). Oh and Seo (2014) added their discovery that family members' smoking status affects their family relationships.

Besides, there are many qualitative kind of research about family relationships with widespread agreement that there is an inherency of humanity, nearly impossible to figure out within quantitative data (Chung, 2005). There is a dispute about what factor affects family relationships and how researchers can figure it out. Nonetheless, all researchers concede one’s subjective perception of family relationships was established above the interaction between

family members (Kwon, 2005; Chung, 2005; Lee et al., 2010; Shin & Jeong, 2014). According to the agreement, the self-satisfaction of family relationships may not be achieved only by changing one member's smoking status. Therefore, this study may support the opinion that individual achievements, such as cessation of smoking, have few or no effects on the self-satisfaction of family relationships.

6.1.4 Change of Health Status and Secondhand Smoking

The negative effect of secondhand smoking on physical and mental health was proved in previous studies (Kim et al., 2003; Lee et al., 2016; Kwon et al., 2020; Jacob et al., 2020). Thus, this study supposes that the improvement of health and life quality would be presented. However, the key variable has insignificant results on various health outcomes, as described in *Table 7*. Similar to the discussion mentioned above, this study's unexpected results may have been caused by the delicate nature of the outcome variable.

6.1.5 Drinking and Smoking

Drinking is a representative additive goods along with smoking, so it seems important to consider the arguments. The relationship between drinking and smoking have been intertwined, hence, it is hard to figure out which one is more overpowering (Lee et al., 2011; Oh & Seo, 2014; Yun,2018; Lee et al., 2019). Although the effect of adjusted smoking behavior by the tax policy on the drinking amount is insignificant, the coefficient of each year of smoking cessation has a positive sign. Some literature provided evidence that the drinking and smoking connected deeply (Gubner et al., 2016; Han et al., 2018; Zadarko-Domaradzka et al., 2018), moreover, various studies proved that mental pressure and morbidity could affect behavioral change in the drinking (Paljärvi et al., 2009; Grzywacz & Almeida, 2008; Sohn, 2010; Lee et al., 2019) and the smoking (Kwon et al., 2016; Yun, 2018). Thus, the positive coefficient on drinking-related outcomes may suggest that more drinking alcohol release the stress that came from the stress of smoking cessation. However, further research will be needed to conclude

whether the relationship between drinking and smoking is correlated.

6.2 Limitation

This study attempts to comprehensively identify the health improvement effects of tobacco tax implementation. There are shreds of evidence that the tax policy may affect public health, some limitations in this study yet. First, most outcome variables have consisted of subjective indicators. Even though abundant literature supported the variables, it does not completely reflect significance to actual health status. Second, in this study, the period of the sample is three years before and after the base year of 2015 due to the data limitation. There is an opportunity to capture more significant results from future data. Thus, more long-term research is needed later. Lastly, the first analysis of this study has driven with a sample of men. The analysis of smokers themselves is conducted without female data. If a researcher can obtain feasible data on female's smoking status, the result can be a difference with this study. Therefore, the results of this study are challenging to fully apply to other smoke-related policies.

7 Conclusion

Korean government implemented an enormous tax increase to tobacco to improve public health in 2015. Hence, this study attempts to identify the policy effect on an individual's physical and mental health. There are many insignificant results; nonetheless, some of the results introduce the possibility to identify the success of policy implementation. In particular, the possibility of mental release and behavioral change in drinking from the first sub-analysis. This study contributes as an empirical attempt on whether the purpose of the tobacco tax policy was succeeded or not. Previous literature was mainly focused on smoking and health or smoking and policy. The negative effects of smoking on an individual's health have been proved with various research, so many researchers attempted to identify whether the tobacco tax policy makes people quit their smoking based on the assumption that less smoke may improve public

health (Kang et al., 2013; Park, 2016; Kim. Y. et al., 2017; Kim. D. & Jung, 2020). In other words, this study attempts to make previous researches more authentically by empirical analysis. However, this study cannot support previous research that presumes the significant positive effects of the tobacco tax policy on public health.

Still, there is some limitation of this study. First, subjective indicators are used in most outcome variables. Even though previous research gave countenance to use the subjective variables, there is a possibility of omitting the actual health status. Second, the period of the data in this research may be too short of proving all effects of policy. If the limitation of raw data is resolved, further research can be advanced. Finally, the sample in the main analysis has consisted of one sex. When the feasibility problem is solved, it may provide more significant results.

8 References

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Appendix

All tables have no supplementary outcome variables to save the space. Table A1 to Table A9 shows that descriptive statistics for all supplementary outcome variables and the omitted covariates X_{it} used in equation (1) and (2) are shown.

Table A1. Change of smoker's health by the tax implement after 2015

	Physical health related outcomes								
	Main analysis	*Supplementary analysis*							
	High rated score on health status (=1)	Extended High rated score on health Status (=1)	Higher score on health Status than last year (=1)	Have Chronic Disease (=1)	Have Smoke Related Chronic Disease (=1)	Number of outpatient treatments in year	Number of Hospitalization in year	Drink more glass of alcohol at the site than last year (=1)	More frequency of drinking in the year than last year (=1)
Individual dummy who smoke at 2014 after 2015 (=1)	0.002	-0.018**	0.003	0.017*	0.002	0.238	0.022	0.009	-0.003
	(0.009)	(0.007)	(0.009)	(0.009)	(0.003)	(0.431)	(0.013)	(0.009)	(0.009)
adj. R-sq	0.034	0.015	0.020	0.010	0.831	0.032	0.013	0.011	0.017
Year fixed effect	Y	Y	Y	Y	Y	Y	Y	Y	Y
Individual fixed effect	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Mental health related outcomes						*Family relationships*		
	CESD-11 score	Suspicion of light depression (=1)	Suspicion of hypostyptic depression (=1)	Suspicion of serious depression (=1)	Rosenburg self-esteem scale	High rated score on life satisfaction (=1)	High rated score on family relationships (=1)	High rated score on spouse relationships (=1)	High rated score on child relationships (=1)
Individual dummy who smoke at 2014 after 2015 (=1)	0.143	0.013	0.007	0.004	-0.112	-0.095***	0.004	-0.010	-0.002
	(0.087)	(0.009)	(0.006)	(0.004)	(0.079)	(0.011)	(0.009)	(0.008)	(0.007)
adj. R-sq	0.010	0.007	0.004	0.001	0.008	0.291	0.004	0.053	0.002
Year fixed effect	Y	Y	Y	Y	Y	Y	Y	Y	Y
Individual fixed effect	Y	Y	Y	Y	Y	Y	Y	Y	Y
Number of observations	33,841								
Number of clusters	5,493								

Note: * p<0.1 ** p<0.05 *** p<0.01; robust standard error clustered within an individual is used. Standard errors in parentheses. The control variables used in as follows: *Marital status, Education level, Living Area, Chronic disease status, Age, Age squared, Household expenditure level*. These variables are not displayed in this table, nonetheless, they are regressed to control for all outcome variables.

Table A2. Change of smokers by years of smoking cessation after the tax implement in 2015 – individual and year fixed effect model

	Main analysis	*Supplementary analysis*							
	High score in self-rated health status (=1)	Extended high score in self-rated health status (=1)	Improved self-rated health score that last year (=1)	Have chronic disease (=1)	Have chronic disease related to smoking (=1)	Number of outpatient treatments in year	Number of hospitalization in year	Drink more glass of alcohol at the table than last year (=1)	More frequency of drinking in the year than last year (=1)
Keep smoking cessation for 1 yr after 2015 (=1)	0.013	-0.016	0.044	0.032	0.020	1.833	0.071	0.048*	0.030
	(0.031)	(0.019)	(0.031)	(0.033)	(0.013)	(1.488)	(0.044)	(0.028)	(0.025)
Keep smoking cessation for 2 yrs after 2015 (=1)	0.030	-0.014	0.027	0.037	0.026*	1.523	0.067	0.057	0.027
	(0.038)	(0.022)	(0.037)	(0.039)	(0.016)	(1.867)	(0.056)	(0.035)	(0.029)
Keep smoking cessation for 3 yrs after 2015 (=1)	0.014	-0.013	-0.002	0.023	0.032*	2.691	0.053	0.060	0.056*
	(0.042)	(0.026)	(0.041)	(0.042)	(0.017)	(2.124)	(0.049)	(0.037)	(0.031)
Keep smoking from 2015 (=1)	0.005	-0.012	-0.005	0.012	-0.001	-0.177	0.016	0.001	-0.010
	(0.009)	(0.007)	(0.009)	(0.009)	(0.003)	(0.421)	(0.014)	(0.009)	(0.009)
adj. R-sq	0.035	0.014	0.020	0.010	0.830	0.032	0.013	0.011	0.014
Year fixed effect	Y	Y	Y	Y	Y	Y	Y	Y	Y
Individual fixed effect	Y	Y	Y	Y	Y	Y	Y	Y	Y

	Mental health related variables						*Family relationships related variables*		
	CESD-11 score	Suspicion of light depression (=1)	Suspicion of hypostyptic depression (=1)	Suspicion of serious depression (=1)	Rosenburg self-esteem scale	High rated score on life satisfaction (=1)	High rated score on family relationships (=1)	High rated score on spouse relationships (=1)	High rated score on child relationships (=1)
Keep smoking cessation for 1 yr after 2015 (=1)	0.205	0.057**	0.028*	0.000	-0.190	-0.008	-0.020	-0.005	0.006
	(0.233)	(0.024)	(0.016)	(0.009)	(0.274)	(0.030)	(0.022)	(0.025)	(0.031)
Keep smoking cessation for 2 yrs after 2015 (=1)	0.021	0.038	0.025	0.005	-0.073	0.007	-0.024	0.022	0.062*
	(0.245)	(0.025)	(0.017)	(0.008)	(0.336)	(0.034)	(0.026)	(0.028)	(0.035)
Keep smoking cessation for 3 yrs after 2015 (=1)	-0.056	0.025	0.023	-0.002	-0.404	0.004	-0.018	0.021	0.060
	(0.264)	(0.027)	(0.017)	(0.007)	(0.366)	(0.037)	(0.028)	(0.031)	(0.037)
Keep smoking from 2015 (=1)	0.088	0.002	0.003	0.004	-0.121	0.001	-0.007	-0.001	-0.107***
	(0.087)	(0.009)	(0.006)	(0.004)	(0.079)	(0.009)	(0.008)	(0.007)	(0.011)
adj. R-sq	0.010	0.007	0.004	0.001	0.008	0.004	0.051	0.002	0.287
Year fixed effect	Y	Y	Y	Y	Y	Y	Y	Y	Y
Individual fixed effect	Y	Y	Y	Y	Y	Y	Y	Y	Y
Number of observations	31,975								
Number of clusters	4,923								

Note: * p<0.1 ** p<0.05 *** p<0.01; robust standard error clustered within an individual is used. Standard errors in parentheses. The control variables used in as follows: *Marital status, Education level, Living Area, Chronic disease status, Age, Age squared, Household expenditure level*. These variables are not displayed in this table, nonetheless, they are regressed to control for all outcome variables.

Table A3. Change of non-smoker by end of secondhand smoking after the tax implementation in 2015

	Physical health related outcomes						
	Main analysis	*Supplementary analysis*					
	High rated score on health status (=1)	Extended High rated score on health Status (=1)	Higher score on health Status than last year (=1)	Have Chronic Disease (=1)	Have Smoke Related Chronic Disease (=1)	Number of outpatient treatments in year	Number of Hospitalization in year
Have family member who ceased smoking at 2015 (=1)	-0.026	-0.005	-0.019	-0.004	0.004	-1.199	0.008
	(0.018)	(0.014)	(0.016)	(0.016)	(0.006)	(1.050)	(0.031)
Have family member who still smoke from 2015 (=1)	-0.010	-0.005	0.017**	-0.001	0.000	0.263	-0.017
	(0.008)	(0.007)	(0.008)	(0.008)	(0.003)	(0.472)	(0.011)
adj. R-sq	0.029	0.012	0.016	0.007	0.822	0.021	0.016
Year fixed effect	Y	Y	Y	Y	Y	Y	Y
Individual fixed effect	Y	Y	Y	Y	Y	Y	Y

	Mental health related outcomes						*Family relationships*		
	CESD-11 score	Suspicion of light depression (=1)	Suspicion of hypostyptic depression (=1)	Suspicion of serious depression (=1)	Rosenburg self-esteem scale	High rated score on life satisfaction (=1)	High rated score on family relationships (=1)	High rated score on spouse relationships (=1)	High rated score on child relationships (=1)
Have family member who ceased smoking at 2015 (=1)	-0.055	-0.002	-0.013	0.006	-0.134	-0.003	-0.031**	-0.007	-0.038**
	(0.175)	(0.018)	(0.010)	(0.007)	(0.148)	(0.017)	(0.015)	(0.012)	(0.019)
Have family member who still smoke from 2015 (=1)	0.186**	0.011	0.009*	0.007**	-0.085	-0.000	-0.028***	0.001	-0.007
	(0.080)	(0.008)	(0.005)	(0.003)	(0.066)	(0.008)	(0.007)	(0.006)	(0.009)
adj. R-sq	0.006	0.005	0.002	0.001	0.007	0.004	0.072	0.002	0.307
Year fixed effect	Y	Y	Y	Y	Y	Y	Y	Y	Y
Individual fixed effect	Y	Y	Y	Y	Y	Y	Y	Y	Y
Number of observations	65,494								
Number of clusters	12,018								

Note: * p<0.1 ** p<0.05 *** p<0.01; robust standard error clustered within an individual is used. Standard errors in parentheses. The control variables used in as follows: *Marital status, Education level, Living Area, Chronic disease status, Age, Age squared, Household expenditure level*. These variables are not displayed in this table, nonetheless, they are regressed to control for all outcome variables.

Table A4. Descriptive statistics of outcome variables for the main analysis

	All	Smokers in 2014	Non-smokers in 2014
Physical health-related outcome	Mean (SD)	Mean (SD)	Mean (SD)
Self-rated health status	2.44 (0.93)	2.31 (0.89)	2.51 (0.95)
High rated score on health status (=1)	0.62 (0.48)	0.69 (0.46)	0.59 (0.49)
Extended high rated score on health status (=1)	0.83 (0.37)	0.87 (0.33)	0.81 (0.39)
Higher score on health status than last year (=1)	0.25 (0.43)	0.25 (0.43)	0.25 (0.43)
Have chronic disease (=1)	0.53 (0.50)	0.43 (0.50)	0.59 (0.49)
Have smoke related chronic disease (=1)	0.51 (0.50)	0.41 (0.49)	0.57 (0.50)
Number of outpatient treatments in year	13.56 (23.12)	10.85 (22.16)	15.00 (23.48)
Number of hospitalization in year	0.15 (0.53)	0.14 (0.52)	0.16 (0.54)
Drink more glass of alcohol at the site than last year (=1)	0.28 (0.45)	0.30 (0.46)	0.26 (0.44)
More frequency of drinking in the year than last year (=1)	0.24 (0.43)	0.25 (0.43)	0.24 (0.42)
Mental health-related outcome			
CESD-11	13.89 (4.19)	14.07 (4.39)	13.80 (4.07)
Suspicion of light depression (=1)	0.19 (0.39)	0.20 (0.40)	0.18 (0.38)
Suspicion of hypostyptic depression (=1)	0.07 (0.25)	0.07 (0.26)	0.06 (0.24)
Suspicion of serious depression (=1)	0.03 (0.16)	0.03 (0.17)	0.03 (0.16)
Rosenburg self-esteem scale	30.76 (4.01)	30.57 (4.12)	30.87 (3.94)
High rated score on life satisfaction (=1)	0.87 (0.33)	0.86 (0.35)	0.88 (0.32)
Family relationships			
High rated score on family relationships (=1)	0.77 (0.42)	0.73 (0.44)	0.80 (0.40)
High rated score on spouse relationships (=1)	0.87 (0.34)	0.86 (0.34)	0.87 (0.33)
High rated score on child relationships (=1)	0.87 (0.33)	0.86 (0.34)	0.88 (0.33)
Extended high rated score on family relationships (=1)	0.95 (0.22)	0.93 (0.25)	0.96 (0.20)
Extended high rated score on spouse relationships (=1)	0.97 (0.16)	0.97 (0.17)	0.98 (0.15)
Extended high rated score on child relationships (=1)	0.97 (0.18)	0.96 (0.19)	0.97 (0.17)
Number of observations	33,841	11,712	22,129

Table A5. Descriptive statistics of control variables for the main analysis

	All	Smokers in 2014	Non-Smokers in 2014
	Mean (SD)	Mean (SD)	Mean (SD)
Age	54.80 (17.22)	49.70 (14.75)	57.49 (17.81)
Age-squared	3299.21 (1907.21)	2687.95 (1561.25)	3622.73 (1992.55)
Married (=1)	0.53 (0.50)	0.43 (0.50)	0.59 (0.49)
Have chronic disease (=1)	0.74 (0.44)	0.68 (0.47)	0.77 (0.42)
Smoking in observation year (=1)	0.36 (0.48)	0.89 (0.31)	0.07 (0.26)
Expenditure level			
Low expenditure level (~33rd percentile) (=1)	0.35 (0.48)	0.28 (0.45)	0.38 (0.48)
Middle expenditure level (~66th percentile) (=1)	0.33 (0.47)	0.38 (0.49)	0.31 (0.46)
High expenditure level (~100th percentile) (=1)	0.32 (0.47)	0.34 (0.47)	0.31 (0.46)
Education level			
Less than middle school graduate (=1)	0.33 (0.47)	0.27 (0.44)	0.36 (0.48)
High school graduate (=1)	0.33 (0.47)	0.41 (0.49)	0.29 (0.45)
College graduate (=1)	0.13 (0.33)	0.15 (0.35)	0.12 (0.32)
University graduate (=1)	0.19 (0.39)	0.17 (0.37)	0.20 (0.40)
Master or PhD degree (=1)	0.03 (0.16)	0.01 (0.12)	0.04 (0.18)
Job status			
White collar job (=1)	0.28 (0.45)	0.28 (0.45)	0.27 (0.45)
Blue collar job (=1)	0.31 (0.46)	0.41 (0.49)	0.26 (0.44)
Agroforestry & Fishery job (=1)	0.13 (0.33)	0.09 (0.28)	0.14 (0.35)
Unemployment (=1)	0.29 (0.45)	0.22 (0.42)	0.32 (0.47)
Residential area			
Living in metropolitan cities include Seoul	0.42 (0.49)	0.44 (0.50)	0.41 (0.49)
Living in cities (=1)	0.39 (0.49)	0.39 (0.49)	0.38 (0.49)
Living in rural area (=1)	0.19 (0.39)	0.17 (0.37)	0.21 (0.40)
Generation			
Teenage (=1)	0.08 (0.27)	0.07 (0.26)	0.08 (0.27)
Twenties (=1)	0.14 (0.35)	0.19 (0.39)	0.11 (0.32)
Thirties (=1)	0.20 (0.40)	0.27 (0.45)	0.16 (0.37)
Forties (=1)	0.17 (0.38)	0.20 (0.40)	0.16 (0.36)
Fifties (=1)	0.15 (0.36)	0.14 (0.34)	0.16 (0.37)
Sixties (=1)	0.18 (0.39)	0.10 (0.29)	0.23 (0.42)
Seventies or more (=1)	0.07 (0.26)	0.03 (0.16)	0.10 (0.30)
Number of observations	33,841	11,712	22,129

Note: Teenage only have nineteen years old since person under nineteen legally suppressed to buy cigarettes.

Table A6. Descriptive statistics of outcome variables for the first sub-analysis

	For the Equation (2)					
	All	Individuals who ceased smoking in 2015 and keeping for 1 year	Individuals who ceased smoking in 2015 and keeping for 2 years	Individuals who ceased smoking in 2015 and keeping for 3 years	Individuals who kept their smoking from 2015	Non-Smokers in 2015
Physical health-related outcome	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Self-rated health status	2.44 (0.93)	2.33 (0.85)	2.27 (0.82)	2.26 (0.79)	2.32 (0.90)	2.51 (0.94)
High rated score on health status (=1)	0.62 (0.48)	0.66 (0.47)	0.70 (0.46)	0.70 (0.46)	0.69 (0.46)	0.58 (0.49)
Extended high rated score on health status (=1)	0.83 (0.37)	0.89 (0.32)	0.91 (0.29)	0.92 (0.28)	0.87 (0.34)	0.81 (0.39)
Higher score on health status than last year (=1)	0.25 (0.43)	0.26 (0.44)	0.26 (0.44)	0.27 (0.44)	0.25 (0.43)	0.25 (0.43)
Have chronic disease (=1)	0.54 (0.50)	0.48 (0.50)	0.49 (0.50)	0.49 (0.50)	0.44 (0.50)	0.60 (0.49)
Have smoke related chronic disease (=1)	0.52 (0.50)	0.44 (0.50)	0.45 (0.50)	0.45 (0.50)	0.41 (0.49)	0.58 (0.49)
Number of outpatient treatments in year	13.70 (23.20)	11.55 (21.46)	11.46 (22.59)	11.80 (23.35)	10.80 (21.87)	15.44 (23.81)
Number of hospitalization in year	0.15 (0.53)	0.14 (0.56)	0.14 (0.60)	0.11 (0.39)	0.14 (0.51)	0.16 (0.54)
Drink more glass of alcohol at the site than last year (=1)	0.28 (0.45)	0.31 (0.46)	0.30 (0.46)	0.29 (0.45)	0.30 (0.46)	0.26 (0.44)
More frequency of drinking in the year than last year (=1)	0.24 (0.43)	0.27 (0.44)	0.25 (0.43)	0.26 (0.44)	0.25 (0.43)	0.23 (0.42)
Mental health-related outcome						
CESD-11 score	13.85 (4.13)	13.71 (3.95)	13.44 (3.59)	13.10 (2.88)	14.03 (4.36)	13.75 (4.00)
Suspicion of light depression (=1)	0.18 (0.39)	0.17 (0.37)	0.15 (0.36)	0.12 (0.33)	0.20 (0.40)	0.18 (0.38)
Suspicion of hypostyptic depression (=1)	0.07 (0.25)	0.05 (0.22)	0.04 (0.20)	0.02 (0.15)	0.07 (0.26)	0.06 (0.24)
Suspicion of serious depression (=1)	0.03 (0.16)	0.02 (0.15)	0.01 (0.12)	0.00 (0.07)	0.03 (0.17)	0.02 (0.15)
Rosenburg self-esteem scale	30.80 (3.98)	30.92 (3.69)	31.06 (3.63)	31.20 (3.50)	30.60 (4.14)	30.91 (3.89)
High rated score on life satisfaction (=1)	0.87 (0.34)	0.87 (0.34)	0.89 (0.31)	0.89 (0.32)	0.85 (0.36)	0.88 (0.32)
Family relationships						
High rated score on family relationships (=1)	0.78 (0.42)	0.76 (0.43)	0.77 (0.42)	0.77 (0.42)	0.74 (0.44)	0.80 (0.40)
High rated score on spouse relationships (=1)	0.87 (0.34)	0.87 (0.33)	0.88 (0.32)	0.89 (0.32)	0.87 (0.34)	0.87 (0.33)
High rated score on child relationships (=1)	0.87 (0.34)	0.88 (0.33)	0.88 (0.33)	0.87 (0.33)	0.86 (0.34)	0.87 (0.33)
Extended high rated score on family relationships (=1)	0.95 (0.22)	0.96 (0.19)	0.97 (0.17)	0.97 (0.17)	0.94 (0.24)	0.96 (0.20)
Extended high rated score on spouse relationships (=1)	0.97 (0.16)	0.98 (0.12)	0.99 (0.12)	0.98 (0.12)	0.97 (0.17)	0.98 (0.15)
Extended high rated score on child relationships (=1)	0.97 (0.18)	0.98 (0.15)	0.97 (0.16)	0.97 (0.16)	0.96 (0.19)	0.97 (0.17)
Number of observations	31,975	759	539	449	11,335	19,881

Note: The treatment groups are consisted of as follow: 'person who ceased smoking in 2015 and keeping for 1 year', 'person who ceased smoking in 2015 and keeping for 2 years', and 'person who ceased smoking in 2015 and keeping for 3 years'.

Table A7. Descriptive statistics of control variables for the first sub-analysis

	All	Individuals who ceased smoking in 2015 and keeping for 1 year	Individuals who ceased smoking in 2015 and keeping for 2 years	Individuals who ceased smoking in 2015 and keeping for 3 years	Individuals who kept their smoking from 2015	Non-Smokers in 2015
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Age	55.10 (17.01)	54.07 (16.80)	54.65 (16.57)	54.93 (16.82)	49.83 (14.72)	58.15 (17.49)
Age-squared	3325.62 (1891.97)	3204.96 (1855.49)	3260.83 (1842.40)	3299.61 (1873.05)	2699.46 (1562.59)	3687.22 (1969.51)
Married (=1)	0.54 (0.50)	0.48 (0.50)	0.49 (0.50)	0.49 (0.50)	0.44 (0.50)	0.60 (0.49)
Have chronic disease (=1)	0.75 (0.43)	0.69 (0.46)	0.72 (0.45)	0.71 (0.45)	0.69 (0.46)	0.79 (0.41)
Smoking in observation year (=1)	0.35 (0.48)	0.42 (0.49)	0.36 (0.48)	0.34 (0.47)	0.90 (0.30)	0.04 (0.19)
Expenditure level						
Low expenditure level (~33rd percentile) (=1)	0.35 (0.48)	0.32 (0.47)	0.29 (0.46)	0.30 (0.46)	0.29 (0.45)	0.38 (0.49)
Middle expenditure level (~66th percentile) (=1)	0.33 (0.47)	0.36 (0.48)	0.37 (0.48)	0.37 (0.48)	0.38 (0.48)	0.31 (0.46)
High expenditure level (~100th percentile) (=1)	0.32 (0.47)	0.32 (0.47)	0.33 (0.47)	0.33 (0.47)	0.34 (0.47)	0.31 (0.46)
Education level						
Less than middle school graduate (=1)	0.33 (0.47)	0.27 (0.44)	0.24 (0.43)	0.23 (0.42)	0.28 (0.45)	0.37 (0.48)
High school graduate (=1)	0.33 (0.47)	0.39 (0.49)	0.45 (0.50)	0.46 (0.50)	0.40 (0.49)	0.28 (0.45)
College graduate (=1)	0.12 (0.33)	0.14 (0.35)	0.13 (0.33)	0.13 (0.34)	0.15 (0.35)	0.11 (0.31)
University graduate (=1)	0.19 (0.39)	0.17 (0.38)	0.15 (0.36)	0.15 (0.36)	0.16 (0.37)	0.20 (0.40)
Master or PhD degree (=1)	0.03 (0.17)	0.02 (0.15)	0.02 (0.15)	0.03 (0.17)	0.02 (0.12)	0.04 (0.19)
Job status						
White collar job (=1)	0.28 (0.45)	0.32 (0.47)	0.29 (0.45)	0.29 (0.46)	0.28 (0.45)	0.27 (0.44)
Blue collar job (=1)	0.31 (0.46)	0.32 (0.47)	0.35 (0.48)	0.36 (0.48)	0.40 (0.49)	0.26 (0.44)
Agroforestry & Fishery job (=1)	0.13 (0.33)	0.11 (0.32)	0.12 (0.33)	0.12 (0.32)	0.09 (0.29)	0.15 (0.36)
Unemployment (=1)	0.28 (0.45)	0.25 (0.43)	0.24 (0.43)	0.23 (0.42)	0.22 (0.41)	0.32 (0.47)
Residential area						
Living in metropolitan cities include Seoul	0.42 (0.49)	0.45 (0.50)	0.46 (0.50)	0.47 (0.50)	0.43 (0.50)	0.41 (0.49)
Living in cities (=1)	0.38 (0.49)	0.39 (0.49)	0.37 (0.48)	0.35 (0.48)	0.40 (0.49)	0.38 (0.48)
Living in rural area (=1)	0.19 (0.40)	0.16 (0.37)	0.17 (0.38)	0.18 (0.38)	0.17 (0.37)	0.21 (0.41)
Generation						
Teenage (=1)	0.07 (0.25)	0.07 (0.26)	0.06 (0.24)	0.06 (0.24)	0.07 (0.26)	0.07 (0.25)
Twenties (=1)	0.14 (0.35)	0.16 (0.37)	0.15 (0.36)	0.16 (0.37)	0.19 (0.39)	0.11 (0.31)
Thirties (=1)	0.20 (0.40)	0.18 (0.39)	0.19 (0.39)	0.17 (0.38)	0.28 (0.45)	0.15 (0.36)
Forties (=1)	0.18 (0.38)	0.22 (0.41)	0.22 (0.41)	0.22 (0.42)	0.20 (0.40)	0.16 (0.37)
Fifties (=1)	0.16 (0.36)	0.14 (0.35)	0.14 (0.35)	0.13 (0.33)	0.14 (0.34)	0.17 (0.38)
Sixties (=1)	0.19 (0.39)	0.15 (0.36)	0.16 (0.36)	0.17 (0.38)	0.10 (0.30)	0.24 (0.42)
Seventies or more (=1)	0.07 (0.26)	0.08 (0.27)	0.08 (0.27)	0.08 (0.28)	0.02 (0.15)	0.10 (0.30)
Number of observations	31,975	759	539	449	11,335	19,881

Note: Teenage only have nineteen years old since person under nineteen legally suppressed to buy cigarettes.

Table A8. Descriptive statistics of outcome variables for the second sub-analysis

	All	Individuals who have any family member who keep smoking cessation from 2015	Individuals who have any family member who still smoking from 2015	Individuals who have family members who are a non-smoker
Physical health-related outcome	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Self-rated health status	2.63 (0.97)	2.43 (0.89)	2.37 (0.89)	2.70 (0.98)
High rated score on health status (=1)	0.53 (0.50)	0.63 (0.48)	0.66 (0.47)	0.50 (0.50)
Extended High rated score on health Status (=1)	0.77 (0.42)	0.84 (0.36)	0.86 (0.35)	0.75 (0.44)
Higher score on health Status than last year (=1)	0.25 (0.43)	0.25 (0.43)	0.24 (0.43)	0.25 (0.44)
Have Chronic Disease (=1)	0.60 (0.49)	0.52 (0.50)	0.46 (0.50)	0.64 (0.48)
Have Smoke Related Chronic Disease (=1)	0.58 (0.49)	0.50 (0.50)	0.44 (0.50)	0.62 (0.48)
Number of outpatient treatments in year	20.02 (30.18)	15.04 (23.80)	14.90 (25.83)	21.49 (31.23)
Number of Hospitalization in year	0.18 (0.57)	0.16 (0.65)	0.15 (0.49)	0.19 (0.58)
Mental health-related outcome				
CESD-11 score	14.75 (4.79)	14.20 (4.11)	14.10 (4.21)	14.94 (4.94)
Suspicion of light depression (=1)	0.26 (0.44)	0.22 (0.41)	0.21 (0.41)	0.27 (0.45)
Suspicion of hypostyptic depression (=1)	0.10 (0.30)	0.07 (0.25)	0.07 (0.25)	0.11 (0.31)
Suspicion of serious depression (=1)	0.04 (0.20)	0.02 (0.14)	0.03 (0.16)	0.05 (0.21)
Rosenburg self-esteem scale	30.43 (4.03)	30.70 (3.69)	31.02 (3.73)	30.27 (4.11)
High rated score on life satisfaction (=1)	0.87 (0.34)	0.86 (0.35)	0.87 (0.33)	0.86 (0.34)
Family relationships				
High rated score on family relationships (=1)	0.78 (0.42)	0.78 (0.41)	0.77 (0.42)	0.78 (0.42)
High rated score on spouse relationships (=1)	0.86 (0.35)	0.85 (0.36)	0.82 (0.38)	0.87 (0.34)
High rated score on child relationships (=1)	0.87 (0.33)	0.90 (0.30)	0.89 (0.31)	0.87 (0.34)
Extended high rated score on family relationships (=1)	0.95 (0.22)	0.95 (0.22)	0.94 (0.23)	0.95 (0.22)
Extended high rated score on spouse relationships (=1)	0.96 (0.19)	0.96 (0.19)	0.95 (0.22)	0.97 (0.18)
Extended high rated score on child relationships (=1)	0.97 (0.18)	0.98 (0.15)	0.98 (0.15)	0.97 (0.18)
Number of observations	65,495	1,989	12,714	50,792

Note: all individual in this sub-analysis is non-smokers themselves regardless of the family's smoking status.

Table A9. Descriptive statistics of control variables for the second sub-analysis

	All	Individuals who have any family member who keep smoking cessation from 2015	Individuals who have any family member who still smoking from 2015	Individuals who have family members who are a non-smoker
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Age	57.00 (18.50)	50.83 (18.23)	48.78 (17.22)	59.30 (18.17)
Age-squared	3591.05 (2040.91)	2915.92 (1885.66)	2675.85 (1774.02)	3846.58 (2037.49)
Male (=1)	0.30 (0.46)	0.22 (0.42)	0.14 (0.35)	0.34 (0.47)
Married (=1)	0.64 (0.48)	0.70 (0.46)	0.72 (0.45)	0.62 (0.48)
Have chronic disease (=1)	0.60 (0.49)	0.52 (0.50)	0.46 (0.50)	0.64 (0.48)
Smoking in observation year (=1)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Expenditure level				
Low expenditure level (~33rd percentile) (=1)	0.33 (0.47)	0.19 (0.39)	0.15 (0.35)	0.39 (0.49)
Middle expenditure level (~66th percentile) (=1)	0.33 (0.47)	0.37 (0.48)	0.41 (0.49)	0.31 (0.46)
High expenditure level (~100th percentile) (=1)	0.33 (0.47)	0.45 (0.50)	0.44 (0.50)	0.30 (0.46)
Education level				
Less than middle school graduate (=1)	0.47 (0.50)	0.43 (0.49)	0.34 (0.47)	0.50 (0.50)
High school graduate (=1)	0.25 (0.43)	0.28 (0.45)	0.33 (0.47)	0.23 (0.42)
College graduate (=1)	0.11 (0.32)	0.14 (0.35)	0.17 (0.37)	0.10 (0.30)
University graduate (=1)	0.14 (0.35)	0.14 (0.35)	0.15 (0.36)	0.14 (0.35)
Master or PhD degree (=1)	0.02 (0.14)	0.01 (0.08)	0.01 (0.10)	0.02 (0.15)
Job status				
White collar job (=1)	0.26 (0.44)	0.30 (0.46)	0.32 (0.47)	0.24 (0.43)
Blue collar job (=1)	0.17 (0.38)	0.18 (0.39)	0.18 (0.39)	0.17 (0.37)
Agroforestry & Fishery job (=1)	0.11 (0.31)	0.12 (0.32)	0.08 (0.27)	0.12 (0.32)
Unemployment (=1)	0.46 (0.50)	0.40 (0.49)	0.42 (0.49)	0.47 (0.50)
Residential area				
Living in metropolitan cities include Seoul	0.42 (0.49)	0.45 (0.50)	0.45 (0.50)	0.41 (0.49)
Living in cities (=1)	0.37 (0.48)	0.37 (0.48)	0.39 (0.49)	0.37 (0.48)
Living in rural area (=1)	0.21 (0.40)	0.18 (0.38)	0.16 (0.37)	0.22 (0.41)
Generation				
Teenage (=1)	0.09 (0.29)	0.16 (0.37)	0.15 (0.35)	0.08 (0.27)
Twenties (=1)	0.12 (0.32)	0.16 (0.36)	0.20 (0.40)	0.10 (0.30)
Thirties (=1)	0.15 (0.35)	0.13 (0.34)	0.18 (0.39)	0.14 (0.35)
Forties (=1)	0.15 (0.35)	0.20 (0.40)	0.18 (0.38)	0.14 (0.34)
Fifties (=1)	0.17 (0.37)	0.18 (0.38)	0.15 (0.36)	0.17 (0.37)
Sixties (=1)	0.23 (0.42)	0.13 (0.33)	0.10 (0.30)	0.26 (0.44)
Seventies or more (=1)	0.10 (0.30)	0.05 (0.21)	0.04 (0.19)	0.12 (0.32)
Number of observations	65,495	1,989		

Note: Teenage only have nineteen years old since person under nineteen legally suppressed to buy cigarettes.