UNIVERSITY OF CALIFORNIA SAN DIEGO

Essays on Applied Economics

A dissertation submitted in partial satisfaction of the
requirements for the degree Doctor of Philosophy

in

Economics

by

Youngju Lee

Committee in charge:

Professor Julie Cullen, Chair
Professor Jeffrey Clemens
Professor Gordon Dahl
Professor Mark Jacobsen
Professor Ruixue Jia

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The Dissertation of Youngju Lee is approved, and it is acceptable in quality and form for publication on microfilm and electronically.

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VITA

2016	Bachelor of Arts, SungKyunKwan University
2017	Master of Arts, SungKyunKwan University
2022	Doctor of Philosophy, University of California, San Diego

ABSTRACT OF THE DISSERTATION

Essays on Applied Economics

by

Youngju Lee

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Professor Julie Cullen, Chair

Research in public and applied economics has established ways for measuring the impact of government policies to answer policy-relevant questions within public, labor, and environmental economics. I tend to analyze the unexpected impacts of government policies that policymakers might not consider ex-ante, and I document the potential mechanisms underlying impacts on subjects.

Chapter 1 studies the question evaluating whether the single-sex schooling makes an impact on the future labor market outcomes, such as extensive margin of entering labor force and earning level. Entering single-sex schooling is not free from selection bias problem, as students choose the education institutes based on their preference. However, in South Korea,

students are randomly assigned to high schools within the education district by lottery system, which makes it possible to find the treatment effect addressing the self-selection bias. We use the individual-level panel data spanned from their high school graduation until the late twenties and find the results which are heterogeneous by gender. Entering female single-sex high school decreases female earnings compared to the co-education high schools, whereas there is no solid evidence entering male single-sex high schools affects male labor market outcomes. We explore possible mechanisms for these asymmetric treatment effects, including the job sector choice and communication skills. Females from single-sex high schools tend to enter the healthcare industry as a worker such as nursing practice which pays lower income on average, and less enter the male dominant industry such as manufacturing. Furthermore, they show lower level of self-evaluation about the communication ability with coworkers compared to the females from the co-education high schools

Chapter 2 explores the impact of air pollution guideline change on pharmaceutical consumption. In South Korea, government changed the air pollution guideline related to the particulate matter 2.5 to improve the awareness of pollution seriousness. According to this change, the labeling of air pollution level became more strict. For example, the day labeled as "Normal" air pollution is now labeled as "Bad" after the policy change though it has the same level of air pollution. Exploiting this policy change and district-level spatial variation, we find that one additional day labeled as bad after the new guideline is associated with 0.9% increase of medicine consumption related to the respiratory system per person. We also find that the impact is more negligible in one day of consecutive days of bad air pollution than a single day of bad air pollution. In addition to it, this impact varies by healthcare institutions; more accessible health care institutions (primary care and pharmacy) show a stronger impact than less accessible (tertiary) health centers.

Chapter 3 analyzes the research question of whether political alignment impacts the tax evasion rate in South Korea. According to the concept of reciprocity in tax morale, it is theoretically argued that a better attitude toward the government can lower the tax evasion

motivation. Therefore, if the political alignment is correlated with attitude toward government, political alignment may affect the tax evasion rate. In this paper, we check this relationship between attitude toward government and political alignment from the Korean General Social Survey data set. Furthermore, by combining several Korean data sets, we find that people evade their tax payments less when politically aligned with the ruling party in South Korea.

Chapter 1

Does single-sex schooling help or hurt labor market outcomes? Evidence from a natural experiment in South Korea

Abstract

In this study, we investigate the effects of attending a single-sex high school on future labor market outcomes through the use of a randomized natural experiment. South Korean students are randomly assigned, by lottery, to single-sex or coeducational schools in their school districts. Using a large set of individual-level panel data, we find that graduating from single-sex schools significantly decreases female future earnings after graduation. In contrast, we find that single-sex education positively affects male future earnings though the estimates are noisy. We explore possible mechanisms for these asymmetric treatment effects, including career choice, postgraduation network effects, and academic performance at school. We do not find strong evidence on other outcomes.

1.1 Introduction

Single-sex education, where students are taught in separate schools or classrooms based on gender, is a common practice in many countries.[1] However, the efficacy of this system is

[1] Single-sex education is especially popular in English-speaking countries, Muslim nations, and Asian countries. For example, according to the National Association for Single-Sex Public Education, the number of public schools in the United States that offer this option increased from about a dozen in 2002 to almost 500 in 2012.

debatable. Advocates for single-sex education argue that the presence of the opposite gender is distracting; thus, single-sex education allows students to focus on academics. Those opposed claim that students in single-sex schools miss the opportunity to benefit from the perspective of the opposite sex, and this gap could make the transition to coeducational situations difficult (Mael et al. (2004)).[2]

Although many studies have investigated the efficacy of single-sex education, convincing empirical evidence is relatively rare, especially regarding long-term outcomes. Two major difficulties have led to this dearth. The first is self-selection bias: Students who wish to attend single-sex schools are likely different in terms of individual characteristics, family background, or other characteristics that are unobservable to econometricians from those who wish to attend coeducation schools. The second difficulty is related to the necessity for comprehensive individual panel data, which must track individuals for many years and require complex and careful maintenance.

To address self-selection and data requirements, we have analyzed a randomized natural experiment in South Korea, where middle school graduates are randomly assigned to in-district high schools by lottery. This practice was originally established as part of a government policy to equalize the nation's high school education quality and the opportunities for education, but it also effectively eliminates complications related to self-selection. Furthermore, South Korea maintains individual-level nationwide panel data following citizens from middle school through to their late 20s. These desirable empirical features allow us to identify causal estimates of the effects of single-sex education on labor outcomes.

Using a randomized natural experiment and individual-level panel data, we find that graduating from single-sex schools significantly decreases female future earnings after graduation, whereas single-sex schooling increases male future earnings though the estimates are noisy. We explore possible mechanisms for these asymmetric treatment effects, including career choice, postgraduation network effects, and academic performance at school. We do not find strong

[2]General discussions of single-sex education are summarized in Mael et al. (2004).

evidence on other outcomes such as extensive margin and household-level outcomes.

We find two possible channels leading to heterogeneous effects on earnings. The first is career choice. We find that female students from single-sex schools are less likely to choose jobs in traditionally male-dominated sectors that offer higher-than-average wages and more likely to choose female-dominated sector jobs such as health care. The second possible mechanism is networking effects. Female students from single-sex schools are less satisfied with their relationships and communication with coworkers, which may lead to lower labor market outcomes.[3]

The main contribution of this paper is a focus on the long-run effect of single-sex schooling on labor market outcomes after graduation, including future earnings and savings, through the use of a compelling design. In the context of the effects of single-sex schools, existing papers mainly investigate their impact on students' academic performance, and the number of papers focusing on future labor market outcomes after graduation is limited. As one of the few exceptions, Sullivan et al. (2011) find that in the United Kingdom, female wages at the age of 42 are higher for those from single-sex schools than for those from coeducational schools. However, their identification is not based on a quasi-experimental design and is still subject to possible self-selection biases. In contrast, we find strong evidence for the negative long-run impacts of single-sex schooling on intensive margins.[4]

More broadly, our paper also contributes to the literature that investigate the effect of single-sex schooling on a variety of educational outcomes such as academic performance. Though there are large body of existing literature that investigate the effect of single sex-schooling

[3]The importance of social connections and peer effects in the workforce has been shown in previous literature (e.g., Bandiera et al. (2009); Mas and Moretti (2009); Giuliano et al. (2011); Cullen and Perez-Truglia (2019); Arai and Nakazawa (2021)).

[4]There are several differences between this paper and Sullivan et al. (2011). First, we use randomized quasi-experimental design, whereas Sullivan et al. (2011) do not and instead control for many predetermined characteristics. Second, we measure outcomes at age 26, 8 years after graduation of high school, whereas Sullivan et al. (2011) measures outcomes at age 42, 24 years after graduation. Third, we focus on academic high schools in metropolitan cities whereas Sullivan et al. (2011) do not impose such restriction. Finally, Sullivan et al. (2011) focus on older 1958 birth cohort in the U.K, whereas we focus on newer 1984 and 1987 birth cohorts in South Korea. These different empirical strategies, different timing of the outcomes measured, and different samples in different areas, cohorts, and countries could lead to different empirical results.

on educational outcomes in South Korea (e.g., Park et al. (2013); Lee et al. (2014b); Chung (2015); Lee and Kang (2015); Sohn (2016); Park et al. (2018); Dustmann et al. (2018); Hahn et al. (2018); Hahn and Wang (2019))[5] and in other countries (e.g., Hoffman et al. (2008); Jackson (2012); Strain (2013); Eisenkopf et al. (2015); Booth et al. (2018)), the empirical evidence are quite "mixed" across papers (Park et al. (2018)). For example, Eisenkopf et al. (2015) and Booth et al. (2018) find that single-sex classes improve the academic performance of female students, whereas Hoffman et al. (2008), Jackson (2012), and Strain (2013) find null or negative effect on student academic performance, using data other than Korea. Empirical evidence of Korean single-sex education are also mixed, and single-sex education has positive, null, and/or adverse effects on student academic performance and related outcomes.[6] We contribute to the generally mixed evidence of single-sex schooling, especially to the former set of studies in South Korea, and discuss the comparison and reconciliation in depth in the mechanism.

The remainder of this paper is organized as follows: The next section discusses institutional background, whereas Section 3 describes the identification strategy. Section 4 provides the data, and Section 5 presents empirical results. Section 6 discusses the underlying mechanisms, and Section 7 shows robustness and placebo tests. Finally, Section 8 concludes.

[5]Regarding the effect on outcomes other than education in South Korea, Choi et al. (2015) find that students attending single-sex schools are more likely to be overweight. Lee et al. (2014a) find no evidence that single-sex schooling reduces the gender gap in competitiveness.

[6]For example, Park et al. (2013) find a positive effect of attending single-sex schools on national language and English. Dustmann et al. (2018) show that switching from single-sex schools to coed schools leads to worse academic outcomes for both boys and girls. In contrast, Lee et al. (2014b) find that boys' achievement is maximized by assignment to a single-sex school but find little effect on girls. Sohn (2016) find little impact of single-sex schooling on test scores, choice of a major, and test-taking behavior. Park et al. (2018) find significantly positive effects for all-boys schools across subjects but not for all-girls schools. Hahn and Wang (2019) find that the effect of single-sex schools on standardized test score is only evident among males in private schools using 2010 data, while the effects of single-sex schools on test scores of females are mostly negative though the estimates are noisy.

1.2 Institutional Background

1.2.1 The Korean Educational System

South Korea adopted a school system patterned after the U.S. system influenced by the U.S. occupation (Mani (2018)). It can be divided into three levels after elementary school, which are as follows: middle school (Grades 7-9), high school (Grades 10-12), and postsecondary education. Middle schools are mandatory and free of charge, whereas high school and postsecondary education are no longer mandatory or free.

Middle School

After completion of primary school, every Korean student must attend middle school, which corresponds to the seventh, eighth, and ninth grades in the US educational system. Students attend school from Monday to Friday and spend most time in one classroom with the same classmates. Middle school curricula are identical across schools (Lee et al. (2014a)),[7] and the national basic curriculum consists of math, Korean, English, social studies, ethics, science, practical course, physical education, music, and art (Ministry of Education (2021)). In addition to classes, students may participate in extracurricular activities, such as sports (Ministry of Education (2021)).

High School

Korean high schools correspond to grades 10-12 of the US educational system. Although high school enrollment is not mandatory, 99.7% of all middle school graduates entered high schools as of 2008 (Hahn et al. (2018)). Graduates can enter either academic or vocational programs.[8][9] About 20% of high school students attend vocational schools, and they are expected

[7] All middle schools are subject to the same educational policies, such as curriculum, number of school, and teacher hiring (Lee et al. (2014a)).

[8] There are also specialized high schools, such as foreign language and science high schools, but the proportion of students who enter these unique schools is very small (Park et al. (2013)). For example, the number of students attending specialized high schools is about 3% of the total student enrollment in academic high schools in 2009 in Seoul (Park et al. (2013)).

[9] There are also autonomous schools but they were introduced in 2010 and are out of scope of this paper.

to enter labor markets directly after graduation or go on to vocational colleges (Sohn (2016)). In contrast, academic high schools provide general education across diverse areas, which account for the major part of all types of high schools (Ministry of Education (2021)). In Korea, more than 95% of students in academic high schools take a national college entrance exam that is given once a year by the government (Park et al. (2018)) and seek the opportunity for higher education. Academic high school students have the discretion to choose their majors according to their interests and future career path.). They can choose their majors (natural science or social studies) in the second year (Sohn (2016)). The regular academic high school curriculum consists of core subjects (Korean, English, and math) and elective subjects (social studies and natural sciences). Promotion to the next grade is based on educational assessment and evaluation, with midterm and final exams at the end of each semester (Mani (2018)).

College and University

Postsecondary education is important in South Korea because it is associated with socioeconomic success. Accordingly, most high school graduates apply for admission to high-ranking colleges and universities. These include regular four-year colleges and universities, two-year junior vocational colleges and four-year teachers' colleges. According to OECD (2020a), South Korea had the highest fraction (69.8%) of young adults (25-34 year-olds) completing postsecondary education (tertiary education) in the OECD countries as of 2019.

1.2.2 Randomization Policy of 1974

Before 1974, enrollment in Korean high schools was based on academic performance. Each high school conducted an entrance examination and made admission decisions based on candidates' scores. However, this policy was criticized for widening the academic gap caused by differences in family backgrounds and school environments (Park et al. (2013)).

Because of growing inequality and social concerns, the Korean government introduced an equalization policy in 1974. Under this policy, the competitive entrance exams in metropolitan

areas were replaced with a randomized lottery. Middle school graduates were randomly assigned to high schools by lottery, regardless of individual and school characteristics. Regarding the supply side, middle school graduates were randomly assigned to academic high schools within their school districts by lottery, and they had to accept the random assignment (Park et al. (2018)). Regarding the demand side, all schools had to give up their right to select new students and were required to take all students assigned by the randomized lottery (Kim and Lee (2003)). The randomization policy was applied to all schools within a school district (Park et al. (2018)) in metropolitan areas with some exceptions (see below), regardless of their school's private, public, single-sex, or coeducational status (Park et al. (2018)). For example, before 2010, 100% of academic high schools had implemented an equalization policy in Seoul, the capital of South Korea (Hahn et al. (2018)). Figure 1 shows the cities that implemented the equalization policy and those that did not in a geographical context.

There were two exceptions to the randomization policy. First, it was conducted only on students in academic high schools and not conducted on special purpose high schools and vocational high schools (Sohn (2016)). Second, some areas loosened this equalization policy in the 1990s; students in mitigated districts were permitted to list two or three in-district schools they wanted to enter, and the school districts randomly chose 30% to 40% of each incoming class from among the students who declared a preference for the school. The remaining 60% to 70% of enrollment was selected by randomized lottery. Thus, these modified districts implemented the equalization policy partially. In our main analysis, we focus on any school district implementing the equalization policy, even in a modified form, and we pool all these districts to increase power. In the robustness section, we also report a sub-sample analysis by using only those school districts that fully implement the policy.

1.3 Identification Strategy

The central challenge for estimating the causal effect of single-sex schooling on labor market outcomes is self-selection bias: Students who wish to attend single-sex schools are likely different in terms of individual characteristics, family background, or other characteristics that are unobservable to econometricians from those who wish to attend coeducation schools. Thus the status of attending a single-sex school is endogenous and correlated with the error term. We address with this problem by exploiting the random assignment in South Korea. In our setting, random assignment operates by district by gender by year, and the assignment probability between students potentially differs by the factors.[10] For example, the relative quantity and quality of single-sex versus coed schools within districts is highly gender specific. District A may have a high ratio of places available for girls at single-sex schools because it is home to many girls-only schools, whereas district B may have few girls-only schools. The opposite may be true for boys. Therefore, district A (B) may attract girls (boys) with a strong preference for attending single-sex schools; in other words, selection into districts is gender specific. Furthermore, every year, the Office of Education gathers information on middle school graduates, implements lotteries, and assigns them. Thus, the assignment probability could also differ by year (cohort). The assignment is random conditional on these risk sets, and controlling for the saturated set of these factors is necessary to isolate random assignment. Thus, we control for saturated indicators for district*year*sex to properly account for gender-specific sorting across districts and cohort effects. What is left over is the variation within a specific gender, district, and year, and the assignment is independent of the outcomes conditional on those factors.

Specifically, to identify the causal effect of graduating from a single-sex school on labor

[10] Recent literature using school lotteries refers to these factors that affect assignment probabilities as risk sets (e.g., Abdulkadiroğlu et al. (2011), Abdulkadiroğlu et al. (2017), Gray-Lobe et al. (2021)).

market outcomes, we estimate the following equation in a pooled boys-and-girls sample:

$$Y_{i,s,d,t} = \alpha + \beta_1 Female\ School_s + \beta_2 Male\ school_s + \gamma Male_{i,s,t,d} + X_{i,s,d,t}\tilde{\gamma} + \Omega_{i,d,t} + \varepsilon_{i,s,d,t} \quad (1.1)$$

where $Y_{i,s,d,t}$ is a labor market outcome for individual i in school s in school district d in year t. $Female\,School_s$ is a dummy taking 1 if an individual went to a single-sex female school and 0 otherwise; $Male\,School_s$ is a dummy taking 1 if an individual went to a single-sex male school and 0 otherwise. $Male_{i,s,d,t}$ is a dummy taking 1 if an individual is male and 0 otherwise. $X_{i,s,d,t}$ is a set of control variables consisting of individual characteristics of age and family background characteristics (parental education, parental ages, family monthly income and consumption, and an indicator for a family-owned house).[11] $\Omega_{i,d,t}$ shows a saturated set of indicators for district*year*sex to properly account for gender-specific sorting across districts and cohort effects. For inference, we use clustered-robust standard errors by school district so that the correlation within the school district can be controlled. Our main interest lies in the coefficients β_1 and β_2, which capture the causal effects of graduating from a single-sex school on future labor market outcomes for boys and girls, respectively. Our identifying assumption is that conditional on a saturated set of indicators for district*year*sex, indicators for single-sex school are not endogenous to labor market outcomes (i.e., uncorrelated with the error term). Accordingly, there is no omitted variable bias, and the coefficient β consistently estimates the linear causal effect. The result of our balance tests is consistent with the random assignment. Inclusion and choice of predetermined variable $X_{i,s,d,t}$ only affect the precision of β.

Table 1 shows the differences in inputs across single sex vs. co-ed schools. As the table illustrates, the difference in characteristics across school is small. This is because the Korean educational system is highly standardized, and variation in curricula, quality, and other basic school resources is minimal (Park et al. (2018)). One exception to this point is private school.

[11] Family earnings and consumption are measured during high school attendance.

In South Korea, single-sex schools are more often private, and about 74.1% of the single-sex schools in our sample are private.[12] It is important to note here that differences in inputs across single sex vs. co-ed schools are not a source of bias and thus we do not control a private school dummy in our Equation (1). Any such differences other than the gender differences in peers, which are channels of interest, are part of the causal impact of being assigned to a single-sex school. Private school is an outcome of random assignment, and our research design allows us to study the effects of sending students to single-sex vs. co-ed schools, not the impacts of changing a school to single-sex holding other things about the school constant.[13]

One potential threat to our identification is the possibility of migration. If students have a strong preference for a specific school, then they and their parents may choose to move from cities that implement the equalization policy to cities that do not. However, less than 1% of the students moved to a new city during the period of our sample, lessening the effect of this complication.

1.4 Data

To organize the necessary data, we created an individual-level panel spanning the years 2004 to 2015 from the Korean Education and Employment Panel (KEEP), which is an individual-level longitudinal survey by a government institution called the Korea Research Institute for Vocational Education and Training (KRIVET). A total of 6,000 students from across the country were randomly selected to participate: 2,000 middle school seniors (ninth graders), 2,000 academic high school seniors, and 2,000 vocational and technical high school seniors. After the first survey was administered in 2004, the government followed the individuals every year. In

[12] In Appendix Table A1, we also show the decomposed result that show the inputs at only girls and only boys schools.

[13] Although single-sex schools are more often private, this difference will not largely affect the result. Under the equalization policy, the Ministry of Education also equalized tuition, salaries, and fiscal deficits in operating cost of private schools with those of public schools, making all private schools similar to public schools (Kim and Lee (2003)). In the robustness section, we also run regression for the sample of students from public school only, and the result is robust to alternative samples.

this survey, students are asked about their school lives, such as classes, academic performance, teachers, majors, and schools. The survey also includes information on family characteristics, such as parents' income and education, and on students' labor market outcomes after graduation, such as earnings and employment.

Our main outcome variables of interest are two labor market outcomes: individual-level monthly earnings and individual-level working status. We also additionally investigate non-labor market outcomes: household-level monthly consumption and household-level monthly savings. First, individual-level monthly earnings are defined as the self-reported amount of average monthly earnings in Korean Won and observed for those who work. We count non-work as attrition for the purposes of the earnings analysis. Second, individual-level employment status are defined as the self-reported employment status whether if an individual works or not at the time of survey and observed for all households. Finally, monthly savings and consumption are defined as self-reported amount of average monthly savings and consumption in Korean Won and observed for all households. Monthly savings and consumption are household level and thus measured at the individual level if an individual is single but measured at the household level if married. All outcomes are measured in the years from 2012 through 2015 at ages 26-29, at 8-11 years after graduation from high school. All units except for working status are shown in the Korean currency; 10,000 Won roughly equals US$10.

It is important to note here that measuring savings and consumption at the household level makes their interpretation more difficult than earnings and employment at individual level. Any effects on family structure would affect the interpretation of these estimates. Thus, we made more careful interpretation about the household-level outcomes in the empirical results. We also look at the effect of attending single-sex school on the indicators for whether a subject is married and has a child.

To create our main analysis sample, we take the following step-by-step procedures for each outcome. First, we focus on academic high school students and drop students who attended special purpose high schools or vocational high schools, because the randomization

policy was only applied to academic high schools. Second, we focus on students who lived in metropolitan cities where the equalization policy was implemented, and thus, were randomly assigned to high schools and drop students who lived in cities where the equalization policy was not implemented. Third, we focus on students with full information of family backgrounds and school characteristics and drop students without those information. Following the above steps, we were left with 2,852 observations (1,252 for girls and 1,600 for boys) for the outcomes other than earnings. Regarding earnings, we have smaller sample size (1,301 observations (667 for girls and 634 for boys)), because we can only observe earnings for those who work and count non-work as attrition.

Table 2 shows the summary statistics of our sample. The upper panel shows statistics for females, and the lower panel shows statistics for males. The father's age was about 47 years and the mother's age was about 43-44 years on average. Nearly three-quarters of the family of students owned their housing. Family monthly earnings were about 340-360 (10,000 Won), which roughly corresponds to the average earnings in South Korea.[14]

The last column of Table 2 shows the results of the balance tests for predetermined characteristics. As explained in the identification strategy section, our underlying assumption for the internal validity is that there is no statistical difference in predetermined characteristics between the control group (students in coed schools) and the treatment group (students in single-sex schools). The results of the paired t-tests show that there is no statistical difference in predetermined characteristics at the conventional levels. One exception is that the number of children is about 0.126 higher for female single-sex school graduates than for female coed-school graduates ($p < 0.10$). However, the statistical significance is only at the 10% level, and the individual and family characteristics are mostly balanced between students who attending single-sex high schools and those attending coed high schools, suggesting that our research design is internally valid. We account for this imbalance by controlling for an indicator for the

[14] According to OECD (2020b), annual Korean wage is 412.2 (10,000 Won), which corresponds to 343.5 (10,000 Won) by month.

number of children. Appendix Table A2 also shows the results of other common randomization tests for predetermined characteristics for each gender after controlling for school districts and private school. The table does not show significant imbalances for many predetermined variables between the treatment and control groups except for mother's age ($p < 0.10$), which also confirms the random assignment.

We also check attrition rates for both graduates from single-sex schools and those from coeducational schools within the same gender. Although we use random assignment, differential attrition may affect the bias of the estimates. Checking this possibility is important because we estimate the long-run impacts of attending a single-sex high school on future labor market outcomes, and there are long periods of time between attending high school and being in labor markets. However, the possibility is unlikely to hold in our sample, which has a small difference in attrition between the control and treatment groups. Appendix Table A3 presents the results of the attrition test. We define attrition as the attrition from the end of high school to age 26. The attrition differs by outcome and we provide attrition rates by each outcome. The estimated differences in attrition rates are close to zero (0.7% for girls and 2.3% for boys) and not statistically significant. Thus, the difference in attrition rate between control and treatment groups is small within the same gender, suggesting that the effect on our analysis is limited.

1.5 Empirical Results

Tables 3-6 show the results of attending a single-sex school on labor market outcomes (monthly earnings, monthly consumption, monthly savings, and working status). The outcomes are measured in years from 2012 to 2015 at ages 26-29, at 8-11 years after graduation from high school. Earnings and employment are considered at the individual level, whereas savings and consumption are considered at the household level if subjects are married.

Table 3 shows estimates of the effect of graduating single-sex high schools on the future earnings of females and males. *Female high school* in the first row reports estimates of β_1 in

Equation (1), and *Male high school* in the second row reports the estimates of β_2. In specification (1) in the first column, we include a saturated set of indicators for district*year*gender. In specification (2) in the second column, we also include variables for predetermined family backgrounds and individual characteristics, such as parents' education and ages.

As is apparent in Table 3, the effect of graduating from a single-sex school on earnings differs by gender. As shown in the first row, the effect of graduating from female high schools on monthly earnings are negative and statistically significant across specifications ($p < 0.10$ in (1) and $p < 0.05$ in (2)). The magnitudes of the estimates do not change drastically across specifications, suggesting that the estimates are robust to alternative specifications. The magnitudes of the estimates suggest that attendance at a single-sex school significantly decreases female earnings by about 10-11%. As discussed in the robustness section, the results are robust to alternative samples. In contrast, as shown in the second row, the effect of graduating from a male single-sex school on monthly earnings is positive (9%), though the estimates are not statistically significant.[15] The results imply that our design is underpowered for detecting effects on some of the dimensions. These results suggest that the effect of single-sex schooling is different by gender. In section 6, we discuss the possible mechanisms underlying this asymmetric treatment effect on earnings by gender.

From Tables 4-6, we show the results for different outcomes other than earnings, using the same specifications and larger samples unconditional on working. Table 4 reports the effect of graduating from a single-sex high school on female and male monthly consumption. Consistent with the results of earnings, all the estimates for female high school in the first row are negative across specifications, and magnitudes of the estimates are not modest. However, the estimates are marginally statistically insignificant in the both columns, due to large standard errors. In contrast, the estimated effects of graduating from a male school on consumption are positive and small across specifications and not statistically significant.[16] One possible reason for this lack of

[15] If the effect size is 18%, then it cannot be ruled out at conventional significance levels.

[16] If the effect size is 20%, then it cannot be ruled out at conventional significance levels.

clear evidence on consumption is because of consumption at the household level. In our data, we only observe consumption at the household level rather than the individual level. Measuring an outcome at the household level makes the interpretation difficult, because any effects on family structure would affect the interpretation of these estimates, making difficult to view these results as effects on labor market outcomes. We will discuss the detail of the family structure effect in the mechanism section.

Table 5 shows the effect of graduating from a single-sex school on both male and female savings. Similar to the results on earnings and consumption, the effect of graduating from a single-sex school on female future savings is negative, but the effect size is modest (3-5%) and not statistically significant. In contrast, the effect of graduating from single-sex schools on male future savings is positive, but the effect size is modest (3-5%) and not statistically significant. Though the signs of the estimates are consistent with the result of earnings, since savings is also measured at the household level in our data, results for savings derived from the household-level data should be interpreted with more caution than results for our primary labor market outcome of earnings.

Finally, Table 6 reports the effect of graduating from single-sex school on male and female future working status. The dependent variable takes 1 if an individual works and 0 otherwise. As in the first row, the estimates for graduating from a female high school on future working status are negative and large (about 8-11% of the effect size). Similarly, in the second row, the estimated effects on male future working status are also negative and large (about 7-12% of the effect size). However, the estimates are not statistically significant, suggesting that our design is underpowered for detecting effects on extensive margin. Unlike the result on earnings, the signs of the effects on employment are same between boys and girls. The results suggest single-sex graduates are less likely to work at age late 20s relative to the comparable co-ed graduates, though the estimates are not statistically significant. This potential selection into employment could also affect the results on earnings presented above.

Overall, the results from Tables 3-6 provide evidence of negative impacts of graduating

from a single-sex high school on female future earnings, but less clear evidence on other outcomes. Though the positive effect on male earnings and the negative effects on working status and female consumption are large in the effect sizes, we do not find statistical significance. Our findings are important because there is little existing evidence on the long-run impacts of a single-sex school. We next investigate the potential mechanisms driving our results.

1.6 Mechanisms

We find that graduating from a single-sex school significantly decreases female future earnings. In contrast, we find positive effect of graduating from a single-sex school on future male earnings, though the effect is not statistically significant. What causes these heterogeneous effects across genders? In this section, we discuss potential channels and mechanisms.

1.6.1 Career Choice

One possible hypothesis for the heterogeneous treatment effect by gender is a differential career choice. Spending several years only with same-gender peers in a single-sex high school is likely to affect career choice later in life. Since high school students interact with each other every day for several years, same-gender peers represent a central aspect of teenagers' social environment and may signify an important social force shaping decisions on future career choice (Brenøe and Zölitz (2020)).

To assess the possibility of differential career choice, we first shed light on the job choice. Differential job choice by gender, if it exists, will directly lead to differential treatment effects on intensive margins. To the best of our knowledge, the existing literature rarely investigates the effect of single-sex schooling on future job choice. To further examine this hypothesis, we regress single-sex school dummies on each job category, using the same specification and controls. The results are shown in Table 7. Regarding the effect of graduating from a girls-only high school, most of the estimates in the first row are close to zero and not statistically significant at the conventional levels. However, the estimate for the healthcare sector, in column (5), is

positive and statistically significant at the conventional levels ($p < 0.05$). This result suggests that girls from single-sex schools are more likely to enter healthcare jobs than those from coed high schools are. Since the wages for the healthcare sector are lower than those in other sectors, this differential job choice is likely to lead to lower earnings for females from single-sex high schools. Similarly, as in column (1), the estimate of the female school for manufacturing is negative and statistically significant ($p < 0.10$), suggesting that women are more likely to avoid a job in manufacturing. Since the average wage for manufacturing is high, this differential job choice could also lead to lower earnings for female school graduates.

There are two possible channels whereby girls from girls-only schools choose more healthcare sector jobs and avoid manufacturing jobs than those from coed schools. One possible direct channel is the differential gender share by job. As shown in the fifth row of the table, the female share in healthcare sector jobs is 84%, and it is the highest among the jobs. The health care sector is a traditionally female job or female-dominant job. The result suggests that girls from female schools prefer jobs in traditionally female-dominated sectors more than girls from coed schools do. The result is consistent with some literature documenting the possibility of future avoidance of mixed-gender situations of single-sex graduates (e.g., Wong et al. (2018)) because of the reduced exposure to mixed-gender interactions and predisposition of individuals to experience mixed-gender anxiety (Dodge et al. (1987), Grover et al. (2007)). Similarly, the manufacturing sector has a low female share (32%), and girls from female schools may avoid jobs in traditionally male-dominated sectors.

Another possible indirect channel is the differential choice of majors at college. Since job choice is somewhat correlated with the choice of majors at college, this differential job choice between single-sex graduates and coed graduates may be driven by the differential major choice. To test this possibility, we ran regressions for majors at college. The results are shown in Appendix Table A4. Consistent with the job choice in Table 7, girls from female high schools are more likely to choose a healthcare major, whereas boys from male high schools are less likely to choose the health care major ($p < 0.10$). The results are consistent with those of Brenøe and

Zölitz (2020), who find that women who are exposed to a higher proportion of female peers are more likely to enter health-related disciplines in college. Our result is also consistent with Zölitz and Feld (2018), who provide supportive evidence of a significant effect of gender composition on the choice of majors in university.[17] The result is also consistent with Korean literature Park et al. (2018), which find that boys from boys-schools are more likely to be interested in science and math and choose STEM majors, whereas girls from girls-schools are more likely to choose non-STEM majors.[18] In contrast, our result is different from that of Anelli and Peri (2019), who do not find significant effects of peer gender on choice of major at college. While Anelli and Peri (2019) observe earnings in one year and consider a male-dominated environment (80% or more), we use a longer panel dataset and focus on a single-sex environment (100% of each gender). Relatedly, Sohn (2016) does not find a causal effect of single-sex school education on the choice of a major. Whereas Sohn (2016) focuses on short-run exposure to the opposite sex and decisions on a major in high school using a smaller sample, we investigate the effect of longer years (three years or more) of exposure to one gender at high school on the choice of a major at university. Overall, our results suggest that lower earnings of women come directly from the choice of jobs in traditionally female-dominated sectors and indirectly from the choice of major at college. In Section 7, we also show that desired career choice at age 15, prior to assignment to high schools, is balanced between those who attended single-sex versus coed schools given gender; this suggests that single-sex schooling is indeed responsible for the gap.

In contrast, the job choice of male-school graduates is opposite to that of female-school graduates. As shown in column (5) of Table 7, boys from boys' high schools are more likely to avoid healthcare jobs ($p < 0.05$), which is a completely opposite pattern to that of girls from female high schools. The result is consistent with the significant negative effect of graduating from male schools on choosing a healthcare major, as shown in Appendix Table A4. Similarly,

[17] Whereas Brenøe and Zölitz (2020) and Zölitz and Feld (2018) consider a continuous proportion of gender peers and identity effects at a different margin of the gender composition, our paper focuses on the effect of single-sex schools.

[18] Park et al. (2018) also find effects of single-sex schooling on the students' academic achievement at school, which will be discussed in the section 6.3.

boys from male high schools are more likely to enter manufacturing sector jobs ($p < 0.10$), as shown in column (1). The estimates for sales and education are also marginally statistically significant ($p < 0.10$), which may offset the effect on earnings for boys from male high schools.

Single-sex education could also affect the career choice of post-secondary education. If the choice is different between single-sex graduates and co-ed school graduates, then the differential choice could also affect the labor market outcomes via difference in human capital. To check this possibility, we also regress a dummy that indicates whether the student completed postsecondary education on single-sex school dummies using the same estimation equation (1) (Appendix Table A5). However, we do not find evidence that that graduating from a single-sex school affects the probability of participating in postsecondary education for both males and females. This null effect on post-secondary education is consistent with Hahn et al. (2018), who do not find effect of single-sex schooling on college attendance rates. In contrast, Park et al. (2018) find positive effects on their attendance at a 4-year vs. 2-year college. It is important to note here that our paper is different from Park et al. (2018) in the following points. First and most importantly, we observe the post-secondary completion whereas Park et al. (2018) look at the college attendance rates. Second, Park et al. (2018) focuses on Seoul city, whereas our paper focuses on metropolitan cities. Third, we more focus on the effect of graduating single-sex high schools, whereas Park et al. (2018) more involves the effect of attending schools. Fourth, we include the saturated gender, district, and cohort fixed effects and do not include school inputs variable such as private school, whereas Park et al. (2018) include district fixed effect and school input variables. These differences could lead to differential results.

1.6.2 Network

Another possible mechanism for the significant negative effect of attending a female high school on future earnings is rooted in the difference in social networks between female graduates from single-sex schools and those from co-educational schools. Since students from single-sex schools interact little with the opposite sex, they are likely to struggle in forming multi-sex peer

relations and social growth (Fabes et al. (2015)).[19] Because mixed-gender interactions in coed school serve unique developmental functions for adolescents (Grover et al. (2007), Glickman and La Greca (2004)), graduates from gender-segregated schools miss important opportunities to learn about distinct behavioral and social norms of the other gender and to practice interpersonal skills, making it harder to communicate effectively and comfortably with the other gender in the workplace and establish and maintain satisfactory mixed-gender relationships (Halpern et al. (2011), Bigler et al. (2014), Hansen et al. (1992), Grover et al. (2007)). Thus, disrupting the process of social skills acquisition and relationship formation in networks may lead to lower labor market outcomes after graduation (Lleras (2008)).[20]

Although the lower social network resulting from graduating from a single-sex school potentially affects both male and female future labor market outcomes, lost benefits would be larger for girls in the male-dominant society in South Korea. Social skills would be more important for females to survive in a male-dominant community with a high gender gap. For example, the fraction of females serving in a management position is only 9.7% in South Korea (ILPO (2018)). The labor force participation rate of women is about 25% lower than that of men (Lee (2020)). Thus, interpersonal skills with the opposite gender are more necessary for females to receive higher returns in the workplace.

To test the above hypothesis, we implement additional analysis using a measure for social networks and communications after graduation in a firm. Although we do not observe direct measures for network and communications with the opposite gender, we have an indirect but closely related measure for network in a firm: How satisfied are you with your communication and relationships with coworkers? The answer is scored on a 5-point scale (1: not satisfied; 5: satisfied).

Table 8 shows the results of our testing of the network hypothesis. In this table, we run the regression for the above network-related outcome using the same specification. Column

[19] For a further discussion on the detrimental effect of single-sex schools on networks, see Wong et al. (2018).

[20] Lleras (2008) finds that students with stronger social skills achieve a higher level of earnings 10 years after their high school graduation than those with lower social skills.

(1) reports the estimate with the full sample. The estimate for male schools in the second row is not statistically significant, which suggests that graduating from a single-sex male school does not have a significant effect on the network-related outcome. In contrast, the estimates for female social skills are negative and statistically significant at the conventional levels ($p < 0.05$). The results suggest that graduates from single-sex female schools are less satisfied with their communication and relationships with coworkers in a firm than female graduates from co-educational schools. The results provide supportive evidence for the social network hypothesis. Furthermore, in column (2), we restrict the sample to females who work for a low-female share firm, and column (3) reports the estimate with the restricted sample with females who work for a high-female share firm. The estimated network effect is larger for male dominated sectors than female dominated sectors, supporting a network effect hypothesis. In the robustness section, we also show that students' social skills at age 15, prior to assignment to high schools, are balanced between those who attended single-sex versus coed schools given gender, suggesting that single-sex schooling is indeed responsible for the gap.

1.6.3 Academic Performance at High School

Attending a single-sex school could affect the academic performance or test scores at school, relative to those counterparts at co-ed schools. These changes in productivity and human capital at single-sex school in the short run could also affect the future labor market outcomes in the long run, compared with those from co-ed schools. The difficult part is that empirical evidence on the effect of single-sex education on academic performance is quite mixed in South Korea and in other countries (Park et al. (2018)). Regarding Korean studies, some papers find that attending single-sex schools or classrooms improves test scores of students regardless of gender (e.g., Park et al. (2013); Dustmann et al. (2018)), whereas other papers find null effect, adverse effect, or different effect by gender (e.g., Sohn (2016); Hahn and Wang (2019)). We find positive long-run effect of single-sex schooling on future male earnings (though it is noisy), which is consistent with existing papers that find positive short-run effect on boy's test scores

and educational attainment (e.g., Park et al. (2013); Lee et al. (2014b); Dustmann et al. (2018); Park et al. (2018); Hahn and Wang (2019)). In contrast, our findings on long-run future negative female earnings are less explained by this mechanism, because the literature on effects on girls' test score is more mixed (e.g., null: Lee et al. (2014b);Sohn (2016);Park et al. (2018), positive: Park et al. (2013); Dustmann et al. (2018), negative: Hahn and Wang (2019)).[21] These comparisons suggest that, for females, the career choice of health care sector and network effect at firms discussed in the previous subsections could work more directly for earnings than the academic achievement at high schools. This is plausible because we observe outcomes at ages late 20s, and their earnings would be more likely to be directly affected by the job choice and/or network at firms than the academic performance about 10 years ago at ages 16-18. Another possibility is the difference in the settings and methodologies. Though both our paper and previous papers are similar in the sense that both exploit randomization in South Korea, they are different in the following points. First, we look at the effect of graduating from single-sex schools, where the exposition to the same gender is longer that that of the effect of attending single-sex schools on the test score at school. Second, our paper focuses on several metropolitan cities including Seoul, whereas some papers more focus on Seoul. Finally, we use a cleaner specification to exploit a random assignment following the recent literature on school lotteries (e.g., Abdulkadiroğlu et al. (2011), Abdulkadiroğlu et al. (2017), Gray-Lobe et al. (2021)) by controlling for the saturated set of gender*district*cohort fixed effects and do not include school inputs variables, whereas other many papers only include the subset of fixed effects and include school input variables. These differences could lead to different results in the long run from some of the previous papers in the short-run effect on academic performance.

[21] Above all, our result of positive effect on male earnings (though it is noisy) and negative effect on female earnings is most consistent with the short-run effect on academic performance by Hahn and Wang (2019), who find that the effect of single-sex schools on standardized test score is only evident among males in private schools using 2010 data, while the effects of single-sex schools on test scores of females are mostly negative.

1.6.4 Family Formation

Finally, entrance into single-sex schooling may affect the probabilities of marriage and parenthood. Smaller mixed-gender experience may affect family formation and relationship (Atherton (1973), Sullivan et al. (2011)).[22] Female peers in adolescence may also directly affect fertility preferences (Brenøe and Zölitz (2020)). Differential effects on household savings and consumption may be driven by differential family formation between single-sex school graduates and coed school graduates. It is also possible that the differential job choice stated in the previous subsection could affect the timing of marriage and children through the differential working environment and compensations.

To test this hypothesis, we run regressions for the probability of marriage and childbirth using the same specification. The results are shown in Table 9. For females, the effects of graduating from a single-sex school on marriage and childbirth are negative and statistically significant. These negative effect on female family formation would also explain the negative effects on female family consumption and family savings in Table 4 and 5. In contrast, the estimated effects on boys are close to zero and not statistically significant at the conventional levels. Overall, the estimated negative effects on female family formation could also have a negative impact on our outcomes at the household level.

1.7 Robustness and Placebo

1.7.1 Robustness

Alternative Sample (Seoul)

In our main analysis, we show that our estimates are robust to alternative specifications, both with and without control variables. In addition, we test whether our result is robust to a smaller alternative sample restricted to students in Seoul. The results are shown in Appendix

[22] Atherton (1973) shows that single-sex school graduates report less satisfactory marriage, and Sullivan et al. (2011) show that single-sex graduates have higher divorce rates than coed school graduates do. Regarding how social factors affect fertility, see the literature review of Balbo and Barban (2014).

Tables A6-A9. Consistent with the main results, the estimates for female earnings are statistically significant and negative across specifications ($p < 0.10$), whereas the estimates for males are statistically insignificant. Regarding the other outcomes, overall, the magnitudes and signs of the estimates are similar to those in the main tables.

Alternative Sample (Public and Private Schools)

In our main analysis, we pool all the students who entered either public or private schools. For the additional robustness test, we also re-estimate the effect for the subsample of students who attended public (private) high schools. The results are shown in Appendix Table A10 and A11. Although the estimates are less precise, reflecting the smaller sample, the pattern of statistical significance and estimates is similar to the baseline results, suggesting that our results are robust to the alternative sample.

1.7.2 Placebo

Desired Career Choice before Entering Single-Sex School

In the main analysis, we show that single-sex high school graduates choose different career paths compared with coed high school graduates. However, it could be that the desired career choice between the treatment group and control group is different even prior to the entrance into high school. To check this possibility, we also run additional regressions for the students' desired career choice at age 15, prior to assignment to high schools. The results are shown in Appendix Table A12. The estimates are close to 0 and not statistically significant. The table shows that desired career choices are balanced between those who attended single-sex versus coed schools at age 15, suggesting that single-sex schooling is indeed responsible for the gap.

Network before Entering Single-Sex School

In the main analysis, we show that single-sex high school graduates have different network and social skills compared with coed high school graduates. However, it could be that the network between the treatment group and control group is different even prior to the entrance

into high school. To check this possibility, we run additional regressions for the measures of students' social skills at age 15 prior to assignment to high schools. The results are shown in Appendix Table A13. The estimates are close to 0 and are not statistically significant for (1) whether a student gets along with classmates and (2) whether a student has a concern about the relationship with a friend. The table shows that students' social skills are balanced between those who attended single-sex versus coed schools at age 15 given gender, suggesting that single-sex schooling is indeed responsible for the gap.

1.8 Conclusion

In this paper, we investigate the effect of graduating from single-sex schools on future labor market outcomes by analyzing a natural experiment in South Korea. Students in South Korea are randomly assigned to single-sex and coeducational high schools within their school districts. Using individual-level panel data, we find that graduating from single-sex high schools significantly decreases female earnings and savings in their late 20s. In contrast, we do not find convincing evidence that single-sex high school education affects male labor market outcomes.

There are two potential channels for explaining this impact—career choice and network effect. Evidence for the former is the heterogeneous career choices demonstrated by the female treatment and control groups. Females from female high schools are more likely to choose a job in a traditionally female-dominated sector, which has a higher fraction of women and pays a lower wage. Regarding the latter, we find that graduates from single-sex female schools are less satisfied with their communication and relationships with coworkers in a firm compared with female graduates from coeducational schools, which also potentially affects labor market outcomes after graduation.

This is one of few papers to examine how single-sex high school education can affect the future lives of students, not just after high school but also after graduation from postsecondary education. In terms of policy implications, this paper highlights the importance of the potential

long-run impact of attending single-sex schools. Our results may be considered unexpected, as single-sex education is intuitively considered to remove distractions and allow students to concentrate on their studies in the short run. However, our findings suggest that it is at least as important to see the long-run effect on career choice and fully develop students' social skills to prepare them for the future.

1.9 Acknowledgements

Chapter 1, in full, is currently being prepared for submission for publication of the material. Lee, Youngju; Nakazawa, Nobuhiko. "Does single-sex schooling help or hurt labor market outcomes? Evidence from a natural experiment in South Korea". The dissertation author was the primary investigator and author of this material.

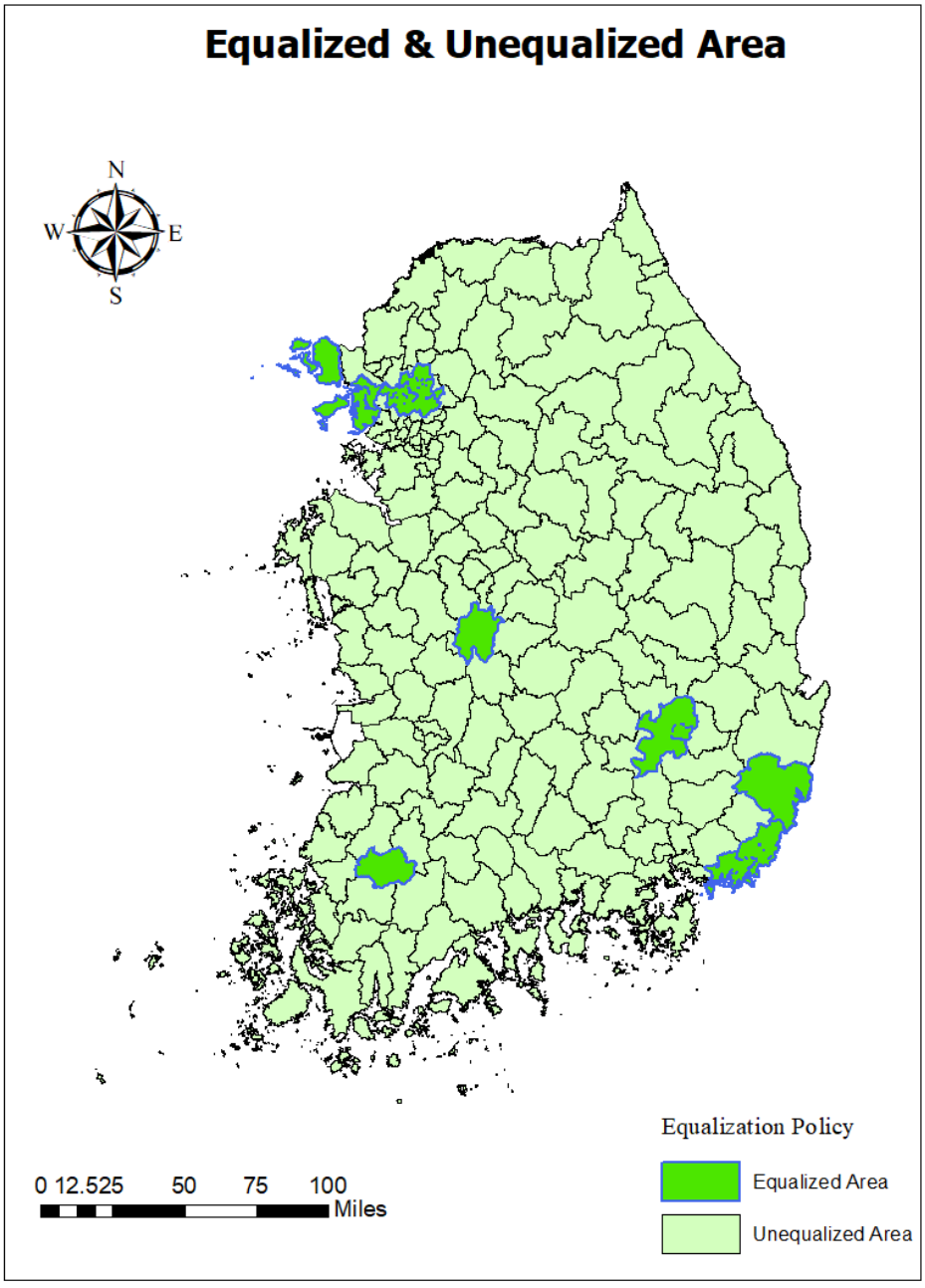


Figure 1.1. Equalized Areas in South Korea

NOTE: This figure shows the areas with and without equalization policies in South Korea . All equalization policy areas are metropolitan cities: Seoul, Busan, Dae-jeon, Dae-gu, Gwangju, Ulsan, and Incheon.

Table 1.1. Comparison of Inputs at Single-Sex and Coed Schools

	Single-sex	Coed	Difference
Number of students	1,244.4	1,305.7	61.34
	(280.9)	(356.4)	(69.36)
Number of teachers	74.00	77.97	3.967
	(14.99)	(19.54)	(3.748)
Private school	0.741	0.267	-0.475***
	(0.442)	(0.450)	(0.100)
Student: attendance rate (%)	97.14	98.48	1.338
	(13.42)	(1.618)	(2.467)
Student: dropout rate (%)	12.50	12.17	-0.333
	(13.75)	(10.87)	(2.890)
Student: disciplinary action rate (%)	7.759	10.20	2.441
	(15.64)	(10.95)	(3.202)
Student: university in Seoul after graduation	90.66	79.13	-11.52
	(82.76)	(67.10)	(17.50)
Student: work after graduation	3.879	14.833	10.954
	(8.497)	(60.836)	(8.095)
Academic performance of school	0.517	0.400	-0.117
	(0.504)	(0.498)	(0.113)
Teacher ability	0.931	0.900	-0.031
	(0.256)	(0.305)	(0.062)
Teacher-student relationship	0.862	0.900	0.038
	(0.348)	(0.305)	(0.075)
Class atmosphere	0.776	0.633	-0.143
	(0.421)	(0.490)	(0.100)
Principal leadership	0.776	0.833	0.058
	(0.421)	(0.379)	(0.092)
Facility	0.328	0.433	0.106
	(0.473)	(0.504)	(0.109)
Local environment	0.483	0.533	0.051
	(0.504)	(0.507)	(0.114)
Commuting condition	0.414	0.533	0.120
	(0.497)	(0.507)	(0.113)
Observations	58	30	

NOTE: The table shows the means and standard deviations (in parentheses) of school characteristics for single-sex schools and coeducational schools. Data are drawn from the Korean Education and Employment Panel (KEEP). The mean differences are tested by paired t-tests in the last column, which reports the differences in the means and corresponding standard errors in parentheses. Statistical significance is indicated by * at the 10% level, ** at the 5% level, and *** at the 1% level. The number of school districts is 24. Detailed data sources and variable definitions are provided in Appendix B.

Table 1.2. Summary Statistics

Panel A: Females	Single-sex		Coed		Difference
	Mean	SD	Mean	SD	
Outcome variables					
Earnings	174.118	49.133	182.580	56.047	
Savings	49.836	48.888	57.368	106.446	
Consumption	65.828	39.049	69.721	95.743	
Work	0.676	0.468	0.695	0.461	
Individual and family background					
Age	27.292	1.828	27.123	1.867	-0.170 (0.105)
Father's age	46.865	3.455	46.340	4.241	-0.524 (0.429)
Mother's age	43.540	3.180	43.336	3.559	-0.204 (0.191)
Family earnings	362.407	254.749	357.986	215.090	-4.421 (13.544)
Family consumption	263.292	149.853	265.948	145.054	2.655 (8.407)
Family-owned house	0.685	0.465	0.740	0.439	0.055** (0.026)
Student has own room	0.801	0.400	0.803	0.398	0.002 (0.023)
Number of children	2.247	0.607	2.167	0.488	-0.081 (0.062)
Father: High school	0.533	0.500	0.603	0.491	0.070 (0.057)
Father: Postsecondary	0.385	0.488	0.331	0.472	-0.054 (0.055)
Mother: High school	0.633	0.483	0.640	0.482	0.006 (0.056)
Mother: Postsecondary	0.219	0.415	0.191	0.395	-0.028 (0.046)
Number of Individuals	698		554		
Panel B: Males	Single-sex		Coed		Difference
	Mean	SD	Mean	SD	
Outcome variables					
Earnings	204.848	65.685	194.047	62.969	
Saving	68.686	253.057	57.565	122.659	
Consumption	60.943	48.365	60.832	50.910	
Work	0.531	0.499	0.574	0.495	
Individual and family background					
Age	28.229	2.364	28.401	1.949	0.172 (0.123)
Father's age	47.265	3.286	47.049	4.072	-0.216 (0.189)
Mother's age	44.333	3.291	44.047	3.390	-0.286 (0.356)
Family earnings	345.596	184.112	356.749	196.032	11.15 (10.011)
Family consumption	257.417	119.857	250.979	113.635	-6.438 (6.271)
Family-owned house	0.766	0.424	0.711	0.455	-0.055 (0.047)
Student has own room	0.884	0.321	0.894	0.309	0.010 (0.017)
Number of children	2.086	0.481	2.082	0.6588	-0.004 (0.029)
Father: High school	0.494	0.501	0.440	0.498	-0.054 (0.053)
Father: Postsecondary	0.402	0.491	0.418	0.495	0.016 (0.052)
Mother: High school	0.657	0.476	0.552	0.499	-0.105** (0.052)
Mother: Postsecondary	0.192	0.395	0.216	0.413	0.025 (0.043)
Number of Individuals	1,074		526		

NOTE: The table reports the means, standard deviations of the main variables for females (Panel A) and males (Panel B). The mean differences are tested by paired t-tests in the last column, which reports the differences of the means and corresponding standard errors in parentheses. Outcomes report monthly earnings, savings, and consumption; monthly savings and consumption are household-level if married. The units are 10,000 Won, which roughly equals $10. Own house (room) is an indicator of whether family (a student) has an own house (room). High school and postsecondary education are indicators for whether parents completed high school or postsecondary education, respectively.

Table 1.3. Effect on Earnings

Dependent variable: Log(earnings)		
	(1)	(2)
Female high school	-0.103*	-0.115**
	(0.055)	(0.044)
Male high school	0.090	0.097
	(0.094)	(0.097)
Control(district, year, sex)	Yes	Yes
Control(family background)	No	Yes
Mean	5.20	5.20
Observations	1,301	1,301
R-squared	0.148	0.174

NOTE: The parameters are results from separate regressions of equation (1) for the logarithm of earnings. *Female high school* in the first row indicates whether students graduate from female high schools, and *Male high school* in the second row indicates whether students graduate from male high schools. In column (1), we control for the indicator for males and the saturated set of indicators for school district, year, and sex. In column (2), we also control for family background variables: ages of family members, parents' educational levels, family monthly income and consumption, and an indicator for a family-owned house. The sample consisted of men and women who graduated from high schools in equalized areas between 2004 and 2007. Standard errors, robust to clustering by school district, are reported in brackets. Statistical significance is indicated by * at the 10% level, ** at the 5% level, and *** at the 1% level. The unit of earnings is 10,000 Won per month, which is roughly equal to $10.

Table 1.4. Effect on Consumption

Dependent variable: Log(consumption)		
	(1)	(2)
Female high school	-0.105	-0.102
	(0.098)	(0.099)
Male high school	-0.052	-0.039
	(0.107)	(0.109)
Control(district, year, sex)	Yes	Yes
Control(family background)	No	Yes
Mean	3.92	3.92
Observation	2,710	2,710
R-squared	0.152	0.159

NOTE: The parameters are results from separate regressions of equation (1) for the logarithm of consumption. For other details, see the notes to Table 3.

Table 1.5. Effect on Savings

Dependent variable: Log(savings)		
	(1)	(2)
Female high school	-0.031	-0.053
	(0.184)	(0.174)
Male high school	0.039	0.047
	(0.123)	(0.118)
Control(district, year, sex)	Yes	Yes
Control(family background)	No	Yes
Mean	2.62	2.62
Observation	2,682	2,682
R-squared	0.407	0.411

NOTE: The parameters are results from separate regressions of equation (1) for the logarithm of savings. For other details, see the notes to Table 3.

Table 1.6. Effect on Entrance to Job Market

Dependent variable: Employment		
	(1)	(2)
Female high school	-0.052	-0.079
	(0.052)	(0.051)
Male high school	-0.040	-0.069
	(0.064)	(0.062)
Control(district, year, sex)	Yes	Yes
Control(family background)	No	Yes
Mean (females)	0.68	0.68
Mean (males)	0.55	0.55
Observations	2,852	2,852
R-squared	0.092	0.102

NOTE: The parameters are results from separate regressions of equation (1) for the indicator of current working status. For other details, see the notes to Table 3.

Table 1.7. Impact on Job Choice

	(1) Manufacturing	(2) Agriculture	(3) Media	(4)Natural resources	(5)Health care
Female school	-0.129*	-0.001	-0.011	0.007	0.125**
	(0.075)	(0.002)	(0.008)	(0.008)	(0.053)
Male school	0.114*	0.008	0.044	-0.007	-0.051**
	(0.062)	(0.006)	(0.029)	(0.018)	(0.023)
Controls	Yes	Yes	Yes	Yes	Yes
Average wage	210.11	227.67	213.00	201.25	179.43
Female share	0.32	0.66	0.33	0.25	0.84
Observations	1,301	1,301	1,301	1,301	1,301
	(6) Entertainment	(7) Construction	(8) Sales	(9)Foods & hotels	(10) Real estate
Female school	0.007	0.013	0.039	0.024	-0.004
	(0.016)	(0.015)	(0.049)	(0.043)	(0.018)
Male school	-0.014	-0.019	-0.087*	0.025	-0.021
	(0.028)	(0.038)	(0.050)	(0.042)	(0.014)
Controls	Yes	Yes	Yes	Yes	Yes
Average wage	156.16	217.76	191.28	141.04	176.92
Female share	0.44	0.29	0.55	0.41	0.42
Observations	1,301	1,301	1,301	1,301	1,301
	(11) Business	(12) Public	(13) Education	(14) Other	
Female school	-0.032	-0.015	-0.030	0.021	
	(0.045)	(0.068)	(0.060)	(0.047)	
Male school	-0.021	-0.021	0.097*	-0.029	
	(0.046)	(0.047)	(0.052)	(0.025)	
Controls	Yes	Yes	Yes	Yes	
Average wage	199.12	168.22	176.13	155.10	
Female share	0.44	0.38	0.80	0.63	
Observations	1,301	1,301	1,301	1,301	

NOTE: The table shows how attendance at a single-sex high school affects job choice after entering the job market. The job categories follow the definitions by Statistics Korea. Each dependent variable is an indicator that takes 1 if the job belongs to the category indicated in the column header. Average wage represents the mean of the regular wages of the job category. Female share reports the fraction of females per job. The control set includes the variables shown in column (2) of Table 3. Standard errors robust to clustering by school districts are reported in brackets. Statistical significance is indicated by * at the 10% level, ** at the 5% level, and *** at the 1% level. For other details, see the notes to Table 3.

Table 1.8. Network in the Workplace

	(1)	(2)	(3)
	Communication and relationships with coworkers		
Female high school	-0.119**	-0.160**	-0.091
	(0.056)	(0.069)	(0.094)
Male high school	0.092	0.026	0.376*
	(0.068)	(0.061)	(0.203)
Sample	All	Low female share	High female share
Controls	Yes	Yes	Yes
Observations	1299	1055	244

NOTE: The parameter is the result of a regression of equation (1) for the measure of network in a workplace. The dependent variable is an answer by a respondent to a question about the respondent's subjective feeling about communication and relationships with coworkers. The dependent variable is scaled from 1 to 5, where 5 means very satisfied or very good, and 1 means very unsatisfied or very bad. Column (1) reports the estimate with the full sample. In column (2), we restrict the sample to females who worked for a low-female share firm (share is below 0.7). Column (3) reports the estimate with the restricted sample with females who work for a high-female share firm (share is 0.7 or above). The control set includes the variables shown in column (2) of Table 3. Standard errors, robust to clustering by school district, are reported in brackets. Statistical significance is indicated by * at the 10% level, ** at the 5% level, and *** at the 1% level. For other details, see the notes to Table 3.

Table 1.9. Effect on Family Structure

	(1)	(2)
	Marriage	Having a child
Female high school	-0.083*	-0.067**
	(0.045)	(0.027)
Male high school	0.016	0.024
	(0.017)	(0.015)
Controls	Yes	Yes
Observation	2,850	2,849

NOTE: The parameters are results from separate regressions of equation (1) for family structure out- comes, as indicated in the column header. The dependent variable in column (1) is an indicator for marriage, and the dependent variable in the second column is an indicator for childbirth. The control set includes the variables shown in the column (2) of Table 3. Standard errors, robust to clustering by school districts, are reported in brackets. Statistical significance is indicated by * at the 10% level, ** at the 5% level, and *** at the 1% level. For other details, see the notes to Table 3.

Table 1.A1. Comparison of Inputs at Coed School, Female School, and Male School

	Coed	Female school	Male school
Number of students	1305.7	1259.3	1233.8
	(356.4)	(275.4)	(288.3)
Number of teachers	77.97	75.17	73.18
	(19.54)	(15.04)	(15.13)
Private school	0.267	0.583	0.853
	(0.450)	(0.504)	(0.359)
Student: attendance rate (%)	98.48	98.74	96.01
	(1.618)	(1.070)	(17.530)
Student: dropout rate (%)	12.17	9.08	14.91
	(10.87)	(9.13)	(15.94)
Student: disciplinary action rate (%)	10.20	4.33	10.18
	(10.95)	(6.80)	(19.39)
Student: university in Seoul after graduation (%)	79.13	101.92	82.71
	(67.10)	(96.66)	(71.85)
Student: work after graduation (%)	14.833	5.750	2.559
	(60.836)	(10.674)	(6.402)
Academic performance of school	0.400	0.375	0.618
	(0.498)	(0.495)	(0.493)
Teacher ability	0.900	0.917	0.941
	(0.305)	(0.282)	(0.239)
Teacher-student relationship	0.900	0.875	0.853
	(0.305)	(0.338)	(0.359)
Class atmosphere	0.633	0.833	0.735
	(0.490)	(0.381)	(0.448)
Principal leadership	0.833	0.750	0.794
	(0.379)	(0.442)	(0.410)
Facility	0.433	0.292	0.353
	(0.504)	(0.464)	(0.485)
Local environment	0.533	0.417	0.529
	(0.507)	(0.504)	(0.507)
Commuting condition	0.533	0.417	0.412
	(0.507)	(0.504)	(0.500)
Observations	30	24	34

NOTE: The table shows the means and standard deviations (in parentheses) of school characteristics for coeducational, male, and female schools. Data are drawn from the Korean Education and Employment Panel (KEEP). The mean differences are tested by paired t-tests in the last column, which reports the differences in the means and corresponding standard errors in parentheses. Statistical significance is indicated by * at the 10% level, ** at the 5% level, and *** at the 1% level. The number of school districts is 24. Detailed data sources and variable definitions are provided in Appendix B.

Table 1.A2. Alternative Randomization Check

	(1) Males Single-sex high school	(2) Females Single-sex high school
Father: High school	0.0287	-0.0664
	(0.064)	(0.133)
Father: Postsecondary	-0.0041	-0.0525
	(0.078)	(0.104)
Mother: High school	0.0915	-0.0458
	(0.064)	(0.073)
Mother: Postsecondary	0.0626	-0.0284
	(0.087)	(0.089)
Father's age	0.0005	0.0033
	(0.009)	(0.009)
Mother's age	0.0074	-0.0101
	(0.010)	(0.010)
Family-owned house	0.0189	-0.0286
	(0.030)	(0.060)
Family monthly earning	-0.00022	0.00002
	(0.00013)	(0.00022)
Family monthly consumption	0.00026	-0.00027
	(0.00027)	(0.00036)
Student has own room	-0.0550	0.0759
	(0.062)	(0.053)
Number of children	0.0231	0.0486*
	(0.033)	(0.024)
School district	Yes	Yes
Observations	1,600	1,252

NOTE: The table reports coefficients from OLS regressions of predetermined characteristics on an indicator of single-sex school for males (column (1)) and females (column (2)), controlling for school district. Statistical significance is indicated by * at the 10% level, ** at the 5% level, and *** at the 1% level. Robust standard errors are in parentheses.

Table 1.A3. Attrition Test

	(1) Earnings	(2) Saving	(3) Consumption	(4) Employment
Female high school	0.0107	-0.0147	0.000711	0.00111
	(0.044)	(0.025)	(0.023)	(0.001)
Male high school	0.0547	-0.00607	0.00497	0.000415
	(0.049)	(0.024)	(0.024)	(0.0003)
Controls	Yes	Yes	Yes	Yes
Observation	1355	2852	2852	3179
R-squared	0.085	0.044	0.036	0.014

NOTE: We regress an indicator for attrition on an indicator for single-sex school and the control set shown in column (2) of Table 4. Statistical significance is indicated by * at the 10% level, ** at the 5% level, and *** at the 1% level. Robust standard errors are in parentheses. For other details, see the notes to Table 3.

Table 1.A4. Undergraduate Major Choice

	(1) Literature	(2) Social science	(3) Education	(4) Engineering
Female high school	-0.009	0.019	-0.047	0.039
	(0.052)	(0.081)	(0.034)	(0.034)
Male high school	0.047	0.009	0.042	0.060
	(0.046)	(0.055)	(0.025)	(0.064)
Controls	Yes	Yes	Yes	Yes
Observations	2,852	2,852	2,852	2,852
	(5) Natural science	(6) Healthcare	(7) Art	
Female high school	-0.090	0.079*	0.045	
	(0.058)	(0.046)	(0.051)	
Male high school	0.036	-0.053*	-0.037	
	(0.048)	(0.031)	(0.037)	
Controls	Yes	Yes	Yes	
Observations	2,852	2,852	2,852	

NOTE: The table shows how attendance at a single-sex high school affects the choice of major at college and universities. The majors follow the definitions by Statistics Korea. Each dependent variable is an indicator that takes 1 if the job belongs to the category indicated in the column header. The control set includes the variables shown in the column (2) of Table 3. Standard errors robust to clustering by school districts are reported in brackets. Statistical significance is indicated by * at the 10% level, ** at the 5% level, and *** at the 1% level. For other details, see the notes to Table 3.

Table 1.A5. Postsecondary Education

	Postsecondary education
Female high school	-0.040
	(0.048)
Male high school	-0.002
	(0.037)
Controls	Yes
Observations	2,852

NOTE: The parameters are results from a regression of equation (1) for the indicator for postsecondary education completion. The control set includes the variables shown in the column (2) of Table 3. Standard errors, robust to clustering by school districts, are reported in brackets. Statistical significance is indicated by * at the 10% level, ** at the 5% level, and *** at the 1% level. For other details, see the notes to Table 3.

Table 1.A6. Effect on Earnings (Sample: Seoul)

Dependent variable: Log(earnings)		
	(1)	(2)
Female high school	-0.111*	-0.095*
	(0.058)	(0.050)
Male high school	-0.039	-0.016
	(0.034)	(0.057)
Control(district, year, sex)	Yes	Yes
Control(family background)	No	Yes
Observations	467	467
R-squared	0.097	0.118

NOTE: The parameters are results from separate regressions of equation (1) for the logarithm of earnings, where the sample is restricted to individuals in Seoul. For other details, see the notes to Table 3.

Table 1.A7. Effect on Consumption

Dependent variable: Log(consumption)		
	(1)	(2)
Female high school	-0.040	-0.011
	(0.137)	(0.142)
Male high school	-0.057	-0.050
	(0.122)	(0.115)
Control(district, year, sex)	Yes	Yes
Control(family background)	No	Yes
Observation	1,080	1,080
R-squared	0.047	0.099

NOTE: The parameters are results from separate regressions of equation (1) for the logarithm of consumption, where the sample is restricted to individuals in Seoul. For other details, see the notes to Table 3.

Table 1.A8. Effect on Savings

Dependent variable: Log(savings)		
	(1)	(2)
Female high school	-0.037	-0.031
	(0.382)	(0.421)
Male high school	0.109	0.114
	(0.189)	(0.198)
Control(district, year, sex)	Yes	Yes
Control(family background)	No	Yes
Observation	1,080	1,080
R-squared	0.328	0.336

NOTE: The parameters are results from separate regressions of equation (1) for the logarithm of savings. For other details, see the notes to Table 3.

Table 1.A9. Effect on Entrance to Job Market (Sample: Seoul)

Dependent variable: Employment		
	(1)	(2)
Female high school	0.037	0.037
	(0.043)	(0.047)
Male high school	-0.062	-0.085
	(0.062)	(0.058)
Control(district, year, sex)	Yes	Yes
Control(family background)	No	Yes
Observations	1,180	1,180
R-squared	0.098	0.118

NOTE: The parameters are results from separate regressions of equation (1) for employment, where the sample is restricted to individuals in Seoul. For other details, see the notes to Table 3.

Table 1.A10. Robustness: Sample for Public School Graduates

	(1)	(2)	(3)
	Log(earnings)	Log(saving)	Log(consumption)
Female high school	-0.186*	0.0714	-0.152
	(0.105)	(0.328)	(0.214)
Male high school	0.0515	-0.00988	-0.185
	(0.106)	(0.239)	(0.176)
Controls	Yes	Yes	Yes
Observation	555	1122	1121
R-squared	0.241	0.394	0.189

NOTE: The parameters are results from separate regressions of equation (1) for the logarithm of earnings, savings, and consumption, where the sample is restricted to individuals who graduated from public high schools. The control set includes the variables shown in the column (2) of Table 3. For other details, see the notes to Table 3.

Table 1.A11. Robustness: Sample for Private School Graduates

	(1) Log(earnings)	(2) Log(saving)	(3) Log(consumption)
Female high school	-0.147**	-0.305	-0.155
	(0.067)	(0.305)	(0.112)
Male high school	0.0933	0.109	0.225
	(0.240)	(0.452)	(0.147)
Controls	Yes	Yes	Yes
Observation	746	1560	1589
R-squared	0.151	0.172	0.153

NOTE: The parameters are results from separate regressions of equation (1) for the logarithm of earnings, savings, and consumption, where the sample is restricted to individuals who graduated from private high schools. The control set includes the variables shown in the column (2) of Table 3. For other details, see the notes to Table 3.

Table 1.A12. Desired Career Choice for Middle School Seniors

	(1) Manufacturing	(2) Communication	(3) Health care
Female high school	-0.007	-0.005	-0.064
	(0.006)	(0.005)	(0.129)
Male high school	-0.009	-0.033	0.069
	(0.008)	(0.031)	(0.142)
Controls	Yes	Yes	Yes
Observations	333	333	333
	(4) Entertainment	(5) Finance	(6) Construction
Female high school	0.022	0.010	0.028
	(0.097)	(0.011)	(0.031)
Male high school	-0.007	-0.042	-0.023
	(0.121)	(0.051)	(0.025)
Controls	Yes	Yes	Yes
Observations	333	333	333
	(7) Food and hotel	(8) Business service	(9) Public
Female high school	-0.019	0.052	-0.024
	(0.020)	(0.047)	(0.039)
Male high school	-0.010	0.105	-0.325
	(0.011)	(0.096)	(0.245)
Controls	Yes	Yes	Yes
Observations	333	333	333
	(10) Education		
Female high school	0.152		
	(0.096)		
Male high school	0.039		
	(0.101)		
Controls	Yes		
Observations	333		

NOTE: The table shows the placebo estimates for attending single-sex schools on desired career choice at age 15 (i.e., prior to assignment to high schools). Each dependent variable is an indicator that takes 1 if the desired job belongs to the category indicated in the column header. The control set includes the variables shown in column (2) of Table 3. Standard errors robust to clustering by high schools are reported in brackets. Statistical significance is indicated by * at the 10% level, ** at the 5% level, and *** at the 1% level. For other details, see the notes to Table 4.

Table 1.A13. Network and Social Skills for Middle School Seniors

	(1) Getting along with classmates	(2) Having concern about friendship
Female high school	-0.087	0.160
	(0.197)	(0.261)
Male high school	0.100	-0.093
	(0.273)	(0.298)
Controls	Yes	Yes
Observations	333	333

NOTE: The table shows the placebo estimates for attending single-sex schools on the majors for social skills at age 15 (i.e., prior to assignment to high schools). The dependent variable in the column (1) is an answer by a respondent for a question whether a student gets along with classmates. The dependent variable in the column (2) is an answer by a respondent for a question whether a student has a concern about the relationship with a friend. The dependent variable is scaled from 1 (strongly disagree) to 5 (strongly agree). The control set includes the variables shown in column (2) of Table 3. Standard errors robust to clustering by high schools are reported in brackets. Statistical significance is indicated by * at the 10% level, ** at the 5% level, and *** at the 1% level. For other details, see the notes to Table 4.

B. Data Appendix

B.1. Data Source

We use data from *KEEP*, an individual-level longitudinal survey by *KRIVET* as a government institution from 2004 through 2015 to analyze the effect of attending a single-sex school on labor market outcomes. KEEP comprises longitudinal data, extracting representative samples from among the population group and following them for over 10 years. The first wave started in 2004, and a total of 6,000 individuals were selected as the target of this survey, comprising 2,000 middle school seniors, 2,000 high school seniors, and 2,000 vocational and technical high school seniors. Furthermore, parents, teachers, and school administrators were surveyed to understand the environment around them. The data are expected to contribute to the establishment of policies and in-depth studies on the current status of education, the educational effect, and the linkages between education and labor markets. The KEEP questionnaires are publicly available on the KRIVET website through the following link (https://www.krivet.re.kr/eng/eu/eg/euCCALs.jsp). Furthermore, the main results of the data and survey are also available on the KRIVET website (https://www.krivet.re.kr/eng/eu/eg/euCDAIn.jsp). However, the use of information on detailed school districts and school names has been restricted by KRIVET. To obtain the confidential detailed data, individuals must apply to KRIVET for data access. Specifically, we sent the purpose of the research, how we would use the data, and the detailed research plan to the person in charge at KRIVET. We also agreed with the data usage and with providing necessary information to KREVIT such as future publication on this project. No fee was charged for the data use. Because of these circumstances, the data cannot be disclosed to third parties and cannot be used for purposes other than research. It is expected that reasonable applications will be accepted. Upon request, we can provide the contact address and are willing to assist persons interested in the data.

B.2. Definition of Variables

Table 1.B1. Definitions of Variables in Table 1

1	Number of students in high school
2	Number of teachers in the high school
3	The school is private high school
4	Average attendance rates of the students
5	Dropout rates of the students
6	Disciplinary action rates of the students
7	Number of students entering universities in Seoul after graduation
8	Number of students entering job market after graduation
9	Academic performance of the high school relative to the near schools
10	Average level of teachers' ability in the high school
11	Average level of teacher and student relationship in the high school
12	Average level of class atmosphere in the classroom
13	Facility condition in the high school
14	Local environment near the high school
15	Commuting condition of students to the high school

NOTE: The table indicates each definition of variables in the Table 1. From 9 to 15, the values are measured by school administrator of each high school and scaled from 0 to 1.

Chapter 2

Does Labeling Air Pollution Levels Matter? Evidence from Consumption of Respiratory Medicine in South Korea

Abstract

In this paper, we analyze how a change in the labeling (guideline) regarding exposure to air pollution affects the consumption of respiratory medicine. In 2018, the Government of South Korea changed air pollution warning standards to a level that was more severe than it was in reality and as compared to earlier, thereby causing people to perceive a greater danger from air pollution than they previously did. Exploiting exogenous policy change and district-level spatial variation, we find that one additional day labeled "bad" after the new guideline is associated with an increase in consumption of medicine related to the respiratory system by 0.9% per person. A heterogeneous analysis reveals that 1) the impact is smaller in one day of consecutive days of bad air pollution than a single day of bad air pollution, 2) the impact is greater for pharmacy and primary care hospitals than tertiary health centers, and 3) the impact varies by type of medicine.

2.1 Introduction

Air pollution is one of the most important factors influencing overall overall quality of life. Air pollution poses a large threat to human health worldwide, and approximately 91% of people are exposed to air pollution, which puts them at increased risk for various diseases (World Health

Organization (2021)). Consequently, 4.2 million people die every year due to ambient outdoor air pollution. The main air pollutant and cause for bad health is fine particulate matter, called PM2.5, which is essentially particles that are 2.5 micrometers (μm) or less in diameter. Since the particles are tiny, they are invisible and easily penetrate deep into the respiratory tract and even reach the lungs. Many scientific papers show that daily exposure to fine particles can reduce lung function, cause diseases such as asthma and chronic bronchitis, and increase mortality from lung cancer and heart disease (Boldo et al., 2006; Currie and Walker, 2011; Haikerwal et al., 2015; Hammitt and Zhou, 2006; Jia and Ku, 2019; Martuzzi et al., 2006; Neidell, 2004; Zhang and Cao, 2015; Zheng et al., 2015). Thus, addressing air pollution is indispensable for improving human welfare.

Although the importance of air pollutants is widely recognized, it is not easy for many countries to decrease PM2.5 emissions. In particular, industrial development in numerous developing countries leads to a high level of these emissions, which is a consequence of achieving sharp economic growth; these emissions tend to spread rather far from the origin through wind flow, even to other countries, thereby making it a global problem. Consequently, although numerous countries are attempting to reduce the levels of air pollution, they cannot trace its origins and, thus, there is loss of life expectancy (Lelieveld et al., 2020). Thus, given the difficulty of reducing air pollutants in the origin country, it is important to implement policies that do not affect merely the supply side of air pollution.

South Korea is one of the countries that suffers from severe air pollution. The country is forecasted to have the highest premature death rate due to air pollution in countries belonging to the Organization for Economic Cooperation and Development (OECD) (OECD, 2016).[1] To address this hazardous situation, South Korea implemented new regulations that do not simply regulate firms but also work to influence the perceptions of people toward air pollution.[2]

[1] Fine particle emissions from China are one of the main factors responsible for harming the air quality in South Korea (Jia and Ku, 2019).

[2] The Korean government is now also trying to make an agreement with the Chinese government to jointly reduce air pollution (Korea Herald (2020)).

Specifically, in 2018, the Korean government adopted a new policy that seeks to increase awareness of the seriousness of PM2.5 emissions by changing the standard of air pollution guidance for PM2.5. In the original version of the PM2.5 guideline, PM2.5 levels above 100 $\mu g/m^3$ were labeled "very bad," between 50 $\mu g/m^3$ and 100 $\mu g/m^3$ labeled "bad," between 15 $\mu g/m^3$ and 50 $\mu g/m^3$ labeled "normal,", and between 0 $\mu g/m^3$ to 15 $\mu g/m^3$ labeled "good". After changing the guideline, the PM2.5 levels are labeled "very bad" when the level is above 75; "bad" when the levels are between 35 and 75; "normal" when the levels are between 15 and 35; and "good" when the levels are between 0 and 15. Hence, the revised air pollution standards changed the guidelines for air pollution to more stringent ones. This drastic change in labeling to a much stricter standard changes the perception of people to believing that their area is more polluted than it was earlier, even though the actual pollution level remains the same. Since PM2.5 particles are invisible, it is difficult for people to know how harmful it is to the human body, and information on pollution levels in other surrounding areas is important for understanding the density of PM2.5 in their local areas.

This increased awareness of air pollution could potentially affect the behavior of individuals. One natural response would be increased health-seeking behavior, such as increased consumption of medicines related to the respiratory system. In the presence of the more severe labeling by the government, residents are likely to be more wary of PM2.5 and change their behavior toward health. This paper investigates whether this new air pollution standard policy that affects individual perceptions has an impact on the usage of medicines related to the respiratory system among residents. The policy implication is large, because cost-free adaptation will be feasible only if the effect is significant.

To test the above hypothesis, we employ difference-in-differences (DID) type of specifications by taking the following steps. First, we collect hourly-level data on air pollutants by district through air pollution monitors and calculate the daily average level of PM2.5. Then, we construct four sections based on the PM2.5 level, as depicted in Figure 1—section 1 from 0 $\mu g/m^3$ to 15 $\mu g/m^3$, section 2 from 15 $\mu g/m^3$ to 35 $\mu g/m^3$, section 3 from 35 $\mu g/m^3$ to 50

$\mu g/m^3$, and section 4 above 50 $\mu g/m^3$. The four sections are mutually exclusive and, therefore, all the daily PM2.5 observations must find their place in each section. Then, we categorize the total number of days into each section and create key independent variables at the monthly level. These key independent variables of the number of days in each section are interacted with an indicator for the time period after which the new labeling standard is applied; then, we test whether the new policy has an impact on the consumption of respiratory medicine. Section 3 is of main interest to us as it shows the change of labeling from "normal" under the old standard to "bad" under the new standard. The dependent variable is the consumption of respiratory medicines divided by the district population.

The key underlying assumption of this approach is that there are no unobservable factors that are correlated with the labeling change that could affect the evolution of respiratory medicine consumption. Although this assumption cannot be directly tested, we implement placebo tests to test the internal validity. First, we implement placebo tests for sections other than Section 3, because there was no labeling change for these sections after the policy change. Second, we implement placebo tests for medicines unrelated to the respiratory system, because air pollution affects only the respiratory system. The results of our placebo tests suggest that the underlying assumption is internally valid.

Exploiting district-level spatial variation and a DID type of specification, we find that adopting a stricter labeling (guideline) on air quality has a positive effect on the consumption of respiratory medicine. Our estimates suggest that one additional day labeled as "bad" after adopting the new air pollution guideline is associated with an increase of 0.9% in the consumption of respiratory medicine. The result suggests that adopting a stricter labeling guideline promotes health-seeking behavior by changing residents' perception of air quality and pollution. In contrast, we do not find a significant impact for sections 2 (normal) and 4 (very bad). This is consistent with the fact that there was no label change for section 2 (normal) after the guideline change and that only a handful of labels changed from "bad" to "very bad." The results are quantitatively robust to alternative specifications, control variables, functional forms, and hourly-level data. We

also pass the placebo tests for the placebo sections and placebo medicine consumption.

To further explore our analysis, we implement the following three extended analyses. First, we explore heterogeneity by different categories of hospital institutions. Our heterogeneous analyses show that there is little heterogeneous effect on pharmaceutical consumption across different medical institutions. Second, we explore heterogeneity by the consecutive days of "bad" levels of air pollution. Having additional days with the same label consecutively would decrease the level of concern among people, and the impact of a single day with the label would be stronger. Our result supports this hypothesis and reveals that the increase in the number of days that are labeled as "bad" levels of air pollution has a 0.5% higher level of response compared to the increase during consecutive days that are labeled as those with "bad" pollution levels. Finally, we explore the heterogeneity by medicine type, and find the effects are larger for respiratory medicine than other medicine which are less related to air pollution.

Our paper contributes to three streams of previous literature. First, the paper con- tributes to information provision. Previous studies typically emphasize the importance of salience and the lack of attention and indicate that information provision significantly changes the behavior of economic entities (e.g., Bhargava and Manoli, 2015; Chetty et al., 2009; Duflo and Saez, 2003; Farhi and Gabaix, 2020; Feldman and Ruffle, 2015; Finkelstein, 2009; Taubinsky and Rees-Jones, 2018) and price of goods markets (e.g., Allcott, 2011; Barber et al., 2005); Busse et al., 2006; Ellison and Ellison, 2009; Ferraro and Price, 2013; Grubb and Osborne, 2015; Jensen, 2007; Jessoe and Rapson, 2014).[3] Our paper contributes to the literature by placing greater focus on

[3]Ellison and Ellison, 2009 find that obfuscation of Internet price search engine tremendously decreases the sensitivity of demand. Barber et al., 2005 argue that the purchase of mutual funds by investors is influenced by salient, attention-grabbing information compared to the operating expenses. Busse et al., 2006 find that more salient cash incentive to the customers in the automobile industry results in larger customer surplus. Chetty et al., 2009 demonstrate the importance of salience by including tax-inclusive prices in grocery stores and check the behavioral responses of customers. Finkelstein, 2009 find the change in tax after adopting the electronic system in tolls makes people less aware regarding the payment, thereby lowering the price elasticity by decreasing the salience of the tax. Feldman and Ruffle, 2015 indicate that subjects spend more when the price of the products is posted exclusive of tax compared to the tax-inclusive price or tax-rebate price. Taubinsky and Rees-Jones, 2018 provide the theoretical and empirical evidence that the efficiency costs of taxation are amplified by differences in under-reaction across individuals and across tax rates. Farhi and Gabaix, 2020 develop the optimal taxation model by encompassing a wide range of biases such as misperceptions and internalities, which are partially produced by the salience effect. Duflo and Saez, 2003 indicate that retirement plan decisions may change when employees are provided benefits

the information provided by the central government and that related to environmental economics in the field of public policies. The number of extant papers regarding information provision by the central government in environmental economics is relatively small.[4]

Second, our paper also contributes to the literature on health economics that investigates the effects of various types of information on risk avoidance and health-seeking behavior (e.g., Ayers and Kronenfeld, 2007; Bickerstaff, 2004; Deguen et al., 2012; Gatersleben and Uzzell, 2000; Kim et al., 2012; Zwane et al., 2011)[5] Although these previous papers typically investigate the effect of information found during the course of the study or provided by other economic entities on health outcomes, our paper focuses more on information provided by policy experts and finds that the perception of experts significantly increases health-seeking behavior. We also contribute to the literature in health economics by focusing more on medicine consumption related to respiratory system in terms of decreasing risk and improving health condition.

Finally, our paper is also related to the impact of air pollution on respiratory outcomes. Previous papers typically show that fine particulate matter has negative effects on health (mainly

information, and Bhargava and Manoli, 2015 find the take-up rates of government transfer programs increase among those who are eligible when information is provided in a simple format. Grubb and Osborne, 2015 argue that consumers have a tendency of restricting their cell phone use minutes when they have information of an approaching higher price tier. Jensen, 2007 shows that the new information technology of mobile phones makes the fish market operate more efficiently. The behavioral response to the environmental policy is also influenced by the impact of social norms and information provision.

[4]Several papers study the information provision in environmental economics. Allcott, 2011 argue that providing information on electricity usage to residential utility customers as compared to that of their neighbors usage reduces energy consumption significantly. Ferraro and Price, 2013 conduct a field experiment and find that there is a significant impact of social norm messages on the residential water demand. In Jessoe and Rapson, 2014, information on residential electricity usage is more frequently provided to the residents, leading people to be three standard deviations more responsive to temporary price increases.

[5]In Zwane et al., 2011, subjects surveyed might show health-seeking behavior after the survey, which implies that the new information or more attention can lead to more frequent health-seeking behavior. Ayers and Kronenfeld, 2007 find that the more frequently people search health information on the Internet, the more likely they are to change their health-seeking behavior. More specifically, when a risk is more visible or more familiar, such as visible smog, people are usually more concerned (Gatersleben and Uzzell, 2000). Moreover, when the risk has known or observable consequences (e.g., frequent news coverage on the health impact of air pollution, having a child with asthma) and has more immediate physiological effects, concern scores will be higher (Bickerstaff, 2004). The subjective perception of the risks of air pollution may in itself play a role in health and quality of life, possibly even to a larger extent than the purely physical effects (Deguen et al., 2012; Kim et al., 2012). This may particularly be the case when the lay publicˆs perceptions of risk are larger than those of scientific and policy experts. This is often linked to broader social norms and attitudes toward air pollution and trust in the central government or in the communicator and it may differ among cities and countries (Bickerstaff, 2004; Gatersleben and Uzzell, 2000).

through damaging the respiratory system) by investigating the 'actual' change in air pollution (Boldo et al., 2006; Haikerwal et al., 2015; Zheng et al., 2015; Zhang and Cao, 2015; Martuzzi et al., 2006; Currie and Walker, 2011; Jia and Ku, 2019; Neidell, 2004; Hammitt and Zhou, 2006).[6] In contrast, we investigate the effect of 'subjective' change (labeling change) on the health outcomes. To the best of our knowledge, there is insufficient evidence to investigate the impact of the change in the perception of air pollution on respiratory-related medicine outcomes. This is because a change in the air pollution guideline is a rare event, and numerous OECD countries have adopted a stringent rules regarding air quality control for ambient air quality (Klimont et al., 2013).

The remainder of this paper is organized in the following manner: The next section discusses institutional background, and Section 3 provides the data. Section 4 describes the identification strategy, and Section 5 presents empirical results. Section 6 discusses the underlying mechanisms, and Section 7 presents the robustness and placebo tests. Finally, Section 8 concludes.

2.2 Institutional Background

2.2.1 PM 2.5 Air Pollution Standard

Air pollution poses a large threat to human health. According to the World Health Organization (2021), approximately 91% of people worldwide are exposed to air pollution levels

[6] According to Deguen et al., 2012, air pollution causes not only physical damage but also psychological damage, which suggests the possible explanation of how the guideline change affects health-related human behavior. This is more evident in the explanation given by Elliott et al., 1999. In this paper, people display psychosocial effects (i.e., worry and concern for future health) when there is an increase in perceived air pollution. A few studies have found a significant association between objective air pollution and health-related quality of life (Yamazaki et al., 2005; Yamazaki et al., 2006; Fleury-Bahi et al., 2015). Others have shown an effect of living in environmentally hazardous neighborhoods (industrial activities, incinerators, and mining areas) on psychological well-being and self-rated health (Lima, 2004; Downey and Van Willigen, 2005; Marques and Lima, 2011; Zullig and Hendryx, 2011). Certain studies have also suggested that the evaluation of the risk of potential health effects from exposure to environmental hazards and pollution can be an important predictor of perceived health (PH) and psychological well-being (Lima, 2004; Wind et al., 2004; Peek et al., 2009; Stenlund et al., 2009). This implies that lower quality of life, stress, and poor PH can be related not only to objective exposure but also to the subjective perception of environmental hazard. It reveals the link between how perceptional change through the air pollution guideline change makes an impact on medicine consumption.

that put them at increased risk for diseases, and 4.2 million people die earlier than expected every year due to ambient outdoor air pollution. The main air pollutant that causes adverse effects on health is fine particulate matter (PM2.5), which penetrates into the respiratory system and causes critical diseases such as lung malfunction, asthma, chronic bronchitis, lung cancer, and heart disease.

As a response to the growing concern related to air pollution and PM2.5 levels, numerous OECD countries have adopted a stringent control measures to maintain ambient air quality (Klimont et al., 2013). Among these countries, South Korea is expected to have the highest premature death rate due to air pollution in OECD countries (OECD, 2016). However, simply regulating the domestic supply side of air pollution is not effective in South Korea, because fine particles spread to far distances from the origin, and PM2.5 emissions from China are a threatening factor for worsening the air quality in South Korea (Jia and Ku, 2019). Controlling the source of such emissions (supply side) in other countries is not easy, because it relates to international politics.

Thus, faced with this hazardous and difficult situation, the Korean government implemented a policy that also affects the demand side (perceptions) of air pollution for Korean citizens that could potentially change their behavior. The Ministry of Environment in South Korea had used the PM2.5 atmosphere environmental standard since 2011, thereby enabling Korean citizens to easily access information on the PM 2.5 forecast and risk. However, the forecast standard of PM2.5 was not sufficiently stringent compared to other developed countries. Thus, the Korean government revised the standard on March 27, 2018 and enforced the new guideline for air pollution pertaining to PM2.5 emissions by making it stricter than the past standard, thereby following the international standard.

Panel (a) of Figure 1 illustrates the original poster of the Korean Ministry of Environment to explain the change in the pollution warning standard beginning March 27, 2018. According to Figure 1, the labels of “good” and “normal” are regarded as safe to spend time outside. In contrast, the poster shows that people should consider reducing prolonged or heavy exertion

in days labeled as "bad." Further, in days labeled as "very bad," people should reduce outdoor activities and remain indoors. Panel (b) of Figure 1 illustrates the simplified version of the policy change. After the reform, the interval of the label "good" did not change, whereas the "normal" tag changed from between 15 and 50 to between 15 and 35 of PM 2.5. Similarly, the "bad" label changed from between 35 and 75 to between 50 and 100, and the range from 75 to 100 was tagged as "very bad" instead of "bad." Among these changes, the range between 35 and 50 was earlier labeled "normal"; for this to now being labeled "bad" is the biggest policy change in terms of exposition.

Theoretically, this policy change on air pollution standard has an impact on individual awareness, because the actual level of air pollution does not change. In fact, according to the survey on the national environmental consciousness conducted by the Korea Environment Institute in 2018, 76.7% of respondents report that they regularly check the air pollution level, and 42.4% of people check the air pollution information every day (Soeun et al., 2018). Therefore, a change in the air pollution guideline impacts numerous residents in South Korea who regularly monitor the air pollution level.

Figure 2 depicts the example of days labeled by each category in accordance with both old and new pollution guidance. In April 2018, at a district called Yeongju-si, 25 days in a month used to be labeled as "normal" before the policy change; however, many of them are labeled as "bad" under the new rule, even though the actual level of pollution remains unchanged. In comparison, days labeled as "good" remain the same as earlier and after the policy change because there is no change in the interval that defines a good day. Similarly, there is only one day labeled as "very bad" in the new guideline, which is a very rare case. Thus, the figure illustrates that the policy change had a significant impact on days that were previously categorized as "normal."

2.2.2 The Korean Medical System

With regard to the Korean medical system, the National Health Insurance (NHI) mandatorily covers all citizens in South Korea as a rule under the law. According to the law, all citizens pay a monthly insurance fee to the NHI based on their job, number of members in the household, and number of assets. By using this insurance, people can use the health care services provided by any institution in South Korea and the NHI covers a partial portion of the cost, including doctor's examination, medicine consumption, and hospital admission.

Further, hospital or pharmacy service providers report the total amount of health service fee to Health Insurance Review and Assessment Service (HIRA), the national health insurance government institution. HIRA assesses the entire process and decides whether it will provide the insurance payment to the hospital or pharmacy. After the decision is made, HIRA asks NHI to pay the insurance to the health care provider, and the provider receives the requisite money amount from the NHI.

2.3 Data

We create county-level monthly panel data that includes information on medicine consumption and air quality spanning three years from 2016 to 2019.

2.3.1 Data on Medicine Consumption

Data on medicine consumption are derived from HIRA, which provides data in an open big data service format. All data regarding medical transactions is recorded by the HIRA, and we collect the data on the quantity and money spent on medicines categorized as code level 3 by the Anatomical Therapeutic Chemical (ATC) Classification System, which categorizes drugs into different groups according to the organ or system on which they act and their chemical, pharmacological, and therapeutic properties. The active substances are classified in a hierarchy with five different levels. The system has 14 main anatomical/pharmacological groups or first

levels. Each ATC group is divided into second levels, which could be either pharmacological or therapeutic groups. The third and fourth levels are chemical, pharmacological, or therapeutic subgroups, and the fifth level is chemical substances WHO (2018). Drug consumption statistics are available for each of these five levels. Detailed ATC codes are provided in the Appendix.

Using this data source, we create the dependent variable: the quantity of monthly pharmaceutical consumption. HIRA also discloses the type of medical institutions in which respiratory medicine is prescribed: primary level hospital, secondary level hospital, tertiary level hospital, and pharmacies.[7] In our extended analysis, we estimate heterogeneous treatment effects by the type of medical institution in which the respiratory medicine is prescribed.

2.3.2 Air Quality Data

We collect air quality data from the Korean Ministry of Environment. This data is publicly available on the Internet, and there are 350 air pollution monitors measuring air pollutants in an hourly basis. These monitors record six categories of air pollutants—Particulate Matter 10 (PM10), Particulate Matter 2.5 (PM2.5), Ozone (O3), Carbon Monoxide (CO), Sulfur Dioxide (SO2), and Nitrogen Monoxide (NO).

Based on the air quality observation data, we can count the number of days with different air pollution labeling at the district level. Figure 3 illustrates the number of days in our sample that were labeled "normal" in terms of PM2.5 emissions and were changed to "bad" by the reform in the guideline. The left panel reports the number of counties that have at least one day labeled as "bad" within a month. In the left panel, the blue bars indicate the numbers under the old rule by year, and the orange bars report the numbers under the new standard by year. The right panel reports the total number of days labeled as "bad" by year in all counties under the old rule (green bars) and new rule (red bars). Both panels indicate that the new labeling change increases the number of counties that have at least one day labeled "bad" and the total number of

[7] According to the Korean hospital category, tertiary hospitals are divided into two kinds—general hospital and certified tertiary hospital.

days labeled “bad.”

Figure 4 presents a geographical illustration of how many day changed from “normal” to “bad” by county in April 2018 relative to March 2018. The figure reveals that the change in labeling is more concentrated in the non-metropolitan areas than metropolitan areas, as indicated by the red boundaries. This is because metropolitan areas already had many days labeled as “bad.” In contrast, non-metropolitan areas had many days of the PM2.5 level between 35 and 50. Thus, the change in the labeling guideline had a greater affect on non-metropolitan areas.

Figure 5 presents the monthly average level of PM 2.5 in South Korea as a function of time. The figure indicates that the actual level of PM2.5 did not change after the policy change in April 2018, thereby suggesting that the policy change mainly affects peoples’ perceptions. The red horizontal line indicates the time at which the new policy was adopted, March 2018, and the left window is two years from this and the right window is one year from this. The seasonality of the PM 2.5 and the overall level variation across the years is evident from the graph; moreover, there is no significant decrease in air pollution level after the new policy. There is almost no difference between pre-mean value and post-mean value of PM 2.5, which demonstrates that the policy change does not affect the actual level of PM2.5 but the perceptions toward PM2.5.

2.3.3 Summary Statistics

Table 1 presents the summary statistics for our data set. The table reports the means, standard deviations, minimum values, and maximum values of each variable. The primary dependent variable is the total quantity of medicines consumed per person, which has the mean of 1.198 and the standard deviation is 1.614. The population in the second row shows the number of residents by district. The next four rows report the number of days categorized in each section. Section 1 reports the number of days within a month in a district with a daily average PM2.5 level between 0 and 15. Section 2 reports the number of days that have a daily average PM2.5 level between 15 and 35. Section 3 reports the number of days that have daily average PM2.5 level between 35 and 50, and section 4 reports the number of days with a daily average PM2.5

level of over 50. Furthermore, six categories of air pollutants are also measured, including SO2, CO, O3, NO2, PM10, and PM2.5. CO, NO, O3, and SO2 use parts per million (PPM) as their units, and PM10 and PM2.5 use microgram per cubic meter $\mu g/m^3$ as their units.

2.4 Identification Strategy

To identify the impact of a change in air pollution guidelines on the usage of pharmaceuticals usage, we first define sections based on the range of PM2.5 level. As shown in panel (b) of Figure 1, we create a total of four sections, and each section shows the range of daily average PM2.5 level. Section 1 ranges from 0 to 15 $\mu g/m^3$ of the daily average PM2.5 level. Section 2 ranges from 15 to 35 $\mu g/m^3$. Section 3 ranges from 35 to 50 $\mu g/m^3$, and section 4 ranges above 50 $\mu g/m^3$. Then, we calculate the number of days categorized in each section. The summation of four sections is equal to the number of days within a month, and each section is mutually exclusive.

Under the old rule, section 1 is labeled as "good"; section 2 is labeled as "normal"; section 3 is also labeled as "normal"; section 4 is labeled as "bad" until 100 $\mu g/m^3$ and as " very bad" after 100 $\mu g/m^3$. After the new rule, the label for sections 1 and 2 remain same. However, the label for section 3 becomes "bad." Therefore, the main change in labeling occurs in section 3. For section 4, though "very bad" begins from 75 $\mu g/m^3$ under the new rule, we pool section 4 as above 50 $\mu g/m^3$ because there are very few days with PM2.5 levels of above 75 $\mu g/m^3$.

After creating four sections based on the PM2.5 level, we run the following fixed effect model:

$$\begin{aligned} Ln(Quantity/Population)_{a,d,t} = {} & \alpha + \beta_1 Section\ 2_{a,d,t} + \beta_2 Section\ 2 \times Post_{d,t} \\ & + \beta_3 Section\ 3_{d,t} + \beta_4 Section\ 3 \times Post_{d,t} + \beta_5 Section\ 4_{d,t} \\ & + \beta_6 Section\ 4 \times Post_{d,t} + Air\ Pollutants_{d,t}\Gamma + District_d \\ & + Year_t + Month_t + \varepsilon_{a,d,t} \end{aligned} \tag{2.1}$$

$Ln(Quantity/Population)_{a,d,t}$ is the logarithm of the quantity of respiratory medicine used divided by the population categorized by ATC code a in a district d at month t. This dependent variable indicates the number of medicines that are consumed per person in a district d at time t per month in log values. The independent variables $Section\ 2_{d,t}$, $Section\ 3_{d,t}$, *and* $Section\ 4_{d,t}$ indicate the number of days that belong to each section in month t in district d. *Section* 1 is omitted to avoid multicollinearity and the baseline in this model. $Post_{d,t}$ is an indicator for the time after adopting the new air pollution guidance. Therefore, the interaction term between *Section* and *Post* indicates the impact of a change in guidance on the dependent variable after the policy change. $Air\ Pollutants_{d,t}$ are the vector of control variables for air pollutants, including PM10, PM2.5, SO2, CO, O3, and NO2. These variables can capture not only the direct effect of air pollutants PM10 and PM2.5 on the dependent variable but can also control the possible endogeneity caused by the correlation between the main explanatory variables—the sections—with SO2, CO, O3, and NO2. $District_d$, $Year_t$, and $Month_t$ are fixed effects to control for the observable and unobservable factors across district, year, and month. β_3 captures the effect of the actual level of PM2.5 between 35 and 50 on the consumption of respiratory medicines before the policy change. Our primary interest is β_4—the coefficient of the interaction term—which captures the heterogeneous effect of recognition as "bad" by the labeling the change in the consumption of respiratory medicines. In other words, since we use interaction terms, we assume that the slope of the effect of section 3 on medical consumption is different before and after the policy change, and β_4 indicates how the slope is different.

The underlying assumption of this approach is that there are no unobservable factors that correlate with the labeling change that could affect the evolution of the consumption of respiratory medicines. Although this assumption cannot be directly tested, this study provides empirical evidence to support the internal validity of our research design. Most importantly, we implement placebo tests for interaction terms for section 2, as there was no labeling change for the section by the policy change. Thus, if the slope of the regression line is significantly different before and after the policy change for the section, then that would violate the internal

validity. We also implement other placebo tests that estimate the effect of labeling change on medicine other than respiratory medicine since they are unrelated to air pollution. The results of our placebo tests suggest that our underlying assumption is internally valid.

2.5 Empirical Results

2.5.1 Main Results

Table 2 reports the estimates based on the above estimation equation. The dependent variable is the logarithm of the number of respiratory medicines consumed per person. In column (1), we only include year- and month- fixed effects. In column (2), we add district fixed effects. Moreover, in column (3), we control for the level of air pollutants for PM10 and PM2.5 and add the other air pollutants (SO2, CO, O3, and NO2) in column (4).

Our primary interest is the estimate for Section $3\times Post$, which captures the heterogeneous effect of a change in the labeling from "normal" to "bad" on the consumption of respiratory medicine. The estimates are positive and statistically significant across specifications, thereby suggesting that the change in labeling significantly increases consumption of respiratory medicine. In column (1) with year fixed effect, the estimate is 0.01 ($p < 0.05$). After adding the district fixed effect in column (2), the magnitude decreases slightly but the statistical significance increases ($p < 0.01$). Furthermore, adding the PM10 and PM2.5 levels in column (3) and other air pollutants in column (4) do not change the magnitudes and statistical significance ($p < 0.01$), thereby suggesting that the estimates are robust across specifications. The estimate in column (4) is 0.0086, which implies that one additional day labeled "bad" after the policy change is associated with an increase of 0.86% in the consumption of respiratory medicine per person. Our preferred specification is Column (4), with all the fixed effects and control variables, here and in what follows.

Section $2\times Post$ in the second row presents the results of the placebo test. The estimates indicates the impact of the number of days with PM2.5 levels between 15 and 35 on the dependent

variable after the policy change, although there is no change in labeling in this category. As expected, the estimates are all statistically insignificant across specifications, providing evidence of the internal validity of our research design. The first row, section 2, indicates the impact of the number of days in the interval of 15 to 35 of PM2.5 level on the dependent variable before the guideline change. The estimates are all statistically insignificant across specifications.

Section 4, in the fifth row, indicates the impact of the number of days in which the PM2.5 level is above 50 on the dependent variable before the policy change. The estimates are positive and significant only in specifications (2) and (3). Section 4$\times$Post in the sixth row indicates that the estimates are not statistically significant, thereby suggesting that the effect of the guideline change on this section is limited. This is consistent with the fact that the number of days categorized as "very bad" are very few.

Overall, the table shows that the policy change increases consumption of respiratory medicines in the section in which the guideline changed, but did not increase the consumption of respiratory medicine in the sections in which the guideline did not change.

2.5.2 Heterogeneity

We find that the severe labeling change in PM2.5 levels significantly increases the consumption of respiratory medicine. The treatment effect is robust across alternative specifications and are different from placebo effects. This effect of labeling change could also differ across groups, such as hospital institutions and medicine type. In this subsection, we investigate the heterogeneous effect by group.

Category of Hospital Institutions

There are different categories of hospital institutions that provide medicines to patients. We categorize these institutions into six groups depending on the definition of HIRA: a small hospital, medium-sized hospital, large sized hospital, nursing hospital, pharmacy, and other institutions. A small hospital is one with less than 30 beds. A medium-sized hospital has more

than 30 and less than 100 beds. A large (general) hospital has more than 100 and less than 500 beds. A nursing hospital is used only for nursing purposes. A pharmacy provides drugs and medications but does not provide medical treatment. Other medical institutions include public health centers, dental clinics, and oriental hospitals. To examine the heterogeneous effect by medical institution, we run separate regressions by the above different institution type.

Table 3 presents the regression result for the log of respiratory medicine consumption. Each column reports the estimate by medical institution indicated in the column header. For the first explanatory variable, section 3, there are a few changes in the sign based on various institutions. The scale of coefficients is rather small across all columns, and there is no significance in any column. In the case of Section 3 $\times$ Post, all columns show highly significant power with positive values. The smallest coefficient is for the Etc group, such as a public health center or oriental hospital, and a relatively large effect is found in the pharmacy sector. This largest effect is sensible, thereby reflecting that the pharmacy would be the most accessible place to buy over-the-counter (OTC) products without a prescription. However, the scale of coefficients is very similar across all institutions, which may indicate that the policy effect of additional days labeled "bad" is captured in most of the hospital institutions. Section 2 indicates positive and somewhat statistically significant results based on different categories. These results are insignificant for the pharmacy but relatively more significant in the case of a nursing hospital. Moreover, the results in Section 2 $\times$ Post are less significant overall as compared to those in Section 2, and almost all institutions show insignificant coefficients except medium-sized hospitals, and column 6. Section 4 shows significant results in all categories, which implies the days with PM 2.5 levels within the 50 and above intervals show that an additional day in this interval is positively correlated with medicine consumption before the guideline change. However, after the guideline change, the section has less and insignificant results, as shown in the section 4 $\times$ Post row variable, although there are a few significant results for medium-sized hospitals and nursing hospitals.

Air Pollution in Consecutive Days

The law of diminishing marginal returns is a common economic principle. In a certain sense, we hypothesize that this principle applies to risk avoidance behavior in a reverse manner. This implies that when people are exposed to danger for a long time, then their awareness and subjective apprehensions about it may decrease with time. To check this, we divide one section into sections with consecutive days and an isolated day.

Specifically, *section 3 (consecutive days)* indicates the number of days on which two or more than two consecutive days are categorized in section 3. On the other hand, *section 3 (consecutive days)* counts the number of days in which yesterday and the next day do not belong to section 3. The sum of the number of days in section 3 (consecutive days) and the number of days in section 3 (non-consecutive days) should be equal to the number of days in section 3 by definition. This regression framework follows the concept of difference-in-difference-in-differences (DDD).

Table 4 shows that *section 3 (consecutive days)*$\times$*post* and *section 3 (not consecutive days)*$\times$*post* show both positive and statistically significant results across different sets of specifications. All columns include section 2, section 2 $\times$ post, section 4, section 4 $\times$ post variables, and fixed effects. Columns 2 and 3 include more control variables pertaining to PM 2.5 level. In column (3), the coefficient of section 3 consecutive post indicates that one more day labeled as "bad" after the policy change is associated with an increase of 0.736% in the consumption of respiratory medicines. For the coefficient of section 3 isolated, the coefficient is 1.23%. This is consistent with our hypothesis that consecutive days labeled "bad" make people less aware and less concerned about the air quality as time goes by.[8]

[8]One can argue that people visit health care institutions and get medicine in the first day of consecutive "bad" days, and consume the medicine not only the day they receive it but also later on the following consecutive days. In this case, they do not have to go to the institutions to purchase the medicine the next day or later and, therefore, this consumption remains hidden. However, the total amount of medicine that a patient receives is recorded and, therefore, it is still sensible to think that section 3 of isolated days show a larger effect.

2.6 Placebo and Robustness

2.6.1 Placebo Test for the Consumption of Non-respiratory Medicine

In our main analysis, we have already showed the result of the placebo test of the impact on medicine consumption of no change in guidelines in section 2. As another placebo test, we estimate the placebo effect of the guideline change on the consumption of medicines that are unrelated to the respiratory system. The impact of a labeling change on the consumption of unrelated medicines should be small or zero. Thus, we run regressions for medicine consumption for the musculoskeletal system and dermatological medicines.

Table 5 presents the result of the placebo test. In the first and third columns, we control for fixed effects and air pollutants. In the second and fourth columns, we additionally control for the pharmaceuticals CPI. The result reveals that the impact of labeling change from "normal" to "bad" does not reject the null hypothesis. The estimated coefficients of section 3 $\times$ Post for the consumption of musculoskeletal system and dermatological medicines are close to zero across specifications, thereby providing supportive evidence for the main result. Overall, the result of the placebo test is consistent with our main result.

2.6.2 6.2 Sensitivity to Particulate Matter 2.5

In Table 6, we implement the sensitivity analysis in response to the different functional forms of the PM 2.5 control variable. It would be worthwhile to check whether the different functional forms of PM 2.5 makes the coefficient of section 3 $\times$ post to change. In the first column, we use the linear functional form for the PM 2.5 level control. In the second column, we additionally control for the squared PM 2.5 level. By adding the squared variable, we allow the functional form of PM 2.5 to be non-linear. This indicates that the relationship between pharmaceutical consumption and PM 2.5 is linearly calculated in the first column, and the curvature is allowed in the second column without change in the sign of the second derivative. In the third column, we additionally control for the cubed PM 2.5 level, which makes the functional

form of PM 2.5 more lenient.

The estimates of section 3 $\times$ post is positive and statistically significant at the 1% level across specifications—0.0085 in the first column, 0.0083 in the second, and 0.009 in the third column. The result is consistent with the main result, and the functional form of PM 2.5 does not drastically change the estimate of our main interest. The result reveals that our result is quantitatively robust to different functional forms and specifications.

2.6.3 Fraction of Hours

In the main table, a section indicates the number of days for a certain PM 2.5 level within a certain interval. In this expansion, we capture the hours information instead of days to see the impact of hours that are labeled as "bad" on the consumption of medicines. To construct the new section variable based on hours instead of days, we use hourly level PM2.5 data and calculate the fraction of hours for each section.

$$Fractional\ section\ 3_{d,t} = \left(\frac{Hours\ (35 \leq PM2.5 < 50)}{Total\ monthly\ hours}\right)_{d,t} * 100 \tag{2.2}$$

$Fractional\ section\ 3_{d,t}$ indicates the percentage of hours which has a PM 2.5 level greater or equal to 35 and less than 50 from among the total monthly hours. There can be some variation of PM2.5 level even within a day, and the labeling of average daily PM 2.5 might exclude some of this information. By using this hourly level variable, we can check whether our result for a daily basis is robust to the hourly result.

Table 7 presents the results based on hourly data. The main result does not change across specifications. In column (1) without air pollutants and pharmaceuticals CPI controls, the estimate of section 3 $\times$ post is positive and statistically significant at the 1% level. The increase in the number of hours within a month in the interval of PM 2.5 between 35 and 50 is associated with the increase in consumption of medicines by 0.548%. The result is robust across different sets of control variables in columns 2 and 3 with air pollutants and CPI controls. In addition, the

magnitude of the estimate is almost the same and statistically significant at the 1% level. Thus, our result on a daily basis is robust to the result based on hourly data.

2.7 Discussion and Conclusion

Changes in the guidelines of air pollution is a rare occurrence. In this paper, we focused on the case of South Korea when it changed air pollution guidelines on March 27, 2018 to more severe levels and caused the population to perceive a more serious level of air pollution than the actual level. We utilized this policy change to measure how the change in guidelines on air pollution affected the behavior of residents, particularly in terms of the consumption of medicines. In this specific policy change, the change of labeling from "normal" to "bad" in section 3 is essential. Using a DID specification and medicine and air quality data, we find that an additional day labeled as "bad" after the policy change (the day belongs to section 3) is statistically significant and positively associated with an increased consumption of medicine per person by 0.92%. Other sections do not show statistically significant results, thereby reflecting no labeling change. The results are quantitatively robust to alternative specifications, functional forms, and hourly-level data. We also pass the placebo tests for the placebo sections that were not affected by the policy change and placebo medicine consumption that are unrelated to air pollution. Moreover, our heterogeneous analyses reveal that there is little heterogeneous effect on pharmaceutical consumption across different medical institutions and larger effects on a single day than on consecutive days belonging to the same section.

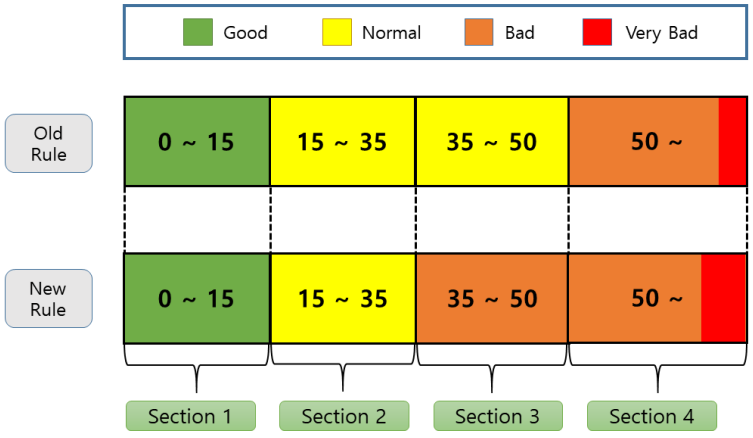
In terms of limitations, this paper focuses more on the short-run effects, and it would be interesting to ascertain long-run effects. The policy implication could differ by time horizons. In this paper, we showed that when there is a provision of information through a channel of salience regarding the levels of the invisible PM2.5, people respond promptly by increasing health-seeking behavior. More research on the topic from other aspects will enable an understanding of how government policy can enable people to improve their welfare.

2.8 Acknowledgements

Chapter 2, in full, is currently being prepared for submission for publication of the material. Lee, Youngju; Nakazawa, Nobuhiko. “Does Labeling Air Pollution Levels Matter? Evidence from Consumption of Respiratory Medicine in South Korea”. The dissertation author was the primary investigator and author of this material.

Level	Good	Normal	Bad	Very bad
Before (~3.26)	0~15	15~50	50~100	100~
After (3.27~)	0~15	15~35	35~75	75~

(a) Change in the Air Pollution Guideline (Original Government Poster)



(b) Change in the Air Pollution Guideline (Simplified Version)

Figure 2.1. Change in the Air Pollution Guideline

NOTE: (a) The figure presents the government poster related to the change in the air pollution guideline for particulate matter 2.5 (PM2.5). The table below the figure indicates how the new standard became more stringent compared to the last one. According to the policy change, the days with PM2.5 levels between 35 and 50 is labeled "bad", and a PM2.5 level between 75 and 100 is labeled "very bad" after the change in the guideline.
(b) The figure simplifies which part of the air pollution level has been affected by the change in the guideline. The main specification of this paper relies on the group that is indicated by a change in color to represent a difference between the old rule and the new rule in the interval between 35 $\mu g/m^3$ and 50 $\mu g/m^3$. Although there is another group that is indicated by a color change, between 75 $\mu g/m^3$ and 100 $\mu g/m^3$, there are not too many days on which the pollution levels are above 75 $\mu g/m^3$. Therefore, I focus on the first changed group.

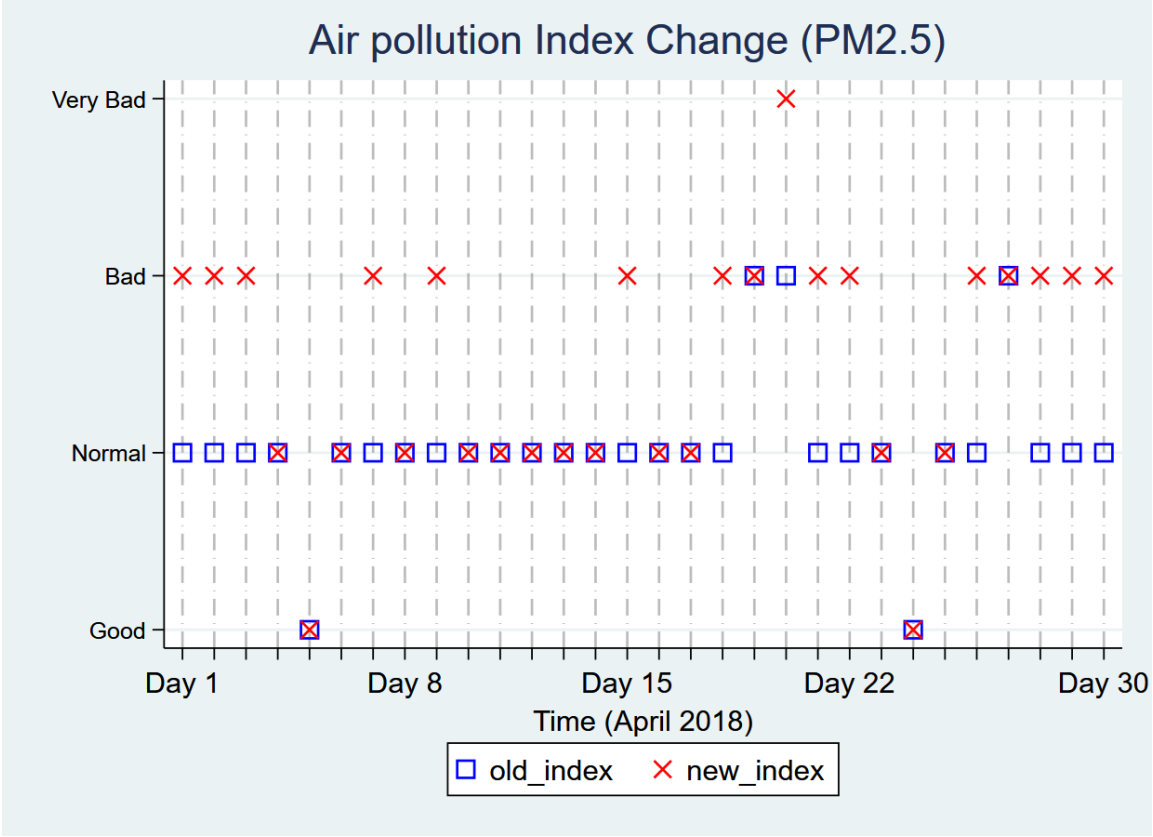


Figure 2.2. Example of Labeling Change in a County

NOTE: The figure indicates how many labels changed in a month because of the new air pollution standard. The specific month in this graph is April, and the x-axis indicates each day within a month. The y-axis presents the label indicating the different standards of air pollution. The blue hollow square is the original standard, and the red X label is the new standard. The county in this figure is Yeongju-si, Gyeongsangbuk-do Province.

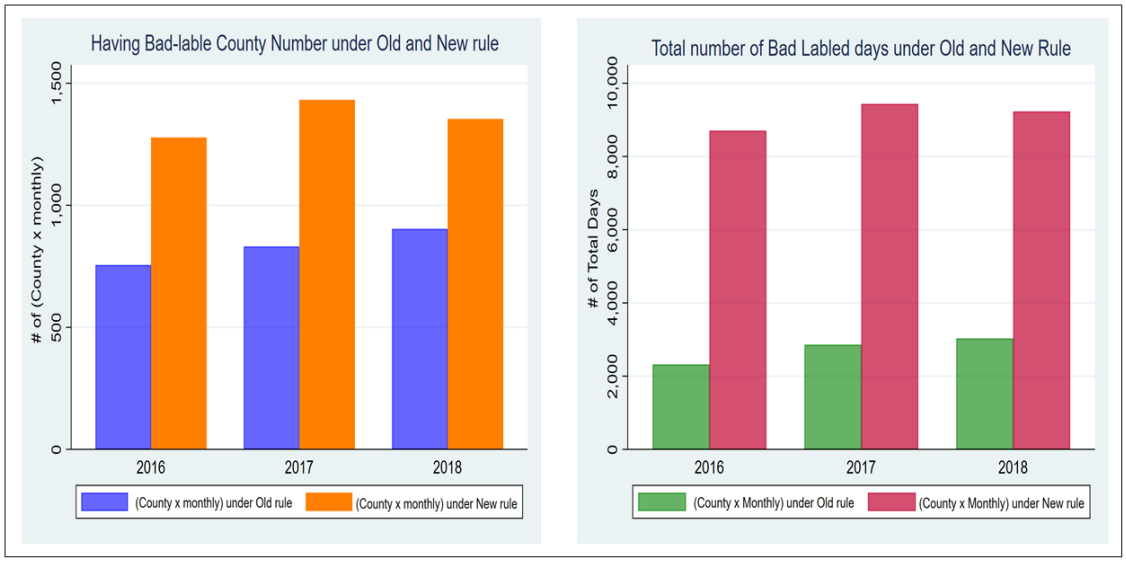


Figure 2.3. Changes in the Number of Days Labeled "Bad"

NOTE: The figure shows how many days have a changed daily average PM2.5 labeling from "normal" to "bad." The y-axis of the left graph presents the number of counties (districts) based on the monthly level when the county has at least one day labeled as "bad" within a month. The x-axis of the graph on the left presents the years 2016, 2017, and 2018. The y-axis of the graph on the right is the total number of days labeled "bad" in each year in all counties (districts) under both the old and new rules. The x-axis of the graph on the left presents the years 2016, 2017, and 2018.

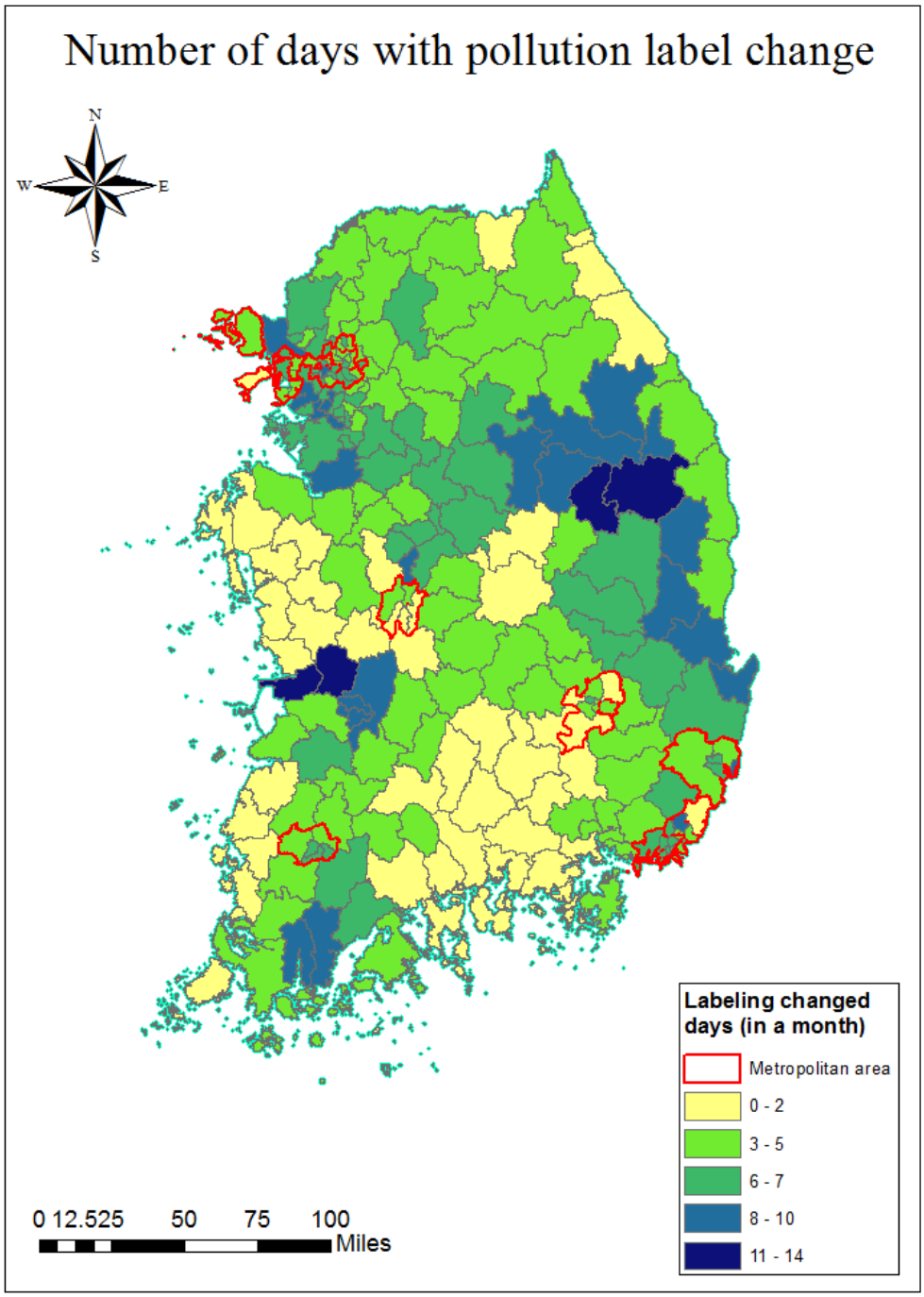


Figure 2.4. The Number of Days with a Change in the Pollution Label in April 2018

NOTE: The figure shows the number of changes in the pollution label by each county in April 2018. There are five classes for the category of label changes, and the red line indicates the boundaries of metropolitan cities. We interpolate the air pollution level for the counties that do not have any air pollution monitor by using nearby air monitors based on the inverse-distance weight.

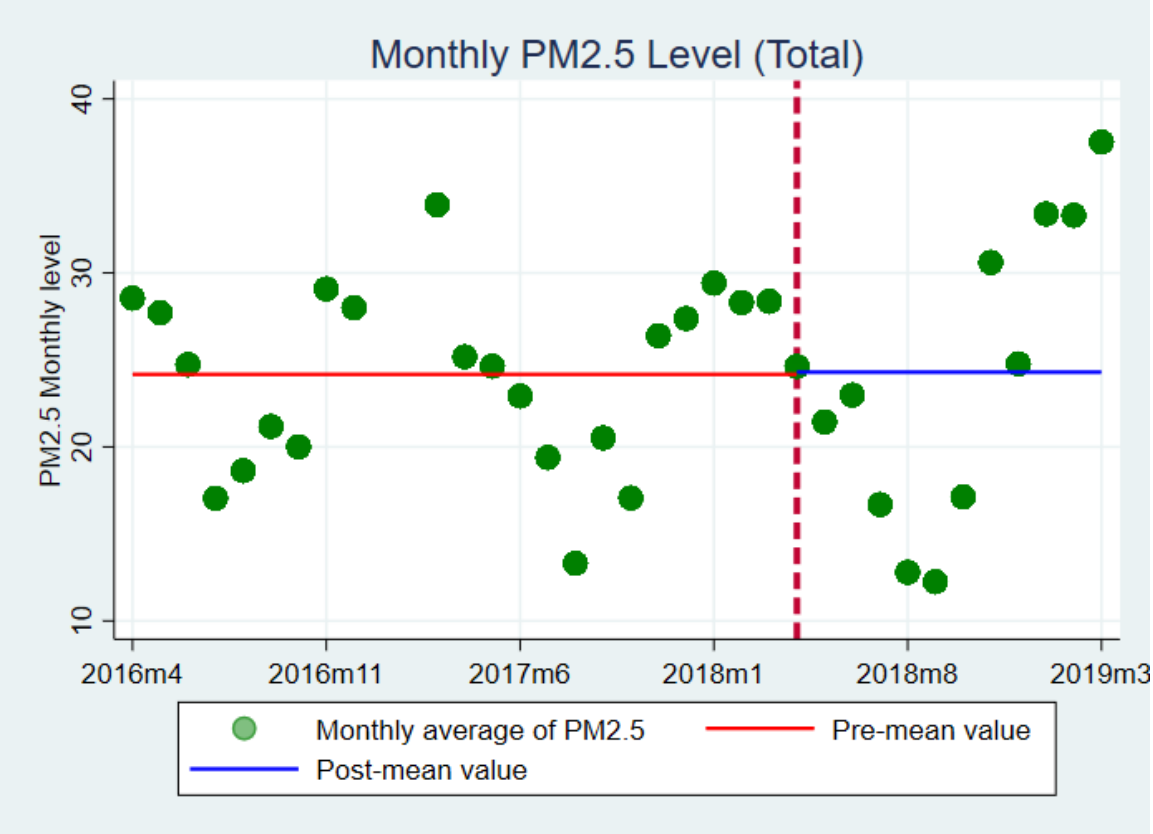


Figure 2.5. Monthly Average of PM 2.5

NOTE: This graph presents the monthly average level of PM 2.5 in South Korea. The Y-axis plots the PM 2.5 levels, and the X-axis plots the time series by monthly level. The red horizontal line indicates the time at which a new policy was adopted, March 2018, and the left window is two years from this and the right window is one year. The red and blue horizontal lines indicate the pre-mean value and post-mean value of PM2.5 from the time of the policy change.

Table 2.1. Descriptive Statistics of the Variables

Variable	N	Mean	SD	Min	Max
Quantity of respiratory medicine consumed per person	4165	2304261	1533073	9760	12100000
Population	4165	324125.829	226481.457	9916.00	1203285.00
Number of days per month in Section 1	4165	8.400	6.906	0.00	31.00
Number of days per month in Section 2	4165	16.085	4.671	0.00	29.00
Number of days per month in Section 3	4165	4.084	3.247	0.00	18.00
Number of days per month in Section 4	4165	1.876	2.711	0.00	23.00
SO2 Level (PPM)	4165	0.004	0.001	0.00	0.01
CO Level (PPM)	4165	0.478	0.140	0.13	1.12
O3 Level (PPM)	4165	0.028	0.011	0.01	0.07
NO2 Level (PPM)	4165	0.022	0.010	0.00	0.06
PM10 Level ($\mu g/m^3$)	4165	45.019	14.141	6.05	92.04
PM2.5 Level ($\mu g/m^3$)	4165	24.963	8.457	4.74	59.34
Pharmaceutical CPI	595	99.734	0.241	99.37	100.49

NOTE: The table provides the summary statistics for the regression models in this paper. "Mean" is the average value of each variable; "sd" is the standard deviation of the variables; "min" and "max" indicate the minimum and maximum values of the variables; "total quantity used per person" is the number of medicine used divided by the population in a district; "population" is the number of people in a district; SO2, CO, O3, NO2, PM10, and PM25 are air pollutants measured by each unit, parts per million (PPM) for SO2, CO, O3, and NO2, and $\mu g/m^3$ for PM10 and PM2.5. Each section represents the number of days labeled as "Good," "Normal," "Bad," and "Very bad" assigned to each section from 1 to 4 within a month in a district based on the daily average value of PM2.5.

Table 2.2. Descriptive Statistics of the Variables

	(1) Ln(Quantity)	(2) Ln(Quantity)	(3) Ln(Quantity)	(4) Ln(Quantity)
Section 2	0.00377	0.000960	0.000649	0.000174
	(0.005)	(0.002)	(0.002)	(0.002)
Section 2 × Post	0.000947	-0.000600	-0.000852	0.000768
	(0.003)	(0.001)	(0.001)	(0.001)
Section 3	-0.000846	-0.000806	-0.00102	-0.00308
	(0.008)	(0.003)	(0.003)	(0.003)
Section 3 × Post	0.0108**	0.00831***	0.00789***	0.00858***
	(0.004)	(0.002)	(0.002)	(0.002)
Section 4	0.00961	0.0101**	0.0108***	0.00571
	(0.015)	(0.004)	(0.004)	(0.004)
Section 4 × Post	-0.00448	-0.000751	-0.00187	0.00190
	(0.006)	(0.003)	(0.003)	(0.003)
PM2.5 level	-0.0000122	0.0000160	-0.000225	0.000939
	(0.006)	(0.002)	(0.002)	(0.002)
Constant	2.493***	2.672***	2.558***	-28.50***
	(0.209)	(0.064)	(0.068)	(2.497)
Time fixed effect	Yes	Yes	Yes	Yes
District fixed effect	No	Yes	Yes	Yes
Air pollutants	No	No	Yes	Yes
Local attribute	No	No	No	Yes
Observations	4165	4165	4165	4165
Adjusted R^2	0.318	0.915	0.916	0.919

NOTE: The table provides the result of regressing the logarithm of quantity of medicine used divided by population on independent variables including sections of labeled days and other control variables. Section 2 represents days labeled as "Normal", section 3 represents days labeled as "Bad", and section 4 represents days labeled as "Very bad." Column (1) only control year and month fixed effect, and column (2) additionally control the district fixed effect. Column (3) also control the real level of air pollutants for PM10, PM2.5, SO2, NO, CO, and O3 with all other fixed effects. Column (4) additionally controls for local pharmaceutical CPI. All regressions are clustered by district level. Statistical significance is indicated by * at the 10% level, ** at the 5% level, and *** at the 1% level.

Table 2.3. Heterogeneous Effects by Medical Institutions

Outcome variable:	Requires prescription			No prescription
Log(Quantity)	Primary	Secondary	Tertiary	required pharmacy
Section 2	0.00115	0.00204	-0.00158	-0.00217
	(0.002)	(0.001)	(0.002)	(0.002)
Section 2 × Post	0.000674	-0.000947	-0.00120	0.00119
	(0.001)	(0.001)	(0.001)	(0.002)
Section 3	-0.00342	0.00127	-0.00398	-0.00245
	(0.003)	(0.003)	(0.003)	(0.005)
Section 3 × Post	0.00809***	0.00752***	0.00699***	0.00874***
	(0.002)	(0.002)	(0.002)	(0.002)
Section 4	0.00541	0.0131***	0.0107**	0.00730*
	(0.004)	(0.004)	(0.005)	(0.004)
Section 4 × Post	-0.00119	-0.00375	-0.00370	0.00550
	(0.003)	(0.003)	(0.003)	(0.005)
PM2.5 level	0.00142	-0.00255	0.0146***	0.0107
	(0.002)	(0.002)	(0.004)	(0.007)
PM2.5 level squared			-0.000273***	-0.000235***
			(0.000)	(0.000)
Constant	-28.67***	2.592***	-25.68***	-28.84***
	(1.847)	(0.067)	(2.283)	(2.664)
Time fixed effect	Yes	Yes	Yes	Yes
District fixed effect	Yes	Yes	Yes	Yes
Air pollutants	Yes	Yes	Yes	Yes
Local attribute	Yes	No	Yes	Yes
Observations	3949	3900	3298	4026
Adjusted R^2	0.924	0.922	0.927	0.877

NOTE: The table provides the regression result by medical institutions, indicated in the column header. All regressions are clustered by district level. Statistical significance is indicated by * at the 10% level, ** at the 5% level, and *** at the 1% level. For other details, see the notes to Table 2.

Table 2.4. Heterogeneous Effects by Consecutive Days Belonging to the Same Section

	(1) Ln(Quantity)	(2) Ln(Quantity)	(3) Ln(Quantity)
Section 3 (consecutive days)	-0.000107	-0.000701	-0.00234
	(0.002)	(0.003)	(0.003)
Section 3 (non consecutive days)	-0.00306	-0.00322	-0.00628
	(0.003)	(0.004)	(0.004)
Section 3 (consecutive days)× post	0.00758***	0.00743***	0.00736***
	(0.002)	(0.002)	(0.002)
Section 3 (non consecutive days)× post	0.0138***	0.0124**	0.0123**
	(0.005)	(0.005)	(0.005)
PM2.5 level		-0.0000113	0.00109
		(0.002)	(0.002)
Sections 2 and 4	Yes	Yes	Yes
Time fixed effect	Yes	Yes	Yes
District fixed effect	Yes	Yes	Yes
Air pollutants	No	Yes	Yes
Time varying control variable	No	No	Yes
Observations	4025	4025	4025
Adjusted R^2	0.915	0.916	0.919

NOTE: The table provides the regression result by consecutive days belonging to the same section. All regressions are clustered by district level. Statistical significance is indicated by * at the 10% level, ** at the 5% level, and *** at the 1% level. For other details, see the notes to Table 2.

Table 2.5. Placebo Effect

ATC Code:	Musculoskeletal System		Dermatologicals	
	Ln(Quantity)	Ln(Quantity)	Ln(Quantity)	Ln(quantity)
Section 3 × Post	0.00127	0.00115	0.00997	0.00998
	(0.001)	(0.001)	(0.007)	(0.007)
Section 3	0.00843	0.00852	-0.00430	-0.00433
	(0.007)	(0.007)	(0.005)	(0.005)
Section 4 × Post	0.00913	0.00898	0.00700	0.00700
	(0.010)	(0.010)	(0.007)	(0.007)
Section 4	0.00610**	0.00628**	-0.00132	-0.00136
	(0.003)	(0.003)	(0.007)	(0.007)
Section 2 × Post	0.000726	0.000682	0.00631	0.00633
	(0.001)	(0.001)	(0.005)	(0.005)
Section 2	0.00120	0.00125	-0.00199	-0.00199
	(0.001)	(0.001)	(0.003)	(0.003)
PM2.5	-0.00677	-0.00703	0.000351	0.000372
	(0.005)	(0.005)	(0.004)	(0.004)
Constant	2.507***	13.75	-1.133***	-461.7***
	(0.061)	(9.482)	(0.115)	(29.440)
Time fixed effect	Yes	Yes	Yes	Yes
District fixed effect	Yes	Yes	Yes	Yes
Air pollutants	Yes	Yes	Yes	Yes
Local attribute	No	Yes	No	Yes
Observations	4062	4059	4049	4046
Adjusted R^2	0.864	0.864	0.925	0.925

NOTE: The table provides the placebo regression result for medical consumption unrelated to respiratory systems, as indicated in the column header. All regressions are clustered by district level. Statistical significance is indicated by * at the 10% level, ** at the 5% level, and *** at the 1% level. For other details, see the notes to Table 2.

Table 2.6. Sensitivity Analysis

	(1) Ln(Quantity)	(2) Ln(Quantity)	(3) Ln(Quantity)
Section 2	0.000174	-0.00294	-0.00312
	(0.002)	(0.002)	(0.002)
Section 2 × Post	0.000768	-0.000351	0.000395
	(0.001)	(0.001)	(0.001)
Section 3	-0.00308	-0.00584*	-0.00678**
	(0.003)	(0.003)	(0.003)
Section 3 × Post	0.00858***	0.00834***	0.00909***
	(0.002)	(0.002)	(0.002)
Section 4	0.00571	0.00864**	0.00742*
	(0.004)	(0.004)	(0.004)
Section 4 × Post	0.00190	0.000411	-0.000108
	(0.003)	(0.003)	(0.003)
PM2.5 level	0.000939	0.0173***	0.00206
	(0.002)	(0.003)	(0.006)
PM2.5 level squared		-0.000286***	0.000337
		(0.000)	(0.000)
PM2.5 level cubed			-0.00000721***
			(0.000)
Time fixed effect	Yes	Yes	Yes
District fixed effect	Yes	Yes	Yes
Air pollutants	Yes	Yes	Yes
Local attribute	Yes	Yes	Yes
Observations	4025	4025	4025
Adjusted R^2	0.919	0.920	0.920

NOTE: The table provides the sensitivity analysis by different functional forms of PM2.5. All regressions are clustered by district level. Statistical significance is indicated by * at the 10% level, ** at the 5% level, and *** at the 1% level. For other details, see the notes to Table 2.

Table 2.7. Robustness Using Hourly Data

	(1) Ln(Quantity)	(2) Ln(Quantity)	(3) Ln(Quantity)
Section 2	0.112	0.0963	0.0630
	(0.079)	(0.077)	(0.076)
Section 2 × Post	-0.0471	-0.0570	-0.0154
	(0.060)	(0.060)	(0.058)
Section 3	0.0366	0.0128	-0.0869
	(0.118)	(0.120)	(0.118)
Section 3 × Post	0.548***	0.538***	0.525***
	(0.115)	(0.113)	(0.109)
Section 4	0.720***	0.742***	0.488**
	(0.202)	(0.201)	(0.196)
Section 4 × Post	-0.190*	-0.228**	-0.0931
	(0.103)	(0.103)	(0.095)
PM25 Level	-0.00498*	-0.00511*	-0.00272
	(0.003)	(0.003)	(0.003)
Constant	2.740***	2.623***	-27.92***
	(0.072)	(0.075)	(2.511)
Time fixed effect	Yes	Yes	Yes
District fixed effect	Yes	Yes	Yes
Air pollutants	No	Yes	Yes
Local attribute	No	No	Yes
Observations	4025	4025	4025
Adjusted R^2	0.915	0.916	0.919

NOTE: The parameters are results of the regressions that each section is constructed by using hourly level PM 2.5 data. By following the method of assigning days within a month to each section, hours are assigned based on the hourly level of PM 2.5. Section 3 is the proportion of hours where the PM 2.5 level is between 35 $\mu g/m^3$ and 50 $\mu g/m^3$, and other sections are interpreted in the same manner as well. Column 1 includes time and district fixed effects, and column 2 adds the air pollutants, which are covered in Table 2. Column 3 controls the time varying economic variable, pharmaceuticals CPI. Statistical significance is indicated by * at the 10% level, ** at the 5% level, and *** at the 1% level.

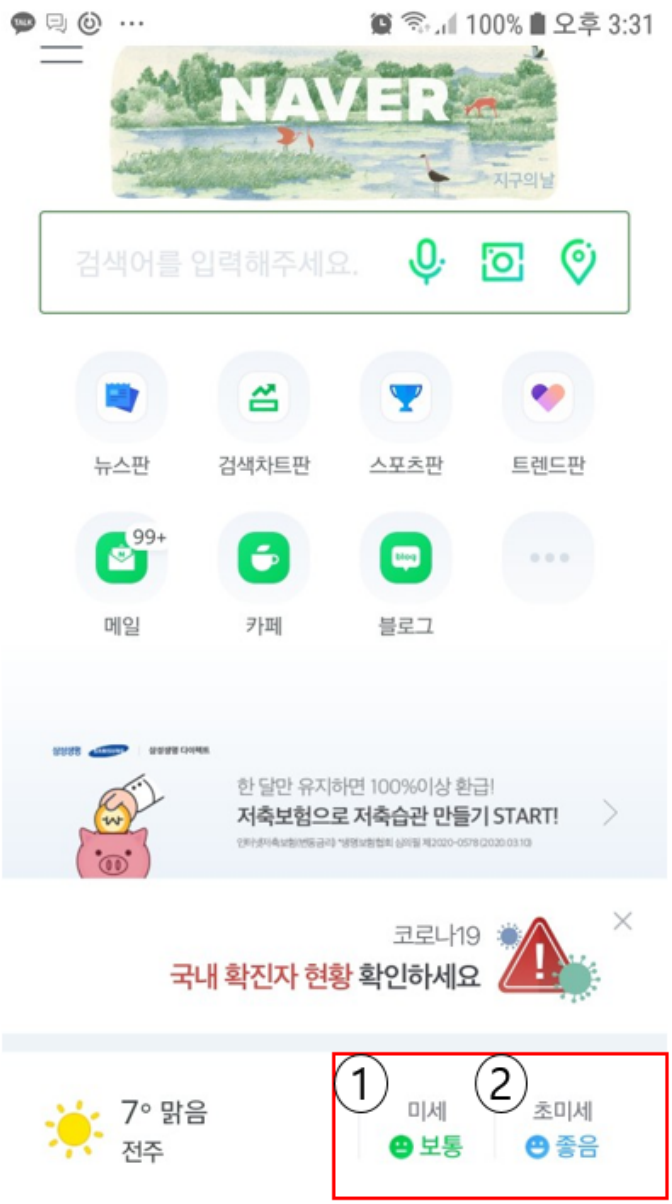


Figure 2.A1. Example of the Channel for Obtaining Information on Air Pollution

NOTE: The figure depicts how people can obtain information on air pollution. This is the screenshot of a smartphone Internet page, called "Naver," which is the most popular web search site in South Korea. People can easily check the air pollution information, particularly the labels based on the air pollution level. The number 1 indicates particulate matter (PM) 10 and number 2 indicates PM2.5.

Chapter 3

Impact of Political Alignment on Tax Evasion : Evidence from South Korea

Abstract

Does political alignment affect tax evasion rates? Theoretically, a better attitude toward the government could lower motivation for tax evasion through the reciprocity concept in tax morale, and if political alignment is correlated with attitude toward government, then political alignment is likely to affect tax evasion rates. Using individual-level tax data and county-level political data from South Korea, we find that people are less likely to evade tax payments when they are politically aligned with the ruling party.

3.1 Introduction

Tax evasion, the illegal and purposeful failure to declare taxable income and information, has been an important issue for many countries due to both its scale and its effects. It impacts government budgets and thus welfare and the economy by constraining the provision of public goods and services. Many studies have provided empirical evidence that tax evasion is sizable and pervasive in many countries. For example, Schneider and Enste (2000) found that OECD countries had an average shadow economy worth 12% of their GDP; the figure was 39% of GDP for developing countries. Slemrod (2007) show that taxable income in the United States was under-reported by 14%. In South Korea, Myung-Ho Park (2008) show that self-employed

workers under-report their income level by 33% more than employed workers. The theory of tax evasion also has been actively studied; for example, Allingham and Sandmo (1972) explain the individual behavior of tax evasion by using a person's risk-averse attitude and utility comparison between evading tax and the probability of being punished.[1]

Recent studies suggest that an individual's attitude toward the government is an important factor for his or her tax-paying behavior (e.g., Hanousek and Palda (2004); Scholz and Lubell (1998); Torgler (2003); Webley et al. (2010)). However, little is known about the relationship between political alignment and tax behavior. The literature contains two major exceptions. Luttmer and Singhal (2014) clarify how tax morale is affected by individual motivations, including the concept of reciprocity, under which people expect greater compensation from a government in exchange for paying their taxes. Using U.S data, Cullen et al. (2021) provide empirical evidence to show that political alignment can affect tax evasion. Our empirical evidence on the relationship between political alignment and tax evasion in South Korea builds on the work of these two papers and is useful for considering the generalization of the results to other developed and developing countries.

Although studying tax evasion is important in terms of its impact and scale, providing convincing empirical evidence is difficult due to the impossibility of directly observing individual-level tax evasion. To address this complication, we infer tax evasion rates by using consumption-based regression, as first suggested by Pissarides and Weber (1989). Through this regression, the predicted income level for self-employed persons can be obtained, and we obtain the tax evasion rate by subtracting the reported income level of the self-employed group from the predicted level.

To identify the causal effect of political alignment on tax evasion, we take the following three steps. First, we observe the relationship between attitude to government and political alignment by using the Korean General Social Survey (KGSS) and find that people politically aligned with the ruling party have a better attitude toward government. Second, we use the

[1] Clotfelter (1983) empirically shows that people have different attitudes about tax evasion based on marginal tax rates and the overall tax system.

Korean Labor & Income Panel Study (KLIPS) to infer tax evasion rates by the methodology stated above. In the final step, we collect county-level voting data for presidential elections and analyze how a change in ruling-party outlook from liberal to conservative affected tax evasion rates in partisan counties.

Using individual-level income data and county-level political data in South Korea, we find a significant and positive impact of political alignment on decreasing tax evasion rates in partisan counties. As a benchmark estimate, an increase of alignment in a generic partisan county leads to a decrease in the tax evasion rate of 1%. The results indicate that people living in areas that are politically aligned with the government, which we refer to as partisan counties, demonstrate lower tax evasion rates than people living in areas that are not politically aligned. This phenomenon can be explained through the theory of the reciprocity channel in tax morale. Our robustness tests suggest that the effect is not driven by job changes from employee to self-employed associated with a change in the ruling party.

Our paper broadly contributes to the literature studying the relationship between trust in government and tax morale. Though several surveys (e.g., Scholz and Lubell (1998); Torgler (2003); Webley et al. (2010)) and experiments (e.g., Hanousek and Palda (2004)) have shown that the percentage of taxes due that is actually paid is correlated with trust in and attitude toward the government, our paper more directly contributes to the literature linking political alignment and tax evasion. It is most closely related to two previous studies. First, Luttmer and Singhal (2014) divided the concept of tax morale into different channels: intrinsic motivation, reciprocity concept, peer effect, cultural impact, and information imperfection.[2] In the present study, we focus on the reciprocity concept to explain the mechanism of tax evasion. According to this concept, citizens are willing to pay taxes based on the expectation that the amounts they pay will be offset by non-pecuniary benefits such as public services and goods. Our paper is also closely related to Cullen et al. (2021), who provided empirical evidence that political alignment can

[2]None of these channels has an exclusive effect on tax evasion; rather, they can simultaneously impact such avoidance.

affect the level of tax evasion in partisan counties in the United States. However, among other developed and developing countries, there is almost no evidence of how political alignment can affect tax evasion, and we do not know whether Cullen et al. (2021)'s results can be generalized to other countries. Our findings on the relationship between attitude toward the government, political alignment, and tax evasion will be helpful for generalizing such results. If the reciprocity concept is indeed applicable, then political alignment will affect tax evasion rates because people who are more politically aligned have more trust in government and thus less desire to evade the taxes they owe. We in fact verify these mechanisms by testing the significance of the relationship between attitude toward the government and political alignment and by running regressions on tax evasion and political alignment.

The remainder of the paper is structured as follows. The next section discusses the relationship between government attitude and political alignment. Section 3 lays out the estimation method for tax evasion and defines a partisan county, and Section 4 shows the impact of political alignment on tax evasion. Section 5 presents robustness and heterogeneity checks, and Section 6 concludes.

3.2 Institutional Background

3.2.1 Political System in South Korea

South Korea's political system is a presidential representative democratic republic. The president is the head of state in a multi-party system. The system was formally established on August 15, 1948 with Syngman Rhee as the first president; the 19th president, Jae-in Moon, is the current head of state.

The presence of a multi-party system makes it difficult to establish a clear standard for separating each political party into liberal or conservative. Furthermore, political parties have often merged or split apart due to political trends and internal conflicts; therefore, party stability has not been strong in South Korea (Park, 2010). Nevertheless, citizens can still recognize the

basic approach of a party through its attitude toward North Korea. Most conservative parties have maintained an aggressive or even hostile attitude toward that country, whereas liberal parties have tended to advocate pursuing peace and trying to help their northern neighbors (Chang and Park, 2018). Based on this distinction, it is possible to categorize all parties along a broad spectrum as conservative or liberal. The literature suggests that liberal parties would include complementary groups that are not explicitly conservative. Thus, some political parties that take centrist or slightly leftist positions can be regarded as liberal (Han and Jang, 2012; Wong et al., 2014).

South Korea is divided into 250 administrative divisions called counties. Following Gerber and Huber (2009), Ansolabehere et al. (2001), and Canes-Wrone et al. (2002), we define a partisan county as one where the vote was more than 50% for either a conservative or liberal party in five consecutive presidential elections; 119 of 250 counties are partisan based on this definition. Of those 119 counties, 80 are conservative partisans, while 39 are liberal partisans. Figure 1 geographically illustrates the situation. Liberal partisan counties are mainly located in the southwestern part of South Korea, whereas conservative party partisan counties are located in the country's eastern half. This division has persisted for decades.[3]

3.3 Data

3.3.1 Government Attitude

To test the relationship between the credibility of the government and political alignment, the KGSS data set is used. This survey began in 2003 and provides nationally representative cross-sectional annual data about general social issues, including the credibility of the government, politics, and social norms.[4] The number of observations per survey is approximately 1,500, and the sample reflects the population of each region. Each round of the KGSS typically includes the topical module surveys of the International Social Survey Programme, and/or the East Asian Social Survey (EASS), an international survey network of four GSS-type surveys from East Asia

[3]There is research about this regional political difference (e.g., Kim (2010), and Noh and Park (1997)).

[4]KGSS follows the format of the General Social Survey (GSS), which started in the United States in the 1980s.

countries: China, Japan, Taiwan, and South Korea.

The statistics for government attitude are summarized in Table 1. The attitude toward each institution is an indicator and takes zero or one. On average, the government had a 0.285 credibility score. In contrast, congress scored 0.141, clergy 0.390, business 0.383, and academia 0.408, which was the highest level of credibility. Regarding political alignment, the mean was 0.545, and the percentage of females among the sample group was 53.8%. The average age of the sample was 45, and 76.8% of respondents were married. A little more than half (57.3%) of respondents were employed, and their average of education was 12.43 years. The mean monthly income level was 8.145, which ranges from US$3,500 to US$4,000.[5] The religious intensity variable shows how strongly respondents believed in their religion and takes a value from one to three; the mean was 1.67. Party ID, which shows a respondent's political status, had a mean of 0.35. Finally, the ideological variable (1 is left wing; 5 is right wing) had a mean of 3.029.

3.3.2 Data for Inferring Tax Evasion

Since we cannot directly observe the amount of tax evasion, we infer it by using the following individual panel data. We use the KLIPS for tax evasion inference; it is a nationally representative panel survey data set associated with broad topics about the labor market and changes in the demographics of South Korean households. This survey started in 1998 and annually followed 5,000 households, including all members of each household.

Table 2 presents the summary statistics of the KLIPS data. During the periods of our sample, from 2006 to 2010 (except 2008), the average annual income of a household was US$32,286. Total consumption was US$24,069, or 74.5% of the total income level. The average number of household members was 3.15, with 1.4 people in a household working, on average. Regarding wealth levels, approximately 53% of households owned their own home, and 8.8% had another residence. Very small numbers of households owned commercial buildings and

[5]The original answer regarding income level is categorized by several intervals, with 0 indicating no income; each upward step represents an additional US$500 to the baseline. The top of the scale is 11, which is the income level more than US$5,000 per month.

forests (1.8% and 1.6%, respectively), and 7.6% of households owned land. As to financial wealth, the average household had US$17,383 in financial accounts of any kind. The average age was around 42, and 75.7% of heads of household were male; the average education level for a head of household was 11.4 years.

3.3.3 Political Turnout

The data on political variables were taken from the National Election Commission of South Korea. We obtained voting data for all 250 counties for the years from 1997 to 2017. In this paper, we define a partisan county as one where the vote was more than 50% for either a conservative or liberal party in five sequential presidential elections; using vote share for defining partisan divisions is a common approach in the literature (e.g., Ansolabehere et al. (2001), Canes-Wrone et al. (2002), and Gerber and Huber (2009)). We used the five elections from the 15th presidential election in 1997 to the 19th in 2017. One potential challenge for defining conservative and liberal partisanship is South Korea's multi-party political system, which can make it difficult to assess whether a given party is conservative or liberal. To address this issue, we adopted the approach used in the literature on political parties in South Korea (e.g., Han and Jang (2012), Kim and Lim (2013), and Chang and Park (2018)).[6]

From the voting data, it is possible to craft a political alignment variable. Unlike the unit in the KGSS data set, it is not an individual-level variable, but the county level of vote share. $Alignment_{ct}$ is the average vote share in five presidential elections for a partisan county when the ruling party is from their side of the political spectrum at time t in county c. The value changes to $1 - Alignment_{ct}$ when the ruling party does not match the county's partisanship. This variable is a determining factor for examining changes in tax evasion rates.

[6]Chang and Park (2018) separate political parties based primarily on their attitude to North Korea. Conservative parties are largely distrustful of North Korea and hostile regarding any action to help that country when it was not cooperative with South Korea. Liberal parties take the position of helping North Korea and trying to cultivate a peaceful atmosphere between South Korea and North Korea.

3.4 Identification

3.4.1 Government Attitude and Political Alignment

Using the pooled, cross-sectional KGSS data set, we ran a fixed effects model to check the causal relationship between attitude toward government and political alignment while controlling for individual covariates:

$$1(Attitude_{i,t}) = \alpha + X_{i,t}\tilde{\gamma} + \beta * Alignment_{i,t} + Region_r * Year_t + \varepsilon_{i,t} \quad (3.1)$$

where $Attitude_{i,t}$ indicates the individual's attitude toward institutions such as government, congress, business, religion, and academia. The question asks how much confidence the respondent has in the institution. We re-scaled the value of the answers on a scale from zero to one, where zero means no confidence at all and one means the highest confidence. The control variables in the vector $X_{i,t}$ include gender, age, marital status, political ideology, income, education, employment status, religious intensity, and party ID. This last value takes values from zero and one, with zero indicating conservative and one indicating liberal. $Alignment_{i,t}$ indicates whether the respondent is politically aligned with the ruling party; it is equal to the value of party ID if the government is from a liberal party and is equal to (1 - party ID) when the government is from a conservative party. Therefore, by controlling for party ID, the regression can more rigorously identify the impact of change in political alignment on change in government regime. We include a $Region_r * Year_t$ fixed effect, which controls for the region-specific fixed effect by year.

3.4.2 Tax Evasion Inference

We can neither directly observe nor access data on tax evasion in South Korea. To deal with this problem, this paper uses a consumption-based tax evasion inference methodology that was first proposed by Pissarides and Weber (1989). This approach is widely used in the tax

evasion literature (e.g., Alm (2012), Shin and Kang (2014), and Slemrod (2007)).

The basic idea is to use consumption levels to infer income levels; this approach requires two key assumptions. The first is that self-employed people have a weak tendency to under-report their income level to the National Tax Service of South Korea, whereas wage employees cannot under-report their income levels. This assumption makes sense because the two groups report their income level differently. Self-employed persons can report their annual income based on calculations of their revenues, whereas employees' incomes are automatically reported to National Tax Service by employers. The second assumption is that the self-employed group and employee group will show similar consumption levels when their income levels are identical, after controlling for other demographic and wealth factors. This assumption also makes sense, because consumption and income are largely correlated with each other, and consumption should not differ between the self-employed and employees.[7] We then regress income level on consumption level and other control variables. This regression only uses the employee group sample, because, under the second assumption, their income level is not under-reported. After running the regression, we predict the dependent variable (reported income) and then find the difference between this variable and the reported revenue of the self-employed. In the final step, we divide the reported value by the predicted value to find the tax evasion rate.

Specifically, the inference of tax evasion is calculated as follows:

$$ln(Reported\ income)_i = \alpha + \beta ln(Consumption_i) + X_{1,i}\tilde{\gamma}_1 + X_{2,i}\tilde{\gamma}_2 + X_{3,i}\tilde{\gamma}_3 + \varepsilon_i \tag{3.2}$$

where $ln(Reported\ income)_i$ indicates the logarithm of the total annual income of household i. This reported income is originally reported in individual-level, post-tax annual labor income. Thus, we summed it at the household level, details of which are presented below. $ln(Consumption_i)$ is the logarithm of the annual household consumption level. In the question-

[7] However, the level of savings between these two groups *can* vary. For example, the self-employed group could prefer saving their money at home instead of in a bank. Therefore, we considered only the relationship between income and consumption in the estimation specification model.

naire, the definition of consumption is the total expenditure for normal living expenses: food, housing, clothes, education, health care, and so on. Therefore, neither savings nor debt payment is part of this category, and expenditures for special cases like car accidents or marriages are also not regarded as consumption in this context.

The complication here is that income is reported at the individual level, whereas consumption is reported at the household level. We thus converted the individual-level income into a household-level figure so the units would match. Furthermore, following the definition of Korean Statistical Information Service (KOSIS), we chose the person with the largest income in a household as the head of that household.[8]

Other variables involve controlling for level of wealth and household demographics. $X_{1,i}$ is the vector of variables associated with a household structure. Thus, it includes the total number of members in the household and the number of those people who were working. $X_{2,i}$ is related to the characteristics of the head of household; it includes age, gender, education level, and the location of the household. Locations are divided into 16 regions based on South Korean districts.[9] $X_{3,i}$ is the vector of dummy variables indicating the household's level of wealth. These variables are indicators of owning a house for living, owning another as a property, owning a commercial building, owning forests, and owning land. Finally, financial wealth was divided into five levels. [10] For the inference, we use heteroskedasticity-robust standard errors.

[8]It was possible for a person who was an employee to be designated the head of household if there was a self-employed member of the household under-reporting his or her income level and thus not selected as head of household. To check for this possibility, we increased the income level of self-employed group people by 10%, 20%, and 30% and found that these income changes did not significantly affect the choice of heads of household or the main results.

[9]There are seven metropolitan cities and nine provinces in South Korea.

[10]The five categories are less than US$10,000, more than US$10,000 and less than or equal to US$50,000, more than US$50,000 and less than or equal to US$100,000, more than US$100,000 and less than or equal to US$500,000, and more than US$500,000. To obtain figures in US dollars, every 1,000 South Korean won are converted into one US dollar.

3.4.3 Impact of Political Alignment on Tax Evasion

From the constructed data set of tax evasion rates and the partisan county alignment variable, we can estimate the impact of political alignment on the tax evasion rates of citizens living in partisan counties. To test this causal relationship, we needed the data for changes in ruling parties at the presidential level. In March 2008, Myung-bak Lee became South Korea's 17th president. Because he was from a conservative party, and the former president, Moo-hyun Roh, was from a liberal party, this change in government can be used to check for the impact investigated in the present study. Hence, to examine tax evasion rate changes related to a change in government, we used the years from 2006 to 2010 but dropped 2008 from the sample, because both political parties ruled the country for part of that year.[11]

Then, we run the following two-way fixed effect model:

$$Tax\ evasion\ rate_{ict} = \alpha + \beta Alignment_{ct} + \gamma ln(RGDP_{ct}) + Year_t + County_c + \varepsilon_{ict} \qquad (3.3)$$

where $Tax\ evasion\ rate_{ict}$ is the inferred tax evasion in county c in year t, $Alignment_{ct}$ is the average vote level in partisan county c at year t, and $ln(RGDP_{ct})$ is the logarithm of the regional GDP level in each county in year t to control for county-level time-varying regional differences.[12] $Year_t$ s a fixed effect for each year, and $County_c$ is the fixed effect for each county in South Korea. The model is clustered at the county level so that clustering can control for serial correlation within a given county.

[11] As Lee became president in March 2008, it is not possible to separate effects before and after March in the annual panel data set used for this research.

[12] Brosio et al. (2002) show that the amount of tax evasion is negatively correlated with per capita regional GDP in Italy; increases or decreases in region-level GDP could thus affect county-level tax evasion.

3.5 Empirical Results

3.5.1 5.1 Attitude toward Government and Political Alignment

Table 3 shows the results of the relationship between attitude toward government and political alignment based on Eq. (1). In columns 2 to column 4, we additionally control for year, regional, and year-specific regional fixed effects. All columns show significant and similar magnitudes of the estimated coefficients, which suggests that people have better attitudes toward government when they are politically aligned with the ruling party. Overall, changes in political alignment increase attitudes toward government from approximately 3% to 4%.[13]

Table 4 shows how political alignment affects other institutions such as congress, business, clergy, and academia. Estimated coefficients are smaller than that for government in Table 3. This makes sense because attitudes toward government are directly related to political alignment, and any president is from the leading party at a given time. Though the magnitude is small, political alignment also improves attitudes toward congress, business, and clergy in columns (1), (2), and (3), respectively, which suggests that political alignment may have spillover effects that cover all of society.

3.5.2 Tax Evasion Inference

Table 5 shows the result of the tax evasion inference based on Eq. (2). In column (1), we only include regional and year fixed effects. In this case, the coefficient for the logarithm of total consumption is 0.361, which means a 1% increase of total consumption level is positively associated with a 0.36% increase in total income level. The scale of this coefficient, however, becomes smaller as other control variables are added. After controlling for the number of family members and workers in the family in column (2), the estimated coefficient becomes 0.265. After additionally controlling for head-of-household characteristics in column (3), it shrinks to 0.195. Finally, in column (4), we obtain an estimate of 0.163 after controlling for wealth level.

[13]This is because the attitude interval is one (from zero to one), and a usual change of alignment would be 0.4 to 0.5 rather one.

This estimated coefficient can be also interpreted as the marginal propensity to consume (MPC), which indicates how much money people spend when their income level increases. The results of many studies in the MPC literature (e.g., (Carroll et al., 2017; Gross et al., 2016)) show that the MPC level of around 0.2 found in this paper is quite reasonable.

The coefficients for other control variables also have reasonable signs and scales. When a household has a larger number of working members, its total income will increase, as the second and third rows in Table 5 indicate. In addition, as the fourth and fifth rows show, the gender and age of the head of household also affect total household income. Other wealth-related variables are also positively correlated with the household income level.

By using the regression results, the predicted values for reported incomes can be obtained and by using these values, the tax evasion rate for the self-employed group can be defined as follows:

$$Tax\ evasion\ rate_{it} = \frac{Predicted\ income_{it} - Reported\ income_{it}}{Predicted\ income_{it}} \tag{3.4}$$

The numerator is the difference between the predicted income level from the regression and the self-reported income level, indicating how much income is under-reported. By dividing the reported values by the predicted values, tax evasion rates can be calculated.

3.5.3 Impact of Political Alignment on Tax evasion

Table 6 shows the results of the impact of political alignment on tax evasion based on Eq. (3) for self-employed persons, employees, and all persons. Among self-employed people, political alignment can affect tax evasion rates significantly, with a one-unit increase in alignment decreasing the tax evasion rate by around 2%, as the first column indicates. The interpretation is that an alignment increase in a generally partisan county would lead to a 1% decrease in tax evasion rates.[14]

[14]Political alignment generally changes not by one, but by 0.4 to 0.5. The scale of alignment indicates the average vote share of a partisan county, and the value can be calculated based on the average change in voting share.

For the second column (employees), the estimate is smaller and not statistically significant. This result is consistent with the fundamental assumption that employees do not have a margin for under-reporting their income level. For the third column (total sample), the alignment variable moves closer to zero. The results thus provide clear evidence that self-employed people react to changes in political alignment by paying more taxes to a government they support.

3.6 Robustness

3.6.1 Extensive margin

It is possible that becoming a politically aligned partisan county can give people some incentives to move to the self-employed sector such as retail sales or industries specific to the local area. Based on Gerber and Huber (2009), people in partisan counties are actually better at forecasting their economic situations, which is shown by an increase of consumption in those areas. Therefore, it is also important to check the extensive margin of changing their type of work, for which we run the following model:

$$\begin{aligned} Self\ Employment_{ict} = \alpha + \beta Alignment_{ct} + Year_t + \gamma ln(RGDP)_{ct} \\ + X_{ict}\tilde{\gamma} + County_c + \varepsilon_{ict} \end{aligned} \tag{3.5}$$

where $Self\ employment_{ict}$ is an indicator for whether person i is self-employed in county c in year t, and the coefficient of $Alignment_{ct}$, β, shows how political alignment can affect the probability of becoming self-employed. X_{ict} includes age, a gender dummy variable,[15], and education level.[16] By using a year fixed effect and probit model, we check whether independent variables have a significant impact on changes in the dependent variable; that is, probability of becoming self-employed.

Table 7 shows the results; we did not find a statistically significant effect, as the estimates

[15] Gërxhani (2007) shows that different gender have heterogeneous attitudes toward tax evasion.

[16] For education, we created the following dummy variables: elementary school graduation, middle school graduation, high school graduation, two-year college graduation, four-year university graduation, and master's degree graduation.

are small and close to zero. This indicates that political alignment does not affect the probability of changing to the self-employed group.

3.7 Conclusion

This paper has studied the connection between political alignment and tax evasion rates in South Korea. To indicate the causal effect, we took three steps. We first checked the relationship between attitude toward government and political alignment by using the Korean General Social Survey (KGSS) and find a strong correlation between them. Specifically, people have a more favorable attitude toward government when they are politically aligned with the ruling party, and this is linked to a decreased tendency to evade taxes through the reciprocity concept. Second, we inferred tax evasion rates by using consumption-based regression, due to the inability to obtain tax evasion data for individuals. Through this regression, the predicted income level for self-employed people can be obtained; it was used to estimate tax evasion rates by subtracting the reported income level of the self-employed group from the predicted level. In the last step, we collected data for presidential election voting at the county level to create the political alignment variable. By merging this political alignment with individual tax evasion data, we regressed the tax evasion rate on political alignment. We found a significant and positive impact of political alignment on decreasing tax evasion rates. Therefore, when people are politically aligned with the ruling party, they demonstrate a better attitude toward the government, and there is a tendency to less tax evasion, on average. As a robustness test, we found, by running a fixed effect probit model, that there was no effect of people in the sample moving to the self-employed group.

3.8 Acknowledgements

Chapter 3, in full, is currently being prepared for submission for publication of the material. Lee, Youngju; Nakazawa, Nobuhiko. “Impact of Political Alignment on Tax Evasion : Evidence from South Korea”. The dissertation author was the primary investigator and author of

this material.

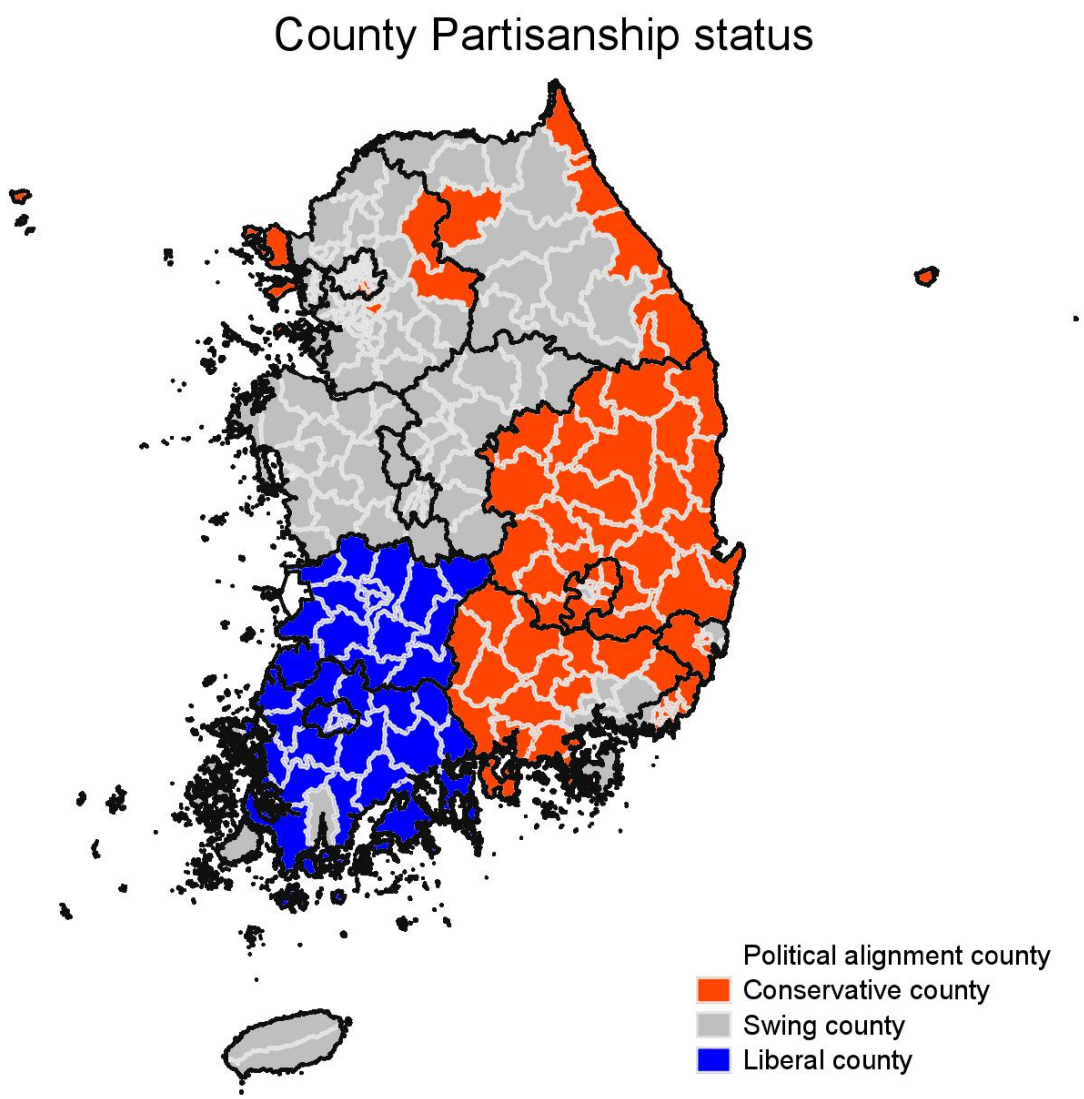


Figure 3.1. County Partisanship in South Korea

NOTE: In this paper, a partisan county is defined as one where the overall vote was more than 50% for either conservative or liberal parties in five straight presidential elections. There are 250 counties in South Korea, 119 of which qualify as partisan under this definition. There are 80 conservative and 39 liberal partisan counties.

Table 3.1. Summary statistics (KGSS)

	Mean	S.D	Min	Max
Attitude(Government)	0.285	0.297	0.000	1.000
Attitude(Congress)	0.141	0.252	0.000	1.000
Attitude(Clergy)	0.390	0.336	0.000	1.000
Attitude(Firm)	0.383	0.297	0.000	1.000
Attitude(Academia)	0.408	0.306	0.000	1.000
Alignment	0.545	0.484	0.000	1.000
Female	0.538	0.499	0.000	1.000
Age	45.027	16.618	18.000	99.000
Marriage	0.768	0.422	0.000	1.000
Employed	0.573	0.495	0.000	1.000
Education	3.490	1.598	0.000	8.000
Income level	8.145	5.615	0.000	21.000
Religious intensity	1.676	0.784	1.000	3.000
Party ID	0.350	0.462	0.000	1.000
Ideology	3.029	0.976	1.000	5.000
Observations		18,605		

NOTE: These are summary statistics from the Korean General Social Survey. All variables related to the attitude toward each institution show how much credibility a respondent accords to a given institution, on a scale from zero to one; a value of one indicates an institution with maximum credibility. Alignment indicates how much a respondent is aligned with the current government. Employment is the working status of respondent, and income level indicates the category of a respondent's monthly income level: zero means no income at all, with additional unit reflecting an increase of US$500 per month. If the income level is higher than US$10,000 per month, then it is in group 21. Religious intensity asks how strongly a person believes in his or her religion. Party ID is constructed based on the method explained in the main text. Ideology is the respondent's political ideology (1 is left wing; 5 is right wing).

Table 3.2. Summary statistics for consumption based regression

	Mean	S.D	Min	Max
Total income	3,228.695	2,198.177	108.000	57,400.000
Total consumption	2,406.964	1,305.496	120.000	15,828.000
Number of household members	3.154	1.244	1.000	10.000
Number of workers in a household	1.439	0.658	0.000	7.000
Age of head of household	41.962	11.313	17.000	85.000
Gender of household head	0.757	0.429	0.000	1.000
Years of education	11.478	3.991	0.000	22.000
Owning a home	0.539	0.498	0.000	1.000
Having another house	0.088	0.283	0.000	1.000
Having a commercial building	0.018	0.134	0.000	1.000
Having forest	0.016	0.126	0.000	1.000
Having land	0.076	0.265	0.000	1.000
Wealth in financial accounts	1,738.315	6,804.887	0.000	520,000.000
Observations	12,601			

NOTE: These are the summary statistics for the consumption-based regression. Total income is the sum of all individual incomes within a household, while total consumption is total expenditure for all categories of routine expenses (food, housing, clothes, education, etc.). Number of workers in a household indicates the number of people working during the previous year before the survey. The house dummy and all other dummies are indicators to check a household's level of wealth. Finally, wealth in financial accounts is the total amount of money held by the household in financial institutions.

Table 3.3. Attitude toward Government

Attitude	(1) Government	(2) Government	(3) Government	(4) Government
Alignment	0.074**	0.071**	0.073**	0.068**
	(0.013)	(0.008)	(0.013)	(0.010)
Gender	-0.004	-0.005	-0.005	-0.006
	(0.004)	(0.004)	(0.004)	(0.003)
Age	0.003***	0.003***	0.003***	0.003***
	(0.000)	(0.000)	(0.000)	(0.000)
Marriage	-0.055**	-0.054**	-0.054**	-0.056**
	(0.009)	(0.009)	(0.009)	(0.008)
Employment	-0.019**	-0.019*	-0.018**	-0.021**
	(0.004)	(0.005)	(0.004)	(0.004)
Education	-0.001	-0.002	-0.002	-0.002
	(0.004)	(0.003)	(0.004)	(0.003)
Income level	0.003**	0.002**	0.002**	0.002**
	(0.000)	(0.000)	(0.000)	(0.000)
Religious intensity	0.022	0.021	0.022	0.020
	(0.009)	(0.009)	(0.009)	(0.009)
Party ID	0.013	0.017*	0.013	0.013*
	(0.006)	(0.006)	(0.006)	(0.004)
Ideology	0.007	0.009*	0.007	0.009**
	(0.003)	(0.002)	(0.003)	(0.002)
Year	No	Yes	No	No
Region	No	No	Yes	No
Year by Region	No	No	No	Yes
Observations	9,534	9,534	9,534	9,534
Adjusted R^2	0.036	0.047	0.038	0.056

NOTE: The parameters are the results from a regression of Eq. (1) for political alignment, with attitude toward government as the dependent variable. The control set includes the variables shown in Table 1. Statistical significance is indicated by * at the 10% level, ** at the 5% level, and *** at the 1% level.

Table 3.4. Attitude toward Other Institutions

	(1)	(2)	(3)	(4)
Attitude	Congress	Firm	Clergy	Academia
Alignment	0.016**	0.027***	0.017**	-0.013
	(0.003)	(0.001)	(0.002)	(0.010)
Gender	0.015	0.013	0.020*	0.022**
	(0.009)	(0.004)	(0.005)	(0.004)
Age	0.002*	0.002*	0.004***	0.003**
	(0.000)	(0.001)	(0.000)	(0.000)
Marriage	-0.043	-0.043**	-0.038**	-0.044***
	(0.019)	(0.008)	(0.008)	(0.003)
Employment	-0.014	-0.023**	-0.008**	-0.004
	(0.010)	(0.005)	(0.002)	(0.007)
Education	-0.006	-0.004	-0.012**	-0.013*
	(0.003)	(0.006)	(0.002)	(0.004)
Income level	-0.002**	0.002**	0.001	-0.001**
	(0.000)	(0.000)	(0.000)	(0.000)
Religious intensity	0.012**	0.012	0.095**	0.010**
	(0.001)	(0.005)	(0.011)	(0.001)
Party ID	-0.016	-0.016**	0.013***	0.028
	(0.007)	(0.003)	(0.001)	(0.010)
Ideology	0.000	0.015***	-0.005	0.000
	(0.001)	(0.001)	(0.004)	(0.006)
Year by Region	Yes	Yes	Yes	Yes
Observations	9,707	9,753	9,792	9,757
Adjusted R^2	0.044	0.046	0.103	0.043

NOTE: The parameters are the results from a regression of Eq. (1) for political alignment, and the dependent variable is attitude toward other institutions. For other details, please see the notes to Table 2.

Table 3.5. Tax Evasion Inference

Dependent variable: ln(Total Income)	(1)	(2)	(3)	(4)
ln(Total consumption)	0.361***	0.265***	0.195***	0.163***
	(0.025)	(0.024)	(0.019)	(0.017)
Number of household members		0.086***	0.084***	0.080***
		(0.008)	(0.007)	(0.007)
Number of workers in household		0.243***	0.283***	0.257***
		(0.010)	(0.009)	(0.009)
Age of head household			-0.002*	-0.004***
			(0.001)	(0.001)
Gender of household head			-0.296***	-0.282***
			(0.016)	(0.015)
Owning a home				0.097***
				(0.013)
Region	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes
Control(Education)	No	No	Yes	Yes
Control(Property and Wealth)	No	No	No	Yes
Observations	11,369	11,369	11,369	11,369
Adjusted R^2	0.231	0.313	0.460	0.504

NOTE: The parameters are the results from a regression of Eq. (2) for tax evasion inference, and the dependent variable is the logarithm of reported income. The sample for this regression is the employee group from the Korean Labor & Income Panel Study. The control set includes the variables shown in Table 4. Statistical significance is indicated by * at the 10% level, ** at the 5% level, and *** at the 1% level.

Table 3.6. Tax Evasion in Partisan Counties

	Self-employed Tax evasion	Employee Tax evasion	Total Tax evasion
Alignment	-1.991**	0.606	-0.239
	(0.877)	(0.454)	(0.458)
Ln(RGDP)	0.425	-3.720*	-2.691
	(3.128)	(2.078)	(1.785)
Location	Yes	Yes	Yes
Year	Yes	Yes	Yes
N	1,992	3,555	5,547
Adjusted R^2	0.003	0.004	0.001

NOTE: The parameters are the results from a regression of Eq. (3) for political alignment, and the dependent variable is tax evasion rate. Alignment indicates how much a county is aligned with the current government, and while Ln(RGDP) is the logarithm of the regional GDP. All specifications have location and time series fixed effects by county and year levels. The sample for this regression is the self-employed group from the Korean Labor & Income Panel Study. Statistical significance is indicated by * at the 10% level, ** at the 5% level, and *** at the 1% level.

Table 3.7. Extensive margin on changing job to self employment

	(1) Self Employment	(2) Self Employment	(3) Self Employment
Alignment	-0.033	-0.030	-0.032
	(0.081)	(0.080)	(0.081)
Ln(RGDP)	-0.052	-0.052	-0.054
	(0.043)	(0.044)	(0.043)
Location	Yes	Yes	Yes
Year	Yes	Yes	Yes
Age	Yes	Yes	Yes
Gender	No	Yes	Yes
Education	No	No	Yes
Observations	5,654	5,654	5,654
Pseudo R^2	0.130	0.131	0.133

NOTE: The parameters are the results from a regression of Eq. (4) for extensive margin of political alignment, and the dependent variable is a dummy variable for self-employment. The sample for this regression is the self-employed group from the Korean Labor & Income Panel Study. Statistical significance is indicated by * at the 10% level, ** at the 5% level, and *** at the 1% level.

Chapter 4

References

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