DO CLASS SIZE REDUCTIONS PROTECT STUDENTS FROM INFECTIOUS DISEASES?
Lessons for COVID-19 Policy from a Flu Epidemic in the Tokyo Metropolitan Area

MASATO OIKAWA
RYUICHI TANAKA
SHUN-ICHIRO BESSHO
HARUKO NOGUCHI

ABSTRACT
We evaluate the causal effect of class size (number of students in a classroom) on incidence of class closure due to the flu, as an outcome of an infectious disease epidemic. For identification of causal effects, we apply a regression discontinuity design using discontinuous variation of class sizes, around the class size cap set by regulation, to administrative data of public primary and middle school students in one of the largest municipalities within the Tokyo metropolitan area from 2015 to 2017. Most classrooms in Japan are constructed in accordance with a standard of classroom area, 63 square meters; class size reduction improves social distancing among students in a classroom. We find that class size reduction is effective in reducing class closures due to the flu: a one-unit reduction of class size decreases class closure by about 5 percent. Additionally, forming small classes with 27 students at most, satisfying the social distancing of 1.5 meters recommended to prevent droplet infection including influenza and COVID-19, reduces class closure by about 90 percent. Moreover, we find that the older the students, the larger the effects of class size reduction. Our findings provide evidence for the effectiveness of social distancing policy in primary and middle schools to protect students from droplet infectious disease spread, including COVID-19.

KEYWORDS: class size, class closure, students’ health, influenza (flu) epidemic, lesson for COVID-19
JEL CLASSIFICATION: I18, I20, I28
I. Introduction

Outbreaks of communicable diseases have affected not only health outcomes but also people’s behaviors and lifestyle, along with engendering various socioeconomic outcomes. Currently, to prevent the spread of the 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 also have negative consequences for social and socioeconomic outcomes.

Closing entire schools is considered to be one such measure useful for controlling flu outbreaks or, particularly during COVID, in epidemics, as school-aged children could otherwise have the greatest frequency of daily contact with those in the same age group during the weekdays (Ibuka et al. 2016). However, school closure would also adversely affect students’ outcomes, because of a reduction of instruction time in schools. In addition, it is known that this adverse effect is more serious for students from disadvantaged households, widening the education gap based on socioeconomic background (Oikawa et al. 2022). To mitigate these adverse effects of school closure on students’ outcomes without exposing them to risk of infection, it is useful to consider less aggressive approaches than shutting down schools.

This paper focuses on a response that increases the physical distance between each student in a classroom; this response is often called social distancing or physical distancing, as an alternative to entire school closure. We utilize information about class size (i.e., number of students in a classroom) as a proxy for social distancing among students in a class and examine how social distancing among students in a class affects epidemic spread of an infectious disease in the class. Given the fixed area of the classroom, students’ physical distance depends on class size (students per teacher); the smaller the class size, the greater the students’ physical distance from one another. While social distancing in schools during outbreaks has been discussed, there is little information on the effects of social distancing policies and procedures in schools other than those concerning prolonged school closure (Uscher-Pines et al. 2018).

To estimate the effect of class size on epidemic spread of infectious disease in the class, we use school administrative data collected by the education board of a city in the Tokyo metropolitan area (hereafter, we refer to this city as City X). We utilize the information of class closure (sending all students in a particular classroom home) due to seasonal flu as an outcome proxying the effects of a flu epidemic within a classroom. Class closure for seasonal flu depends on decisions made by local stakeholders, such as municipalities and/or

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1 As previous studies indicate a positive relation between instruction time in schools and students’ achievements (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, Oggensuss, and Wolter 2017; Besho et al. 2019), decreased instruction time due to school closures will tend to affect students’ current and future outcomes negatively.

2 One alternative is to fine-tune the rules governing school closure to reduce the risk of unnecessary school shutdown. For example, New York City set a policy for temporary school closure due to COVID-19 requiring that the source of infection be in the school (Shapiro 2021).

3 We anonymize the city name because the education board does not allow us to disclose this detail.
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 a flu epidemic in classrooms (Suzue et al. 2012). To see the causal relationship of how smaller classes reduce the effects of exposure to droplets, we apply a regression discontinuity design established by Angrist and Lavy (1999) using discontinuous variation of class sizes around the class size cap due to the regulation to control for endogeneity of class sizes.

Estimation results reveal that a one-unit reduction in class size decreases class closure due to flu by about 5.2–5.3 percent in comparison to the overall mean, and that we could reduce class closure by about 90 percent if we reduced the size of all classes to less than or equal to 27. Given the area of a classroom in Japan, which is 63 square meters as set by regulations, a class size of 27 is the largest at which students can maintain a physical distance of 1.5 meters. The distance of 1.5 meters is the threshold for reducing the risk of infection caused by large droplets exhaled by infected persons (L. Liu et al. 2017). Additionally, when we use a cubic function of class size and estimate class size effects, the estimation results show that the marginal effects are statistically significant at 10 percent 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 maintain a certain level of physical distance, additional class size reduction is no longer effective to decrease the probability of flu infection. The results show that the older the students, the stronger the effects of class size reduction.

This paper is related to the strand of literature in education economics that has a special focus on the effects of class size. Many papers analyze the causal effects of class size on students’ outcomes, using data sets from both experimental settings (e.g., Tennessee’s Project Star) and quasi-experimental settings, such as studies using a regression discontinuity design. While previous studies have focused on outcomes such as student achievement (e.g., Angrist and Lavy 1999; Hoxby 2000; Dobbelsteen, Levin, and Oosterbeek 2002; Bonesronning 2003; Leuven, Oosterbeek, and Renning 2008; Hojo 2013; Akabayashi and Nakamura 2014; Angrist et al. 2019), long-term outcomes (Krueger and Whitmore 2001; Chetty et al. 2011; Fredriksson, Öckert, and Oosterbeek et al. 2013; Leuven and Løkken 2020), parental responses (Fredriksson, Öckert, and Oosterbeek 2016), and manipulation of students’ test scores by teachers (Angrist, Battistin, and Vuri 2017), less attention has been paid to protection of student health. Therefore, we will focus on students’ health outcomes, which could provide new insight to class size effect studies. In addition, according to our results, we could also say that class size reduction may positively affect students’ achievements because the reduction protects students’ health from infectious diseases. It is also because students are not sick and out of school, which could enhance learning because they are not out of the class (spillovers from sick classmates). In other words, the class size reduction could contribute to improving students’ study environments. Therefore, our

4 Jakobsson, Persson, and Svensson (2013) analyzed the effects of class size on adolescents’ mental health problems and well-being using a Swedish data set and concluded that the results cannot show that class size does not affect mental health problems and well-being.
results could explain a mechanism behind class size effects on academic achievements and future outcomes found in previous studies. Our findings indicate the importance of including not only academic outcomes but also health outcomes of students as a part of the benefits in the cost-benefit analysis of class size reduction.

Our estimation results can also contribute to recent research analyzing social distancing behaviors under the COVID-19 pandemic in Japan. For example, Sasaki, Kurokawa, and Ohtake (2020) analyze the effect of nudge messages on contact and infection prevention behaviors and life satisfaction; Shoji et al. (2020) estimate the association between the number of new COVID-19 cases in a local area and the social distancing behaviors of the residents, such as frequency of face-to-face conversation; Yamamura and Tsutsui (2022) estimate the effect of a declaration of a state of emergency on infection prevention behaviors and mental health; and Watanabe and Yabu (2021) estimate the effect of the declaration of the state of emergency on stay-at-home measures, using smartphone location data. While behavioral changes are observed in the aforesaid studies, it is still unclear whether the changes in social distancing behaviors could reduce the infections. Since our results suggest that the increase in physical distance could prevent a spread of infectious diseases in a particular space, the behavioral changes observed under the current pandemic could contribute to preventing the spread of infection.

The remainder of the paper is organized as follows: Section II explains the institutional background, and Section III discusses the data and descriptive statistics. Section IV describes the estimation model, and Section V discusses the estimation results. Section VI provides some additional remarks, and Section VII concludes this paper, with suggestions for further research.

II. Institutional Background

In this section, we briefly summarize the institutional settings of education in Japan related to (1) who decides when classes should be closed; (2) regulation of class size; (3) surface area of the classroom; and (4) other features of Japanese classes related to flu spread in classrooms.

Class closures due to influenza are common in Japan. The majority of these closures are reactive closures, as defined in Cauchemez et al. (2009): closure of a school/class when many children, staff, or both are experiencing illness. While school closure is expected to be a non-pharmaceutical intervention to mitigate a local flu epidemic in general, in Japan, reactive closures are considered to be a measure to allow absent students to catch up with their peers more easily once they are healthy again (Ministry of Health, Labour, and Welfare of Japan 2009). One reason why reactive school closures are common in Japanese society may be due to the general support shown for this equity concern. The School Health and Safety Act gives school administrators discretion to shut down schools, grades, and classes under their jurisdiction to prevent the spread of viral infections and to guarantee learning opportunities for absenteeism due to the flu. In the case of public primary and middle schools, it is the education boards of local municipalities and not school principals that decide whether to shut them down. The national government does not provide explicit criteria for deciding when to shut down classes. In some cases, prefectural or
municipal education boards set the criteria 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 absenteeism rate reaches 20 percent. In Japan, the flu is a major cause of class shutdowns. Since flu infection increases in the winter season, most class closures are observed during this time. In 2018–19 in Tokyo, the number of flu infections increased from December, peaked in January, and reduced to zero in February, and class closure was mainly observed in January and February.5

Public elementary (grades one to six) and middle (grades seven to nine) schools in Japan have an upper limit of class size set by the 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 to class size as long as the limit is below the national standard. Public schools in City X have an upper limit of 35 students for first, second, and seventh grades and 40 students for the other grades (third, fourth, fifth, sixth, eighth, and ninth grades). These upper limits are considered exogenous for City X because they are based on the classroom arrangement standards of the education board of the prefecture in which City X is situated.6,7 Students experience changes in the upper limit of class sizes and class reshuffle simultaneously. Students who were previously in the same class for some years get reshuffled, which commonly happens in City X when students go from second to third grade and when students get promoted from elementary to middle schools.8

Next, we explain the surface area standard for a classroom in Japan. The standard for the surface area in classrooms under the Standard Design of Reinforced Concrete School Buildings of 1950 is 63 square meters. According to Mori (2019), the surface area in classrooms is distributed around the standard, 63 square meters, 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.9 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 its related changes largely determine the students’ potential for physical distancing in the classroom. If the surface area in a classroom is 63 square meters, the area

5 http://idsc.tokyo-eiken.go.jp/diseases/flu/flu2018/
6 In Japan, the upper limit of the class size for each grade in elementary and middle school is determined by education boards of prefectures based on national standards. The education board of a municipality follows the standards determined by the prefecture in which the municipality belongs.
7 In Japanese elementary and middle schools, the upper limit of class sizes had been of 40 students until 2010; this was lowered nationwide to 35 only for first graders in 2011, as lowering the limit for all grades would incur significant costs. The first graders need intensive care from teachers as they may be especially affected by reduced class sizes, because they experience dramatic changes in their surroundings when entering schools. In addition, in some financially rich prefectures, including the prefecture to which City X belongs, the upper limit of 35 is applied not only to first graders but also to second graders and seventh graders. The second graders are still at a stage of adjusting to these dramatic changes, and the seventh graders experience dramatic changes in their surroundings once again upon entering middle school.
8 We discuss the class reshuffle in Online Appendix A.1.
9 A distribution of surface areas of classrooms is presented on page 87 of Mori (2019).
per person is 1.54 square meters for classes with a teacher and 40 students, that is, a class size of 40, and 2.25 square meters for a class size of 27. Increase in the classroom area per person should expand social distance among people in the classroom.

Finally, we explain other aspects of how schools in Japan are organized in a manner that is relevant for flu spread within classrooms. In most Japanese classrooms, students have their own desks, and desks are arranged to face the front of the classroom. Since students have their own desks, it is not difficult to arrange desks depending on the situation. For example, students can arrange desks to maintain their physical distance and prevent infections if they have enough space. In Japanese public schools, it is common in homeroom classes to open doors and windows for ventilation (hereafter referred to as natural ventilation). 10 For natural ventilation, the guidelines of facility maintenance for elementary schools 11 and for middle schools 12 recommend the construction of doors and windows with proper layout, size, and forms to allow effective ventilation via opening the doors and windows. Natural ventilation could be implemented even in the winter season, when flu infections increase, because most of the public elementary schools in an area, including the Tokyo metropolitan area, have heating systems (Yoshino et al. 2009). For preventing infection by seasonal flu, handwashing and wearing facial masks are recommended in a handbook by the Japanese Society of School Health. 13

III. Data

This paper utilizes the school administrative data collected by the education board of City X. City X is a large municipality with more than 300,000 households and a population of more than 600,000 people, as of 2015. In 2015, City X had about 70 public elementary schools with approximately 1,000 classes, and about 40 public middle schools with around 400 classes. The data cover various information related to educational administration, such as the list of students who are together in classes and the list of the instances of class shutdowns for all public elementary and middle schools operated by City X. 14 As previously explained, since the education boards of local governments make the final decision on

10 About 31 percent of the public elementary schools in an area including the Tokyo metropolitan area had ventilation systems in homeroom classes in 2005 (Yoshino et al. 2009).
11 https://www.mext.go.jp/content/20220624-uxt_kouhou01-000023406_02.pdf (accessed September 24, 2022; Japanese only)
12 https://www.mext.go.jp/content/20220624-uxt_kouhou01-000023406_03.pdf (accessed September 24, 2022; Japanese only)
13 https://www.gakkohoken.jp/book/ebook/ebook_H290100/data/199/src/H290100.pdf?d=1626864804639 (accessed July 21, 2021; Japanese only)
14 We do not have a physical classroom identifier in our data set. In general, it is important to control for the classroom and building characteristics, but the lack of information about which specific students are in specific rooms within the building does not seem to cause serious bias because of highly homogeneous school building characteristics under strict regulation set by the Ministry of Education. However, to address this issue, we implemented a robustness check using grade-school fixed effects as a proxy for the classroom building characteristics, and found that our main results are robust. Online Appendix A.2 shows the results of the robustness check.
class closure in Japanese public schools, the education board of City X keeps the records on school shutdown for schools operated by them. The shutdown data include two types of closures: class closures and grade closures, where one class (or grade) would be kept home but another allowed to go to school. In this paper, we consider both types of closure and hereafter, for simplicity, will call both class closure. While the data contain students’ information over a long period, information about class closure due to the flu is available for only three years, from 2015 to 2017. Using the data, we construct three-year class-level data, which include classes’ characteristics and incidence of class closure. We exclude classes with fewer than 17 students and classes in grades with fewer than 30 students, as there are not many classes or grades with very few students. After the sample restriction, 4,271 observations in public elementary and middle schools are available for analysis.

Table 1 summarizes the sample average and standard deviation of variables. Column 1 shows statistics for entire classes, and columns 2–5 represent grade categories. We divide the grades into four groups: first to third graders, fourth to sixth graders, seventh to eighth graders, and ninth graders. The first two groups belong to elementary schools, and the other groups belong to middle schools. According to column 1, among the full sample, the average class size is about 31.5, and about 17.3 percent of classes have 27 or fewer students. It is possible that nearly one-fifth of classes could maintain enough students’ physical distance to prevent droplet exposures, because the cutoff of 27 students could be interpreted as an indicator of whether students have enough physical distance to prevent droplet infection of flu, which is discussed in more detail in Section IV. Therefore, about 17.3 percent of classes could enable sufficient physical distancing for students. The higher the grade, the larger the class sizes, but the increases are not substantial (columns 2–5). The proportion of

| TABLE 1. Summary statistics | Whole (1) | 1st–3rd (2) | 4th–6th (3) | 7th and 8th (4) | 9th (5) |
|-----------------------------|----------|------------|------------|----------------|--------|
| 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                | 4,271    | 1,582      | 1,468      | 818            | 403    |

Note: Mean values and standard deviations are reported. Standard deviations are in square brackets.
class closure due to the flu among the entire sample is about 8.6 percent (column 1) and decreases with an increase in grade (columns 2–5).¹⁵

Figure 1 shows the number of closed classes due to a 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. Data from all three years indicate the same tendency. The average length of class closures does not change by month, and ranges between two and three days.

Table 2 summarizes mean values of class characteristics such as ratio of girls to boys, proportion of students receiving financial support, and class averages of standardized scores of the test conducted by City X, to compare the characteristics of the classes that experience any closure relative to the rest of the classes. The proportion of students receiving financial support represents an average economic condition within classes, because if students are economically disadvantaged, they can receive financial support from the local government. We cannot utilize the proportion of first graders in 2015 and 2016 and the class average of standardized test scores for first graders in all the years because of data limitations.¹⁶ Columns 2 and 1 show mean values for classes that experience any class closures (“closed”) and for the remaining classes (“not closed”), respectively. Column 3 shows

¹⁵ Since some classes experience multiple class closures in a year, the class closure dummy takes the value of 1 if a class experiences at least one class closure per school year. The ratio of classes closed due to seasonal flu twice a year to all the classes that experience class closure in the year is about 5 percent.

¹⁶ We do not utilize these variables for the estimation as control variables because the data are not available for the entire sample.
raw differences between columns 1 and 2. Column 4 reports differences between columns 1 and 2 after we control for school, year, and grade fixed effects (FEs): when we regress each variable on the dummy and the fixed effects. According to Table 2, the proportion of students receiving financial support among classes experiencing any closure is statistically lower than that among the rest of the classes, while the difference becomes smaller and statistically insignificant when we control for the year, school, and grade fixed effects. After we control for the fixed effects, only the difference in class sizes between the two subgroups is positively and statistically significantly estimated, suggesting that the classes are more likely to be closed among those with larger sizes.

Next, we discuss whether class closures could capture the extent of the flu epidemic within classrooms. Figure 2 shows the distribution of the absentee rate in classes just before the classes are closed due to flu.\(^{17}\) Basically, when a class in a public school is closed due to

\(^{17}\) 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.
a flu epidemic, the school has to report related details, such as the number of students who are absent due to the flu as of the day when the class closure is determined, to the education board operating the school. Since we have the number of students who are absent due to the flu for classes closed due to flu, we do not have the data on how many students are absent from classes not closed due to flu, so we can draw Figure 2 only for the closed classes. According to Figure 2, among closed classes, the minimum value of the absentee ratio is about 10 percent. However, this does not necessarily imply that an absentee ratio of 10 percent 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 percent to 40 percent, with a mean value of 34.0 percent; the median is 33.3 percent. The closed classes have a certain extent of absentees, suggesting that the class closures could be a proxy for the flu epidemic within classes. Note that there is variation in the absentee ratio. One explanation of the variation of the absentee ratio is that homeroom teachers observe the state of flu spread in classrooms in other ways in addition to the absentee ratio, such as how many students are coughing in class, and report the situation to school principals. In this

FIGURE 2. Absentee ratio in closed classes before the closure. We draw the figure using the data for classes actually closed due to a flu epidemic because the data for absence rate are available only for those classes.

18 For example, if the class is closed before noon on a school day and students return home in the afternoon, the school reports the number of absentees due to the flu as of the morning to the education board. 
19 After we control for school, year, and grade fixed effects, the standard deviation of the absentee ratio is about 26.4 percent smaller than that for the raw one, while there still remains variation in the absentee ratio. The fixed effects could explain about 46 percent of the raw absentee ratio. Online Appendix A.1 discusses this point further.
case, it is possible that class closures capture the flu epidemic in classrooms more accurately than the absentee ratio. In addition, if teachers in smaller classes can observe students’ health condition more accurately, the smaller classes are more likely to be closed, and our estimation results may underestimate the actual impact of class size on within-class transmission of flu. However, our estimates should be conservative even if this is the case.

Furthermore, we show a relationship between class size and absentee ratio before class closure to discuss the validity of class closures as a proxy for the flu epidemic in classrooms. As mentioned in Section II, the national government in Japan does not provide explicit criteria for class closure, and local education boards can make the decision on class closure flexibly. In such a context, interpretation of the class size effects on class closures is complicated. The class closure is no longer a good proxy for a flu epidemic in classrooms if the education board more rapidly selects class closure in larger classes to prevent the epidemic in entire schools even when the proportion of infected students in the classes is low. If the education board quickly decides 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 classes just before class closure. We confirm whether a negative relationship exists using a class-closure-case-level data set with class characteristics because, unfortunately, the data on absentee ratio cover only classes actually closed due to a flu epidemic.20

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20 Since some classes experienced closure twice, we do not use a class-level data set but instead a case-level data set, 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.
the data set, a regression model of the absentee rate on the class size variable is developed, and the set of control variables is estimated.21

Table 3 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 with the overall mean, a one-unit increase in class size decreases the absentee ratio by 0.7 percent. The magnitude for the absentee ratio is much smaller than the magnitude of effects of class size reduction on class closures (discussed in Section V). This tendency is robust against the definition of the class size variable (column 2). Therefore, the result suggests that the education board of City X does not decide class closures depending on the class sizes, and the event of class closure is a suitable proxy for the extent of the flu epidemic within classrooms.

IV. Estimation Model

The estimation equation is as follows:

\[
\text{Closure}_{jstg} = \alpha + \beta \text{ClassSize}_{jstg} + x_{jstg}' \delta + \eta_t + \xi_s + \lambda_g + u_{jstg}
\]

(1)

where \( j, s, g, \) and \( t \) are indices of class, school, grade, and year. The dependent variable \( \text{Closure}_{jstg} \) takes the value of 1 if the class is closed due to a flu epidemic. We utilize closure as a proxy for a flu epidemic in classrooms because it is a useful assessment measure of the trend of epidemic phenomena (Suzue et al. 2012). Although one could argue that the absence rate in a class is a better outcome variable than class closure, we cannot use it in the analysis because of the lack of data availability: the data for absence rate are available only for classes actually closed due to a flu epidemic. However, class closure is informative about a flu epidemic in our setting because closing a class is considered by the education board of the municipality when the absence rate exceeds a common threshold in the municipality (called reactive closures in (Cauchemez et al. 2009). Thus, it is natural to think that the absence rate of classes without closure is lower on average than those with closure.22

The variable \( \text{ClassSize}_{jstg} \) represents 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 the value of 1 if the class size is less than or equal to 27. If a classroom is 63 square meters in size,

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21 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.

22 One of the ideal outcome variables to examine our hypothesis is a class’s absentee ratio due to flu during the flu season from December to March, while we utilize the class closure dummy as an outcome variable because of data limitations. The dependent variable, the class closure dummy, may have measurement errors, and if the measurement errors are correlated with class sizes, the coefficient of class size is no longer consistently estimated. For example, the education board may more rapidly select class closure in larger classes to prevent a flu epidemic in entire schools even when the proportion of infected students in the classes is low. In this case, measurement error and class size are correlated, and the effect of class size reduction on class closures is not consistently estimated. Fortunately, Table 3 does not support the above possibility, and we can thus conclude that class closures are not a bad proxy for a flu epidemic.
a class size of 27 is the threshold where the area per person in the classroom becomes over 2.25 square meters when the class size is reduced. Being within 1.5 meters of an infected person increases the risk of droplet infection, and a class size of 27 could provide an area of square 1.5 meters on a side (2.25 square meters) for each person: the people in the classroom can maintain a physical distance of 1.5 meters. Therefore, the dummy variable could be interpreted as an indicator of whether students have enough physical distance to prevent droplet infection caused by the flu. The vector $x_{jg}$ is a set of control variables that include 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 $\eta$, $\xi$, and $\lambda$ capture the year, school, and grade FEs. Year FEs could capture the status of a flu epidemic outside of schools, which is one determinant of a 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 two public schools per square kilometer. Flu spread outside of school may not differ substantially within City X. The final term, $u_{jg}$, is an unobserved error term. In equation 1, $\beta$ 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, such as students with physical/mental health problems, disabilities, 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 the class size. For example, if both the upper limit and the number of enrollees are 40, a class of 40 students is organized in this grade. If the number of enrollees increases to 41, then 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 II, 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:

$$M_{size_{jg}} = \frac{SchoolSize_{jg}}{\left(\frac{SchoolSize_{jg} - 1}{\text{int}_{jg}} + 1\right)}$$

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23 The area per person is 2.17 square meters for classes with a teacher and 28 students.

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

25 The area of City X is about 50 square kilometers, and the number of public schools as of 2015 is 100.
where SchoolSize\textsubscript{gt} 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 first, second, and seventh grades, and 40 for other grades.

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

We estimate equation 1 by two-stage least squares (2SLS) using the predicted class sizes as the instrumental variable. The first-stage equation is as follows:

\[
\text{ClassSize}_{jgt} = \pi + \rho \text{Msize}_{jgt} + \chi_{jgt} \gamma + \phi_t + \theta_s + \mu_g + v_{jgt}
\]  

We use the same control variables as equation 1. The parameters \( \phi_t, \theta_s, \) and \( \mu_g \) respectively capture the year, school, and grade FEs, and the parameter \( v_{jgt} \) is an unobserved error term.

Empirical work with instrumental variable strategies often encounter weak instruments. We will investigate the possibility of weak instruments by comparing the effective \( F \)-statistics of Montiel Olea and Pflueger (2013) with the rule-of-thumb value of 10, for the case of one endogenous variable.\(^26\) The procedure is recommended by Andrews, Stock, and Sun (2019).

An identification assumption, the absence of 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 attain 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. However, since City X sets upper caps on 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. Therefore, there are uncertainties in school choice, and it is difficult to manipulate enrollment perfectly.\(^27\) Second, in cities of the Tokyo metropolitan area that are introducing school choice programs, students apply to the programs mostly because of reasons unrelated to academic achievement, for example, proximity of houses to schools and friends’ plan to enroll in the school.\(^28\) Therefore, it is unlikely

\(^{26}\) We utilize a user-written Stata command, “weakivtest” to calculate the effective \( F \)-statistics.

\(^{27}\) Parents can also choose a school by moving to the area that the school covers. However, it is very costly for households to move. Hojo (2013) and Akabayashi and Nakamura (2014), who analyzed class size effects in Japan, argued that moving for school enrollment is costly and does not occur often.

\(^{28}\) According to Yasui (2012), in a city, students who enroll in schools other than the assigned school choose to do so mostly because their friends plan to enroll there. In other cities, the proximity of houses to schools is the most common reason why students choose the school (http://www.city.sumida.lg.jp/kosodate_kyouiku/kyouiku/school/inuyen_nyuugaku/annke-tokekka/files/ANKETTOCHOUSAKEKKAIGYOU.pdf, accessed June 19, 2020; Japanese only; and https://www.city.minato.tokyo.jp/gakuji/documents/r4anke.pdf, accessed September 24, 2022; Japanese only).
that the school choice program is being used to place children in the small classes. Additionally, we put school FEs in the estimation model to control for the school’s unobserved characteristics.  

V. Results

Table 4 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

29 It is also possible that there is a sorting of particular types of children to particular types of classrooms, a concern related to the endogeneity of class sizes. For example, a student with health problems may be assigned to a small class in a classroom with a larger surface area to protect the student from infectious diseases. In this case, the classroom characteristic is related to both incidence of class closures and class sizes, resulting in the endogeneity problem. While controlling for classroom characteristics may be preferable for providing causal effects net of sorting, we do not have data on these because we do not know the physical characteristics of the classroom for each student. To estimate the potential threat of sorting on classrooms, we implement a robustness check using grade by school fixed effects rather than the classroom by building characteristics, and our results are robust to this. This may be because classrooms in the Japanese public schools are constructed following some standards of classroom construction: the standard of surface area of 63 square meters and the guideline for doors and windows for effective ventilation. Online Appendix A.2 shows the results of the robustness check. In addition, we check the possibility of the sorting by comparing students’ characteristics by the observable class characteristic, class sizes, as a proxy of classroom characteristics, and the result shows that smaller and larger classes have the same conditions, at least by measuring the observable characteristics such as girl ratio and students’ financial background. The result is available upon request.
using the class size dummy, which takes the value of 1 if the class size is less than or equal to 27. We report the results using ordinary least squares (OLS; columns 1 and 4) and 2SLS (columns 2 and 5). We also report the results by 2SLS with classes in the schools whose enrollments are between the cutoff values plus 6 and minus 6, and the restriction is implemented to extract the class size effects around the discontinuous jump at the cutoffs (columns 3 and 6). In Table 4, standard errors robust against school-level clustering are reported in parentheses.

According to Table 4, by OLS estimation, the estimate of class size is 0.0031, statistically significant at the 10 percent 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 an approximately 3.6 percent decrease in the probability of class closure. Since, as mentioned, there is the possibility that the OLS estimate suffers from the endogeneity bias, this causal result must be interpreted with caution.

To control for the 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 percent (column 2). The effective F-statistic is about 1,084.30, 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 percent. The magnitude of the 2SLS estimate is about 48.4 percent larger than that of the OLS estimate. Therefore, there seems to be a downward bias in the absolute value in the OLS estimate. This may be because schools with students who need more intensive instruction from teachers, such as those having health problems which may

| Table 4. Effects of class size on class closure |
|-----------------------------------------------|
|                                              |
|                                               |
| Class size                                   |
| 0.0031<sup>a</sup>                          |
| (0.0016)                                     |
| Class size ≤ 27                              |
| −0.0281<sup>c</sup>                         |
| (0.0156)                                     |
| Observations                                 |
| 4,271                                        |
| Effective F-statistics                       |
| 1,084.30                                     |
| Overall mean                                 |
| 0.086                                        |
| Mean in bigger class                         |
| 3.6                                          |
| %Δ from mean in bigger class                 |
| −32.2                                        |
| %Δ from overall mean                         |
| 0.087                                        |
| %Δ from overall mean                         |
| 5.3                                          |
| %Δ from overall mean                         |
| 0.101                                        |
| Note: 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 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. <sup>b</sup>p < 0.05, <sup>c</sup>p < 0.10. |
also affect the within-class transmission of flu, may utilize small classes. In this case, the OLS estimate of class sizes should be underestimated. When we restrict the sample to classes in the schools whose enrollments are between the cutoff values plus 6 and minus 6, the estimate by 2SLS is 0.0051 and statistically significant at the 10 percent level (column 3). Compared with the overall mean, a one-unit reduction in class size decreases the probability of closure by 5.2 percent, 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 (0.0046 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 effective $F$-statistic is 306.86, 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, the one-unit reduction in class size decreases the probability of class closure by about 5.2–5.3 percent. 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 ≤ 27") is $-0.0757$, statistically significant at 5 percent (column 5), while the OLS estimate is $-0.0281$ and is statistically significant at 10 percent (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 a flu epidemic is decreased by 86.6 percent. The size of the effect is about $-87.1$ percent when we use classes in schools whose enrollments are 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 percent).

Next, we implement a subgroup analysis by grade in school. Table 5 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: first, second, and third; fourth, fifth, and sixth; and seventh and eighth. The first two categories (first through third and fourth through sixth) correspond

TABLE 5. Heterogeneous effects by grades

|                  | 1st, 2nd, and 3rd | 4th, 5th, and 6th | 7th and 8th |
|------------------|-------------------|-------------------|-------------|
|                  | OLS (1)           | 2SLS (2)          | OLS (3)     | 2SLS (4) | OLS (5) | 2SLS (6) |
| Class size       | 0.0017            | 0.0028            | 0.0045$^b$  | 0.0061$^b$ | 0.0087$^c$ | 0.0134$^b$ |
| (0.0030)         | (0.0038)          | (0.0019)          | (0.0025)    |          | (0.0047) | (0.0068) |
| Observations     | 1,582             | 1,582             | 1,468       | 1,468    | 818     | 818      |
| Effective $F$-statistics | 616.02          | 454.66            | 120.04      |          |         |          |
| 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     |

Note: 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. $^b p < 0.05$, $^c p < 0.10$. 
to classes in elementary schools, and the third category (seventh and eighth) corresponds to those in middle schools.\textsuperscript{30} We estimate only two types of models, OLS and 2SLS, because the 2SLS and 2SLS ± 6 estimates are not different and there is less variation when we utilize school FEs and restrict the sample.

According to Table 5, the higher the grade, the larger the magnitude of the estimates. Among fourth, fifth, and sixth grades, the 2SLS estimate is 0.0061 and statistically significant; compared with the overall mean (0.074), a one-unit reduction of class size decreases the probability of class closure by 8.3 percent (column 4). In the case of seventh and eighth grades, the 2SLS estimate is 0.0134 (column 6), statistically significant, and about double the estimate for fourth, fifth, and sixth. Compared with the overall mean (0.076), the probability of closure is reduced by 17.7 percent by a one-unit decrease in class sizes. The estimate for first, second, and third grades is about one-fourth that for fourth, fifth, and sixth grades, and statistically insignificant.

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 class size reduction mitigates the epidemic caused by a flu virus in the classroom among older students.

VI. Discussion

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

A. INTERPRETATION OF EFFECTS OF CLASS SIZE ON CLASS CLOSURE

In this subsection, we discuss (1) possible mechanisms behind the effects of class size on class closures and (2) the effect of preventing class closures by class size reduction on students’ human capital accumulation.

The first possible interpretation of the mechanism behind the effects of class sizes on class closures is that as class size decreases, the spread of a flu epidemic slows. This may be because of the increase in social distancing in classrooms. Increasing physical distance from others is one key strategy to prevent the spread of viruses. As explained, in Japan, since most classrooms have almost the same surface area, class size determines physical distance for each student. The smaller the class size, the larger students’ physical distance from others. If a classroom has a surface area of 63 square meters, the reduction of class size from 40 to 27 increases the area per student by about 46.1 percent: from 1.54 to 2.25 square meters. Students can then maintain a physical distance of 1.5 meters, which is the threshold that reduces the risk of infection due to relatively large droplets exhaled by each student according to L. Liu et al. (2017), when class size is reduced to 27. According to the estimation

\textsuperscript{30} We exclude the ninth grade from the middle school category to prevent the estimation results from becoming noisy, as was observed to be the case with its inclusion. In Japan, ninth grade students take a high school entrance exam mainly between January and March, and the peak of a flu epidemic overlaps with these months. Therefore, ninth grade students are likely to get a flu vaccination to avoid missing this exam. The data support this possibility: the rate of class closure in ninth grade is about 3 percent, one-fourth of the rate among first to third grades. By considering the means of these aspects, the results could become noisy.
results, among classes with 27 or fewer students, the probability of class closure substantially drops (86.6–87.1 percent) compared with the classes with over 27 students. This may be because these students 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 results show that the marginal effects are statistically significant at the 10 percent level between class sizes of 27 and 34. The estimation result implies that if students do not have a certain level of physical distance to prevent exposure to droplets, class size reductions are not effective to prevent flu epidemics in classrooms. The result also implies that once students are able to maintain enough physical distance, class size reduction is no longer effective to decrease the probability of flu infection.\textsuperscript{31} Therefore, the reduction of class size can help prevent a flu epidemic in classrooms only when it is effective to reduce reachability of droplets.\textsuperscript{32}

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 a flu epidemic. However, since a previous study among Swedish ninth graders found no class size effects on health conditions, such as with mental health problems and well-being (Jakobsson, Persson, and Svensson 2013), it is likely to be more effective to focus on increasing physical distance by reducing class size than on other possibilities, including increasing teachers’ time spent with each student in the case of health outcomes.

The social distancing hypothesis could provide an explanation for the heterogeneous effects by grade in school. According to a report by the Ministry of Education, Culture, Sports, Science, and Technology in 2009, first to third graders are at the stage of skill development where they understand and determine the good and bad by following what their parents and teachers teach them.\textsuperscript{33} Therefore, class size reduction does not work well for prevention of a flu epidemic among younger students because it is possible that first to third graders are not as capable of following other protective measures to prevent flu transmission in schools, such as wearing facial masks and washing their hands carefully, compared with older students, even though they maintain enough physical distancing.\textsuperscript{34}

The second possibility to explain the class size effects is that the education board more rapidly selects class closure in larger classes to prevent a flu epidemic, even when the proportion of infected students is low. According to the discussion in Sections III and IV, we

\textsuperscript{31} Online Appendix A.3 discusses more details of the estimation results with the cubic function.

\textsuperscript{32} 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 infection spread in classrooms.

\textsuperscript{33} https://www.mext.go.jp/b_menu/shingi/chousa/shoutou/053/gaiyou/attach/1283165.htm (accessed June 19, 2021; Japanese only)

\textsuperscript{34} The upper limit of class size is another possible explanation for the heterogeneity. It is possible that we do not obtain significant class size effect for first to third graders because, according to Table 1, they have smaller class sizes than older students with enough physical distancing to prevent transmission of the virus in all classes. However, this explanation contradicts the summary statistics showing that first to third graders are more likely to experience class closure. Therefore, we would like to emphasize the first explanation.
can conclude that the possibility of a more rapid decision by the education board on class closure for larger classes, regardless of the intensity of virus spread, should not greatly contribute to the interpretation of the results of the class size effects on class closures.

The third possibility is that the larger the class size, the higher the probability that the class has at least one student infected by the flu outside classrooms, which could be a starting point of a flu epidemic within the class. In this case, the positive relation between class sizes and class closures should be observed even if the increase in students’ physical distance by class size reductions does not affect within-class transmission of flu. We discuss this possibility using Figure 4, showing the results of a simulation of the relationship between class sizes and the probability that classes have at least one student infected by the flu outside of the classrooms. If the increase in class sizes greatly increases the probability that classes have at least one student infected by the flu outside of the classrooms, our estimated effects may also include the systematic relationship. We assume for simplicity that the probability that a student gets infected by the flu outside classrooms is independent and identically distributed, and utilize three values, 0.075, 0.1, and 0.125, as the probability that a student gets infected.35 Using the three values, we calculate the probability that classes

35 According to a report by the Japanese Ministry of Health, Labour, and Welfare, estimated numbers of people infected by seasonal flu are about 9.91 million for the 2015 season, about 10.46 million for the 2016 season, and about 14.58 million for the 2017 season (https://www.mhlw.go.jp/content/000509899.pdf, accessed July 19, 2021; Japanese only). Population estimates for April 1 are 12.691 million in 2015, 12.698 million
have at least one student infected with the flu outside classrooms for each class size. According to Figure 4, the larger the class size, the higher the probability that classes have at least one infected student, and the probability reaches 90 percent in all three scenarios when the class size is 30. The probability that classes have at least one student infected with the flu outside classrooms decreases by about 1.4–5.5 percent when the class size changes from 40 to 30. According to the 2SLS model in Table 4, a 10-unit decrease in class size prevents about 53 percent of class closures compared with the overall mean (column 2 in Table 4), and the magnitude is much larger than the percentage change in simulated probability when the class size changes from 40 to 30. Therefore, the mechanical effect that the larger the class size, the higher the probability that the class has a student being a starting point of a flu epidemic within the class would not greatly contribute to the interpretation of the results found in the previous section.

Next, we discuss whether the prevention of class closures by class size reductions affects students’ human capital accumulation. According to a study by Oikawa et al. (2022) that analyzes effects of class closures on students’ achievements using the data from City X, experiencing class closures due to seasonal flu decreases mathematics test scores by 8.68 percent of a standard deviation among elementary school boys from disadvantaged households. Using the estimated damage by Oikawa et al. (2022) and the estimated effects of class size on class closures among fourth to sixth graders, 8.3 percent (%Δ from overall mean in column 4 of Table 5), we can calculate that a ten-unit reduction of class size increases mathematics test scores among elementary school boys from disadvantaged households by 7.1 percent of a standard deviation. For example, the magnitude is comparable to an effect of an additional school instructional hour per week on PISA (Program for International Student Assessment) scores, 5.8 percent of a standard deviation, as estimated by Lavy (2015). Therefore, social distancing created by class size reductions affects not only flu epidemic prevention but also consequent student achievements. It is also possible that the smaller class sizes could create an opportunity for students to learn more in person and to foster interactive learning among students and teachers, resulting the more human capital accumulation for students.

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, and could affect students’ consequent achievements. In addition, since class or school closures force working parents to reduce their working hours, and have economic costs through factors such as reduced working hours, according to Viner et al. (2020), it is possible that the prevention of flu transmission by reduced class sizes could save on these economic costs. Although class size reduction is costly with regard to aspects such as hiring new teachers and arranging appropriate facilities, our results indicate that it is important to include students’ academic and health outcomes and additional costs due to school closures as part of the benefits of class size reduction in the full calculation of its cost-benefit analysis. We would in 2016, and 12.679 million in 2017. By dividing the estimated number of people infected by seasonal flu by the population estimate, we can calculate a probability that a person gets infected as 7.81 percent, 8.24 percent, and 11.5 percent for 2015, 2016, and 2017, respectively. The three values, 0.075, 0.1, and 0.125, cover the calculated probabilities for 2015 to 2017.
expect this social distancing to be effective not only against the flu but also against other viruses such as COVID-19. In the next subsection, we discuss the policy implications of our study for the current COVID-19 pandemic.

B. POLICY IMPLICATIONS FOR SCHOOLS 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 on the basis of 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 a flu epidemic in classrooms. In this subsection, we would like to discuss class size policy when schools reopen during the COVID-19 crisis using our estimation results for the effects of class size on class closure due to the flu.

Creating the appropriate physical distance for each student is a way to protect students from exposure to droplets exhaled by an infected student. In terms of reducing exposure, increases in physical distance by class size reductions should have the same effects for both the flu and COVID-19. According to L. Liu et al. (2017), the exposure to droplets exhaled by a source substantially increases within the distance of 1.5 meters from the source. Actually, the distance of 1.5 meters is utilized as a guideline of social distancing for the current COVID-19 crisis in some countries such as Australia, Belgium, Germany, and Italy. Therefore, we consider that the class size reduction is an effective way to protect students from exposure to droplets from other students not only for the flu but also for COVID-19.

On the other hand, however, the heterogeneity of infectivity between the flu and COVID-19 may make a difference in the effectiveness of the class size reduction even if we protect students from heavy exposure to droplets from an infected student. According to previous studies, COVID-19 is likely more infectious than the flu among the entire population, although further discussion is warranted for the case of children. For COVID-19, a meta-analysis found preliminary evidence that children have lower susceptibility to COVID-19 than do adults (Viner et al. 2021). According to the estimates of Dattner et al. (2021), the susceptibility of children is 43 percent of that of adults, and the infectivity of children is 63 percent of that of adults. In contrast, for the flu, according to a meta-analysis conducted in Tokars, Olsen, and Reed (2018), children are more likely to be infected than are adults: the incidence rate of the flu among children is 8.7 percent while that among adults

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36 https://www.bbc.com/news/science-environment-52522460 (accessed June 23, 2020).

37 The basic reproduction number \( \mathcal{R}_0 \) is a measure of infectivity defined as “the average number of new infections that one case generates, in an entirely susceptible population, during the time they are infectious” (Coburn, Wagner, and Blower 2009, 2), and of the novel coronavirus, this is estimated to be higher than the estimated \( R_0 \) of the flu. A recent review article reported that the estimated \( R_0 \) of the novel coronavirus has a mean of 3.28 and a median of 2.79 (Y. Liu et al. 2020), while the estimated \( R_0 \) ranges from 0.9 to 2.1 with a mean of 1.3 for the seasonal flu, from 1.4 to 2.8 for the 1918–19 pandemic strain, and from 1.4 to 1.6 for the novel influenza (Coburn, Wagner, and Blower 2009). Compared with the mean \( R_0 \) of the seasonal flu, that of the novel coronavirus is about 2.5 times higher.
is 5.1 percent. Using these values, we can assume that among children, infectivity of COVID-19 is comparable to that of the flu. In the case that the infectivity of COVID-19 is comparable to that of the flu, our estimation results can be applicable to the COVID-19 pandemic. Class size reductions could reduce within-class transmissions of COVID-19.

Since current studies found that variants of COVID-19 that are currently prevalent are more infectious than the ancestral type of COVID-19 (Y. Liu and Rocklöv 2021), the above assumption for children may no longer be maintained for the case of the delta variant. In this case, the risk of infection may be increased even if the exposure to the droplet is not intense, and the estimated effects of class size reductions for the flu could be an upper bound in terms of the absolute value of the effects for the delta variant. If so, our result is applicable for the delta variant at least in the point that the reduction of class size and consequent increase in physical distance in classrooms do not prevent infection of the delta variant in classrooms among the younger students. Therefore, among the younger students, interventions other than social distancing should be implemented to prevent delta variant infection in classrooms. In addition, many other new variants of COVID-19 could arise, and we need to carefully discuss the application of our estimation results to the case for other variants of COVID-19. Further analyses of the effect of social distancing on COVID-19 infection, such as quantitative analysis using mathematical models, can give us more insight for discussing whether class size reduction is effective for COVID-19 and its variants.

Current studies report long-term health consequences of COVID-19, the so-called long COVID, among children (e.g., Buonsenso et al. 2021; Buonsenso, Munblit, and Simpson 2022; Brackel et al. 2021; Ludvigsson 2021; Say et al. 2021). For example, Buonsenso et al. (2021) conducted follow-up surveys for children infected with COVID-19 and found that among children surveyed 120 days after the diagnosis, about 31 percent had one to two symptoms, and about 20 percent had three or more symptoms. According to Brackel et al. (2021), 89 children in the Netherlands are suspected to have prognostic symptoms, and about 36 percent of them have experienced severe limitations in daily life. Since previous studies have found a positive relationship between childhood health and future outcomes (Currie 2009), these long-term health consequences of COVID-19 may affect children’s life cycles in the long run. In the case of COVID-19, enabling social distancing in classrooms by class size reductions would be a way to protect students from not only short-run but also long-run harm.

VII. Conclusion

This paper analyzes the effects of class size reduction on class closure due to a flu epidemic using administrative data from City X in the Tokyo metropolitan area, and the instrumental

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38 Suppose that an adult infected with COVID-19 generates an additional 3.28 new infections and that compared with adults, children generate an additional 63 percent of the number of new infections among adults, that is, 2.0664 new infections. On the one hand, suppose that an adult infected with COVID-19 generates an additional 1.3 new infections and that compared with adults, children generate an additional 1.7 ($\approx 8.7/5.1$) times the number of new infections among adults, that is, 2.21 new infections. Then, the number of new infections by a child infected with COVID-19 is comparable to that for the flu.
variable strategy with the Maimonides’ rule. According to the estimation results, a one-unit reduction in class size decreases the incidence of class closure due to the flu by about 5.2–5.3 percent, and forming small classes with 27 students reduces class closure by about 90 percent. If a classroom has 63 square meters of area, an established standard for the classroom area in Japan, by reducing the class size to below 27, students can maintain physical distance of 1.5 meters from others, which is the threshold for reducing the risk of infection due to relatively large droplets 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 the class size of 27 and 34, implying that once students maintain 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 a 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 could 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 implemented in schools during the COVID-19 pandemic. Spread of viruses affects not only students’ health but also their academic achievement. A 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 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 VI). For further analysis, we need more detailed data sets; for example, data individually tracking students’ absences and reasons for their absences would allow us to better analyze the spread of the virus in classrooms. If students’ absence data are available, we can construct the absence rate in the winter, when the number of flu infections increases, for all classes, and utilize it as an outcome variable indicating a flu epidemic in classrooms. We can also construct the absence rate during the summer, when sickness is less likely to be influenced by within-class transmission and which can be interpreted as a proxy of students’ health capital. The availability of the absence rate in summer allows us to implement a placebo test to confirm whether students’ health capital is related to our instruments. Evaluation of the effectiveness of class closure policy for the prevention of subsequent spread of the flu in class and school reviewed in Cauchemez et al. (2009) is another important topic to be addressed in future research. 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.

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**REFERENCES**

Akabayashi, H., and R. Nakamura, R. 2014. “Can Small Class Policy Close the Gap? An Empirical Analysis of Class Size Effects in Japan.” *Japanese Economic Review* 65 (3): 253–81.

Andrews, I., J. H. Stock, and L. Sun. 2019. “Weak Instruments in Instrumental Variables Regression: Theory and Practice.” *Annual Review of Economics* 11 (1): 727–53.

Andrietti, V. 2015. “The Causal Effects of Increased Learning Intensity on Student Achievement: Evidence from a Natural Experiment.” SSRN.

Angrist, J. D., E. Battistin, and D. Vuri. 2017. “In a Small Moment: Class Size and Moral Hazard in the Italian Mezzogiorno.” *American Economic Journal: Applied Economics* 9 (4): 216–49.

Angrist, J. D., and V. Lavy. 1999. “Using Maimonides’ Rule to Estimate the Effect of Class Size on Scholastic Achievement.” *Quarterly Journal of Economics* 114 (2): 533–75.

Angrist, J. D., V. Lavy, J. Leder-Luis, and A. Shany. 2019. “Maimonides’ Rule Redux.” *American Economic Review: Insights* 1 (3): 309–24.

Battistin, E., and E. C. Meroni. 2016. “Should We Increase Instruction Time in Low Achieving Schools? Evidence from Southern Italy.” *Economics of Education Review* 55:39–56.

Bellei, C. 2009. “Does Lengthening the School Day Increase Students’ Academic Achievement? Results from a Natural Experiment in Chile.” *Economics of Education Review* 28 (5): 629–40.

Bessho, S., H. Noguchi, A. Kawamura, R. Tanaka, and K. Ushijima. 2019. “Evaluating Remedial Education in Elementary Schools: Administrative Data from a Municipality in Japan.” *Japan and the World Economy* 50:36–46.

Bonesronning, H. 2003. “Class Size Effects on Student Achievement in Norway: Patterns and Explanations.” *Southern Economic Journal* 69 (4): 952–65.

Brackel, C. L., C. R. Lap, E. P. Buddingh, M. A. van Houten, L. J. van der Sande, E. J. Langereis, M. A. Bannier, M. W. Pijnenburg, S. Hashimoto, and S. W. Terheggen-Lagro. 2021. “Pediatric Long-COVID: An Overlooked Phenomenon?” *Pediatric Pulmonology* 56 (8): 2495–502.
Buonsenso, D., D. Munblit, C. De Rose, D Sinatti, A. Ricchiuto, A. Carfi, and P. Valentini. 2021. “Preliminary Evidence on Long COVID in Children.” *Acta Paediatrica* 110 (7): 2208–11.

Buonsenso, D., F. E. Pujol, D. Munblit, D. Pata, S. McFarland, and F. K. Simpson. 2022. “Clinical Characteristics, Activity Levels and Mental Health Problems in Children with Long Coronavirus Disease: A Survey of 510 Children.” *Future Microbiology* 17 (8): 577–88.

Cattaneo, M. A., C. Oggenfuss, and S. C. Wolter. 2017. “The More, the Better? The Impact of Instructional Time on Student Performance.” *Education Economics* 25 (5): 433–45.

Cauchemez, S., N. M. Ferguson, C. Wachtel, A. Tegnell, G. Saour, B. Duncan, and A. Nicoll. 2009. “Closure of Schools during an Influenza Pandemic.” *The Lancet Infectious Diseases* 9 (8): 473–81.

Chetty, R., J. N. Friedman, N. Hilger, E. Saez, D. W. Schanzenbach, and D. Yagan. 2011. “How Does Your Kindergarten Classroom Affect Your Earnings? Evidence from Project Star.” *Quarterly Journal of Economics* 126 (4): 1593–660.

Coburn, B. J., B. G. Wagner, and S. Blower. 2009. “Modeling Influenza Epidemics and Panemics: Insights into the Future of Swine Flu (H1N1).” *BMC Medicine* 7:30.

Currie, J. 2009. “Healthy, Wealthy, and Wise: Socioeconomic Status, Poor Health in Childhood, and Human Capital Development.” *Journal of Economic Literature* 47 (1): 87–122.

Dattner, I., Y. Goldberg, G. Katriel, R. Yaari, N. Gal, Y. Miron, A. Ziv, R. Sheffer, Y. Hamo, and A. Huppert. 2021. “The Role of Children in the Spread of COVID-19: Using Household Data from Bnei Brak, Israel, to Estimate the Relative Susceptibility and Infectivity of Children.” *PLoS Computational Biology* 17 (2): e1008559.

Dobbelsteen, S., J. Levin, and H. Oosterbeek. 2002. “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* 64 (1): 17–38.

Fredriksson, P., B. Öckert, and H. Oosterbeek. 2013. “Long-Term Effects of Class Size.” *Quarterly Journal of Economics* 128 (1): 249–85.

———. 2016. “Parental Responses to Public Investments in Children: Evidence from a Maximum Class Size Rule.” *Journal of Human Resources* 51 (4): 832–68.

Gary-Bobo, R. J., and M.-B. Mahjoub. 2013. “Estimation of Class-Size Effects, Using ‘Maimonides’ Rule’ and Other Instruments: The Case of French Junior High Schools.” *Annals of Economics and Statistics*, no. 111/112, 193.

Hansen, B. 2013. “School Year Length and Student Performance: Quasi-Experimental Evidence.” SSRN.

Hojo, M. 2013. “Class-Size Effects in Japanese Schools: A Spline Regression Approach.” *Economics Letters* 120 (3): 583–87.

Hoxby, C. M. 2000. “The Effects of Class Size on Student Achievement: New Evidence from Population Variation.” *Quarterly Journal of Economics* 115 (4): 1239–85.

Ibuka, Y., Y. Ohkusa, T. Sugawara, G. B. Chapman, D. Yamin, K. E. Atkins, K. Taniguchi, N. Okabe, and A. P. Galvani. 2016. “Social Contacts, Vaccination Decisions and Influenza in Japan.” *Journal of Epidemiology and Community Health* 70 (2): 162–67.
Jakobsson, N., M. Persson, and M. Svensson. 2013. “Class-Size Effects on Adolescents’ Mental Health and Well-Being in Swedish Schools.” *Education Economics* 21 (3): 248–63.

Kikuchi, N. 2014. “The Effect of Instructional Time Reduction on Educational Attainment: Evidence from the Japanese Curriculum Standards Revision.” *Journal of the Japanese and International Economics* 32:17–41.

Krueger, A. B., and D. M. Whitmore. 2001. “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* 111 (468): 1–28.

Lavy, V. 2015. “Do Differences in Schools’ Instruction Time Explain International Achievement Gaps? Evidence from Developed and Developing Countries.” *Economic Journal* 125 (588): F397–424.

Leuven, E., and S. A. Løkken. 2020. “Long-Term Impacts of Class Size in Compulsory School.” *Journal of Human Resources* 55 (1): 309–48.

Leuven, E., H. Oosterbeek, and M. Ronning. 2008. “Quasi-Experimental Estimates of the Effect of Class Size on Achievement in Norway.” *Scandinavian Journal of Economics* 110 (4): 663–93.

Liu, L., Y. Li, P. V. Nielsen, J. Wei, and R. L. Jensen. 2017. “Short-Range Airborne Transmission of Expiratory Droplets between Two People.” *Indoor Air* 27 (2): 452–62.

Liu, Y., A. A. Gayle, A. Wilder-Smith, and J. Rocklöv. 2020. “The Reproductive Number of COVID-19 Is Higher Compared to SARS Coronavirus.” *Journal of Travel Medicine* 27 (2): taaa021.

Liu, Y., and J. Rocklöv. 2021. “The Reproductive Number of the Delta Variant of SARS-CoV-2 is Far Higher Compared to the Ancestral SARS-CoV-2 Virus.” *Journal of Travel Medicine* 3 (27): 584–86.

Ludvigsson, J. F. 2021. “Case Report and Systematic Review Suggest that Children May Experience Similar Long-Term Effects to Adults After Clinical COVID-19.” *Acta Paediatrica* 110 (3): 914–21.

Ministry of Health, Labour, and Welfare of Japan. 2009. “Gakkou-hoiku-shisetsu tou no rinji kyugyou no yousui tou ni kansuru kihonteki kangaekata ni tsuite” [Basic policy on requests for temporary closure of schools and childcare facilities]. Technical report. Accessed July 28, 2021. https://www.mhlw.go.jp/kinkyu/influenza/hourei/2009/09/dl/info0924-01.pdf.

Montiel Olea, J. L., and C. Pflueger. 2013. “A Robust Test for Weak Instruments.” *Journal of Business and Economic Statistics* 31 (3): 358–69.

Mori, M. 2019. “Active learning no shiten ni tatta gakusyu-kuukan ni kansuru tyousakenkyu” [Research on learning space from the viewpoint of active learning]. Technical report, National Institute for Educational Policy Research. Accessed May 22, 2020. https://www.nier.go.jp/shisetsu/pdf/20190409-02.pdf.

Oikawa, M., R. Tanaka, S. Bessho, A. Kawamura, and H. Noguchi. 2022. “Do Class Closures Affect Students’ Achievements? Heterogeneous Effects of Students’ Socioeconomic Backgrounds.” RIETI Discussion Paper Series No. 22-E-042.

Pischke, J. 2007. “The Impact of Length of the School Year on Student Performance and Earnings: Evidence from the German Short School Years.” *Economic Journal* 117 (523): 1216–42.
Rivkin, S. G., and J. C. Schiman. 2015. “Instruction Time, Classroom Quality, and Academic Achievement.” *Economic Journal* 125 (588): F425–48.

Sasaki, S., H. Kurokawa, and F. Ohtake. 2020. “Short-Term Responses to Nudge-Based Messages for Preventing the Spread of COVID-19 Infection: Intention, Behavior, and Life Satisfaction.”

Say, D., N. Crawford, S. McNab, D. Wurzel, A. Steer, and S. Tosif. 2021. “Post-acute COVID-19 Outcomes in Children with Mild and Asymptomatic Disease.” *The Lancet Child and Adolescent Health* 5 (6): e22–23.

Shapiro, E. 2021. “N.Y.C.’s Mayor Says a New Virus Rule Will Reduce Temporary Public School Closures.” *New York Times*, April 8, 2021. https://www.nytimes.com/2021/04/08/nyregion/new-york-school-closure-rules.html.

Shoji, M., S. Cato, T. Iida, K. Ishida, A. Ito, and K. M. McElwain. 2020. “COVID-19 and Social Distancing in the Absence of Legal Enforcement: Survey Evidence from Japan.” MPRA Paper No. 100723.

Suzue, T., Y. Hoshikawa, S. Nishihara, A. Fujikawa, N. Miyatake, N. Sakano, T. Yoda, A. Yoshioka, and T. Hirao. 2012. “The New School Absentees Reporting System for Pandemic Influenza A/H1N1 2009 Infection in Japan.” *PLoS ONE* 7 (2): e30639.

Tokars, J. I., S. J. Olsen, and C. Reed. 2018. “Seasonal Incidence of Symptomatic Influenza in the United States.” *Clinical Infectious Diseases* 66 (10): 1511–18.

Uscher-Pines, L., H. L. Schwartz, F. Ahmed, Y. Zheteyeva, E. Meza, G. Baker, and A. Uzicanin. 2018. “School Practices to Promote Social Distancing in K-12 Schools: Review of Influenza Pandemic Policies and Practices.” *BMC Public Health* 18 (1): 406.

Viner, R. M., O. T. Mytton, C. Bonell, G. J. Melendez-Torres, J. Ward, L. Hudson, C. Waddington, et al. 2021. “Susceptibility to SARS-CoV-2 Infection among Children and Adolescents Compared with Adults: A Systematic Review and Meta-Analysis.” *JAMA Pediatrics* 175 (2): 143–56.

Viner, R. M., S. J. Russell, H. Croker, J. Packer, J. Ward, C. Stansfeld, O. Mytton, C. Bonell, and R. Booy. 2020. “School Closure and Management Practices during Coronavirus Outbreaks Including COVID-19: A Rapid Systematic Review.” *The Lancet Child and Adolescent Health* 4 (5): 397–404.

Watanabe, T., and T. Yabu. 2021. “Japan’s Voluntary Lockdown.” *PLoS ONE* 16 (6): e0252468.

Wößmann, L. 2003. “Schooling Resources, Educational Institutions and Student Performance: The International Evidence.” *Oxford Bulletin of Economics and Statistics* 65 (2): 117–70.

Yamamura, E., and Y. Tsutsui. 2022. “How Does the Impact of the COVID-19 State of Emergency Change? An Analysis of Preventive Behaviors and Mental Health Using Panel Data in Japan.” *Journal of the Japanese and International Economics* 64:101194.

Yasui, T. 2012. “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* 41:83–96.

Yoshino, H., Y. Iino, N. Takizawa, G. Iwashita, K. Kumagai, T. Kurabuchi, S. Nagasawa, A. Nagata, A. Hasegawa, and S. Muramatsu. 2009. “Regional Installing and Operating Conditions of HVAC Systems in Public Elementary Schools.” *Journal of Environmental Engineering* 74 (639): 643–50.