Impact of Smoking Bans on Smoking in South Korea: A Synthetic Control Approach

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Abstract

This study evaluates the impact of South Korea's 2011 smoking bans, including indoor and outdoor restrictions, on national smoking prevalence. While prior studies have focused primarily on secondhand smoke exposure and short-term behavioral changes, few have examined population-level smoking outcomes using causal inference methods. Leveraging the Synthetic Control Method (SCM), I construct a counterfactual "Synthetic Korea" from a weighted combination of 27 OECD countries that did not implement similar nationwide smoking bans during the same period. Using country-level panel data from 1995 to 2015, the analysis isolates the effect of the 2011 smoking bans while avoiding confounding from later interventions such as a major tobacco tax increase in 2015 and the introduction of pictorial warning labels in 2016. Results show that the smoking bans led to an average reduction of 2.3 percentage points in smoking prevalence, representing an 8.5 percent decline ($p < 0.036$) from the 2011 baseline. This equates to approximately 1.2 million fewer smokers in South Korea, either through cessation or prevention. Based on standard valuation methods, this reduction is estimated to have generated approximately USD 207 billion in economic value through gains in life expectancy. These findings provide robust evidence of the effectiveness of smoking bans in reducing smoking prevalence and offer valuable insights for policymakers in other middle-income and high-income countries considering similar non-price tobacco control strategies.

Keywords: Observation studies, Tobacco Control Policy, Synthetic Control Methods
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1 Introduction

Smoking is a major concern for policymakers in South Korea. The average smoking rate recorded 35%[1] in 2000, 62.8% among the male population and 7.1% among the female population (See Figure 1 for trends in smoking prevalence). South Korea is the 7th highest male smoking rate in OECD countries based on 2017 OECD Health Statistics estimates (Figure 2). According to Jung et al. (2013), approximately 58,000 people experience premature death related to smoking each year. Also, Oh et al. (2012) using the nationally representative claims data from the National Health Insurance Corporation, estimated the total economic cost of smoking-related cancers reached USD 3 billion in 2008.

Reducing the smoking prevalence could help reduce substantial amount of national healthcare spending and prevent individual health problems. The South Korean government has made a great effort to reduce the prevalence of smoking and its consumption, especially starting from 2011 when the government observed a steady increase in the smoking rate. Since 2011, a wide range of smoking bans have been implemented, including indoor smoking bans[2] and outdoor smoking bans. The amendment of National Health Promotion Act that passed in 2010 gave local authorities the power to enact bylaws banning smoking in outdoor public places (Cho, 2014). The outdoor smoking bans were rapidly spread across the country when Seoul metropolitan city passed bill on preventing second-hand smoke in 2011. Due to the amendment, the smoke-free zone expanded to public areas including bus stops, subway station entrances, and public parks. The amendment also introduced 100,000 Won (USD 90.10[3]) fine to people who smoke in the prohibited area. The tobacco control policy was enhanced by introducing the comprehensive indoor smoke-free policy in 2011, prohibiting smoking in large restaurants, bars, cafes, and offices, which later expanded to all restaurants, bars, cafes, and offices. Police were actively enforcing the fines on smokers

[1]The smoking prevalence represents the share of the general population aged 19 years or older who reported currently smoking. Source: KNHANES

[2]The indoor smoking ban is equivalent to an indoor air law or comprehensive smoke-free legislation.

[3]Based on the exchange rate of USD 1 to 1,100 Korean Won.

who smoked in the prohibited area. In 2015, policymakers increased the tax on cigarettes, resulting in 80% price increase—from 2,500 Won (USD 2.30) to 4,500 Won (USD 4.10). In 2016, the Korean government passed a law to mandate to include pictorial warning labels (Figure 3) on all cigarette packages. In 2017 and 2018, the smoke-free zone expanded to all sports facilities and kindergarten areas.

Studies have shown that comprehensive smoke-free policy in Korea led to increased indoor air quality, and reduced second-hand smoke which are the primary intention of the policy. Kim et al. (2016) measured indoor air quality of 148 bars located in Seoul and Changwon before and after the implementation of comprehensive smoke-free policy, found that $PM_{2.5}$ concentration of all bars gradually decreased from 98.4 $\mu g/m^3$ to 26.6 $\mu g/m^3$. Park et al. (2020) examined biochemical markers specific to second-hand smoke to measure the exposure under different smoking restriction settings. The authors concluded that comprehensive indoor smoking bans reduced second-hand smoke in hospitals, internet cafes, karaoke, and billiard halls. These findings are align with the findings in New Zealand (Edwards et al., 2008).

Smoking restrictions in outdoor public spaces have emerged relatively recently, with research exploring their effectiveness still developing. Johns et al. (2015) analyzed New York State Adult Tobacco Survey and found that the 2011 New York City smoking bans in public parks and beaches was associated with reduced smoke exposure. Similarly, Okoli et al. (2013) reported observed reductions in smoking rates following outdoor smoking restrictions in Vancouver. However, these studies relied on observational data, limiting causal inference.

While many studies examine the effect of smoking bans on smoke exposure and cessation outcomes, relatively few have focused on population-level smoking prevalence as an outcome (Hahn, 2010). Some Evidence suggests that smoking prevalence may initially decline following the introduction of smoking bans, but these reductions might not persist in the long term. Heloma and Jaakkola (2003) and Helakorpi et al. (2008) reported that the enactment of a smoke-free workplace law in Finland reduced smoking rates by 15% during the first year; however, smoking rates remained unchanged over the subsequent three years. A study on Irish bar workers found a significant decline in the number of cigarettes smoked per day, but no significant reduction in smoking prevalence during the first year after the smoke-free law was implemented. Anger et al. (2011) used variation in the timing of smoke-free bar policies across German states and found that individuals who frequented bars reduced smoking, though average smoking behavior in the general population remained unchanged. Boes et al. (2015), exploiting the staggered implementation of smoking bans in public venues in Switzerland, found a 1% reduction in smoking prevalence after one year. In the United States, Carton et al. (2016), using Behavioral Risk Factor Surveillance System (BRFSS) data, found that comprehensive indoor smoking bans are associated with a 2.35% to 3.29% average reduction in smoking prevalence.

On the other hand, Lee, Glantz, and Millett (2011) studied the implementation of a smoke-free policy in England and found a significant reduction in smoking behavior in prohibited areas, which contributed to a decline in smoking prevalence. However, they concluded that the reduction was barely the trend, suggesting that the policy neither accelerated nor slowed the decline. Several other studies also report no clear effect of smoking bans on smoking prevalence, though they do find increases in quit attempts (Nagelhout et al., 2012; Edwards et al., 2008). Overall, the literature on the effects of smoking bans on population-level smoking prevalence offers mixed evidence.

Given the mixed evidence on the impact of smoking bans on smoking prevalence, providing additional evidence from South Korea can contribute meaningfully to the literature. Several studies have examined the effects of the 2011 smoking ban implementations in South Korea. Kang and Cho (2020) investigated the impact of comprehensive indoor smoking bans on adolescent smoking behavior and found a significant decline in smoking prevalence among boys from 16% to 9%, and among girls from 9% to 3% between 2006 and 2017. Ko (2020), exploiting variation in the timing of outdoor smoking bans across local governments, found that these bans increased the probability of making a quit attempt by 16%, consistent with findings from Nagelhout et al. (2012) and Edwards et al. (2008). However, Ko (2020) found no significant effect of outdoor smoking bans on overall smoking prevalence.

Notably, studies that reported effects of smoke-free policies (Kim et al., 2016; Park et al., 2020; Kang et al., 2020) primarily relied on pre-post analysis, which could lead to a biased estimates due to uncontrolled nation-specific, time-varying factors. Although Ko (2020) provided a causal estimate of the outdoor smoking ban's effect, the analysis controlled for the 2011 indoor smoke-free policy, which may have absorbed the policy's overall effect on smoking prevalence.

In theory, as more places become smoke-free, the cost of smoking increases in both time and mental effort. Restriction reduces smokers' opportunity to consume tobacco products, forcing them to invest additional time and effort to find permitted areas. Also, the changes in social norms regarding acceptability of smoking increases stress on smokers. However, if the cost is not high enough to counter the addiction, smoker will continue to smoke (Chaloupka and Warner, 2000). Considering the cost of smoking is monotonically increasing as various tobacco policies being implemented, analyzing the impact of smoking bans as a whole, including indoor and outdoor smoking bans, is plausible when estimating the reduction in smoking prevalence. Growing literature in causal inferences suggests that the synthetic control method could provide useful insight in this case.

In this paper, I empirically estimate the effect of smoking bans in South Korea by estimating the reduction of the average smoking rates using country-level panel data and the synthetic control method (Abadie and Gardeazabla 2003, Abadie, Diamond, and Hainmueller 2010, 2015, Andersson 2019, Abadie 2021). From a group of OECD countries, I construct the counterfactual, "Synthetic Korea": a comparable unit consisting of a weighted combination of countries that did not implement a sequence of large price policies and non-price policies during the treatment period and that prior to treatment resemble Korea on several key predictors of smoking rates and have similar levels and paths of smoking rates. The synthetic control method provides an estimated average smoking rate reduction of 2.3 percentage points from the baseline smoking rate of 27.1% in 2011, which is an 8.5% reduction. In other words, the smoking bans effectively deterred 1.2 million people from smoking, either through cessation of the current smokers or preventing the initiation of new smokers. This reduction is estimated to have generated approximately USD 207 billion in economic value through gains in life expectancy.

This paper offers several contributions to the literature. First, it adds to the growing body of research on the effects of smoking bans[4] on smoking prevalence by examining their effectiveness in a non-Western, middle-high-income country context. Second, it contributes to the literature on non-price tobacco control policies, which remain understudied relative to price-based measures, by evaluating the combined impact of indoor and outdoor smoking bans. Third, it applies the synthetic control method (SCM) to plausibly estimate the overall causal effect of smoking bans, offering methodological insight for evaluating nationally and simultaneously implemented policies. Finally, the paper introduces a newly hand-collected, country-level panel dataset on smoking prevalence across OECD countries, which may serve as a valuable resource for future research.

The remainder of the paper is organized as follows. Section 2 presents detailed background on South Korea's tobacco control policies. Section 3 presents the data and methods used for the estimation of smoking prevalence reductions. Section 4 presents the results of the empirical analysis as well as several robustness checks. Finally, section 5 concludes.

2 Background

Smoking was very common among adult males in South Korea in 1990, with a smoking rate of 75.3%, while only 7.7% of adult females smoked, bringing the overall average down to 41.5%. At the time, strong social norms discouraged women from smoking. In 1995, South Korean policymakers began to recognize smoking as a serious public health issue and

[4]Smoking Bans include comprehensive indoor smoking bans such as comprehensive smoke-free policies (SFP) and indoor air laws (IAL), as well as outdoor smoking bans.

enacted the National Health Promotion Act, which introduced tobacco control measures such as designating schools and hospitals as smoke-free zones and restricting tobacco advertising and exposure on television (Cho, 2014). Table 1[5] shows the changes in cigarette taxes and prices beginning in 1991. Following these tax adjustments, tobacco prices rose gradually from 1994 to 2002, followed by significant increases in 2002 and 2005, with prices rising by 500 Won each time from a base of 1,500 Won—a 60% increase overall. This led to a sharp decline in smoking prevalence among men, from 60.5% in 2002 to 45.9% in 2006. However, the impact of this initial price policy soon diminished, as smoking rates began to rise steadily again among both male and female populations.

Although South Korea ratified the WHO Framework Convention on Tobacco Control (FCTC)[6], the efforts to regulate smoking have been weak (Cho, 2014). Tobacco advertising, promotion, and sponsorship are not comprehensively restricted, the sale of tobacco products to minors is poorly enforced, though it is prohibited, and smoking cessation services are not covered by the public health insurance program.

Starting from 2011, South Korean policymakers implemented a series of tobacco control policies. The National Health Promotion Act was amended in 2010, granting local authorities the authority to establish regulations prohibiting smoking in outdoor public spaces (Cho, 2014). The implementation of outdoor smoking bans gained momentum nationwide after Seoul metropolitan city passed a bill on preventing second-hand smoke in 2011. This led to the expansion of smoke-free zones to various public areas, including commonly frequented sites like bus stops, subway station entrances, and public parks. A new fine of 100,000 Won (USD 90.10) was introduced and actively enforced on people who smoke in the prohibited area. The introduction of the indoor smoking bans in 2011, prohibiting smoking in large restaurants, bars, cafes, and offices, later expanded to all restaurants, and bars made smokers substantially inconvenient to smoke.

[5]Source: Park (2016)

[6]The first international treaty negotiated under WHO to advance the implementation of tobacco control policies.

This marked a critical shift from a partial smoke-free policy to a comprehensive smoke-free policy. Under the partial policy, smoking was allowed in designated areas within indoor venues, such as specific rooms or sections in restaurants and bars. However, these areas were not required to be completely enclosed or separated, allowing smoke to travel to adjacent non-smoking areas. In contrast, the comprehensive policy implemented in 2011 prohibited smoking entirely in such venues, unless a designated smoking area was completely isolated with physical barriers and independent ventilation to prevent smoke from spreading. Figure 4 visually illustrates this shift, comparing an environment with partial restrictions to one with comprehensive protections. As part of policy implementation, smoking booths were introduced in some indoor and outdoor locations to provide smokers with enclosed spaces compliant with the new regulations. Figures 5 and 6 show examples of these facilities. To reinforce compliance, the government also installed highly visible no-smoking signs across smoke-free zones, such as the one depicted in Figure 7, which clearly state the 100,000 Won fine for violations. Together, these physical measures and visual cues enhanced the visibility, enforcement, and social acceptance of the smoke-free policies. Table 2 and 3 present the number of designated smoking ban sites and the number of fines issued, respectively.

In 2015, a large tax increase led to an 80% rise in cigarette prices, from 2,500 Won (USD 2.30) to 4,500 Won (USD 4.10). Several studies researched the effect of the tobacco price policy in 2015 since the increase was huge. Kim and Kim (2017) and Han (2019) estimated that the tobacco price increase in 2015 reduced the average smoking rate by 3%. Lim and Khang (2021) found that low-income Korean smokers were more responsive to changes in tobacco prices. Jeong Da-hae (2020) found that education level and income level were significantly higher among non-smokers than smokers in 2018. Cheon et al. (2021) reports no changes in smoking habits among Korean male cancer survivors. Only temporary effect on the stage of smoking cessation among Korean male smokers (Kwon et al., 2021).

In 2016, the Korean government mandated the inclusion of pictorial warning labels on all cigarette packages. In the following two years, smoke-free zones were further expanded to cover all sports facilities and kindergarten areas. Heated tobacco products, a type of non-conventional cigarette product[7], were introduced in the market in 2017. Figure 8 displays the quarterly sales trends of conventional tobacco products and heated tobacco products (Lee, 2020).

A timeline of key tobacco control policies in South Korea is presented in Figure 9, highlighting the major legislative and policy milestones between 1995 and 2020. This paper focuses on the period from 1995 to 2015 in order to isolate the effect of the smoking bans introduced in 2011. This window allows sufficient pre- and post-intervention observations while avoiding confounding influences from major policy changes implemented after 2015. Specifically, the large tobacco tax increase in 2015, the mandatory inclusion of pictorial warning labels in 2016, and the introduction of heated tobacco products in 2017 could each independently affect smoking behavior, making it difficult to attribute changes in smoking prevalence solely to the 2011 smoking bans. By restricting the analysis period to 1995–2015, this study aims to provide a cleaner estimate of the impact of indoor and outdoor smoking bans.

3 Empirical Methodology

3.1 Data

To empirically analyze the effect of the 2011 smoking bans on smoking prevalence, I use annual country-level panel data covering the period from 1995 to 2015. The sample is restricted to 28 OECD countries, including South Korea, based on the availability of smoking prevalence data. These data are compiled from multiple sources, including International Smoking Statistics (Forey et al., 2006), the World Bank's World Development

[7]Electronic nicotine delivery systems (ENDS), such as e-cigarettes, may also raise concerns. However, according to data from the Korea National Health and Nutrition Examination Survey (KNHANES), the prevalence of e-cigarette use among adults increased only modestly from 0.9% in 2013 to 2.6% by 2015 (Sung, 2018). This trend is unlikely to significantly bias our results due to the high rate of dual use of conventional cigarettes and e-cigarettes during this period (Jeon et al., 2016).

Indicators (WDI), and tobacco use data from the World Health Organization (WHO). For South Korea, I rely on smoking prevalence data from the Korea National Health and Nutrition Examination Survey (KNHANES).

To construct a consistent measure of smoking prevalence, I limit the sample to individuals aged 15 and older who reported smoking manufactured cigarettes in the past month. However, because not all countries conduct annual surveys on smoking prevalence, the dataset includes several missing values. I address this by linearly interpolating between available data points. National indicators such as GDP per capita, age distribution, industry composition, and alcohol consumption per capita are drawn from the WDI dataset.

The analysis period begins in 1995 and runs through 2015. This provides 17 years of pre-intervention data and 5 years of post-intervention data following the introduction of comprehensive tobacco control policies in 2011. I choose 2015 as the cutoff year to isolate the effects of the smoking bans, avoiding potential confounding from the 2015 cigarette price increase and the 2016 mandate for pictorial warning labels.

From the initial pool of 37 OECD countries (excluding South Korea), I exclude 10 countries due to a lack of consistent smoking prevalence data: Chile, Colombia, Costa Rica, Latvia, Lithuania, Luxembourg, Mexico, the Slovak Republic, Slovenia, and Turkiye. The final donor pool therefore consists of 27 countries: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Estonia, France, Finland, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Israel, Netherlands, New Zealand, Norway, Poland, Portugal, Spain, Sweden, Switzerland, the United States, and the United Kingdom. Table 4 presents the smoking prevalence data for these countries from 1995 to 2015.

3.2 The Synthetic Control Method

The Difference-in-Differences (DiD) estimator is commonly used in comparative case studies. It relies on using a unit similar to the treated unit as a control to represent the counterfactual—i.e., what would have happened to the treated unit in the absence of the intervention. The treatment effect is estimated by comparing changes in the outcome variable before and after the intervention, for both the treated and control units.

A key advantage of the DiD approach is that, by differencing over time, it removes the influence of unobserved time-invariant covariates that affect the outcome. This relies on two core assumptions: (1) the effect of unobserved covariates is constant over time, and (2) macroeconomic shocks or other time effects are common across both the treated and control units. These assumptions are collectively known as the parallel trends assumption—in this context, implying that in the absence of the 2011 smoking bans, South Korea and the control unit would have followed parallel trends in smoking prevalence.

However, the parallel trends assumption is difficult to satisfy when policies are implemented nationally and simultaneously, as no single untreated unit closely resembles the treated one. This is a major limitation of the DiD method in evaluating nationwide policy interventions. The DiD estimator will be biased if the treated and control units do not share a common trend. Figure 10 compares the trend in smoking prevalence in South Korea with the average trend across the 27 OECD donor countries. The figure shows a lack of evidence to support the parallel trends assumption in the pre-treatment period, indicating that DiD is not suitable in this case.

The Synthetic Control Method (SCM), introduced by Abadie et al. (2010)[8], offers a compelling alternative. Rather than relying on a single comparison unit, SCM constructs a synthetic control unit as a weighted average of multiple untreated units. These weights are chosen so that the synthetic unit best approximates the treated unit's characteristics and outcome trajectory in the pre-intervention period. This method ensures that the parallel trends assumption holds by construction, even in the absence of a single comparable control unit.

Let $J+1$ denote the total number of units, with unit $j = 1$ corresponding to South Korea, the treated unit, and $j = 2, \ldots, J+1$ denoting the J donor units. Let T_0 represent the last

[8] See Abadie (2021) for a formal exposition of the method. For earlier development and empirical applications, see Abadie and Gardeazabal (2003) and Andersson (2019).

pre-treatment period, and T the total number of time periods. Let Y_{jt} be the smoking prevalence for unit j in year t, and let A_{jt} be an indicator equal to 1 if unit j is exposed to the treatment at time t, and 0 otherwise.

The observed outcome for South Korea can be expressed as:

$$Y_{1t} = Y_{1t}^N + \tau_t A_{1t},$$

where Y_{1t}^N is the *counterfactual* smoking prevalence (in the absence of treatment), and τ_t is the *treatment effect* at time t.

The synthetic control is defined as:

$$\hat{Y}_{1t}^N = \sum_{j=2}^{J+1} w_j Y_{jt},$$

where $w_j \geq 0$ and $\sum_{j=2}^{J+1} w_j = 1$. The weights $W = (w_2, \ldots, w_{J+1})'$ are chosen to minimize the *Root Mean Squared Prediction Error (RMSPE)* between the treated unit and the synthetic control in the pre-treatment period, based on selected predictors and the outcome variable. Specifically, the weights are chosen to minimize:

$$\|X_1 - X_0\mathbf{W}\| = \left(\sum_{h=1}^{k} v_h (X_{h1} - w_2 X_{h2} - \cdots - w_{J+1} X_{h,J+1})^2 \right)^{1/2} \tag{1}$$

where X_1 is the vector of predictor values for the treated unit, X_0 is the matrix of predictor values for the control units, v_h are predictor-specific importance weights, and k is the number of predictors.

The estimated treatment effect is then:

$$\hat{\tau}_{1t} = Y_{1t} - \hat{Y}_{1t}^{N} = Y_{1t} - \sum_{j=2}^{J+1} w_j Y_{jt} \quad \text{for } t > T_0 \tag{2}$$

Because the method uses a convex combination of donor units with non-negative weights, it cannot generate a good synthetic control if the treated unit is a strong outlier. However, this is not a concern in our case, as the trend in smoking prevalence in South Korea is not an outlier within the dataset (see Figure 11).

The key predictors used in the construction of the synthetic control are: the log of GDP per capita, the proportion of the population aged 20–29, the share of employment in agriculture, forestry, and fisheries, and alcohol consumption per capita. Most of these predictors—excluding the industrial composition variable—were also used by Abadie et al. (2010) in their evaluation of California's tobacco control policy. I include the agricultural sector's employment share because individuals working in these sectors tend to have higher smoking rates and are generally less responsive to tobacco control policies. Each of these four predictors is averaged over the pre-treatment period (1995–2010). In addition, I include lagged smoking prevalence values for the years 2000, 2006, and 2010 to further improve the pre-treatment fit.

4 Results

4.1 South Korea versus Synthetic South Korea

If Synthetic South Korea closely tracks the actual smoking rates in South Korea during the pre-treatment period and reproduces the values of key predictors, it lends credibility to the identification assumption that the synthetic control unit approximates the counterfactual smoking trajectory in the absence of smoking bans.

Figure 12 shows that prior to treatment, smoking rates in South Korea and its synthetic counterpart align closely, except for the years between 2002 and 2005. During this period, a rapid decline in smoking rates occurred due to a major price shock, making it difficult to achieve a perfect match while maintaining an overall good fit for the pre-treatment period. Moreover, since tobacco control has been a global public health priority under the WHO Framework Convention on Tobacco Control (FCTC), it is nearly impossible to find a country that did not implement any tobacco control policies during the post-treatment period. Therefore, this estimate captures the effect of South Korea's specific sequence of tobacco control policies compared to a composite of countries that also adopted some tobacco control measures—not a comparison to a complete absence of regulation. While this may result in a conservative (downward-biased) estimate of the policy effect, it reflects a more realistic and policy-relevant counterfactual scenario.

Table 6 shows the descriptive statistics of South Korea and synthetic South Korea comparing the values of the key predictors in the pre-treatment period. For all predictors, except the proportion of the population aged 20-29, South Korea and its synthetic version have almost identical values. It supports our synthetic control unit reasonably tracks the real South Korea well, supporting the quality of the synthetic control as a counterfactual.

The weights used to construct Synthetic South Korea are reported in Table 7. The smoking trends in South Korea are best approximated by a weighted combination of Austria, the Czech Republic, Greece, Ireland, Iceland, and Israel. The remaining countries in the donor pool received zero weight. These positively weighted countries share similar economic structures and health trends with South Korea. The fact that the synthetic control is constructed from multiple countries with similar weights underscores the challenge of finding a single suitable comparison country, further justifying the use of the synthetic control method.

4.2 Smoking Prevalence Reductions

The treatment effect is estimated as the average difference in smoking prevalence between South Korea and Synthetic South Korea in the post-treatment period, as shown in Figure

12. These differences are further illustrated in the gap plot (Figure 13). The introduction of smoking bans led to a consistent reduction in smoking prevalence over time: approximately 1.5 percentage points in the first year, gradually increasing to about 4 percentage points by the fourth year, despite a slight reversal in the third year. By 2015, the final year in the sample, the observed smoking rate in South Korea was 22.4%—4 percentage points lower than the estimated counterfactual level in the absence of the treatment. Given a pre-treatment baseline of 27.1% in 2011, this represents a 15% reduction.

The average treatment effect, calculated as the mean difference in smoking rates during the post-treatment period, is 2.3 percentage points—an 8.5% reduction relative to the 2011 baseline. In absolute terms, this implies that the smoking bans effectively prevented approximately 1.2 million people from smoking, either by cessation of the current smokers or preventing the initiation of new smokers.

Levy and Friend (2001) reports that clean air laws can reduce cigarette consumption by 10–20% and may also shift social norms to discourage initiation in the long term. Although this study does not directly estimate changes in cigarette consumption, the observed 8.5% reduction in smoking prevalence suggests a substantial impact on the extensive margin.

4.3 Robustness Check

To examine the robustness of the main findings, I estimate alternative specifications of the synthetic control model using different sets of lagged smoking prevalence values prior to the policy intervention. These lagged variables serve as key predictors and play an important role in ensuring a good pre-treatment fit between Korea and its synthetic counterpart.

Figure 14 displays the results from two alternative specifications. Panel (a) presents a model in which biennial lagged smoking prevalence values—1996, 1998, 2000, 2002, 2004, 2006, 2008, and 2010—are included in the predictor set. Panel (b) instead uses triennial lagged values—1995, 1998, 2001, 2004, 2007, and 2010. In both models, other predictors from the baseline specification remain unchanged. Across both panels, the smoking prevalence trajectory of synthetic Korea closely matches the observed rates prior to 2011, confirming a strong pre-intervention fit. After the policy implementation, the divergence between the treated unit (solid line) and its synthetic control (dashed line) remains consistent with the main findings, supporting the conclusion that comprehensive smoke-free policies led to a meaningful reduction in smoking prevalence. These results suggest that the estimated treatment effect is robust to reasonable changes in the specification of lagged outcome variables.

As an additional robustness check, I estimate the synthetic control model using only lagged smoking prevalence values as predictors, without including any covariates such as GDP per capita, population shares, alcohol consumption, or industry composition. This specification includes biennial and triennial lags of smoking prevalence only (See Figure 15). The resulting pre-treatment fit is slightly less precise than in the main model with covariates, but the post-treatment gap remains nearly unchanged. This reinforces that the primary results are not driven by the inclusion of auxiliary covariates and are instead supported by the smoking prevalence dynamics themselves.

4.4 Placebo Tests

To further assess the validity of the results, I conducted both in-time and in-space placebo tests. For the in-time placebo test (see Figure 16) the synthetic control method is applied as if the smoking ban had been implemented in 2004, 2005, 2006, 2007, 2008, or 2009. For each test year, the predictor set is constructed using data only from 1995 up to the placebo treatment year. The goal is to verify that these placebo interventions do not result in a post-treatment divergence in smoking prevalence between Korea and its synthetic control, except in the actual treatment year, 2011. If substantial placebo effects appear in years prior to 2011, it would cast doubt on the causal interpretation of the divergence shown in Figures 12 and 13. Encouragingly, no such divergence is observed in Figure 16, supporting the credibility of the 2011 effect.

For the in-space placebo test, the treatment is iteratively reassigned to every country in the donor pool, and synthetic counterparts are constructed using the same methodology. This approach helps assess whether the estimated effect for South Korea is unusually large compared to placebo effects in other countries. It also enables inference via a permutation test, in which the p-value is calculated as the fraction of countries that display an effect size as large as or larger than that observed for Korea.

Figure 17 presents the results. Panel A shows that for some countries, the synthetic control method fails to generate a good pre-treatment fit. To address this, Panel B excludes countries with a root mean squared prediction error (RMSPE) greater than 1.25. The excluded countries are: Australia, Austria, Belgium, Canada, Germany, Denmark, Spain, Finland, the United Kingdom, Greece, Ireland, Iceland, Italy, Japan, the Netherlands, Norway, Poland, Portugal, Sweden, and the United States. This leaves eight countries in the refined donor pool. Among them, South Korea exhibits the largest post-treatment gap in smoking prevalence. The resulting p-value—calculated as 1 out of 28—is 0.036, suggesting the observed effect is statistically significant and unlikely to be driven by chance.

4.5 Augmented Synthetic Control Method

Recent developments in the Synthetic Control Method (SCM) literature have introduced extensions that address key limitations of the traditional approach. One notable advancement is the Augmented Synthetic Control Method (ASCM), proposed by Ben-Michael, Feller, and Rothstein (2021). While traditional SCM constructs a synthetic control unit using non-negative weights that minimize the root mean squared prediction error (RMSPE) in the pre-treatment period, ASCM allows for negative weights by incorporating ridge regression to estimate the weights. This flexibility permits arbitrary extrapolation, enabling a better fit in some contexts.

The core distinction between SCM and ASCM is this allowance for negative weights in constructing the synthetic unit. When the pre-treatment fit is strong, the extrapolation bias introduced by ASCM is minimal, and the resulting estimates tend to align closely with those of traditional SCM. Figures 18 presents the ASCM results, which closely resemble the findings from the original SCM model, further validating the robustness of the estimates.

4.6 Possible Confounder

As discussed earlier, the synthetic control unit does not represent the absence of all tobacco control policies; rather, it reflects the absence of South Korea's 2011 smoking bans. Countries included in the synthetic control may have implemented their own tobacco control measures during the post-treatment period.

To examine whether such policies could bias the results, I review the major tobacco control initiatives adopted by countries contributing positive weights to the synthetic control. This analysis helps assess whether the estimated treatment effect might be confounded by concurrent policies in donor countries. Details of this investigation are provided in Appendix A.

4.7 Economic Value of Smoking Bans

In addition to public health benefits, the 2011 smoking bans generated substantial economic value by preventing smoking-related mortality. Based on the estimated reduction of 1.2 million smokers between 2011 and 2015, I calculate the aggregate value of life-years saved using a South Korea-specific Value of a Statistical Life (VSL) of USD 1.18 million[9] ($2015) as estimated by Jeon (2020). Drawing on standard valuation methods outlined in Robinson et al. (2019), I convert the VSL into a Value of a Statistical Life-Year (VSLY) by dividing by 41.05, which represents half of the average life expectancy in South Korea in 2015. This yields a VSLY of approximately USD 28,745. Following estimates from Taylor Jr et al. (2002), each prevented smoker is expected to gain roughly six additional years of life, implying a total of 7.2 million life-years saved. Multiplying this figure by the VSLY results in a total economic benefit of approximately USD 207 billion. This back-of-the-envelope

[9] 1.3 Billion Won converted to USD using the exchange rate of USD 1 to 1,100 Korean Won.

estimate underscores the considerable societal return from non-price tobacco control interventions such as comprehensive smoke-free laws.

5 Conclusion

In 2011, the South Korean government implemented a comprehensive set of tobacco control policies aimed at reducing cigarette consumption and smoking prevalence. These included both indoor and outdoor smoking bans, marking a significant escalation in the country's anti-smoking efforts. This study uses the synthetic control method to estimate the causal effect of these smoking bans on national smoking rates. By comparing South Korea's post-policy smoking prevalence with that of a weighted combination of similar countries that did not implement comparable policies, I find that the 2011 smoking bans led to an average reduction of 2.3 percentage points in smoking prevalence. Given a baseline rate of 27.1% in 2011, this corresponds to an 8.5% decline ($p < 0.036$), equivalent to roughly 1.2 million fewer smokers—through either cessation or prevention of initiation. The decline in smoking prevalence translates into an estimated USD 207 billion in economic value from added life-years.

The indoor smoking ban prohibited smoking in public transportation, government buildings, medical facilities, nurseries, schools, large restaurants and bars, and other public venues. Smoking was allowed only in specially designated rooms that were fully enclosed and separately ventilated; violators were subject to monetary fines. These restrictions were gradually extended: beginning in 2013, the indoor smoking ban was applied to restaurants and cafes larger than 150 square meters, then to those over 100 square meters in 2014, and finally to all establishments by 2015. Prior to these changes, the policy had not significantly evolved since 1995, when establishments were merely required to designate separate smoking and non-smoking areas.

The outdoor smoking bans were another critical element of the 2011 reforms. Enabled by amendments to the National Health Promotion Act in 2010, local governments were granted authority to establish smoke-free outdoor zones. These bans were rapidly adopted, beginning with Seoul and spreading nationwide. Public areas such as bus stops, subway entrances, parks, and school zones were designated as smoke-free zones, often marked with visible signage and enforced with fines. The expansion of smoking restrictions into outdoor environments not only increased the inconvenience of smoking but also reinforced changing social norms around tobacco use and second-hand smoke exposure in open spaces.

While several prior studies have documented improvements in indoor air quality (Kim et al., 2016) and reductions in second-hand smoke exposure (Park et al., 2020) following the implementation of comprehensive smoke-free policies, these studies rely on pre-post designs that may suffer from biases due to unobserved, time-varying national factors. In contrast, this study is the first to apply the synthetic control method to estimate the effect of South Korea's 2011 smoking bans, constructing a credible counterfactual from panel data covering 28 high-income countries from 1995 to 2015.

The dataset combines information from the International Smoking Statistics (ISS), the Korea National Health and Nutrition Examination Survey (KNHANES), the World Health Organization (WHO), and the World Bank's World Development Indicators (WDI).

The results indicate that the smoking bans effectively reduced smoking prevalence by an average of 2.3 percentage points ($p < 0.036$) compared to the synthetic counterfactual. This amounts to an 8.5% reduction relative to the 2011 baseline and implies that approximately 1.2 million individuals were deterred from smoking—either through cessation or prevention—due to the implementation of South Korea's smoking bans. The estimated reduction in smoking is associated with an economic gain of roughly USD 207 billion, driven by increased life expectancy.

These findings highlight the effectiveness of smoking bans in reducing smoking prevalence, even in high-smoking, middle- to high-income countries. The findings offer practical evidence for policymakers in other countries considering similar reforms. Future research can explore the heterogeneous impacts of these policies across different population subgroups and assess their interaction with emerging tobacco products and tax policies.

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Tables

Table 1: Cigarette Tax and Price Changes in South Korea

Year	1991.1	1994.1	1996.7	1997.5	1999.1	2001.1	2002.2	2002.8	2005.1	2015.1
Cigarette Tax (Won)	360	480	648	650	750	889	1065	1111	1565	3318
Cigarette Price (Won)	600	900	1000	1100	1100	1300	1500	2000	2500	4500

Source: Park (2016)

Table 2: Expansion of Smoke-free Area

Year	2012	2013	2014	2015	2016	2017	2018
Number of Smoking-free Sites	398,545	664,992	688,321	1,278,343	1,334,473	1,452,540	1,527,987

Source: Kim (2019)

Table 3: Number of Enforcement

Year	2012	2013	2014	2015	2018
Number of fines enforced					
Nationwide	–	27,533	–	57,708	61,830
Seoul	11,387	25,653	38,045	40,229	–

Source: Seoul Open Data Plaza, Ministry of Health and Welfare of South Korea

Table 4: Smoking Prevalence by Country: All

	Year																				
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Smoking Rates:																					
Australia	25.6	25.8	26	26.4	23	24.3	24.3	23	21.8	20.6	21.1	20.4	19.7	18.9	18.5	18.2	17.5	16.9	16.3	16	15.7
Austria	35.3	33.5	32.2	31.7	31.8	32.1	31.6	31	31.3	30.3	29.4	28.8	29.3	29.7	30	30.1	29.5	29.5	29.2	28.4	27.1
Belgium	36.3	33.8	30.1	30	30.6	29.7	28.9	30.7	29.4	27.2	27.8	25.9	26	25.7	26	26.2	25.8	25.9	26.2	25.9	25.7
Canada	27.5	26	25.8	26	25.2	24.4	21.7	21.4	20.9	19.6	18.7	18.6	19.2	17.9	17.5	16.7	17.3	16.1	16	15.9	15.8
Czechia	36.6	36.3	36	35.5	35	34.2	33	31.9	31.7	31.5	31.4	28.8	27.4	26.7	26.45	26.4	27	29.2	29.5	29.7	29.9
Denmark	42.6	37.5	35	35.7	36.1	34.2	33.8	31	30	26.6	28.1	27.7	28	27	26	24.9	23.9	23.1	22.2	21.6	21.1
Estonia	37.5	38.1	38.8	38.2	37.2	36.9	36.8	35.4	35	34.6	33.8	33.6	34.4	35.4	36.1	37.2	36.5	35.5	34.7	33.8	33.3
France	36.4	35.3	35	33.9	33.8	34.2	36	33.6	34.4	33.7	32.8	32.8	32.9	33	33.2	33.4	33.3	33.4	33.4	33.4	33.2
Finland	28.9	28	28.9	28.7	28.6	29.7	29.1	29.3	28	27.3	26.3	24.7	25.7	24.2	23	22.6	22.5	22	21.7	21.9	21.5
Germany	38.5	36.8	35.7	34.1	33.1	32.7	32	32.5	32.2	31	30.9	30.9	29.5	28.4	28	27.2	25.8	25.6	25.3	26.4	24.9
Greece	44.6	44.2	44.3	44.7	45.3	44.1	43	41.9	41.3	40.9	40.7	39.3	39.5	40.1	40.05	38.25	38.8	39.6	39	38.6	37.9
Hungary	35.6	35.9	36.3	35.6	35.4	33.6	33.9	33.9	32.8	29.8	30.7	32.8	31.8	33.8	31.4	33.3	34.1	33.8	33.2	32.9	33.2
Iceland	32.3	31	30.8	31.3	30.4	27.5	26.1	25.4	25.4	24	22.6	22.2	22.6	20.9	18.8	18.1	18.5	17	16.2	15.8	14.7
Ireland	31.9	32.1	32.4	32.4	32.2	31	31.2	34.4	28.4	28.5	28.9	28.8	28	27.4	27.3	27.1	26.5	25.8	24.8	24.5	23.8
Italy	31.9	26.6	26.4	25	24.9	25.1	24.1	24.1	24.3	23.8	22.4	23.1	22.6	22.6	22.9	24.5	24.1	23.8	23.9	23.8	23.8
Japan	33.4	33.9	33.6	32.3	32	30.6	29	28.1	29.2	28.3	26.8	25.7	25.7	23.5	24	21.8	20.8	20.7	20.1	19.8	19.6
Israel	36.3	35.4	34.7	33.9	32.8	31.7	31.2	30.7	29.8	29.3	28.6	28.2	27.7	27.2	26.6	26	25.8	25.2	24.4	23.8	23.4
Korea, Rep.	36.4	35.9	35.5	35.1	34.7	35	33.8	32.5	29.6	30.4	28.8	28.2	28	27.8	27.3	27.5	27.1	25.8	24.1	24.2	22.4
Netherlands	37.8	35.8	35.5	34.5	33.3	32.8	30.6	30.7	29.9	27.9	28.3	27.9	27.2	26.4	27	26	24.8	25.1	24.7	24.3	23.9
New Zealand	26.4	26.05	26.55	24.95	25.3	24.95	24.7	24.4	24.2	23.05	23.6	20.95	19.95	20.05	19.8	20.1	19.75	19.05	18.05	17.35	16.5
Norway	42.2	42.2	41.6	41	40.2	39.9	38.4	37.3	36.1	34.4	33.3	31.7	29.5	28.5	28.1	27.7	26.4	25.1	23.7	22.1	20.7
Poland	36.9	37.3	35.6	34.3	32.5	32.5	32.4	33.7	33.2	30.1	31.5	33.4	31	29.9	28.1	26.4	29	30.9	29.4	28.3	27.2
Portugal	25.4	24.5	23.5	22.9	23	22	21.9	21.7	21.4	21.3	21.3	20.8	22.7	22.3	21.2	20	21.3	21.9	21.6	21.6	22
Spain	38.8	37.2	37.2	35.9	36.4	35.7	34.8	34.4	33.9	34.1	33.2	32.4	32.8	32	30.1	31.9	31.5	30.9	30.7	30.3	29.7
Sweden	45.2	44.9	44.5	43.7	43.6	43.6	42.3	41.1	39.8	38.7	37.6	36.7	35.8	34.7	33.3	32.3	31.8	30.7	30.2	28.9	27.9
Switzerland	32.1	32.7	33.2	32.3	31. 5	30.2	29.7	29.5	28.7	27.8	27.3	26.3	26.2	26.4	26.7	26.9	26.7	26.4	26.3	26.1	25.9
United States	28.9	28.9	29.7	27.8	26.1	26.1	26.1	27.3	26.8	26.4	26.4	25.9	25.4	25.1	24.8	24.2	22	20	18.1	16.2	15.2
United Kingdom	32	30.6	30	29.8	28.8	29	28.7	28.2	27.5	26.2	25.5	24.1	23.1	22.4	21.6	20.8	20.5	19.5	18.9	18.3	18

Table 6: Smoking Rates Predictor Means in Pre-Treatment Period

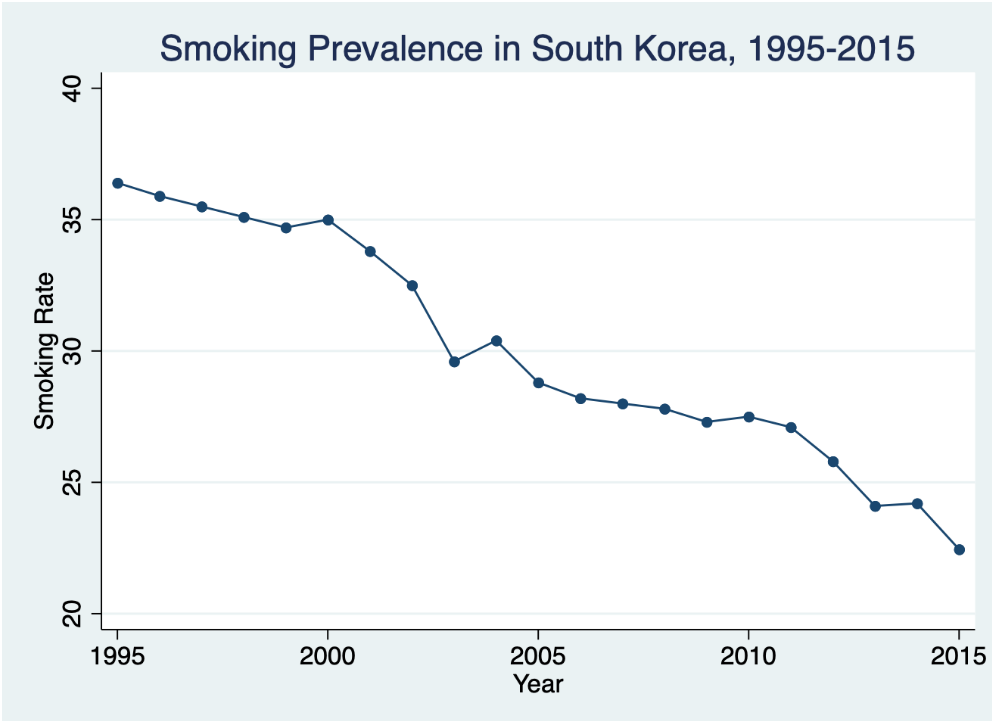
	Real South Korea	Synthetic South Korea
log GDP per Capita	9.84	10.16
Percent Aged 20-29	33.57	30.72
Industry: Agriculture & Forestry & Fishery	3.36	3.36
Alcohol Consumption per Capita	10.95	10.95
Smoking Rate 2000	35.00	34.09
Smoking Rate 2006	28.20	28.70
Smoking Rate 2010	27.50	27.22

Table 7: Country Weights in Synthetic South Korea

Country	Weight	Country	Weight
Australia	0	**Greece**	**0.16**
Austria	**0.10**	Hungary	0
Belgium	0	**Ireland**	**0.17**
Canada	0	**Iceland**	**0.17**
Switzerland	0	**Israel**	**0.12**
Czech Republic	**0.28**	Italy	0
Germany	0	Japan	0
Denmark	0	Netherlands	0
Spain	0	Norway	0
Estonia	0	New Zealand	0
Finland	0	Poland	0
France	0	Portugal	0
United Kingdom	0	Sweden	0
United States	0		

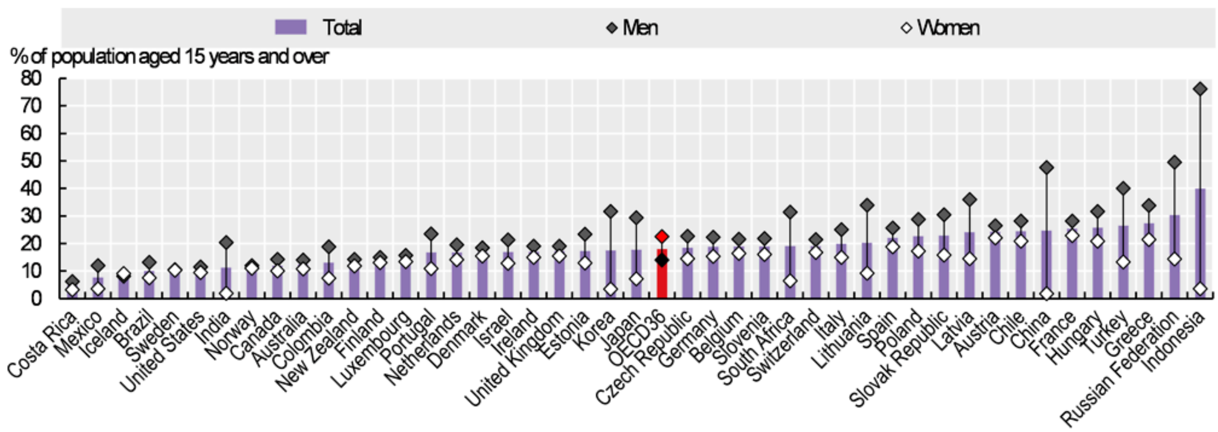
Figures

Figure 1: Average Smoking Rates in South Korea from 1995 to 2015



Note: The data is based on the Korea National Health and Nutrition Examination Survey (KNHANES), a survey question of 'Are you currently smoking?' to indicates whether an individual has been smoking in the past 30 days. The prevalence represents the share of the general population aged 19 years or older who reported to currently smoking.

Figure 2: OECD Countries Average Smoking Rates in 2017

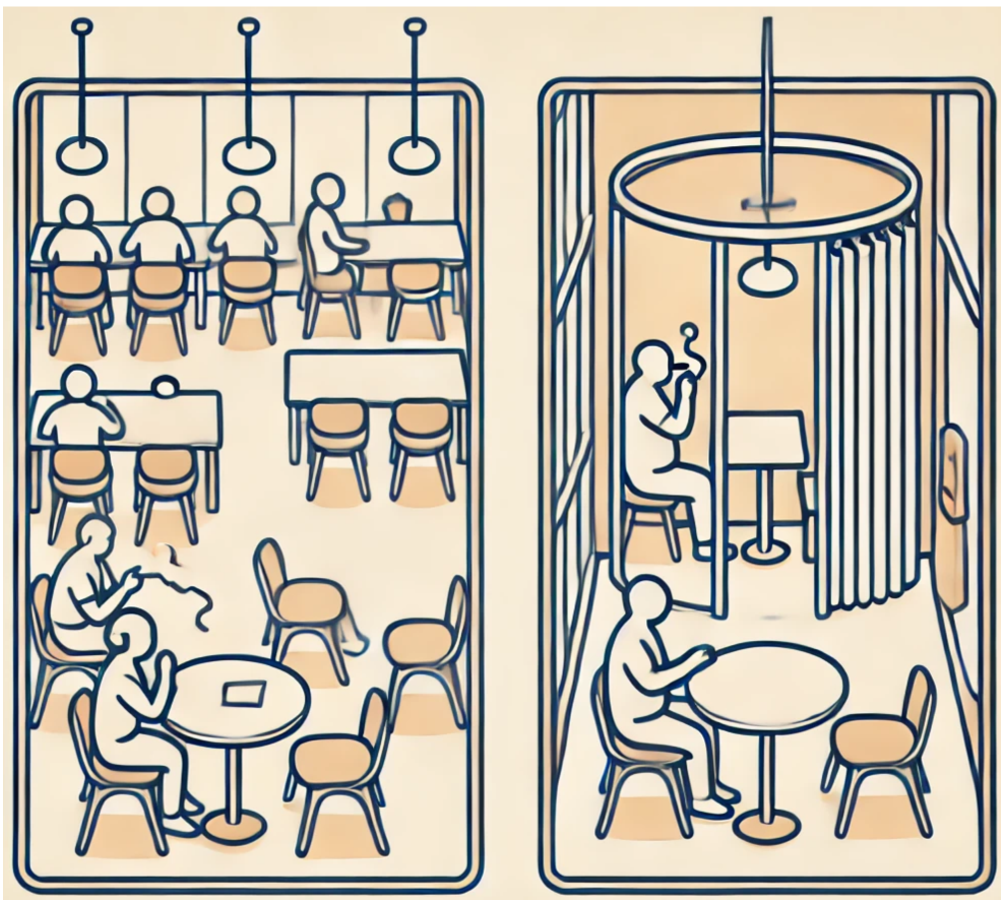


Note: The smoking prevalence among male population is highest in Indonesia, followed by Russia, China, Turkiye, Latvia, Lithuania, and Korea. *Source*: OECD Health Statistics

Figure 3: Example of Picture Warning Labels

Note: The pictures above are three examples out of twelve pictorial warning labels. Consumers receive random pictorial warning labels out of twelve samples. Pictures are renewed every two years to prevent consumers from adaptation to existing warning labels.

Figure 4: Illustration: Partial vs Comprehensive Smoke-free Law



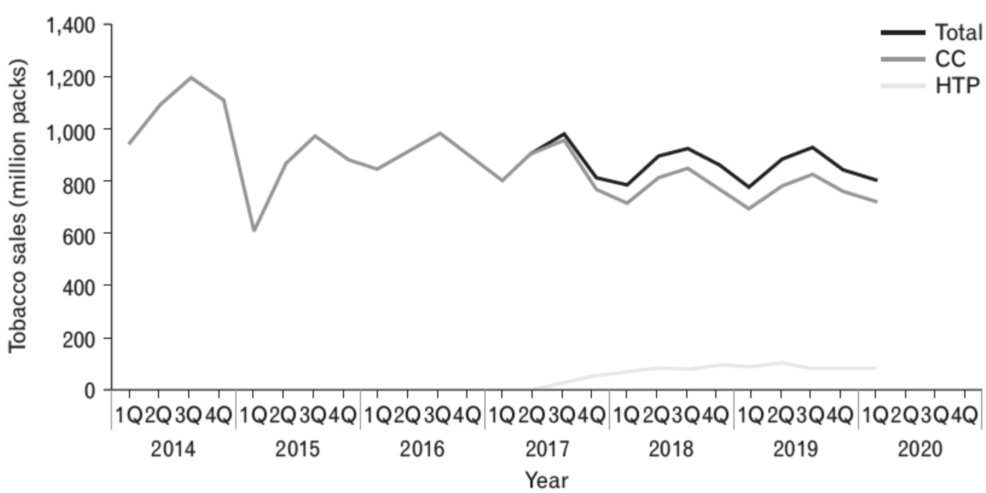
Partial Smoke-free Policy **Comprehensive Smoke-free Policy**

Figure 5: Examples of Indoor Smoking Booths

Figure 6: Examples of Outdoor Smoking Booths

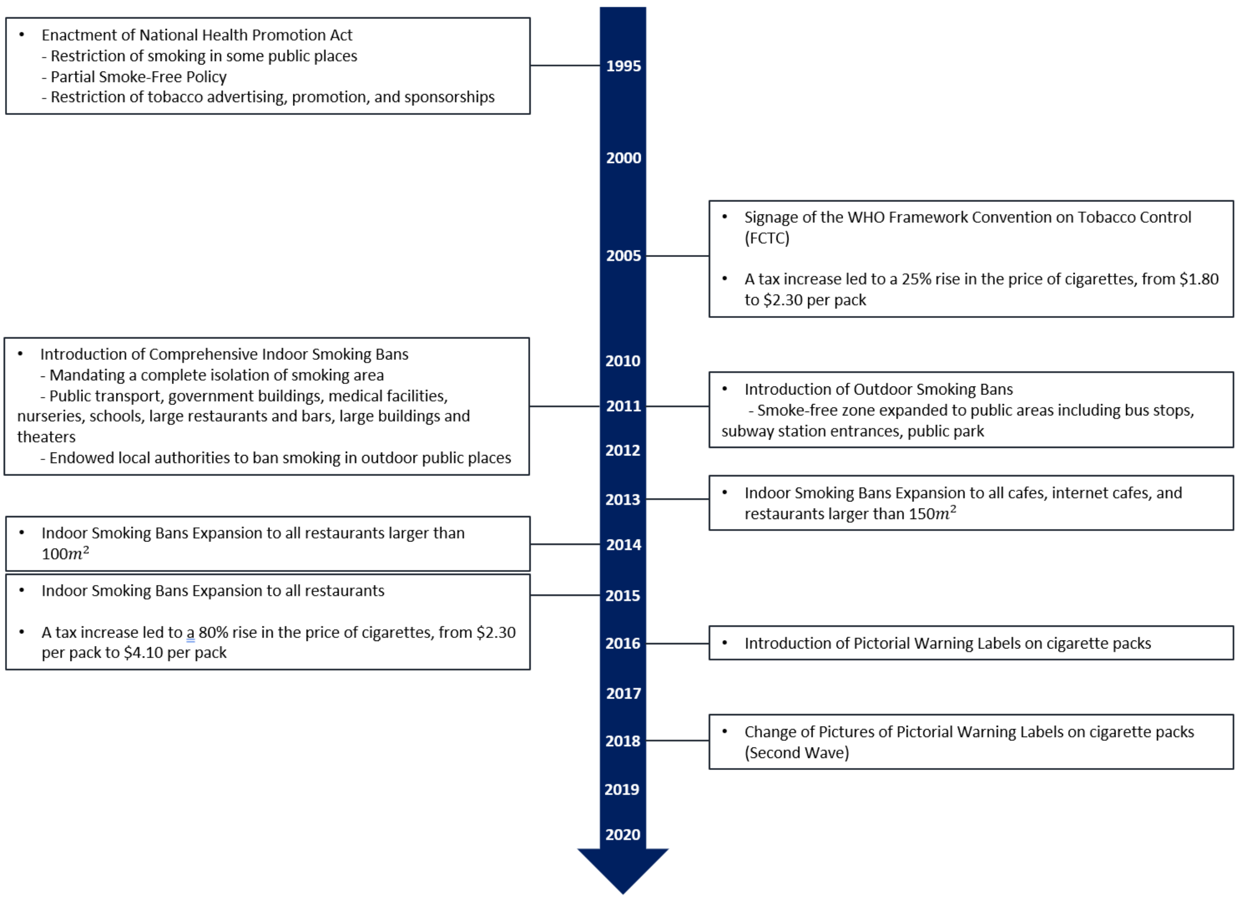
Figure 7: No Smoking Sign with Fine Notice

Figure 8: Quaterly Sales Trend of Conventional Cigarette and Heated Tobacco Products



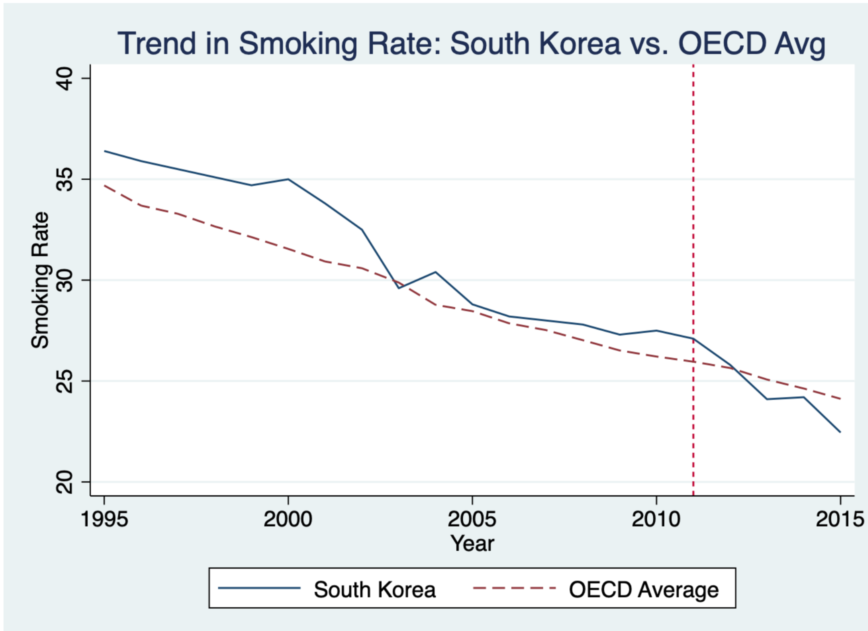
Source: Lee (2020)

Figure 9: Timeline of Tobacco Control Policies in South Korea, 1995-2020



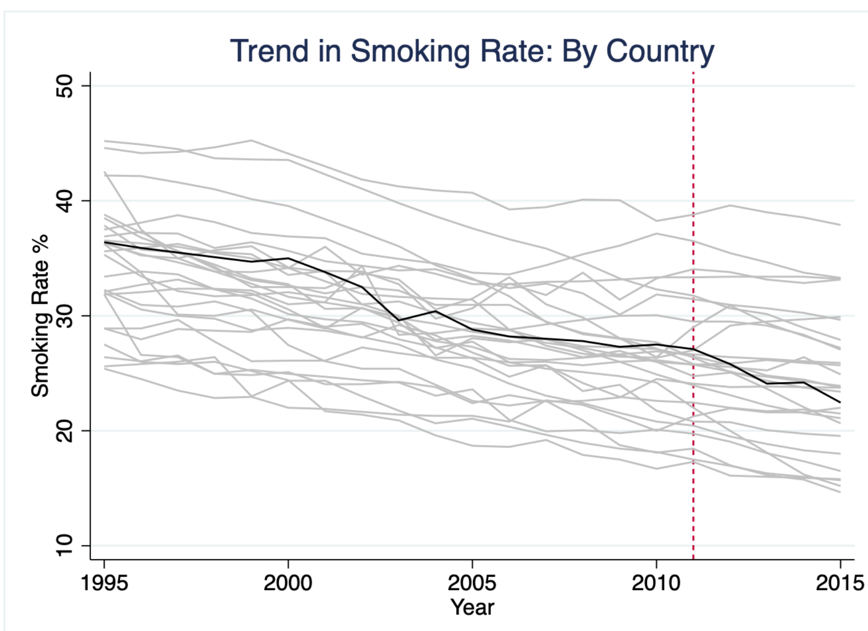
Source: Cho (2014)

Figure 10: Path Plot of Smoking Prevalence During 1995-2015: South Korea Versus OECD Average of the 27 Donor Countries



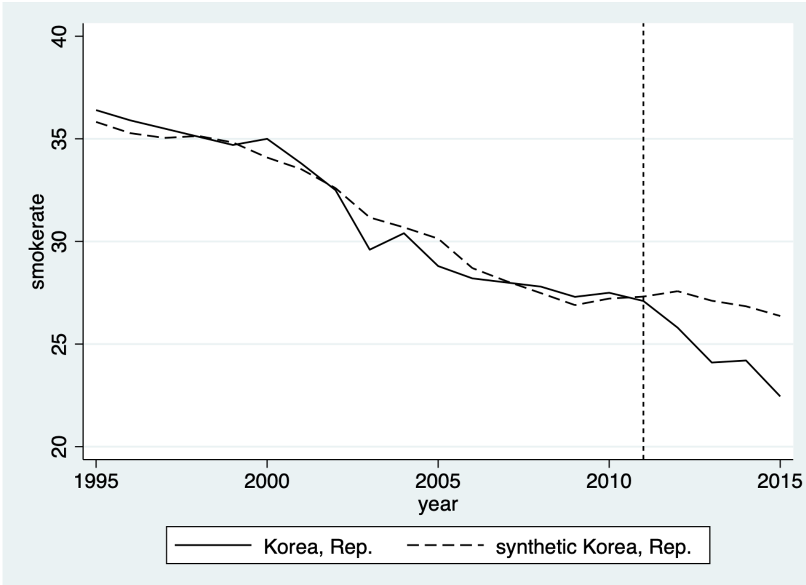
Note: 27 donor countries include Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Estonia, France, Finland, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Israel, Netherlands, New Zealand, Norway, Poland, Portugal, Spain, Sweden, Switzerland, the United States, and the United Kingdom.

Figure 11: Smoking Rates Trend by Country



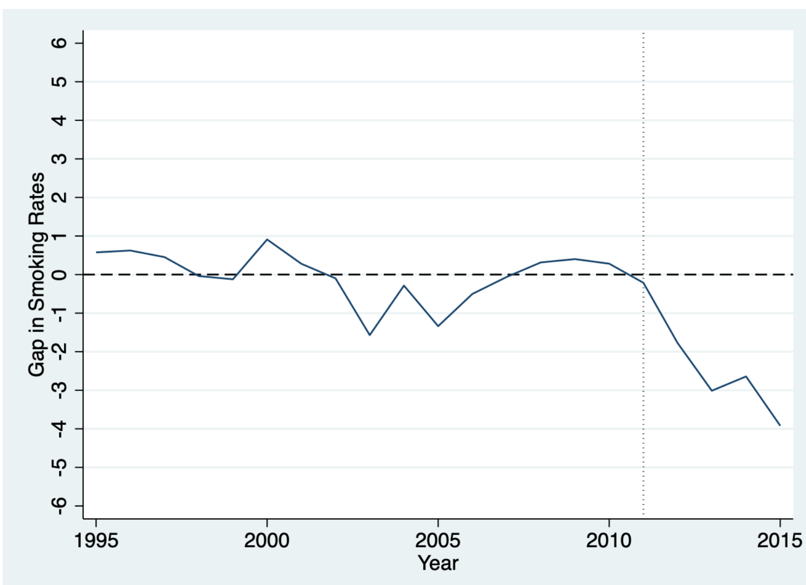
Note: The solid line represents smoking prevalence for South Korea. The grey lines represent smoking prevalence in each country in the donor pool.

Figure 12: Path Plot of Smoking Rates During 1995-2015: South Korea vs Synthetic South Korea



Note: This figure shows the path plot of smoking prevalence between 1995 and 2015. The solid line represents the smoking rates in South Korea based on the survey data of KNHANES. The dotted line represents the smoking rates in synthetic South Korea that had not implemented the comprehensive smoke-free policies in 2011.

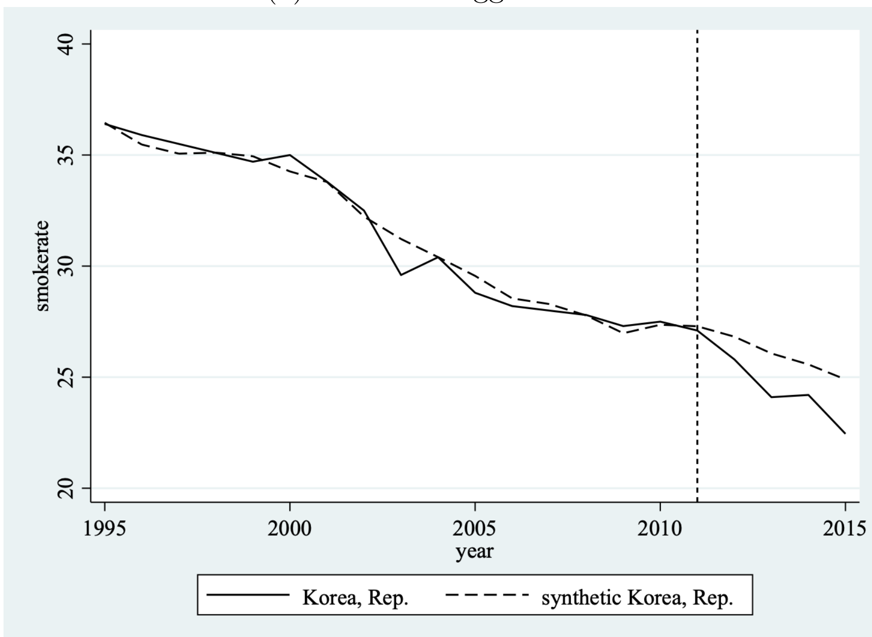
Figure 13: Gap in Smoking Rates Between South Korea and Synthetic South Korea During 1995-2015



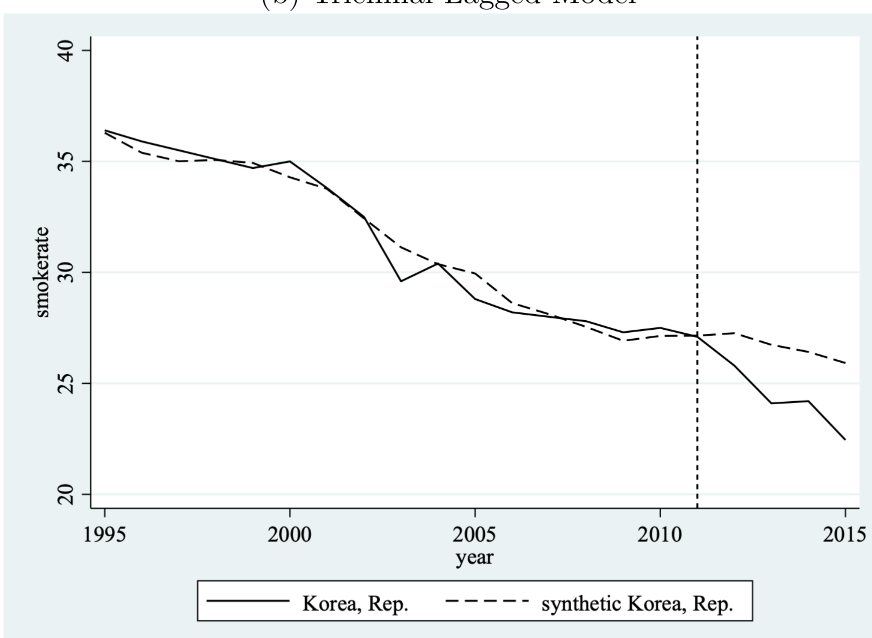
Note: This figure shows the smoking prevalence gap between actual South Korea and synthetic South Korea between 1995 and 2015. We can estimate the average treatment effect by calculating the average reduction in smoking prevalence during 2011-2015. The average treatment effect is -2.3117.

Figure 14: Lag-Specification Robustness

(a) Biennial Lagged Model



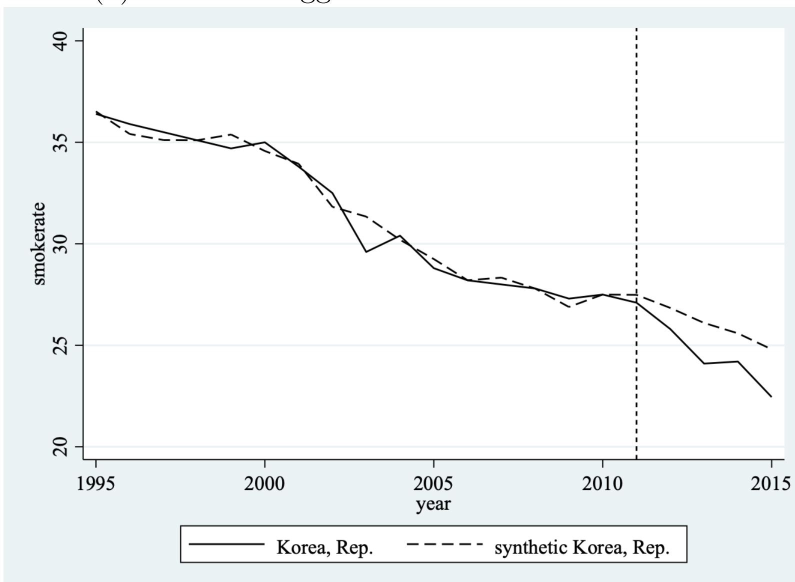
(b) Triennial Lagged Model



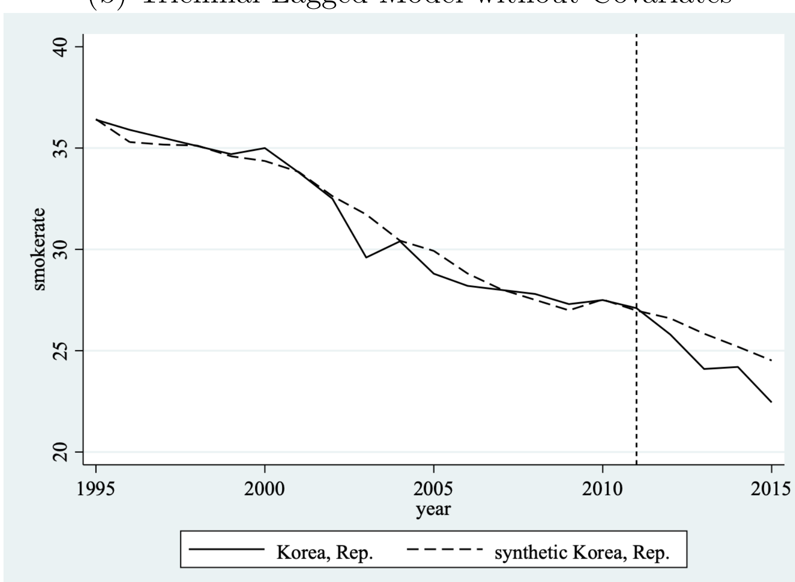
Notes: These figures present the path plot of smoking prevalence between 1995 and 2015. In each panel, the solid line plots the observed smoking rates from the KNHANES survey, while the dotted line represents the smoking rates in synthetic South Korea that had not implemented the comprehensive smoke-free policies in 2011. To assess the robustness of the main model, Panel (a) adds biennial lagged values of the smoking prevalence prior to the treatment—1996, 1998, 2000, 2002, 2004, 2006, 2008, and 2010—whereas Panel (b) adds triennial lagged values of the smoking prevalence prior to the treatment—1995, 1998, 2001, 2004, 2007, and 2010—on top of the predictors used in the main model.

Figure 15: Lag-Specification without Covariates

(a) Biennial Lagged Model without Covariates



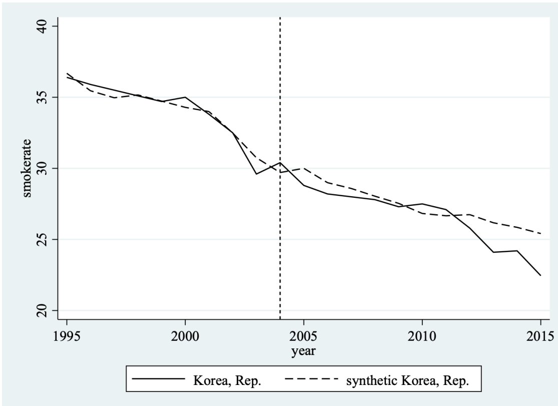
(b) Triennial Lagged Model without Covariates



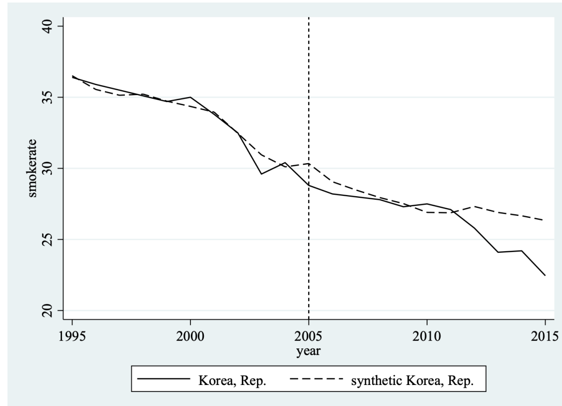
Notes: These figures present the path plot of smoking prevalence between 1995 and 2015. In each panel, the solid line plots the observed smoking rates from the KNHANES survey, while the dotted line represents the smoking rates in synthetic South Korea that had not implemented the comprehensive smoke-free policies in 2011. To assess the robustness of the main model both model estimates without any covariates, Panel (a) adds biennial lagged values of the smoking prevalence prior to the treatment—1996, 1998, 2000, 2002, 2004, 2006, 2008, and 2010—whereas Panel (b) adds triennial lagged values of the smoking prevalence prior to the treatment—1995, 1998, 2001, 2004, 2007, and 2010.

Figure 16: The Placebo Treatment in Time: 2004, 2005, 2006, 2007, 2008, 2009

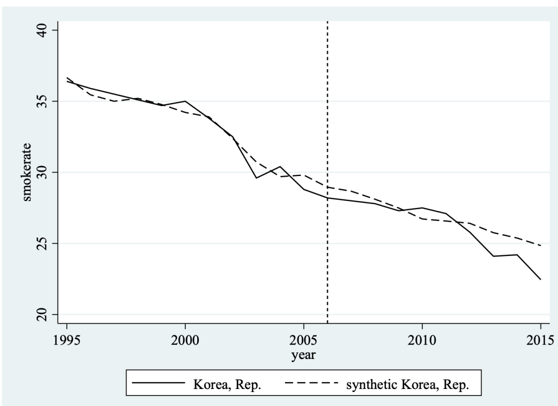
(a) The Placebo Treatment in 2004



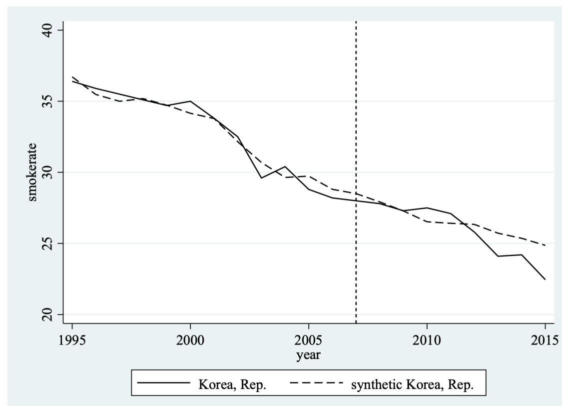
(b) The Placebo Treatment in 2005



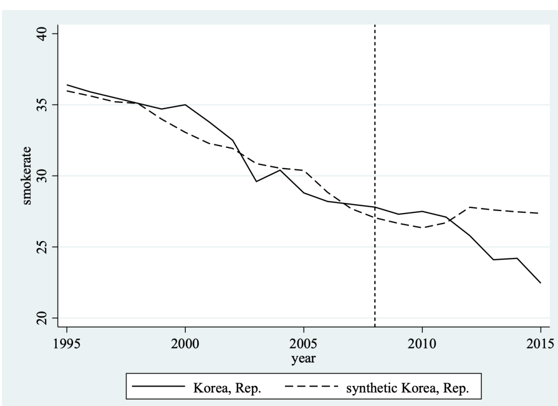
(c) The Placebo Treatment in 2006



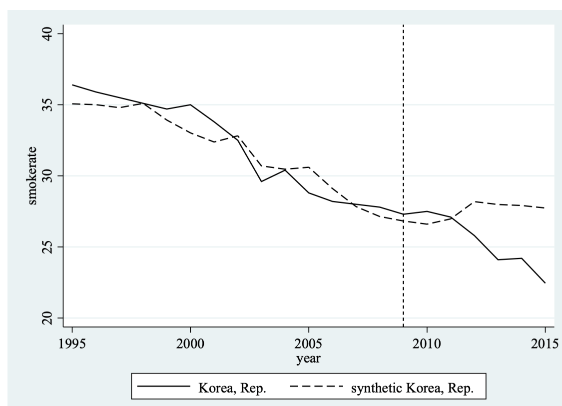
(d) The Placebo Treatment in 2007



(e) The Placebo Treatment in 2008

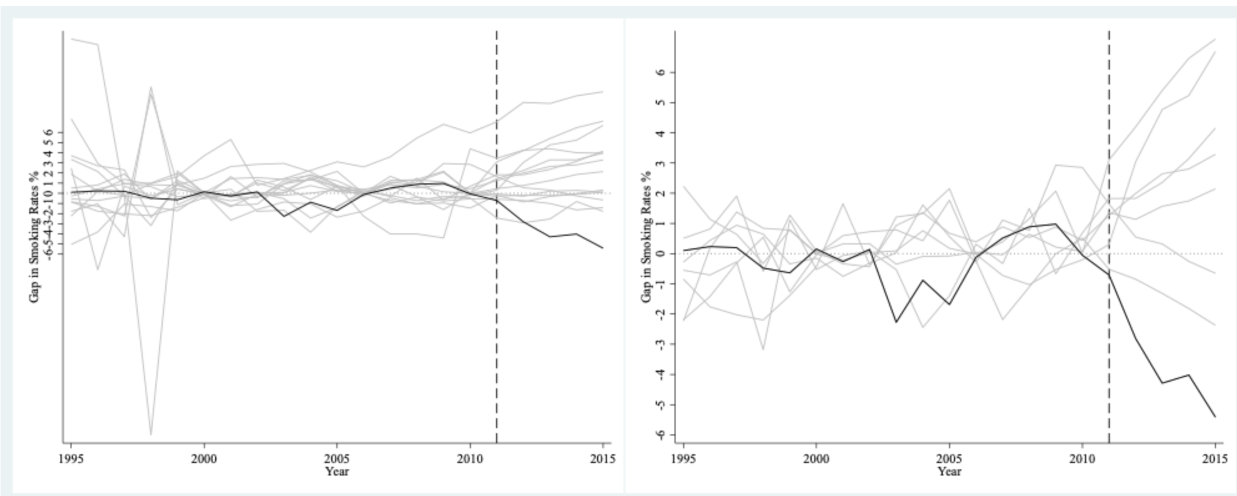


(f) The Placebo Treatment in 2009



Note: These figures show in-time placebo. Figure (a) shows the path plot of smoking prevalence between real Korea and synthetic Korea when the placebo policy is introduced in 2004, seven years prior to actual policy changes. Figure (b) shows when the placebo policy is introduced in 2005, Figure (c) in 2006, Figure (d) in 2007, Figure (e) in 2008, and Figure (f) in 2009.

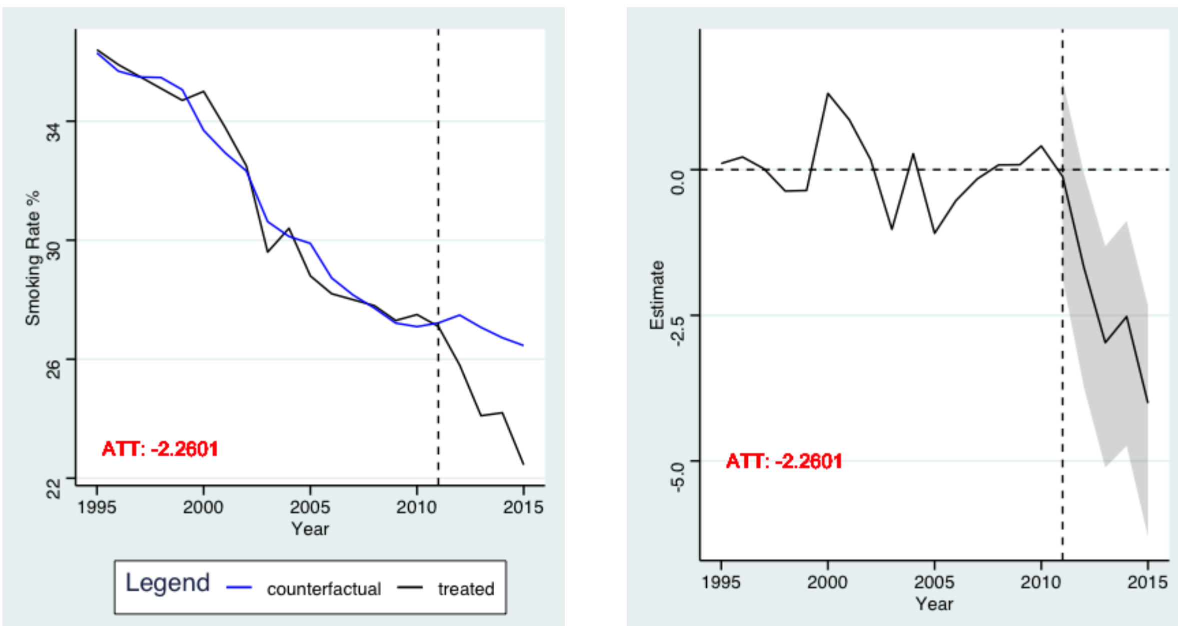
Figure 17: In-space Placebo Test: Smoking Rates Gap in South Korea and Placebo Gaps for the Control Countries



Note: Both figures show in-space placebo tests, the treatment is iteratively reassigned to every country in the donor pool using a synthetic control method to construct synthetic counterparts. The left figure indicates that for some countries in the donor pool, the synthetic control method is unable to find a convex combination of countries that will replicate the path of smoking rates in the pre-treatment period. In the right figure, all the countries with a pretreatment MSPE (mean squared prediction error) larger than 1.25 are excluded. The gap in smoking rates for South Korea in the post-treatment period is the largest of all remaining countries.

Figure 18: Result Using Augmented Synthetic Control Method

Smoking Prevalence | The Gap Between Actual vs Synthetic



Note: Left panel shows the path plot of smoking prevalence between 1995 and 2015 using the augmented synthetic control method. The black line represents the smoking rates in South Korea based on the survey data of KNHANES. The blue line represents the smoking rates in synthetic South Korea that had not implemented the comprehensive smoke-free policies in 2011. The right panel shows the smoking prevalence gap between actual South Korea and synthetic South Korea between 1995 and 2015 using the augmented synthetic control method. We can estimate the average treatment effect by calculating the average reduction in smoking prevalence during 2011-2015. The average treatment effect is -2.2601.

A Tobacco Control Policies and Cigarette Prices in Countries Selected for Synthetic Korea

A1. Austria (0.10)

- 1995: Federal Tobacco Act passed
- 2005: Signed WHO FCTC
- 2008: Expansion on No Smoking signs
- 2016: Mandate on pictorial warning labels
- 2019: Total ban on smoking at bars and restaurants

A2. Czech Republic (0.28)

- 1995: Advertisement regulation on tobacco
- 2003: Mandate on text warning labels
- 2005: Smoke-free zone on schools, medical facilities, and public areas
- 2012: Signed WHO FCTC
- 2016: Mandate on pictorial warning labels

A3. Greece (0.16)

- 2003: Advertisement regulation on tobacco
- 2006: Signed WHO FCTC
- 2009: Smoke-free zone on schools, healthcare facilities, indoor working spaces, and public areas
- 2016: Mandate on pictorial warning labels

A4. Ireland (0.17)

- 2004: Smoke-free zone on schools, healthcare facilities, indoor working spaces, public areas, restaurants, and bars
- 2005: Signed WHO FCTC
- 2016: Mandate on pictorial warning labels

A5. Iceland (0.17)

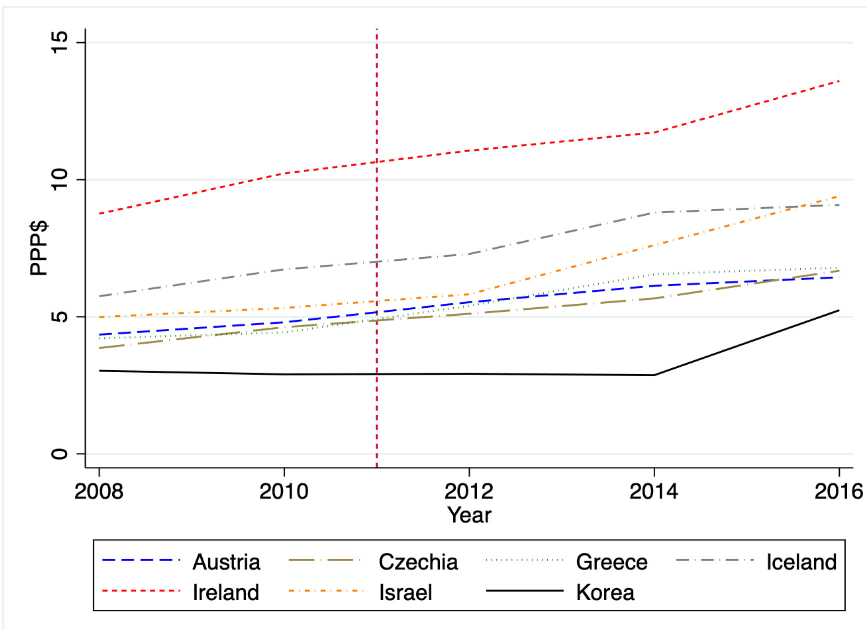
- 2002: Smoke-free zone on schools, healthcare facilities, indoor public gatherings
- 2003: Mandate on text warning labels
- 2005: Signed WHO FCTC
- 2007: Smoke-free zone in public areas and businesses
- 2016: Mandate on pictorial warning labels

A6. Israel (0.12)

- 1983: National tobacco control began, no smoking in public spaces
- 2002: Mandate on text warning labels
- 2005: Signed WHO FCTC
- 2012: Smoke-free zone in schools and hospitals

A7. Cigarette Prices in Countries Selected for Synthetic Korea

Changes in Cigarette Prices for South Korea and the Countries Included in Synthetic South Korea



Note: The cigarette price is the lowest among the countries that construct the synthetic Korea. All of the countries included in the synthetic Korea increased the cigarette price during 2011-2015 which may contribute to the reduction of smoking prevalence in the synthetic Korea that will bias the results toward less average treatment effect. The average treatment effect estimated from the synthetic control method will be the lower bound of the actual average treatment effect.