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ABSTRACT

Do Class Size Reductions Protect Students from Infectious Disease? Lessons for COVID-19 Policy from Flu Epidemic in Tokyo Metropolitan Area*

We evaluate the causal effect of class size (i.e., number of students in a classroom) on incidence of class closure due to flu epidemic in 2015, 2016, and 2017, applying an instrumental variable method with the Maimonides rule to administrative data of public primary and middle school students in one of the largest municipalities within the City of Tokyo Metropolitan Area. Given the classroom area of 63m^2 set by regulation in Japan, class size reduction improves social distancing among students in a classroom. We find that class size reduction is effective to reduce class closure due to flu: one unit reduction of class size decreases class closure by about 5%; and forming small classes with 27 students at most, satisfying the social distancing of 1.5 m recommended to prevent droplet infection including influenza and COVID-19, reduces class closure by about 90%. In addition, we find that the older are students, the larger are the effects of class size reduction. Our findings provide supportive evidence for the effectiveness of social distancing policy in primary and middle schools to protect students from droplet infectious disease including COVID-19.

JEL Classification: I18, I21, I28

Keywords: class size, class closure, students health, influenza(flu) epidemic, lesson for COVID-19, COVID-19

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* The contents and opinions in this article are solely the personal views of the authors. All remaining errors are our own.

1 Introduction

Outbreaks of communicable diseases have affected not only health outcomes but also people's behavior and lifestyle, along with various socioeconomic outcomes. Currently, to prevent the spread of coronavirus disease 2019, known as COVID-19, national and subnational governments in many countries have decided to implement policies restricting interactions among individuals, which are believed to save human lives but have negative consequences for social and socioeconomic markers.[1] School closure is one of the most extreme forms of such restrictive policies. According to an estimate by the National Council for School System Evaluation (CNESCO) in France, 134 countries had closed schools nationwide in the face of COVID-19 as of June 3, 2020.[2] School closure is considered as an effective measure to control flu pandemic, as school-aged children would have the greatest frequency of daily contacts with those in the same age group during the weekdays (Ibuka et al., 2016). On the other hand, closure may not be valid for coronaviruses like severe acute respiratory syndrome (SARS), since school-aged children are less likely to develop the disease and to reach serious status.(Viner et al., 2020)[3] Such an approach would also affect students' outcomes adversely due to reduction of instruction time in schools. As previous studies indicate positive relation between instruction time in schools and students' achievements, (e.g., Wößmann, 2003; Pischke, 2007; Bellei, 2009; Gary-Bobo and Mahjoub, 2013; Hansen, 2013; Kikuchi, 2014; Andrietti, 2015; Lavy, 2015; Rivkin and Schiman, 2015; Battistin and Meroni, 2016; Cattaneo et al., 2017; Bessho et al., 2019)[4] , decreased instruction time due to school closures will tend to affect students' current and future outcomes negatively. In addition, it is known that this adverse effect is more serious for students from disadvantaged households, widening the gap in education by socioeconomic background.[5] To mitigate this adverse effect of school closure, it is an urgent

[1] For example, Friedson et al. (2020) found that California's shelter-in-place order reduced cases and deaths of COVID-19 but cased four hundreds job losses per life saved. Additionally, since there is a relationship between unemployment and suicide (Milner et al., 2013), job losses caused by the lockdown may increase the number of suicides.

[2] The number of countries implementing the nation-wide school closure reached its maximum in early April, at 194. Please see `https://en.unesco.org/covid19/educationresponse` for more details. (accessed on June 5, 2020)

[3] Viner et al. (2020) also mentioned that school closure was not effective for SARS outbreaks in China, Hong Kong, and Singapore, while studies for SARS using a modeling approach had predicted opposite results. Based on current modeling studies on COVID-19, school closures alone have prevented 2%-4% of deaths, which is much less than other interventions. (Viner et al., 2020)

[4] Meyer and Van Klaveren (2013) found that there are no effects on students achievements.

[5] Alexander et al. (2007) and Downey et al. (2004) found that gaps in student achievement by socioeconomic status expand during the summer vacation. In the Japanese context, Kawaguchi (2016) found that the 2002 Japanese education reform, which decreased in-schools instruction time, increases socioeconomic gaps. Kubota (2016) also analyzed the effects of the 2002 reform, and found that households with higher socioeconomic background increased spending on supplementary after-school education. On the other hand, Motegi and Oikawa (2019) analyzed the 2002 reform from the perspective of school resources, and found school instruction time becomes more effective when combined with

policy issue to seek a safe way to reopen schools without exposing students to risk of infections.

One such policies to prevent the spread of viruses in schools is to increase the physical distance of each student, in so-called social distancing or physical distancing, in classrooms. While social distancing in schools under outbreaks has been discussed, there is little information on the effects of social distancing policies and procedures in schools other than under prolonged school closure (Uscher-Pines et al., 2018). This paper focuses on class size reduction, that is the decrease in the number of students in a classroom, as a feasible means of social distancing in classrooms. Given the fixed area of the classroom, the physical distance between students depends on class size: the smaller class sizes, the greater students' physical distance.

We estimate the effect of class size reduction on the incidence of class closure using school administrative data collected by the Education Board of City X in Tokyo Metropolitan Area. We utilize school closure as an outcome proxying flu epidemic in classrooms, rather than policy intervention. Due to the COVID-19 pandemic, which does not yet have any vaccine or silver bullet, in many countries national governments decided to close schools across entire nations at once, regardless of the spread of infection. Unlike in the case of COVID-19, however, class closure for seasonal flu depends on decisions made by local stakeholders, such as municipalities and/or school directors. They consider various potential adverse effects, discussed above, and take measures according to the epidemic trend of seasonal flu. Therefore, class closure could be a useful assessment measure of flu epidemic in classrooms.(Suzue et al., 2012) To identify the causal effect of class size reduction, we utilize an instrumental variable estimation using the Maimonides' rule, established by Angrist and Lavy (1999), to control for endogeneity of class sizes.

Estimation results reveal that one-unit reduction in class size decreases class closure due to flu by about 5.2%-5.3% in comparison to the overall mean and that we could have reduced class closer by about 90% if we reduced size of all classes to less than or equal to 27. Given the area of a classroom in Japan, which is $63m^2$ as set by regulations, a class size of 27 is the largest with which students can maintain physical distance of $1.5m$. The distance of $1.5m$ is the threshold reducing the risk of infection due to large droplet exhaled by the infected person. Additionally, when we use a cubic function of class size and estimate class size effects, the estimation result shows that the marginal effects are statistically significant at least 10% at a class size of between 27 and 34. One possible interpretation of the class size effect is that class size reduction increases the physical distance between students and consequently, prevents flu spread in classrooms. This result also implies that once students get a certain level of physical distance, additional class size reduction is

higher-quality teachers and that the effects are larger for students with lower socioeconomic backgrounds. Battistin and Meroni (2016) found that increases in schools' instruction time increased test scores among students of the least advantaged backgrounds in Italy.

no longer effective to decrease the probability of flu infection. The results show that the older are students, the stronger are the effects of class size reduction.

This paper is related to the strand of literature of education economics with special focus on the effects of class size. Many papers analyze the causal effects of class size on students' outcomes, using datasets from both experimental settings (e.g., Tennessee's Project Star) and quasi-experimental settings, like studies using the Maimonides' rule. While previous studies have focused on outcomes such as student achievement (e.g., Angrist and Lavy, 1999; Hoxby, 2000; Dobbelsteen et al., 2002; Bonesronning, 2003; Leuven et al., 2008; Hojo, 2013; Akabayashi and Nakamura, 2014; Angrist et al., 2019), long-term outcomes (e.g., Krueger and Whitmore, 2001; Chetty et al., 2011; Fredriksson et al., 2013; Leuven and Løkken, 2020), parental responses (Fredriksson et al., 2016), and manipulation of students' test scores by teachers (Angrist et al., 2017) , less attention has been paid to protection of student health.[6] Therefore, we will focus on students' health outcome, which could provide new insight to class size effect studies.

The remainder of the paper is organized as follows: section 2 explains the institutional background, and section 3 discusses the data and descriptive statistics. Section 4 describes the estimation model, and section 5 discusses the estimation results. Section 6 provides some additional remarks, and section 7 concludes this paper, with suggestions for further research.

2 Institutional Background

In this section, we briefly summarize the institutional settings of education in Japan related to: 1) judgment of class closure; 2) regulation of class size; and 3) surface area of classroom.

In Japan, it is set by the School Health and Safety Act that school administrators have discretion to shut down schools, grades, and classes under their jurisdictions to prevent expansions of viral infections. In the case of public primary and middle schools, not school principals but education board of local municipalities decide whether or not to shut down them. The national government does not provide explicit criterion for judgment of the shutdown. In some cases, prefectural or municipal education boards set the criterion for judgment for their public schools. The criteria vary across prefectures and municipalities, but in many cases education boards decide to close classes, grades, or schools when the rate of absentees reached 20%. In Japan, flu is a major cause of class shutdowns. Since flu infection expands in winter seasons, most of the class closure are observed in the seasons. In 2018-2019 of Tokyo, the number of flu infection increased from December, peaked

[6] Jakobsson et al. (2013) analyzed the effects of class size on adolescents' mental health problems and well-being using a Swedish dataset and concluded that the results cannot show that class size does not effect mental health problems and well-being.

in January, and got closer to zero in February, and class closure is mainly observed in January and February.[7]

Public elementary and middle schools in Japan have an upper limit of class sizes by Act on Standards for Class Formation and Fixed Number of School Personnel of Public Compulsory Education Schools. The law allows education boards of the governments to set an original upper limit of class sizes as long as the limit is below the national standard. Public schools in City X have the upper limit of class sizes: 35 students for 1st, 2nd, and 7th grades, and 40 students for the other grades (3rd, 4th, 5th, 6th, 8th, and 9th grades).

Next, we explain the surface area standard for classroom in Japan. The standard for surface area in classrooms under the Standard Design of Reinforced Concrete School Buildings of 1950 is $63m^2$. According to Mori (2019), surface area in classrooms is distributed around the standard, $63m^2$, in both elementary and middle schools: the average value of surface areas is 64.80 for elementary schools and 65.05 for middle schools, and the median values are 64 and 65, respectively.[8] Since most classrooms are constructed in accordance with the standard, there is less variation in the area of classrooms than in the number of students in a classroom. Therefore, the number of students in the classroom and change in it largely determines the students' potential for physical distancing in the classroom. If surface area in a classroom is $63m^2$, the area per person is $1.54m^2$ for classes with a teacher and 40 students, that is, class size 40, and $2.25m^2$ for class size 27. Increase in classroom area per person should expand social distance among people in the classroom.

3 Data

This paper utilizes the school administrative data collected by the Education Board of City X in Tokyo Metropolitan Area. City X is a large municipality with more than 300 thousand households and a population of more than 600 thousand in 2015. In 2015, City X had about 70 public elementary schools with about 1000 classes and about 40 public middle schools with about 400 classes. The data cover various information related to educational administration, such as the list of students in classrooms and the instance of class shutdowns, for all public elementary and middle schools operated by City X. Since, as explained, the education boards of local governments make the final decision on class closure in Japanese public schools, the Education Board of City X keeps the records on school shutdown in schools operated by them. The shutdown data include two types of closures: class closures and grade closures, one class (or grade) would be kept home but another allowed to go to school. In this paper, we utilize the both types of closure and hereafter,

[7] http://idsc.tokyo-eiken.go.jp/diseases/flu/flu2018/

[8] Distribution of surface areas of classrooms is presented on p. 87 of Mori (2019).

for simplicity, will call both class closure. While the data contains students' information for a long period, information about class closure due to flu is only available for three years, from 2015-2017. Using the data, we construct three-year class-level data which includes classes' characteristics and incidence of class closure. We exclude classes with less than 17 students and classes in grades with less than 30 students, as there are a few classes or grades with very few students. After the sample restriction, 4271 observations in public elementary and middle schools are available for analysis.

[Table 1 about here.]

Table 1 summarizes the sample average and standard deviation for variables. Column (1) shows statistics for entire classes, and Columns (2)-(5) are those for grade categories. According to Column (1), among the entire sample, about 17.3% of classes have 27 students or less and average class size is about 31.5. The higher the grade, the larger the class sizes, but the increases are not substantial (Columns (2)-(5)). The proportion of class closure due to flu among the entire sample is about 8.6% (Column (1)) and decreases as the grade goes up (Columns (2)-(5)).

[Figure 1 about here.]

[Figure 2 about here.]

Figure 1 shows the number of closed classes due to flu epidemic by month. In public schools in City X, the peak of the flu epidemic is observed between December and February, the winter season in Japan. All three years have same tendency. Figure 2 shows the distribution of the absentee rate in classes just before class closure.[9] According to Figure 2, among closed classes, the minimum value of the absentee ratio is about 10%. However, this does not necessarily imply that an absentee ratio of 10% is a criterion for class closure, because the data on the absentee ratio are available only for the closed classes. Most of the closed classes have an absentee ratio from 25% to 40%, with mean value of 34.0% and median is 33.3%.

4 Estimation Model

The estimation equation is as follows:

$$Closure_{jsgt} = \alpha + \beta ClassSize_{jsgt} + x'_{jsgt}\delta + \eta_t + \xi_s + \lambda_g + u_{jsgt} \tag{1}$$

[9] This figure excludes the case of grade closure, because it is difficult to identify the number of absentees in each class in such a situation.

where j, s, g, and t are indices of class, school, grade, and year. The dependent variable $Closure_{jsgt}$ takes one if the class is closed due to the flu epidemic. We utilize closure as a proxy for the flu epidemic in classrooms because it is a useful assessment measure of the trend of epidemic phenomena (Suzue et al., 2012). The variable $ClassSize_{jsgt}$ represents the class size. In this paper, we use two definitions of the class size variable: the linear term of class size and a dummy variable that takes one if the class size is less than or equal to 27. If a classroom has $63m^2$, class size of 27 is the threshold that the area per person in the classroom becomes over $2.25m^2$ when the class size is reduced.[10] Being within $1.5m$ of an infected person increases the risk of droplet infection[11] , and class size of 27 could provide an area of square $1.5m$ on a side ($2.25m^2$) for each person: the people in the classroom could maintain a physical distance of $1.5m$. Therefore, the dummy variable could be interpreted as an indicator of whether students have enough physical distance to prevent droplet infection of flu. The vector x_{jsgt} is a set of control variables that includes the linear and squared terms of the number of enrollees in a grade in the school and the ratio of girls in the class. The parameters η_t, ξ_s, and λ_g capture the year, school, and grade fixed effects (FEs). Year fixed effects could capture the status of flu epidemic outside of schools, which is one determinant of flu epidemic in classrooms and may be correlated with class size. Public schools in City X are close to each other: City X has about 2 public schools per one square kilometer[12] , flu spread outside of school may not differ substantially within City X. u_{jsgt} is an unobserved error term. In Equation (1), β is the parameter of interest in this paper.

Identifying the causal effect of class size is challenging when the class size is endogenous. Schools that have students who need more intensive instruction from teachers, for example, students with physical/mental health problems, disability, or problem behaviors such as hyperactivity disorder, may utilize a small class. These students' characteristics are likely to affect class closure because students with health problems may be more susceptible to the virus and it may be difficult to keep up social distancing particularly among such students. In this case, the effect is underestimated in the absolute value. This paper utilizes an instrumental variable approach using the upper limit of class size.

Angrist and Lavy (1999) utilized the fact that class size changes discontinuously when the number of enrollees in a grade increases around the upper limit of class size. For example, if

[10] The area per person is $2.17m^2$ for classes with a teacher and 28 students.

[11] According to a guideline for influenza by the Japanese government, the relatively large droplet exhaled by a person infected flu can directly enter the respiratory organs of surrounding people at a distance of 1 to $1.5m$ and cause a virus infection. Please see a footnote in p.4 in `https://www.mhlw.go.jp/bunya/kenkou/kekkaku-kansenshou01/dl/tebiki25.pdf#page=4` (accessed on June 23, 2020). Liu et al. (2017) found that the distance of $1.5m$ is a threshold substantially increase in airborne exposure to droplet exhaled by the source.

[12] The area of City X is about $50km^2$, and the number of public schools as of 2015 is 100.

both the upper limit and the number of enrollees are 40, a class of 40 students is organized in this grade, but if the number of enrollees increases to 41, the class is divided into two classes: a class of 20 students and a class of 21 students, because a class size of 41 exceeds the upper limit. The identification strategy relies on this discontinuous change due to the administrative rule called the Maimonides' rule. Since, as explained in Section 2, public schools in Japan follow similar class organization rules, we utilize this rule to identify the causal effect of class size. Following Angrist and Lavy (1999), we predict class size by the Maimonides' rule as follows:

$$Msize_{jsgt} = \frac{SchoolSize_{sgt}}{int(\frac{SchoolSize_{sgt}-1}{L_{sgt}} + 1)} \tag{2}$$

where $SchoolSize_{sgt}$ is the number of enrollees in a grade in a school and L is the upper limit of class size. As explained, City X sets the upper limit in public schools as 35 for 1st, 2nd, and 7th grades, and 40 for other grades.

[Figure 3 about here.]

Figure 3 shows the actual class sizes and the class size predicted by the Maimonides' rule. Most of the actual class size overlap the predicted class sizes.

We estimate Equation (1) by 2-Stage Least Squares (2SLS) using the predicted class sizes as the instrumental variable. The first stage equation is as follows:

$$ClassSize_{jsgt} = \pi + \rho Msize_{jsgt} + x'_{jsgt}\gamma + \phi_t + \theta_s + \mu_g + v_{jgt}. \tag{3}$$

We use the same control variables as Equation (1). The parameters ϕ_t, θ_s, and μ_g respectively capture the year, school, and grade fixed effects, and the parameter v_{jsgt} is an unobserved error term. Empirical works with instrumental variable strategies often encounter weak instruments. We will investigate the possibility of weak instruments using first-stage F-statistics and the rule-of-thumb value of 10.

An identification assumption, absent the manipulation of enrollment by parents, should be satisfied to allow the instrumental variable estimation to be employed. Since City X has introduced a school choice program for public schools, parents could partially choose a school for their children in our sample period (see below). If parents want their children to enroll in smaller classes, in which the children may receive more intensive instruction and get higher achievement, and if the parents then choose a school by predicting class size with the Maimonides' rule, the identification assumption is violated. However, the influence of manipulation on estimation results should be little, for the following reasons. First, City X assigns children to public schools based on the children's residential addresses, like other Japanese municipalities, and students are ensured enrollment in their assigned school if they choose it. If parents want their children to enroll in a school other than the assigned school, they can apply to the school choice program. Since City X sets upper caps of the number of enrollees in the school in advance depending on the number of residents around the school, children are not always able to choose a school, however. Therefore, there are uncertainties in school choice, and it is difficult to manipulate enrollment perfectly.[13] Second, in cities of Tokyo Metropolitan Area introducing school choice programs, students apply the programs mostly because of reasons not related to academic achievement, for example, closeness between houses and schools and the friends plan to enroll the school.[14] Therefore, it is unlikely that the school choice program is being used to put children in small classes. Additionally, we put school fixed effects in the estimation model to control for the school's unobserved characteristics.

5 Results

[Table 2 about here.]

Table 2 shows the estimation results for the effects of class size on class closure. Columns (1), (2), and (3) are the results using the linear term of class size, and Columns (4), (5), and (6) are those using the class size dummy, which takes one if the class size is less than or equal to 27. We report the results using Ordinary Least Squares (OLS) (Columns (1) and (4)), those using 2SLS (Columns (2) and (5)), and those using 2SLS for classes in the schools whose enrollments are between the cutoff values plus 6 and minus 6 (Columns (3) and (6)). In Table 2, standard errors robust against school-level clustering are reported in parentheses.

According to Table 2, by OLS estimation, the estimate of class size ("class size") is 0.0031, statistically significant at the 10% level (Column (1)). By comparing the estimate with the overall mean, 0.086, we see that a one-unit decrease in class size is associated with about a 3.6% decrease in the probability of class closure. Since, as mentioned, there is the possibility that the OLS estimate suffers from endogeneity bias, this causal interpretation requires a caution.

[13] Parents also can choose a school by moving to the area which the school covers. However, it is very costly for households to move. Hojo (2013) and Akabayashi and Nakamura (2014), which analyzed class size effects in Japan, argued that moving for school enrollment is costly and does not occur much.

[14] According to Yasui (2012), in a city, students who enroll in schools other than the assigned school choose the school mostly because their friends plan to enroll there. In other cities, the closeness between houses and schools are most chosen reason why students choose the school. (`http://www.city.sumida.lg.jp/kosodate_kyouiku/kyouiku/school/nyuuen_nyuugaku/annke-tokekka.files/ANKEITOCHOUSAKEKKAGAIYOU.pdf` accessed on June 19, 2020)(`https://www.city.minato.tokyo.jp/gakkouuneishien/kodomo/gakko/tetsuzuki/tennyugaku/sentaku/enquete/documents/29anke.pdf` accessed on June 19, 2020)

To control for endogeneity bias, we also estimate Equation (1) using 2SLS. According to the estimation result, the estimate of class size is 0.0046, statistically significant at 5% (Column (2)). The F-statistic for the first stage is about 1074.41, over the rule-of-thumb value of 10, which suggests that the instrumental variable in the first stage works well. By reducing one unit of class size, compared with the overall mean, the probability of class closure is thus decreased by 5.3%. The magnitude of the 2SLS estimate is about 48.4% larger than that of the OLS estimate. Therefore, there seems to be a downward bias in absolute value in the OLS estimate. When we restrict the sample to classes in the schools whose enrollments are in between the cutoff values plus 6 and minus 6, the estimate by 2SLS is 0.0051 and statistically significant at the 10% level (Column (3)). Compared with the overall mean, a one-unit reduction in class size decreases the probability of closure by 5.2%, which is almost the same level as the result of standard 2SLS, while the magnitude of the estimate is slightly larger than that of the standard 2SLS estimate (0.046 vs 0.0051). Therefore, the restriction of the sample around the discontinuity does not affect the estimation results. On the other hand, compared with 2SLS, the standard error of "2SLS±6" is higher, and thus, the significance level goes down. In this specification, the F-statistic is 304.08, over the rule-of-thumb value of 10. The results using 2SLS suggest that after we control for the endogeneity bias using the Maimonides' rule, one-unit reduction in class size decreases the probability of class closure by about 5.2%-5.3%.

The estimation results are robust when we utilize the other definition of the class size variable. The estimate of the class size dummy using 2SLS ("class size $\leq$ 27") is -0.0757, statistically significant at 5% (Column (5)), while the OLS estimate is -0.0281 and is statistically significant at 10% (Column (4)). By reduction of the class size from over 27 to 27 or below, compared with the mean in classes with over 27 students, 0.087, the probability of class closure due to flu epidemic is thus decreased by 86.6%. The size of the effect is about -87.1%[15] when we use classes in schools whose enrollments are in between the cutoff values plus 6 and minus 6 (Column (6)). Therefore, we can reduce class closure substantially if we reduce class size to less than or equal to 27 (86.6%-87.1%).

[Table 3 about here.]

Next, we implement a subgroup analysis by grade in school. Table 3 shows the estimation results using the linear term of class size by grade. In this analysis, we divide the classes into three categories by grade: "1st, 2nd, and 3rd," "4th, 5th, and 6th," and "7th and 8th." The categories "1st, 2nd, and 3rd" and "4th, 5th, and 6th" correspond to classes in elementary schools and "7th

[15] $= -0.0878/0.101$

and 8th" to those in middle schools.[16] We estimate only two types of models, "OLS" and "2SLS," because the estimate of "2SLS" and that of "2SLS ± 6" are not different and there is less variation when we utilize school fixed effects and restrict the sample.

According to Table 3, the higher the grades, the larger the magnitude of the estimates. Among "4th, 5th, and 6th," the 2SLS estimate is 0.0061 and statistically significant; compared to the overall mean (0.074), a one unit reduction of class size decreases the probability of class closure by 8.3% (Column (4)). In the case of "7th and 8th," the 2SLS estimate is 0.0134, statistically significant, and about double the estimate for "4th, 5th, and 6th" (Column (6)). Compared to the overall mean (0.076), the probability of closure is reduced by 17.7% by a one unit decrease in class sizes. The estimate for "1st, 2nd, and 3rd" is about one-fourth that for "4th, 5th, and 6th," and statistically insignificant. Class size reduction does not work well for prevention of flu epidemic among younger students because younger students may not be good at social distancing.

To sum up, we found that reduction in class size decreases the incidence of class closure and that the effect is strong for the higher grades. These results suggest that the class size reduction mitigates the epidemic of flu virus in the classroom among older students.

6 Discussion

In this section, we interpret the effects and give policy implications for schools reopening during the COVID-19 crisis.

6.1 Interpretation of Class Size Effects on Class Closure

As mentioned in Section 2, the national government in Japan does not provide explicit criteria for class closure. Therefore, local education boards can make the decision on class closure flexibly. In such a context, interpretation of the class size effects is complicated. One possible interpretation is that the education board more rapidly select class closure in larger classes to prevent flu epidemic even when the proportion of infected students is low. Another is that as class size decreases, the slower the spread of the flu epidemic becomes. This may be because of the increase in social distancing in classrooms and/or the increase in time teachers can spend with each student. In the

[16] We exclude the 9th grade from the middle school category, because when we include 9th grade classes in this category the estimation results become noisy. In Japan, 9th grade students take a high school entrance exam mainly between January and March and the peak of flu epidemic overlaps with these months. Therefore, 9th grade students are likely to get a flu vaccination because they don't want to miss their big exam. The data support this possibility: the rate of class closure in 9th grade is about 3%, one-fourth of the rate among 1st to 3rd grades. By means of these, the results could become noisy.

former case, the estimation results do not necessarily support the argument that class size reduction can mitigate the flu epidemic in classrooms.

First, we discuss the former possibility: the education board more rapidly selects class closure in larger classes, using the information about the absentee ratio in classrooms just before class closure. If the education board more rapidly decide on class closure for large classes regardless of the intensity of virus spread, there should be a negative relationship between class size and the absentee ratio in classrooms just before class closure. We construct a class-closure-case-level dataset and merge it with the class characteristics.[17] Using the dataset, a regression model of the absentee rate on the class size variable is developed, and the set of control variables is estimated.[18]

[Table 4 about here.]

Table 4 summarizes the estimation results. The analysis sample consists of all cases of class closure in both elementary and middle schools. After controlling for observable characteristics, the coefficient of class size is negative but statistically insignificant (Column (1)). Compared to the overall mean, a one unit increase in class size decreases the absentee ratio by 0.7%. According to Table 2, a one unit reduction in class size decreases the probability of class closure by 5.2%-5.3%, ten times larger than the magnitude for the absentee ratio. This tendency is robust against the definition of the class size variable (Column (2)). Therefore, the possibility, that the education board more rapidly decide on class closure for larger classes regardless of the intensity of virus spread should not greatly contribute to the interpretation of the results.

Second, we discuss the latter possibility: as class size decreases, the slower the spread of the flu epidemic becomes. One possible interpretation is social distancing in classrooms. Increasing physical distance from others is one key strategy to prevent spread of viruses. As explained, in Japan, since most classrooms have almost the same surface area, class sizes (student numbers) determine physical distance for each student. The smaller the class sizes, the larger students' physical distance from others. If a classroom has a surface area of $63m^2$, the reduction of class size from 40 to 27 increases the area per student by about 46.1%: from 1.54 to $2.25m^2$. Students can then maintain a physical distance of $1.5m$, which is the threshold reducing the risk of infection due to relatively large droplet exhaled by the person when class size is decreased to 27. According to the estimation results, among classes with 27 or fewer students, the probability of class closure substantially drops (86.6%-87.1%) compared to the classes with over 27 students. This may be because these students

[17] Since some classes experienced closure twice, we use not class-level dataset but case-level dataset to increase the sample size. For simplicity, we exclude the case of grade closure, because it is difficult to identify the number of absentees in each class.

[18] We utilize number of students in a grade in a school, squared number of students in a grade in a school, girl ratio, grade FEs, and year FEs as the control variables.

can maintain the ideal level of distance from other students in the classroom. Additionally, when we use a cubic function of class size and estimate the class size effects, the estimation result shows that the marginal effects are statistically significant at 10 % between class sizes of 27 and 34. This estimation result implies that once students get enough physical distance, class size reduction is no longer effective to decrease the probability of flu infection.[19] Therefore, it is possible that the increase in physical distance for each student by the reduction of class size can help prevent the flu epidemic in classrooms.[20] It is also possible that the reduction in class size gives teachers more time to spend with each student and that this intensive instruction prevents the flu epidemic. However, since some previous studies have found no effect of class size on students' achievement (e.g., Hoxby, 2000; Dobbelsteen et al., 2002; Angrist et al., 2019) and one study found no class-size effects on mental health problems or well-being among Swedish 9th graders (Jakobsson et al., 2013), it is likely to be more effective to focus on increasing physical distance by reducing class size than on other possibilities, like increasing teachers' time spent with each student.

To sum up, social distancing due to the class size reduction is one possible account of the positive effects of class size on the probability of class closure due to flu. If so, we would expect this social distancing to be effective not only against flu but also against other viruses like COVID-19. In the next subsection, we would like to discuss the policy implications of our study for the current COVID-19 pandemic.

6.2 Policy Implications for Schools Reopening During the COVID-19 Crisis

Currently, in many countries, schools are shut down because of the COVID-19 pandemic. Since the reduction of school instruction time negatively affects student achievement and expands the gap in achievement by socioeconomic situations, school reopening is an important policy issue that needs to be dealt with promptly. Social distancing for students should have a key role when schools restart, and reduction of class size is a way to create the needed physical distance. As explained above, according to our estimation results, class size reduction can prevent flu epidemic in classrooms. In this subsection, we would like to discuss class size policy when schools are reopened during the COVID-19 crisis using our estimation results for the effects of class size on class closure due to flu.

Creating the physical distance for each student is a way to protect students from exposure of droplet exhaled by an infected student. According to Liu et al. (2017), the exposure of droplet exhaled by a source substantially increases within the distance of 1.5m from the source. In terms

[19] Appendix A.1 discusses more details of the estimation results with the cubic function.

[20] If the prevention of droplet infection reduces the incidence of epidemics in classrooms, other ways to prevent droplet infection than the class size reduction, such as wearing face masks in classrooms and setting up partitioning screens between students, may also help to reduce epidemic in classrooms.

of reducing the exposure, increases in physical distance by class size reductions should have same effects for both flu and COVID-19. Actually, the distance of $1.5m$ is utilized as a guideline of “social distancing" for the current COVID-19 crisis in some countries such as Australia, Belgium, Germany, and Italy.[21] Therefore, we consider that the class size reduction is an effective way to protect students from the exposure of droplet from other students not only for flu but also for COVID-19.

On the other hand, however, the heterogeneity of infectivity between flu and COVID-19 may make a difference in the effectiveness of the class size reduction even if we protect students from the heavy exposure of droplet from the infected student. According to previous studies, it is possible that COVID-19 is likely more infectious than flu.[22] In case that COVID-19 is more infectious, the risk of infection may be increased even if the exposure of the droplet is not intense. If so, the estimated effects of class size reduction for flu could be an upper bound in terms of absolute value of the effects for COVID-19. In this case, our result is applicable for COVID-19 at least in the point that the reduction of class size and consequent increase in physical distance in classrooms do not prevent COVID-19 infection in classrooms among the younger students. Therefore, among the younger students, other interventions should be implemented to prevent COVID-19 infection in classrooms. However, this is just a potential scenario, and there is an opposite possibility: if COVID-19 is less infectious than flu among school-aged children, our estimated effects are lower bounds in terms of absolute value of the effects for COVID-19. In that case, our estimation result should be a conservative evaluation of effects of class size reduction for COVID-19. Further analyses of the effect of social distancing on COVID-19 infection such as quantitative analysis using mathematical models gives us more insight for discussing whether or not class size reduction is effective for COVID-19. Even if there are some possible scenarios as discussed above, the class size reduction and consequent increase in social distancing could at least protects students from exposure of droplet exhaled by an infected student.

[21] `https://www.bbc.com/news/science-environment-52522460` (accessed on June 23, 2020).

[22] The basic reproduction number (R_0), which is a measurement of the infectivity and is defined as “the average number of new infections that one case generates, in an entirely susceptible population, during the time they are infectious” (Coburn et al., 2009, p.2), of COVID-19 is estimated to be higher than the estimated R_0 of flu. A recent review article reported that the estimated R_0 of COVID-19 has a mean of 3.28 and median of 2.79 (Liu et al., 2020), while the estimated R_0 ranges from 0.9 to 2.1 with mean of 1.3 for seasonal flu, from 1.4 to 2.8 for the 1918-1919 pandemic strain, and from 1.4 to 1.6 for novel influenza (Coburn et al., 2009). Compared with the mean R_0 of seasonal flu, that of COVID-19 is about 2.5 times higher.

7 Conclusion

This paper analyzes the effects of class size reduction on class closure due to flu epidemic using administrative data from City X in Tokyo Metropolitan Area, and the the instrumental variable strategy with the Maimonides' rule. According to the estimation results, one-unit reduction in class size decreases the incidence of class closure due to flu by about 5.2%-5.3%, and forming small classes with 27 students reduces class closure by about 90%. If a classroom has $63m^2$ of area, a standard for classroom area in Japan, by reducing the class size to below 27, students can maintain 1.5 meters' physical distance from others, which is the threshold reducing the risk of infection due to relatively large droplet exhaled by the person. Additionally, when we use a cubic function for class size and estimate class size effects, the estimation result shows that the marginal effects of class sizes are statistically significant between class size of 27 and 34, implying that once students get a certain level of physical distance, class size reduction is no longer effective to further decrease the probability of flu infection. Thus, taken as a whole, the results seem to show that class size reduction increases physical distance between students and consequently prevents flu epidemic in classrooms. The results also show that the class size reduction is effective only among older students. Our results on class-size effects may be applicable to COVID-19, but we need to proceed carefully. For safety of students and teachers, increasing students' physical distancing by class size reduction should be considered when schools are restarted during the COVID-19 pandemic without any vaccine or silver bullet. Spread of viruses affects not only students' health but also their academic achievement. Decrease in school instruction time as a result of class closures due to virus spread is likely to affect student achievement and expand socioeconomic gaps in achievement.

Before concluding, we will mention two limitations of this paper that should be addressed in future work. First, the decrease in probability of class closures by class size reduction does not necessarily imply a decrease in flu infection in classrooms due to social distancing; there may be other explanations (though we eliminate one critical explanation in Section 6). For further analysis, we need more detailed datasets, for example, data individually tracking students' absence and reasons for it allows us to better analyze the spread of the virus in classrooms. Second, more detailed heterogeneous effects of student and teacher characteristics should be analyzed. For example, the combination of class size reduction and allocating teachers with strong ability to manage students may boost class size effects.

Appendix

A.1 Estimation Results Using Other Functional Forms of Class Size

[Table 5 about here.]

[Table 6 about here.]

[Figure 4 about here.]

[Figure 5 about here.]

This appendix briefly summarizes the estimation results for the class size effect using the quadratic and cubic functions of class sizes. We estimate Equation (1) using class size, squared class size, and cubed class size. Table 5 shows the estimation results with full sample. We report not only coefficients of class size variables but also Kleibergen-Paap rk Wald F statistics for weak identification and p values for testing, with the hypothesis that all of the coefficients are zero.

According to Table 5, when we used the quadratic function, among both OLS and 2SLS models, the coefficient of class size and that of squared class size are insignificant, while the p value for the test is 0.056 when we use the 2SLS model. In the case of cubic function, among both OLS and 2SLS, all of the coefficients are statistically significant. For both quadratic and cubic functions, the Kleibergen-Paap rk Wald F statistics are over 10.

Table 6 summarizes the estimated marginal effects of class size using the estimated coefficient in Columns (2) and (4) of Table 5, while Figures 4 and 5 plot the marginal effects with 95% confidence intervals. The standard errors are calculated using the delta method. According to Columns (1) of Table 6, the marginal effects of class size are upward-sloping and statistically significant at least 10% between class sizes of 29 and 37 when we utilize the quadratic function of class sizes. Column (2) of Table 6 shows that the marginal effects of class size are statistically significant at least 10% between class sizes of 27 and 34.

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References

Akabayashi, Hideo and Ryosuke Nakamura, "Can small class policy close the gap? An empirical analysis of class size effects in Japan," *Japanese Economic Review*, 2014, *65* (3), 253–281.

Alexander, Karl L., Doris R. Entwisle, and Linda Steffel Olson, "Lasting consequences of the summer learning gap," *American Sociological Review*, 2007, *72* (2), 167–180.

Andrietti, Vincenzo, "The Causal Effects of Increased Learning Intensity on Student Achievement: Evidence from a Natural Experiment," *SSRN Electronic Journal*, 2015, (June).

Angrist, Joshua D. and Victor Lavy, "Using Maimonides ' Rule to Estimate the Effect of Class Size on Scholastic Achievement," *The Quarterly Journal of Economics*, 1999, *114* (2), 533–575.

_ , Erich Battistin, and Daniela Vuri, "In a small moment: Class size and moral hazard in the Italian Mezzogiorno," *American Economic Journal: Applied Economics*, 2017, *9* (4), 216–249.

_ , Victor Lavy, Jetson Leder-Luis, and Adi Shany, "Maimonides' Rule Redux," *American Economic Review: Insights*, sep 2019, *1* (3), 309–324.

Battistin, Erich and Elena Claudia Meroni, "Should we increase instruction time in low achieving schools? Evidence from Southern Italy," *Economics of Education Review*, 2016, *55*, 39–56.

Bellei, Cristián, "Does lengthening the school day increase students' academic achievement? Results from a natural experiment in Chile," *Economics of Education Review*, 2009, *28* (5), 629–640.

Bessho, Shun-ichiro, Haruko Noguchi, Akira Kawamura, Ryuichi Tanaka, and Koichi Ushijima, "Evaluating remedial education in elementary schools: Administrative data from a municipality in Japan," *Japan and the World Economy*, 2019, *50* (April), 36–46.

Bonesronning, Hans, "Class Size Effects on Student Achievement in Norway: Patterns and Explanations," *Southern Economic Journal*, 2003, *69* (4), 952.

Cattaneo, Maria A., Chantal Oggenfuss, and Stefan C. Wolter, "The more, the better? The impact of instructional time on student performance," *Education Economics*, 2017, *25* (5), 433–445.

Chetty, Raj, John N. Friedman, Nathaniel Hilger, Emmanuel Saez, Diane Whitmore Schanzenbach, and Danny Yagan, "How does your kindergarten classroom affect your earnings? Evidence from project star," *Quarterly Journal of Economics*, 2011, *126* (4), 1593–1660.

Coburn, Brian J., Bradley G. Wagner, and Sally Blower, "Modeling influenza epidemics and pandemics: Insights into the future of swine flu (H1N1)," *BMC Medicine*, 2009, *7*, 1–8.

Dobbelsteen, Simone, Jesse Levin, and Hessel Oosterbeek, "The causal effect of class size on scholastic achievement: Distinguishing the pure class size effect from the effect of changes in class composition," *Oxford Bulletin of Economics and Statistics*, 2002, *64* (1), 17–38.

Downey, Douglas B., Paul T. von Hippel, and Beckett A. Broh, “Are schools the great equalizer? Cognitive inequality during the summer months and the school year,” *American Sociological Review*, 2004, *69* (5), 613–635.

Fredriksson, Peter, Björn Öckert, and Hessel Oosterbeek, “Long-Term Effects of Class Size,” *The Quarterly Journal of Economics*, feb 2013, *128* (1), 249–285.

_ , _ , and _ , “Parental responses to public investments in children: Evidence from a maximum class size rule,” *Journal of Human Resources*, 2016, *51* (4), 832–868.

Friedson, Andrew, Drew McNichols, Joseph Sabia, and Dhaval Dave, “Did California’s Shelter-in-Place Order Work? Early Coronavirus-Related Public Health Effects,” Technical Report, National Bureau of Economic Research, Cambridge, MA apr 2020.

Gary-Bobo, Robert J. and Mohamed-Badrane Mahjoub, “Estimation of Class-Size Effects, Using "Maimonides’ Rule" and Other Instruments: the Case of French Junior High Schools,” *Annals of Economics and Statistics*, 2013, (111/112), 193.

Hansen, Benjamin, “School Year Length and Student Performance: Quasi-Experimental Evidence,” *SSRN Electronic Journal*, 2013.

Hojo, Masakazu, “Class-size effects in Japanese schools: A spline regression approach,” *Economics Letters*, 2013, *120* (3), 583–587.

Hoxby, Caroline M., “The Effects of Class Size on Student Achievement: New Evidence from Population Variation,” *The Quarterly Journal of Economics*, 2000, *115* (4), 1239–1285.

Ibuka, Yoko, Yasushi Ohkusa, Tamie Sugawara, Gretchen B. Chapman, Dan Yamin, Katherine E. Atkins, Kiyosu Taniguchi, Nobuhiko Okabe, and Alison P. Galvani, “Social contacts, vaccination decisions and influenza in Japan,” *Journal of Epidemiology and Community Health*, 2016, *70* (2), 162–167.

Jakobsson, Niklas, Mattias Persson, and Mikael Svensson, “Class-size effects on adolescents’ mental health and well-being in Swedish schools,” *Education Economics*, 2013, *21* (3), 248–263.

Kawaguchi, Daiji, “Fewer school days, more inequality,” *Journal of the Japanese and International Economies*, 2016, *39*, 35–52.

Kikuchi, Nobuyoshi, “The effect of instructional time reduction on educational attainment: Evidence from the Japanese curriculum standards revision,” *Journal of the Japanese and International Economies*, 2014, *32*, 17–41.

Krueger, Alan B. and Diane M. Whitmore, “The effect of attending a small class in the early grades on college-test taking and middle school test results: Evidence from project star,” *Economic Journal*, 2001, *111* (468), 1–28.

Kubota, Kohei, “Effects of Japanese compulsory educational reforms on household educational expenditure,” *Journal of the Japanese and International Economies*, 2016, *42*, 47–60.

Lavy, Victor, "Do Differences in Schools' Instruction Time Explain International Achievement Gaps? Evidence from Developed and Developing Countries," *Economic Journal*, 2015, *125* (588), F397–F424.

Leuven, Edwin and Sturla A. Løkken, "Long-Term Impacts of Class Size in Compulsory School," *Journal of Human Resources*, 2020, *55* (1), 309–348.

_ **, Hessel Oosterbeek, and Marte Rønning**, "Quasi-experimental estimates of the effect of class size on achievement in Norway," *Scandinavian Journal of Economics*, 2008, *110* (4), 663–693.

Liu, L., Y. Li, P. V. Nielsen, J. Wei, and R. L. Jensen, "Short-range airborne transmission of expiratory droplets between two people," *Indoor Air*, 2017, *27* (2), 452–462.

Liu, Ying, Albert A. Gayle, Annelies Wilder-Smith, and Joacim Rocklöv, "The reproductive number of COVID-19 is higher compared to SARS coronavirus," *Journal of Travel Medicine*, 2020, *27* (2), 1–4.

Meyer, Erik and Chris Van Klaveren, "The effectiveness of extended day programs: Evidence from a randomized field experiment in the Netherlands," *Economics of Education Review*, 2013, *36*, 1–11.

Milner, Allison, Andrew Page, and Anthony D. LaMontagne, "Long-Term Unemployment and Suicide: A Systematic Review and Meta-Analysis," *PLoS ONE*, 2013, *8* (1), 1–6.

Mori, Masayuki, "Active Learning No Shiten Ni Tatta Gakusyu-Kuukan Ni Kansuru Tyousa-Kenkyu," Technical Report, National Institute for Educational Policy Research 2019. `https://www.nier.go.jp/shisetsu/pdf/20190409-02.pdf` (accessed on May 22, 2020) [English Translated Title: Research On Learning Space From The Viewpoint Of Active Learning].

Motegi, Hiroyuki and Masato Oikawa, "The effect of instructional quality on student achievement: Evidence from Japan," *Japan and the World Economy*, 2019, *52* (June).

Pischke, JörnSteffen, "The Impact of Length of the School Year on Student Performance and Earnings: Evidence from the German Short School Years," *The Economic Journal*, oct 2007, *117* (523), 1216–1242.

Rivkin, Steven G. and Jeffrey C. Schiman, "Instruction Time, Classroom Quality, and Academic Achievement," *Economic Journal*, 2015, *125* (588), F425–F448.

Suzue, Takeshi, Yoichi Hoshikawa, Shuzo Nishihara, Ai Fujikawa, Nobuyuki Miyatake, Noriko Sakano, Takeshi Yoda, Akira Yoshioka, and Tomohiro Hirao, "The new school absentees reporting system for pandemic influenza A/H1N1 2009 infection in Japan," *PLoS ONE*, 2012, *7* (2), 1–4.

Uscher-Pines, Lori, Heather L. Schwartz, Faruque Ahmed, Yenlik Zheteyeva, Erika Meza, Garrett Baker, and Amra Uzicanin, "School practices to promote social distancing in K-12 schools: Review of influenza pandemic policies and practices," *BMC Public Health*, 2018, *18* (1), 1–13.

Viner, Russell M., Simon J. Russell, Helen Croker, Jessica Packer, Joseph Ward, Claire Stansfield, Oliver Mytton, Chris Bonell, and Robert Booy, "School closure and management practices during coronavirus outbreaks including COVID-19: a rapid systematic review," *The Lancet Child and Adolescent Health*, 2020, *4* (5), 397–404.

Wößmann, Ludger, "Schooling resources, educational institutions and student performance: The international evidence," *Oxford Bulletin of Economics and Statistics*, 2003, *65* (2), 117–170.

Yasui, Tomoe, "A Case Study of the School Selection System in Adachi-ku, Tokyo : Research Made through Interviews with the Adachi School Board and those Connected with the Schools, Adachi-ku," *Bulletin of Gifu Women's University*, 2012, *41*, 83–96.

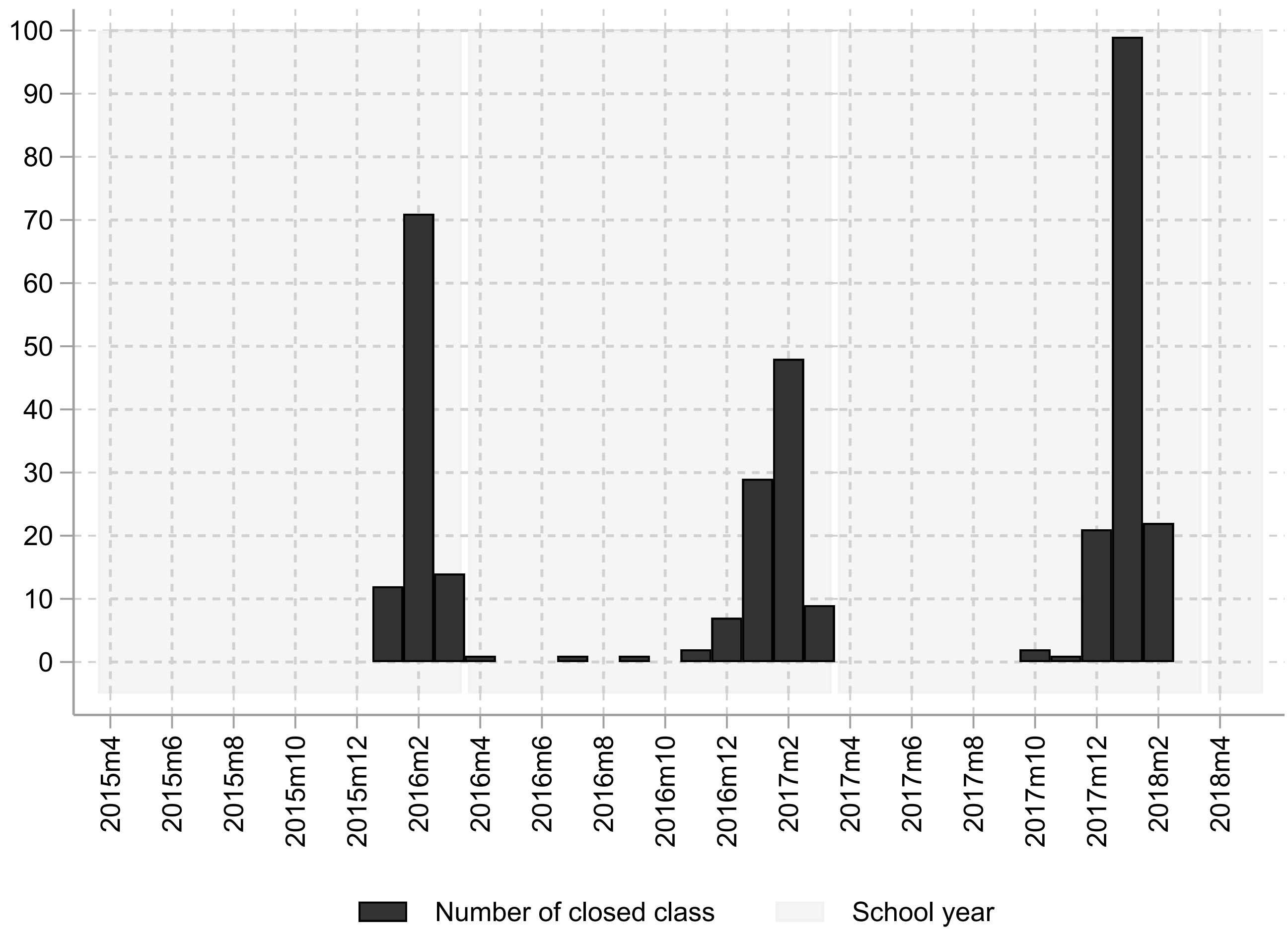


Figure 1: Timing of Class Closure Due to Flu Epidemic in City X

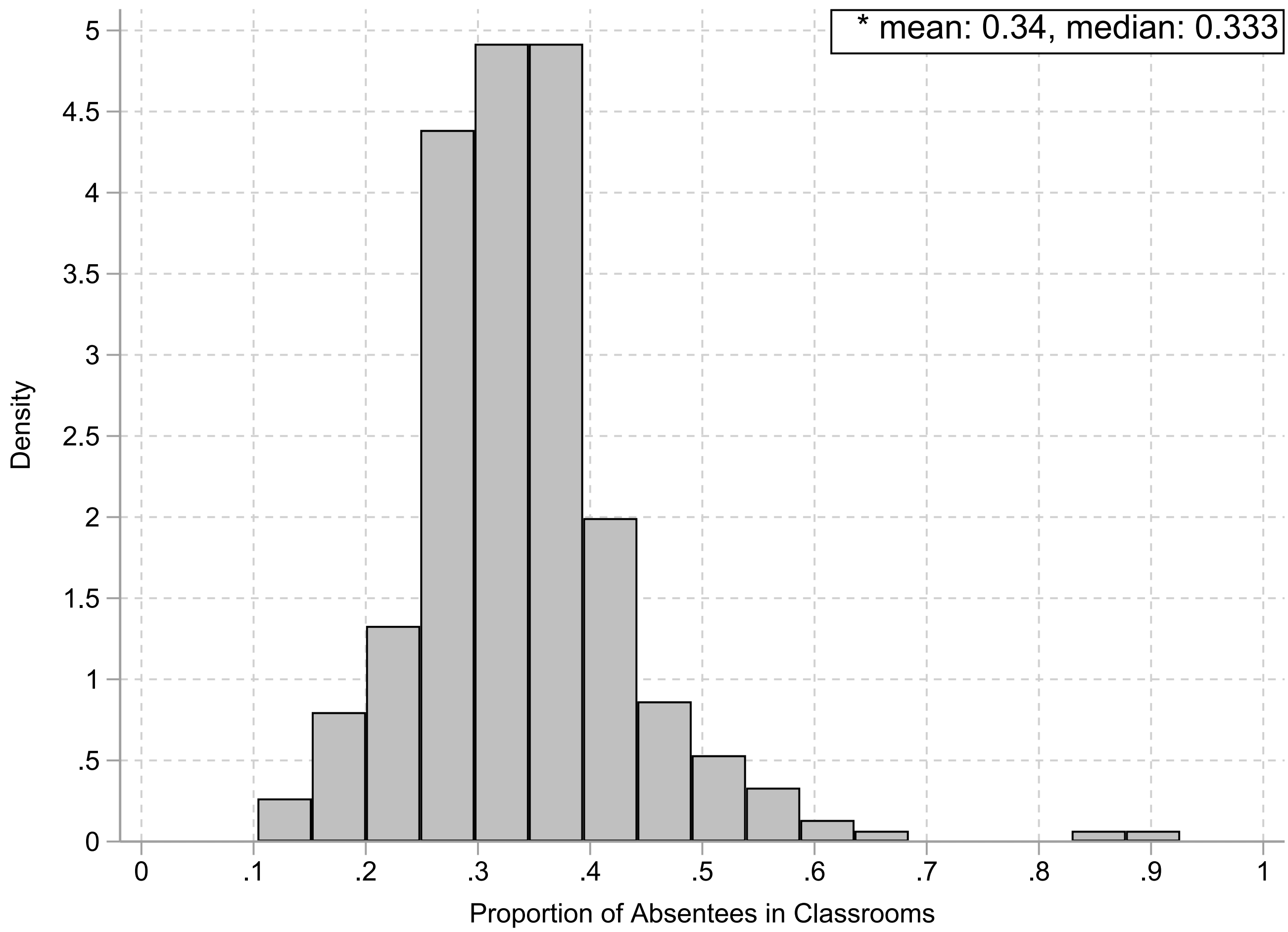
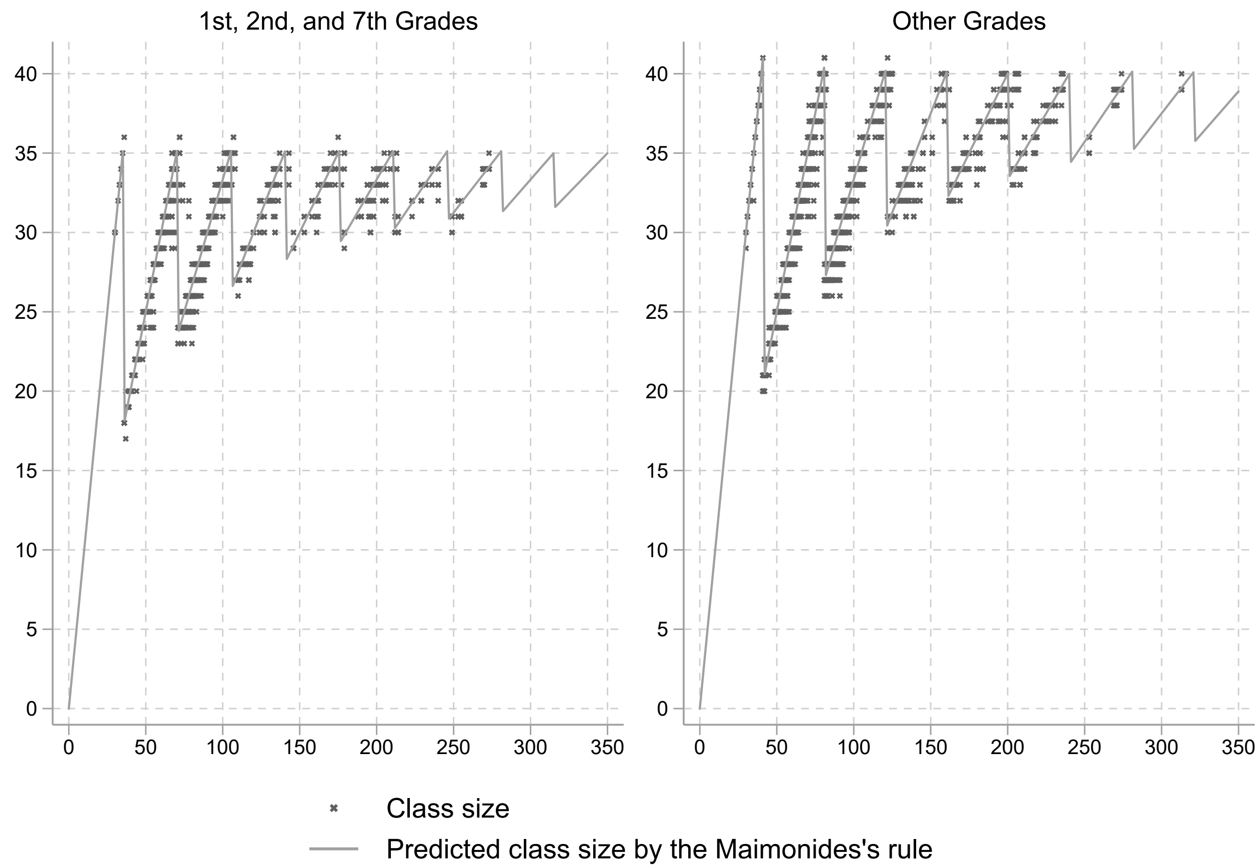


Figure 2: Absentees Ratio in Closed Classes Before The Closure



* X-axis shows the number of students in a grade in school.

Figure 3: Actual and Predicted Class Sizes

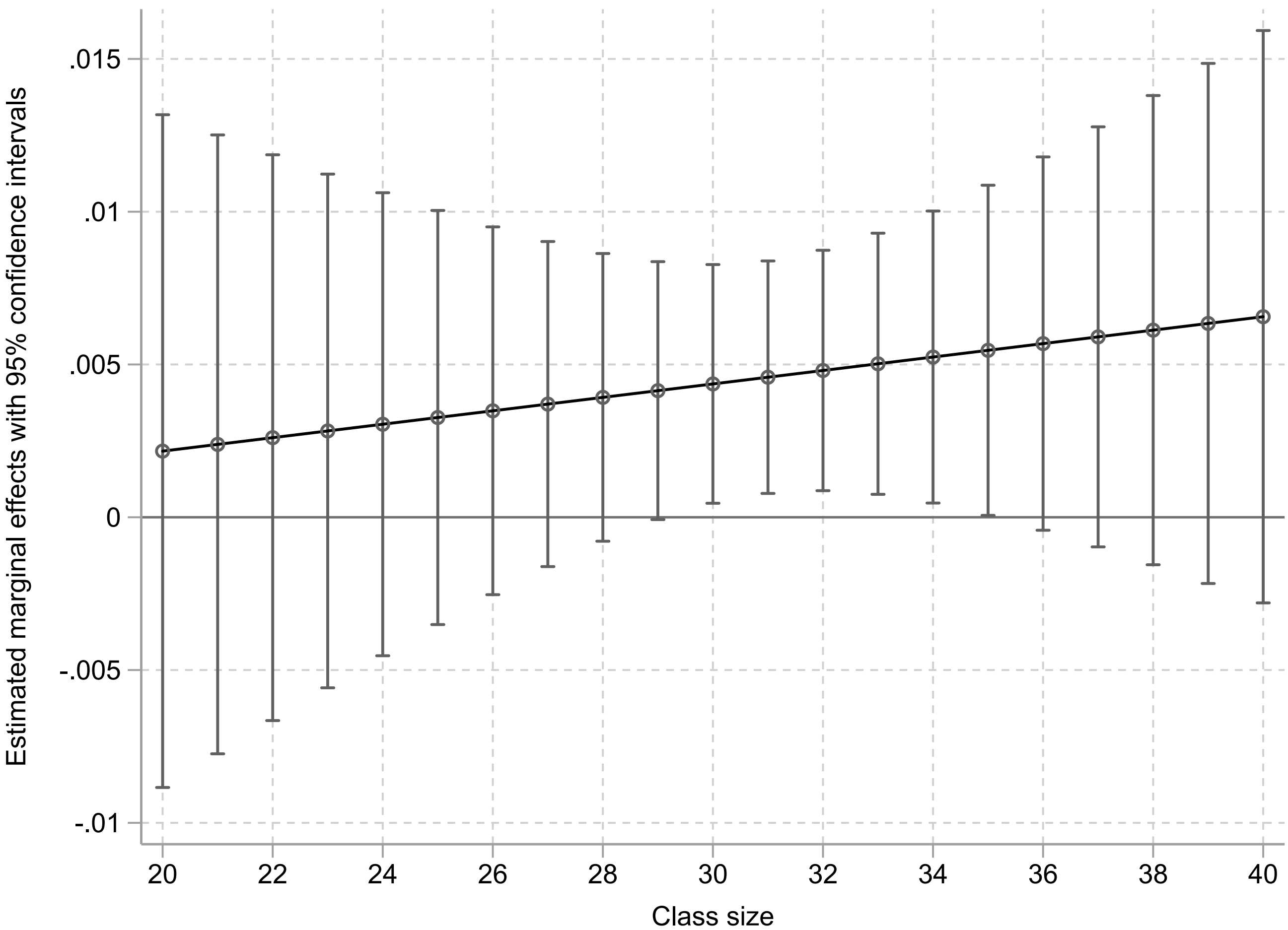


Figure 4: Marginal Effects of Class Sizes for 2SLS Calculated Using Column (2) of Table 5

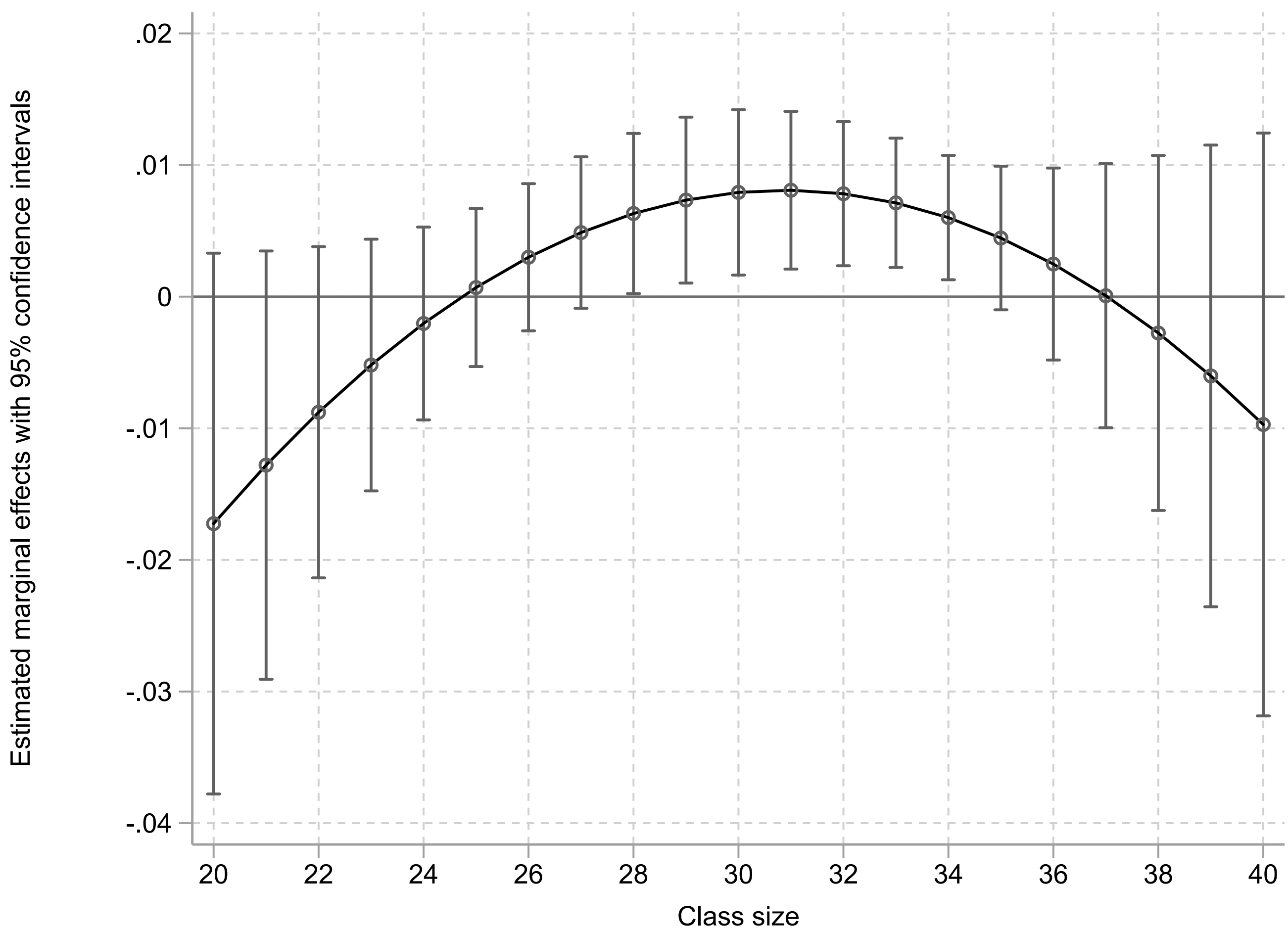


Figure 5: Marginal Effects of Class Sizes for 2SLS Calculated Using Column (4) of Table 5

Table 1: Summary Statistics

	(1) Whole	(2) 1st-3rd	(3) 4th-6th	(4) 7th and 8th	(5) 9th
Class size	31.539	29.932	31.388	33.233	34.963
	[4.381]	[3.938]	[4.438]	[3.815]	[3.693]
Class size ≤ 27	0.173	0.256	0.175	0.078	0.030
	[0.378]	[0.437]	[0.380]	[0.269]	[0.170]
Class Closure	0.086	0.118	0.074	0.076	0.030
	[0.281]	[0.323]	[0.261]	[0.265]	[0.170]
Number of students in a grade in school	105.928	87.576	82.540	156.991	159.521
	[54.677]	[38.773]	[31.018]	[59.139]	[60.950]
Girl ratio	0.489	0.484	0.494	0.494	0.484
	[0.059]	[0.061]	[0.063]	[0.048]	[0.053]
Observations	4271	1582	1468	818	403

Mean values and standard deviations are reported. Standard deviations are in square brackets.

Table 2: Effects of Class Size on Class Closure

	(1) OLS	(2) 2SLS	(3) 2SLS ±6	(4) OLS	(5) 2SLS	(6) 2SLS ±6
Class size	0.0031*	0.0046**	0.0051*			
	(0.0016)	(0.0019)	(0.0027)			
Class size ≤ 27				-0.0281*	-0.0757**	-0.0878*
				(0.0156)	(0.0331)	(0.0466)
Observations	4271	4271	1373	4271	4271	1373
1st stage F-statistics		1074.41	304.08		204.37	159.59
Overall mean	0.086	0.086	0.098			
%Δ from overall mean	3.6	5.3	5.2			
Mean in bigger class				0.087	0.087	0.101
%Δ from mean in bigger class				-32.2	-86.6	-87.1

Dependent variables are the class closure dummy variables. Standard errors robust against school-level clustering are in parenthesis. All models include number of students in a grade in a school, squared number of students in a grade in a school, girl ratio, grade FEs, school FEs, and year FEs. In columns named “2SLS ±6”, we use the classes in the schools with enrollments between “cutoff value 6” and “cutoff value + 6”. Inference: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 3: Heterogeneous Effects By Grades

	1st, 2nd, and 3rd		4th, 5th, and 6th		7th and 8th	
	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	2SLS	OLS	2SLS	OLS	IV
Class size	0.0017	0.0028	0.0045**	0.0061**	0.0087*	0.0134**
	(0.0030)	(0.0038)	(0.0019)	(0.0025)	(0.0047)	(0.0068)
Observations	1582	1582	1468	1468	818	818
1st stage F-statistics		607.48		448.38		117.02
Overall mean	0.118	0.118	0.074	0.074	0.076	0.076
%Δ from overall mean	1.4	2.4	6.1	8.3	11.4	17.7

Dependent variables are the class closure dummy variables. Standard errors robust against school-level clustering are in parenthesis. All models include number of students in a grade in school, squared number of students in a grade in school, girl ratio, grade FEs, school FEs, and year FEs. Inference: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 4: Relationship Between Class Size and Absentee Ratio Before Class Closure

	(1)	(2)
Class size	-0.0022	
	(0.0015)	
Class size ≤ 27		0.0122
		(0.0168)
Observations	311	311
Overall mean	0.340	
%Δ from overall mean	-0.7	
Mean in bigger class		0.334
%Δ from mean in bigger class		3.7

The unit of observation is cases of class closure. The dependent variable is the absentee rate just before class closure. Standard errors robust against school-level clustering are in parentheses. All models include number of students in a grade in a school, squared number of students in a grade in a school, girl ratio, grade fixed effects, and year fixed effects. Inference: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 5: Estimation Results Using Class Size, Squared Class Size, Cubed Class Size

	Quadratic		Cubic	
	(1)	(2)	(3)	(4)
	OLS	2SLS	OLS	2SLS
Class size	0.01269	-0.00223	-0.26422***	-0.19597*
	(0.01279)	(0.01503)	(0.09268)	(0.10813)
Squared class size	-0.00015	0.00011	0.00903***	0.00661*
	(0.00020)	(0.00024)	(0.00310)	(0.00370)
Cubed class size			-0.00010***	-0.00007*
			(0.00003)	(0.00004)
Observations	4271	4271	4271	4271
Kleibergen-Paap rk Wald F statistic		174.74		50.00
Joint test for coeffcients of class size	0.150	0.056	0.013	0.184
Overall mean	0.086		0.086	

Dependent variables are the class closure dummy variables. Standard errors robust against school-level clustering are in parentheses. All models include number of students in a grade in school, squared number of students in a grade in school, girl ratio, grade FEs, school FEs, and year FEs. Inference: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 6: Marginal Effects of Class Sizes for 2SLS Calculated Using Table 5

	(1) Quadratic		(2) Cubic	
	Marginal effects	Standard errors	Marginal effects	Standard errors
Class size				
20	0.0022	(0.0056)	-0.0172	(0.0105)
21	0.0024	(0.0052)	-0.0128	(0.0083)
22	0.0026	(0.0047)	-0.0088	(0.0064)
23	0.0028	(0.0043)	-0.0052	(0.0049)
24	0.0030	(0.0039)	-0.0020	(0.0037)
25	0.0033	(0.0035)	0.0007	(0.0031)
26	0.0035	(0.0031)	0.0030	(0.0029)
27	0.0037	(0.0027)	0.0049*	(0.0029)
28	0.0039	(0.0024)	0.0063**	(0.0031)
29	0.0041*	(0.0022)	0.0073**	(0.0032)
30	0.0044**	(0.0020)	0.0079**	(0.0032)
31	0.0046**	(0.0019)	0.0081***	(0.0031)
32	0.0048**	(0.0020)	0.0078***	(0.0028)
33	0.0050**	(0.0022)	0.0071***	(0.0025)
34	0.0052**	(0.0024)	0.0060**	(0.0024)
35	0.0055**	(0.0028)	0.0045	(0.0028)
36	0.0057*	(0.0031)	0.0025	(0.0037)
37	0.0059*	(0.0035)	0.0001	(0.0051)
38	0.0061	(0.0039)	-0.0028	(0.0069)
39	0.0063	(0.0043)	-0.0060	(0.0089)
40	0.0066	(0.0048)	-0.0097	(0.0113)
Observations	4271		4271	

This table summarizes the marginal effects reported in Figures 4 and 5, and their standard errors. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.