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Does Re-Opening Schools Contribute to the Spread of Sars-Cov-2? Evidence From Staggered Summer Breaks in Germany

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Does re-opening schools contribute to the spread of SARS-CoV-2? Evidence from staggered summer breaks in Germany*

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Abstract. This paper studies the effect of the end of school summer breaks on SARS-CoV-2 cases in Germany. The staggered timing of summer breaks across federal states allows us to implement an event study design. We base our analysis on official daily counts of confirmed coronavirus infections by age groups across all 401 German counties. We consider an event window of two weeks before and four weeks after the end of summer breaks. We do not find evidence of a positive effect of school re-openings on case numbers. For individuals aged between 5-59 years, which comprise school-aged children and their parents, our preferred specification indicates that the end of summer breaks had a negative but insignificant effect on the number of new confirmed cases. Our results are not explained by changes in mobility patterns around school re-openings arising from travel returnees. Analyses of Google Trends data suggest that behavioral changes of parents may have contributed to contain larger outbreaks after school re-openings. We conclude that school re-openings in Germany under strict hygiene measures combined with quarantine and containment measures have not increased the number of newly confirmed SARS-CoV-2 infections.

Keywords: COVID-19, schooling, education, Germany

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1 Introduction

School closures have been among the most common non-pharmaceutical interventions to slow down the spread of the novel coronavirus (SARS-CoV-2). According to UNESCO estimates, these affected over 60 percent of the world's student population.[1] Closing schools is expected to widen gaps by socio-economic status in school performance and longer-term career outcomes, especially for students from disadvantaged households (Fuchs-Schündeln et al., 2020). Despite large expected costs of school closures, in many countries policymakers remain hesitant to re-open schools. In cases where schools have re-opened, confirmed cases and quarantine measures in schools draw disproportional media attention. Closing schools remains a commonly cited option to counter newly rising case numbers. A heated debate between advocates of online-only solutions vs. on-site education, as recently summarized by Levinson et al. (2020) for the U.S., is characterized by the lack of empirical evidence on how school re-openings affect the spread of the novel coronavirus.

Against this background, we provide estimates of how the end of summer breaks and the associated school re-openings under strict hygiene measures in Germany have affected the course of the SARS-CoV2 pandemic. We exploit the staggered timing of summer breaks across German federal states. We implement an event study design in which we compare changes in newly confirmed cases in re-opening states over the end of summer breaks. States having not (yet) re-opened schools act as a control group. We base our estimations on official daily case counts by age group across all 401 German counties. In all specifications, we control for mobility patterns, measured by Google Mobility Reports and commercial mobile phone data. We do not find any evidence for a positive effect of the end of summer breaks on the number of confirmed cases. Instead, for age groups 5-59, comprising of school-aged children, parents as well as teachers, our preferred specification indicates that the end of summer breaks had a negative but insignificant effect on the number of new confirmed cases. Result patterns remain robust towards a large number of robustness checks and subgroup analyses, including accounting for confounding dynamic heterogeneous treatment effects following de Chaisemartin and D'Haultfoeuille (2020), and excluding single or groups of states.

We offer two explanations for the potentially surprising absence of an increase in cases following the end of summer breaks. First, re-opening schools moves students into a controlled environment for a large part of the day on weekdays. Schools re-opened under strict hygiene and containment measures, including mandatory mask wearing and teaching in fixed groups. Infections among students or teachers led to rapid testing and quarantining of contact persons. Second, re-openings led to changes in parental behavior. Opportunity costs of caring for an symptomatic child at home suddenly increased as students with corona-related symptoms were barred from school until negatively tested. We find corroborating evidence for parental behavioral changes as a likely mechanism by analyzing *Google trends* search frequencies. Searches for children's symptoms and school hygiene measures are pacing up three weeks before school re-openings and remain constant thereafter.

Our results have implications for policymakers world-wide. We provide causal evidence on the effect of school re-openings associated with the end of summer breaks in a quasi-

[1]See `https://en.unesco.org/covid19/educationresponse` (last accessed: 23 September 2020).

experimental design. In a situation where schools re-open under strict hygiene measures, case numbers did not positively respond to the end of summer breaks. Freely available rapid testing for teachers and students as well as decentralized quarantine and containment measures appear to have been sufficient to keep the pandemic under control and simultaneously allow for universal in-class teaching. In addition, open schools appear to lead to more cautious behavior of parents which even contributes to a containment of the pandemic, compared to the situation during the summer breaks. Given the high immediate and longer-run human capital costs of school closures, our results should be taken serious in re-evaluating the cost-benefit considerations of moving back to on-site schooling. Yet, in doing so, the context of our estimation of a situation of low community spread and the restricted time horizon of four weeks after the school re-openings after the summer breaks has to be kept in mind. In particular, the increasingly accelerating number of new infections in the overall population, which occurred in Germany in October and November 2020, may increase the risk of more infections among students. Furthermore, colder temperatures and worse weather conditions in fall and winter may hamper outdoor activities and ventilation of classrooms, which may also facilitate outbreaks in schools.

2 Background

School closures and re-openings during a pandemic. The effectiveness of school closures to counter the spread of the SARS-CoV2 pandemic is controversially debated because of conflicting evidence and a lack of understanding of specific mechanisms. Only few studies have addressed the role of school *re-openings*, which are not necessarily the flip side of school closures during exponential growth of case numbers in the first wave.

Studies investigating the role of school closures in mitigating earlier epidemics have provided mixed empirical evidence heavily depending on the local context. Jackson et al. (2013) provide a systematic review of 65 studies which analyze situations where influenza outbreaks coincided with planned or unplanned school closures. In general, influenza incidence declined after school closure. Only in a few cases, this effect was reversed after school re-openings. The authors stress that the effect of school closures is difficult to isolate from a natural decline of case numbers as school closures are in general enacted late in a pandemic wave. It is also difficult to disentangle from other non-pharmaceutical interventions like social distancing strategies when these are implemented coincidentally.

A subset of studies therefore focuses on regular school closures due to summer breaks (De Luca et al., 2018; Chu et al., 2017), finding mitigating effects in the context of influenza epidemics. An advantage of the analysis of regular summer breaks, also exploited in our own analysis, is that these do typically not coincide with further non-pharmaceutical interventions. Yet, one has to take into account that summer breaks affect case numbers through different mechanisms: School closures, but also differences in social mixing and mobility patterns can reduce or increase the number of new infections (Eames et al., 2012; Apolloni et al., 2013).

For the specific case of SARS-CoV-2, early descriptive association studies mirror the mixed evidence found for previous epidemic outbreaks. Viner et al. (2020) conclude in an early review of 16 studies on school closures in China and Hong Kong that these did not contribute to the containment of the epidemic. (Auger et al., 2020) find lower infection rates after school closures in a U.S. setting. Direct contact tracing studies report a lack of evidence for transmissions among primary school children, e.g., in Ireland (Heavey et al., 2020), France (Fontanet et al., 2020) and Australia (Macartney et al., 2020). Macartney et al. (2020) highlight the role of case-contact testing and epidemic management strategies in contributing to low transmission rates. Based on a quasi-experimental design and Swedish register data, Vlachos et al. (2020) exploit the setting of partial school closures at the onset of the pandemic, when upper secondary schools moved to online instruction while lower secondary schools remained open. They find that among parents exposure to open rather than closed schools resulted in a only modest increase of 15 percentage points in confirmed infections. Yet, the infection rate among lower secondary teachers doubled relative to upper secondary teachers.

To the best of our knowledge only two studies attempt to estimate how school *re-openings* causally affect the spread of SARS-CoV-2. Stage et al. (2020) conclude that partial re-openings before the summer breaks in Germany and Scandinavian countries have not resulted in significant increases in the growth rate of new cases. Our paper is close to a very recent working paper by von Bismarck-Osten et al. (2020) using the same data and identification strategy as our own approach. Their results unsurprisingly confirm our own in the short term. Our study differs in three important ways: first, we focus on a longer post-treatment window. This is important as rising case numbers after school re-openings might need some time to emerge. By focusing on a too-short time window, one might falsely conclude that school re-openings are unrelated to rising case numbers. Second, we control for various measures of mobility patterns as important confounding variables surrounding the end of summer breaks. Third and maybe most important, we do not treat the fact that case numbers slightly decrease after school re-openings as an empirical puzzle, but as the outcome of changes in parental behavior and incentives, a channel for which we provide suggestive evidence by Google Trends data.[2]

School closures during the COVID-19 pandemic in Germany. In Germany, the number of confirmed SARS-CoV-2 infections started to increase exponentially in early March. Closures of schools and daycare facilities for children were an integral part of policymakers' immediate response to the coronavirus outbreak. Figure 1 shows the development of the total number of confirmed cases as well as the phases of schools closures and re-openings in Germany. While the decision to close schools is in the responsibility of the 16 states, the federal and the state governments had agreed on a coordinated approach such that the onset of school closures occurred in all states during the days from 16 to 18 March 2020. Only children of

[2]The working paper version by von Bismarck-Osten et al. (2020) was published on 23 November 2020, six weeks after we made our own draft public via the *IZA Discussion Paper Series*. The authors have confirmed that the paper has been independently developed from ours. In addition to the end of summer breaks, the paper also uses the beginning of summer- and autumn breaks as additional treatments. We deliberately focus on school re-openings after summer breaks only and do not consider these additional treatments. School closures at the beginning of summer breaks do not work as a homogeneous treatment as federal states differed significantly in the extent they returned to in-class teaching before the summer breaks. Autumn breaks provide too little variation in timing and additionally differ in length between federal states. Finally, the majority of primary schools provides in-class formal care during at least one week of autumn breaks.

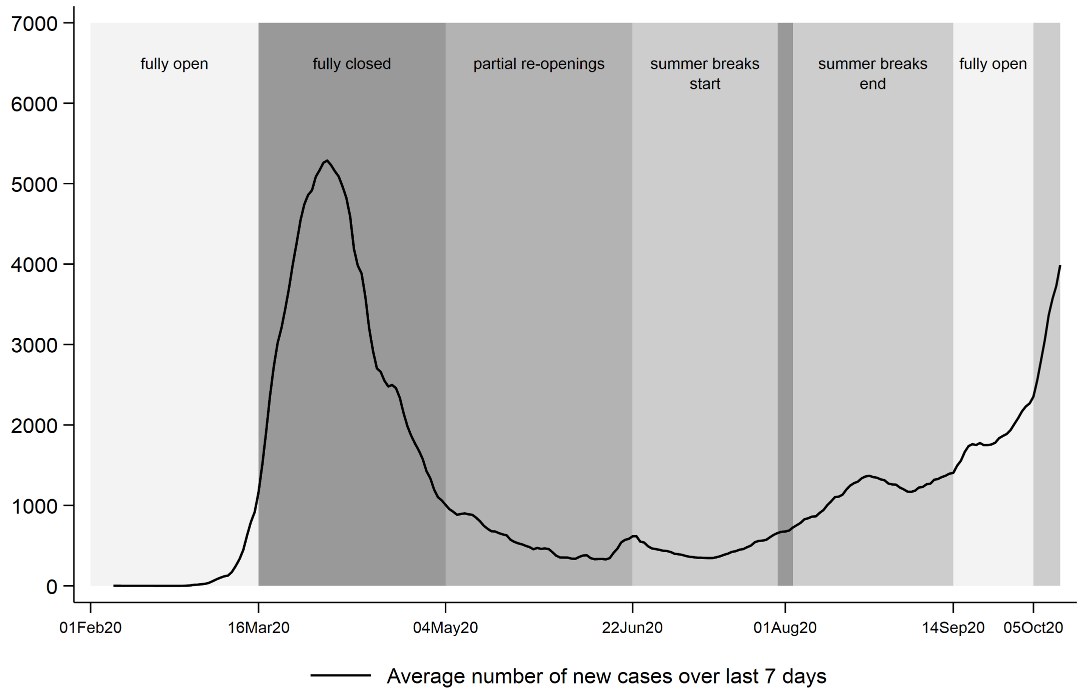

Figure 1: Timeline of COVID-19 Pandemic and School Closures and Openings in Germany

Note: This graph shows the evolution of the average number of new confirmed cases of SARS-CoV-2 infections over the last seven days in Germany (solid line). The shaded areas describe the different phases of school closures and re-openings in Germany. Source: RKI, own presentation.

parents working in essential occupations were eligible for emergency care in schools and daycare facilities. Before that, schools had operated under pre-pandemic ("normal") conditions, i.e., without hygiene measures, social distancing or separation of groups.

After a phase of rigorous restrictions of physical contact (*Kontaktbeschränkungen*) in March and April, state governments started to partially re-open schools under strict hygiene measures and social distancing rules from mid-April onward. Children were admitted to school on a rotating basis, only for certain grades, and in small groups on few days. The degree of partial re-openings of schools differed between states.

The school year 2019/2020 ended as planned between 22 June and 30 July followed by summer breaks of six weeks. Traditionally, starting and ending dates of summer breaks differ between states to prevent the entire German population to go on holidays at the same time. The staggered summer breaks avoid traffic congestion as well as excess demand for holiday accommodation in tourist regions. A long-term scheduling of summer vacation periods across states (currently up to 2024) is decided by the Standing Conference of the Ministers of Education and Cultural Affairs (*Kultusministerkonferenz*, KMK), a consortium of state ministers responsible for education and schooling.[3] Proposals to adjust the summer break schedule in response to the pandemic were discussed, but eventually rejected. Thus, the summer breaks remained unaffected by regional differences in the spread of the pandemic.

[3]See `https://www.kmk.org/service/ferien.html` for details (last accessed: September 10, 2020).

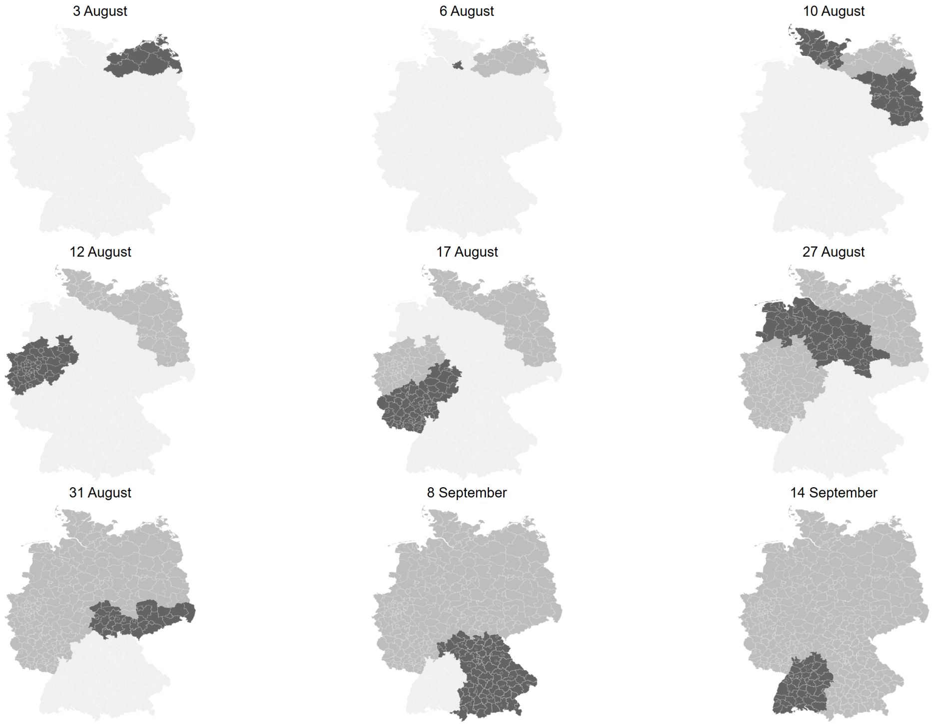

Figure 2: School Opening Dates after Summer Vacation 2020 in Germany

Note: This graph shows a map of German counties highlighting the counties in states by date of school opening after summer vacation 2020. Counties (states) highlighted in dark gray start the new school year on the respective date, while light gray indicates that they are still on summer vacation and medium gray indicates that they had already re-opened schools at an earlier date. Schools re-openings: 3 August: Mecklenburg-Vorpommern, 6 August: Hamburg, 10 August: Schleswig-Holstein, Berlin, Brandenburg, 12 August: North Rhine Westphalia, 17 August: Hessia, Rhineland-Palatinate, and Saarland, 27 August: Lower Saxony, Bremen, and Saxony-Anhalt, 31 August: Saxony and Thuringia, 8 September: Bavaria, 14 September: Baden-Wuerttemberg. Source: KMK.

Figure 2 displays the spatial and temporal variation in school starting dates after the summer break across German states. Only for a few days around 1 August all schools in Germany are closed due to summer breaks. We focus on the phase of full re-opening of schools in all states after the summer breaks which took place from early-August to mid-September 2020.

School re-openings under strict hygiene measures. Throughout the summer breaks, state and school administrations discussed best practices of how to allow schools to be re-opened by simultaneously minimizing the risk of spreading the virus. In mid-July, the KMK agreed on a common framework for measures to be implemented by state governments, such that schools re-opened after the summer breaks under fairly homogeneous conditions (Kultusministerkonferenz, 2020). This common framework provided guidelines for a wide range of hygiene measures, wearing of face masks, ventilation and disinfection of classrooms, social distancing rules, separation of groups to facilitate contact tracing and regular testing of teachers and students. Students, teachers and parents showing symptoms related to COVID-19 were not allowed to enter the school perimeter. When new infections were detected, relevant groups were immediately quarantined, with other groups remaining in school and being closely monitored for additional new cases. A much-noticed statement by the German national academy of sciences supported this strategy, further stressing the importance of fixed and separated epidemiological groups, systematic testing and rapid quarantining (Leopoldina, 2020).

As responsibilities ultimately lie with the federal state authorities, specific rules differed between states at school re-opening. In almost all states, mask wearing was mandatory for older students, often even during class. For primary school students, masks were worn on the way to the classroom, but not in class. Teaching was kept in fixed groups, in general on classroom basis. These groups remained physically separated throughout the school day. Testing was readily available for affected children and teachers. Symptomatic students went into 14 days of quarantine. Sports and music classes were suspended. Schools were allowed to impose stricter measures than the minimum requirements.

3 Data

Confirmed cases of SARS-CoV-2 infections. Our main data source comprises daily new confirmed SARS-CoV-2 cases by German counties (*Kreise*). This data is collected from the official COVID-19 reporting database which is maintained by Germany's main public health institute, the Robert-Koch-Institut (RKI). In accordance with the Infection Protection Act (*Infektionsschutzgesetz*), the RKI collects daily reports from county-level public health offices on newly detected cases and deaths. Case reports are transmitted to the RKI by 0:00 a.m. on the respective day.

The records contain the exact date on which the local public health office became aware of the case and recorded it electronically. We focus on this date in our empirical analysis.[4] Cases are separately recorded by fixed age groups. For the purpose of our analysis, we consider three age categories: 5–14 (school-aged children), 15–59 (older students, parents and the majority of teachers) and 60+.[5] To take into account regional differences in population density, we normalize case numbers by 100K population by county and age group. Daily case counts are regularly updated based on delayed lab confirmations and deaths of earlier recorded cases. The analysis of this paper is based on a snapshot of the full data set from 16 November 2020 and we consider the observation window from 1 July to 12 October 2020.

Table 1 summarizes case numbers over the period of observation by age group, and separately for periods before and after the school re-openings. Two patterns are noteworthy. First, while initial infections during the peak of the pandemic in early-April were more concentrated among vulnerable age groups 60+, over the summer the share of younger age groups among the total number of confirmed cases has grown strongly. Confirmed cases are highest among 15–59 year old which display with about 1.7 cases per 100K population a distinctly larger case rate than school-aged children aged 5–14 (1.1 cases per 100K population) and almost 3

[4]For cases where symptoms were present before the testing, the data contains additional information on when the patient became ill with clinical symptoms according to the patient's own statement or according to the statement of the treating physician (onset of symptoms). Since testing has strongly been extended over the summer months, and the share of detected asymptomatic cases has increased (or at least the share of infected patients being tested before they develop symptoms), we do not take the date of onset of symptoms into account.

[5]Unfortunately, the age cut-off at age 15 is fixed by the data provider and cannot be altered to more appropriately capture school-aged children or the cohort most likely to have school-aged children.

Table 1: Summary Statistics - confirmed cases of SARS-CoV-2 (by county and day)

	Full Period		Before School Opening		After School Opening	
	Mean	SD	Mean	SD	Mean	SD
Age Group						
5-14	1.108	3.798	0.817	3.317	1.455	4.276
15-59	1.708	3.223	1.100	2.808	2.434	3.522
60+	0.591	1.930	0.265	0.995	0.980	2.591
All Ages	1.363	2.438	0.862	1.990	1.960	2.766
Observations	41,704		18,143		15,220	

Note: This table summarizes means and standard deviations of confirmed cases of SARS-CoV-2 normalized by 100K population by county and age group. The full observation period covers 1 July–12 October 2020.
Source: RKI and Statistical Office.

times as many cases than older patients 60+ (0.59 cases per 100K population). After cases in Germany had decreased for a period of almost three months since the peak of the pandemic, they started to rise again since early July (see Figure 1). Case numbers are thus higher in each age group after the school re-opening compared to the situation before. Our empirical analysis will determine to what extent the end of school summer breaks is causally related to this increase.

Mobility patterns. The end of summer breaks necessarily leads to coinciding changes which might have independent effects on the course of the pandemic. Summer breaks are characterized by significantly different mobility patterns, decreased commuting and lower usage of public transportation. These changes might affect the spread of the pandemic independently from re-opening of schools and might ask for different policy responses. To disentangle the effect of school re-openings as good as possible from these coinciding changes in mobility patterns, we keep the latter constant by controlling for several measures of mobile phone mobility. First, we use commercial data on daily levels of mobile phone mobility within and across counties covering about one third of Germany's mobile phone market provided by *Teralytics*. Specifically, we control for the daily number of within-county mobility as well as between-county mobility both within and across states. Second, we draw on state-level information on relative duration of stays at different places from *Google Mobility Reports*: groceries, parks, home, retail and recreation, transit stations and workplaces.[6]

[6]Figures A.10 and A.11 in the Supplementary Appendix show how mobility patterns change surrounding the end of summer breaks. Mobility within states (both within and across counties of the same state) gradually increases before the end of the summer break and remains constant thereafter. Mobility related to everyday life activities (grocery and retail shopping, commuting and work) gradually increases before the end of summer breaks and does not change much afterwards, reflecting that families with school-aged children gradually return to their places of residence and take up everyday activities.

4 Empirical Approach

The aim of this study is to disentangle the causal effect of the end of summer breaks and the associated school re-openings on the spread of the pandemic from coinciding patterns in the evolution of cases. We do so by exploiting the staggered summer break schedule across federal states. Intuitively, we compare changes in the number of confirmed case numbers in states where summer breaks have ended (the treatment group) with control states where summer breaks have not yet ended.

Our analysis relies on the assumption that cases after summer breaks would have developed similarly as in control states in the counterfactual and unobservable situation that schools would have remained closed. To support this identification assumption, we present our estimates in the form of event study graphs to establish that trends in cases between treatment and control states behaved similarly in the days preceding the end of summer breaks.[7] Our empirical model reads:

$$\text{CoV}^{g}_{ist} = \alpha_i + \mu_t + \sum_{\tau=-15,\tau\neq 0}^{29} \beta_\tau SchoolsOpen_{s,t-\tau} + X'_{it}\gamma + \varepsilon_{ist} \tag{1}$$

where CoV^{g}_{ist} denotes the number of new confirmed cases of SARS-CoV-2 infections in county i in state s on date of reporting t per 100K of population of age group g. The indicator $SchoolsOpen_{s,t-\tau}$ takes a value of one if the county i's state s has schools open on date t. Following Schmidheiny and Siegloch (2019), we limit the effect window to a finite number of leads and lags of two weeks before and four weeks after the end of the summer breaks and create bins for the endpoints of the event window. County fixed effects α_i control for time-invariant unobserved characteristics, most notably population density and age structure. Date fixed effects μ_t control for any unobserved influence that affects the evolution of cases globally across counties. This includes, among others, changes in nation-wide counter-measures or the testing regime in place.[8] Our baseline period is $\tau = 0$, i.e., the first school day after the summer break. While the direct effect of school openings on case numbers may be expected to kick in only after some days, indirect effects of school openings acting through parental behavior may lead to more immediate changes. Therefore, we present results relative to the first day at school. We additionally control for time-varying variables X_{it} which most importantly include changing mobility patterns assessed by mobile phone movements and Google Mobility Reports.[9] To determine heterogeneous effects on different age groups, we estimate Equation (1) separately for the overall number of cases and case numbers by age groups. Standard

[7] In Section A.1 in the Supplementary Appendix, we discuss and provide supportive evidence against remaining potential confounders that would coincide with the school openings.

[8] The frequency of testing for SARS-CoV-2 substantially increased for age groups under 60 during early-August, most likely due to testing of travel returnees. The weekly number of tests, especially among children of school age (5–14 years) remained constant since then. However, the share of infected children significantly decreased from mid-August (about 1.5%) to below 0.75% in early-September. See `https://ars.rki.de/Docs/SARS_CoV2/Wochenberichte/20201013_wochenbericht.pdf` (last accessed: 16 October 2020).

[9] In the Supplementary Appendix, we discuss the specific role of travel returnees and provide several pieces of evidence that speak against that higher numbers among travel returnees contribute to our results pattern.

errors ε_{ist} in all estimations are clustered at the federal state level.

5 Empirical results

In this section, we present estimates for the effect of the end of summer breaks on the number of confirmed cases for different age groups. Figure 3 reports estimated coefficients of Equation (1) separately for overall cases and cases by different age groups. Overall, the results do not speak in favor of any positive effect of school re-openings on case numbers. Rather, we observe a slight but insignificant reduction of case numbers. Confidence intervals are sufficiently small: we can rule out any positive effect after 28 days that is larger than 0.34 cases per 100K population. The observed reduction is driven by age groups comprising school-aged children (5-14 years) as well as older students and their parents (15-59 years). In the following section, we will explore changes in parental behavior as a potential driver of this effect. Older individuals who would have been at a significantly higher risk of severe cases of Covid-19 remain unaffected.

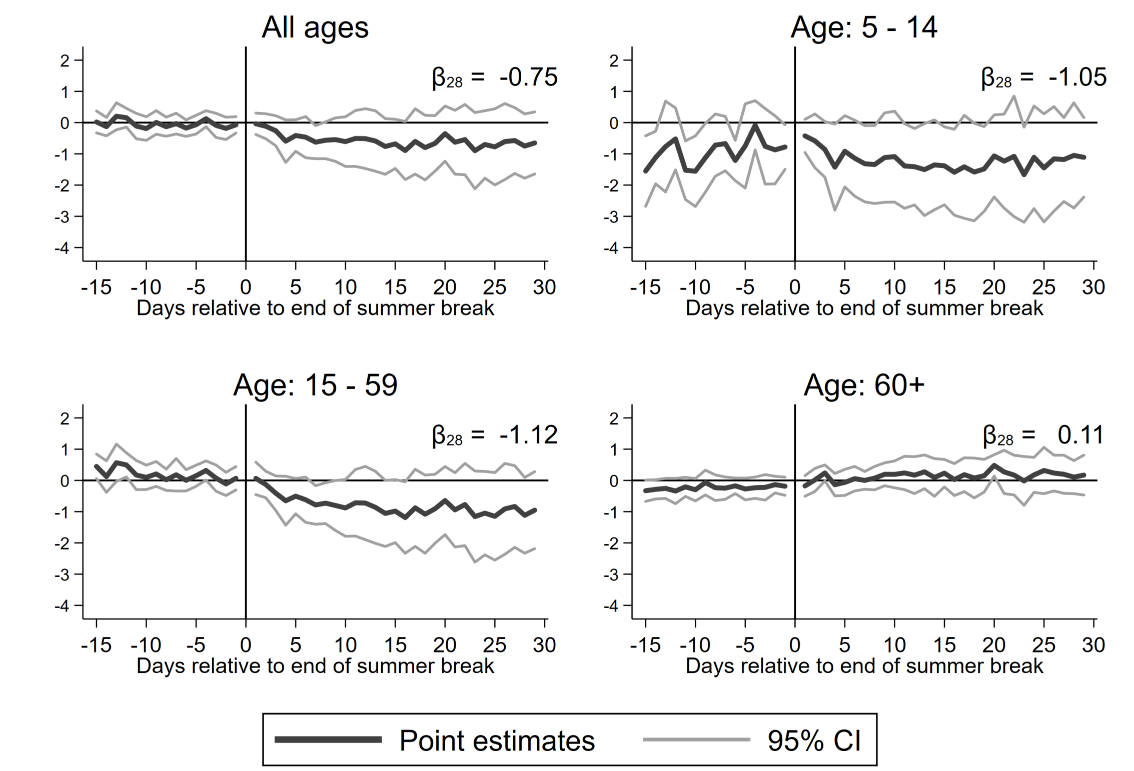

Figure 3: The Effect of the End of Summer Breaks on Confirmed Cases by Age Groups

Note: This graph plots the point estimates ($\hat{\beta_\tau}, \tau \in [-15, 29]$) and corresponding 95% percent confidence intervals of the event study model as defined in Equation (1), separately estimated overall case numbers and cases by age groups 5–14, 15–59 and 60+. The dependent variable is always the daily count of confirmed cases per 100K population per county and age group. The vertical line at $\tau = 0$ indicates the school opening. The regressions include fixed effects on the county and day level. Standard errors are clustered at the federal state level.

We ran an extensive set of robustness checks and subgroup analyses to corroborate these main results. The identified result patterns remain robust towards accounting for heterogeneous dynamic treatment effects relying on the method proposed by de Chaisemartin and D'Haultfoeuille (2020). Subgroup analyses by early vs late re-opening and East vs West German states show that reductions in case numbers after school re-openings are primarily driven by early re-opening West German states. Excluding single states from the regression confirms that results are not driven by outliers. None of the robustness checks would allow for the conclusion that there was any increase in case numbers in response to the school re-openings. The results of robustness checks and subgroup analysis are summarized in in Section A.1 in the Supplementary Appendix.

6 Context and plausible mechanisms

The negative effect of the end of summer breaks and associated school re-openings on the number of confirmed cases may run counter to established priors and contradicts media reports on individual and partial school closures due to detected cases after the re-opening. In the following, we set our results into perspective by discussing the counterfactual situation surrounding the end of summer breaks. We further discuss mechanisms of altered parental behavior which potentially explain our results.

The counterfactual situation. Comprehensive school closures were viewed as a drastic but necessary non-pharmaceutical intervention to effectively slow down the spread of SARS-CoV-2 at the very beginning of the epidemic in Germany around mid-March 2020. Several pieces of evidence indicate that school closures play a significant role in reducing infection rates (Auger et al., 2020; Stage et al., 2020; Jackson et al., 2013). Yet, this evidence does not necessarily contradict the reported negative effects of school *re-openings* as the counterfactual situations differ strongly.

School closures were effective against the counterfactual situation of keeping schools open during the early period of exponential growth in new case numbers in March and April 2020. Up until the comprehensive school closures in mid-March, schools had operated without any hygiene concept, mask-wearing was not yet established, testing was restricted to symptomatic cases only and daily case numbers were substantially higher than the average case numbers in July and August (see Figure 1).

The re-openings after the summer breaks in August and September 2020, which are the setting for this study, do not represent the flip side of the coin of the school closures during March and April. They differ with respect to at least two dimensions. First, case numbers decreased strongly during the early summer months, and levels of community spread were very low during the time of the re-opening. Yet at the same time, compliance and agreement with social distance measures decreased strongly. In a recurring representative survey of the German population's perception of risks from the new type of coronavirus, 79 percent of respondents reported that they meet family and friends less frequently and 73 percent stated to leave their home less often in early June. These numbers dropped to 60 percent and 51 percent, respectively, in mid-September even though over this period a constant share of respondents (around 60 percent) perceived the risk of infection through proximity to other people as high or very high. Consequently, private gatherings and also traveling became important risk factors for the spread of the virus.[10]

Second, schools provided a very different environment after re-opening in August and September in comparison to the time before they were closed down in mid-March 2020. Knowledge about the characteristics of the novel coronavirus and successful measures to prevent or at least minimize its spread had diffused widely among both policymakers and the population. This has led to the strict hygiene measures described in Section 2. In addition, decentralized quarantine measures were put in place following clearly established guidelines.

Changes in parental and student behavior. A second related mechanism likely at play works through parental opportunity costs of children staying at home due to an infection. During summer breaks, child care through schools was not an option, and corona-like symptoms of children did not necessarily affect a child's care situation. After school re-openings, most children were back in full-day child care through schools and after-school care. Children with corona-related symptoms were prohibited from attending school until recovery, or at least until a negative test result is received. Thus, opportunity costs of a child's respiratory infection (not necessarily COVID-19) increased strongly with the end of the summer breaks. We argue that this change in opportunity costs led to behavioral changes among parents which resulted in more careful social distancing than during the summer breaks.

We corroborate the idea of changes in parental behavior as a potential mechanism by suggestive evidence based on *Google Trends* data. To do this, we examine search intensity indices for four groups of search words: leisure-related searches, corona-related searches, child-symptom-related searches (irrespective whether they are combined with corona-related terms) and searches for corona-related hygiene rules in schools.[11] Search terms are grouped by federal state frequency into weekly bins to avoid excessive zeros and are standardized by federal state.[12] We use the search indicators as dependent variables of event studies akin to Equation (1), albeit on the weekly instead of daily level, using an event window of five weeks before and after the school openings.

Figure 4 summarizes the results. Panel A shows that frequencies of leisure-related searches do not respond to the end of summer breaks. This again supports the identification assumption of our main results, as it suggests that leisure activities are not changing dramatically around the end of the summer breaks. Similarly, general coronavirus-related searches

[10] See BfR Corona MONITOR, 15-16 September, `https://www.bfr.bund.de/cm/343/200915-bfr-corona-monitor.pdf` (last accessed: 25 September 2020) and Daily Situation Report of the Robert Koch Institute, `https://www.rki.de/DE/Content/InfAZ/N/Neuartiges_Coronavirus/Situationsberichte/Sept_2020/2020-09-24-en.pdf?__blob=publicationFile` (last accessed: 25 September 2020).

[11] Leisure-related keywords contain *departure time, destination, timetable, party, gym, leisure activities, birthday party, cinema, pub, concert, restaurant, public swimming pool, event, zoo, opening hours.* Corona-related keywords contain *Corona, Covid 19, Covid symptoms, case numbers, masks and quarantine.* Child-symptom-related keywords contain *children stomachache, children headaches, children pneumonia, children tiredness, children colds, children fever, children cough, children snuff, pediatrician*. Searches for corona-related hygiene rules in schools contain the following combinations: *corona school, covid school, school mask, school quarantine, mandatory mask wearing children school, face cover school*.

[12] Publicly available *Google trends* data does not provide absolute search frequencies, but normalizes search frequencies to the maximum observed during a specified search window (in our case 1 February to 20 October).

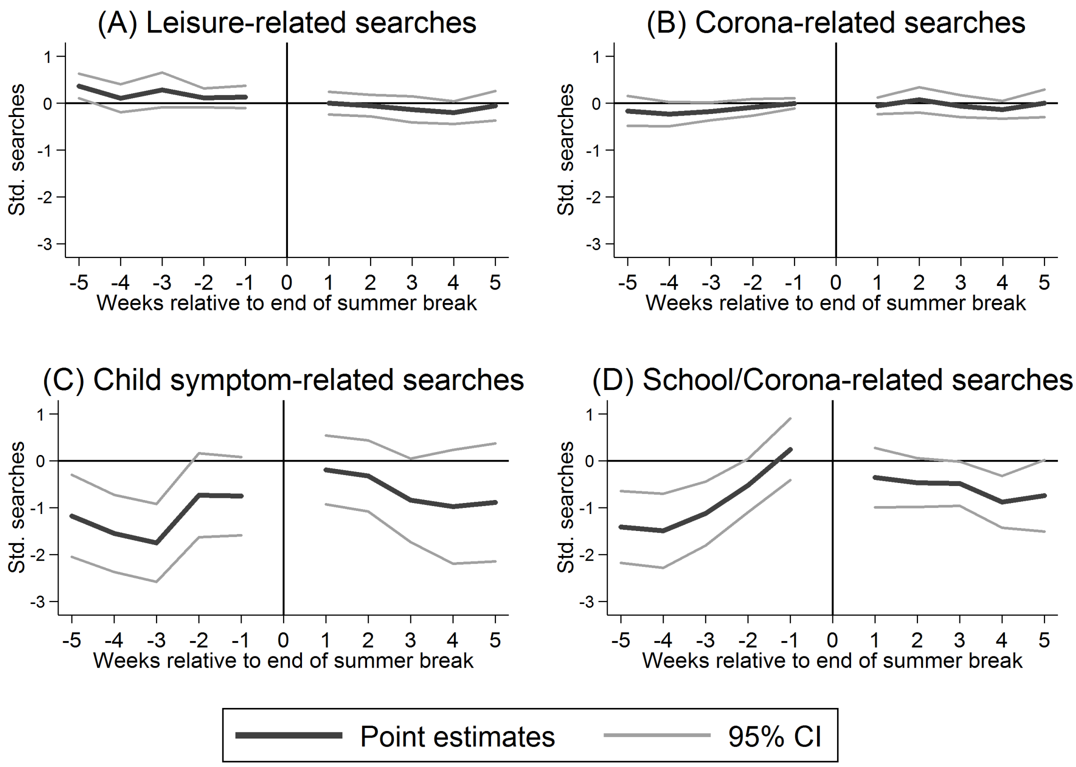

Figure 4: The Effect of the End of Summer Breaks on Search Frequencies (*Google Trends*)

Note: This graph plots the point estimates ($\hat{\beta_\tau}, \tau \in [-5, 5]$) and corresponding 95% percent confidence intervals of the modified version of the event study model as defined in Equation (1), leisure-related searches, corona-related searches, child-symptom-related searches and searches for corona-related hygiene measures in schools. The dependent variable is always the standardized weekly search frequency by federal state. The vertical line at $\tau = 0$ indicates the week schools re-opened. The regressions include fixed effects on the state and week level. Standard errors are clustered at the federal state level.

(Panel B) appear not to vary with the end of the summer breaks, suggesting that the awareness of the overall population towards the pandemic is not affected by the summer breaks. Panels C and D display frequencies of searches which can credibly be associated with parents and older students. Panel C displays how searches for symptoms of children related to COVID-19 react to the end of the summer breaks. Under the hygiene rules in place after summer, students were prohibited to go to school if they had these symptoms. Search frequencies start to rise about three weeks before school re-opening and remain stable thereafter. Search frequencies for hygiene rules and mask requirements in school are coinciding with this pattern, increasing from three weeks before up to the end of summer breaks, and remaining constant thereafter (Panel D).

The responsiveness of search frequencies for child symptoms and school hygiene rules three weeks before school re-openings supports the idea that higher parental awareness might be a driving factor behind our results. The timing coincides well with the observed gradual reduction in case numbers: Parents become more cautious about children's infections about three weeks before cases start to drop, which explains why case numbers start to decrease immediately from the end of summer breaks.

7 Conclusions

In this paper, we estimate the effect of the end of summer breaks in Germany on the number of new SARS-CoV-2 cases. We identify a causal effect of the end of summer breaks by exploiting the staggered schedule of summer breaks across German federal states. We implement an event study design using an event window of two weeks before and four weeks after the summer breaks. Our results indicate over a large number of specifications, sub-group analyses and robustness checks that the end of summer breaks is not associated with an increase in the number of SARS-CoV-2 cases. For age groups comprising school-aged children and their parents, we even detect a slight but insignificant reduction in case numbers. We show that changes in mobility do not contribute to this pattern. Our findings indicate that school re-openings under strict hygiene measures as well as quarantine and containment measures functioned well after the summer breaks in Germany and reduced the risk of larger outbreaks in schools. Changes in parental behavior due to higher opportunity costs of children in quarantine might be an important mechanism at play.

We acknowledge two caveats of the analysis. First, in terms of external validity, one has to keep in mind the specific counterfactual situation described in Section 6. Schools re-opened after the summer breaks during a time of, in general, low infection rates. This cannot be interpreted as the flip side of school closures during the peak of first wave of the pandemic in March. In particular, the increasingly accelerating number of new infections in the overall population during October and November 2020 may increase the risk of more infections among students. Second, schools re-opened after the summer breaks in August and September when weather conditions (warm temperatures and little precipitation) were favorable for outdoor activities and ventilation of classrooms. These conditions may be hampered by colder temperatures and worse weather conditions in fall and winter, which could facilitate outbreaks in schools.

Having these caveats in mind, our paper provides causal evidence of the absence of an increase of cases after school re-openings at the end of summer breaks in Germany. This finding stands in stark contrast to concerns about hotspots and super-spreading events in schools which dominate debates about school re-openings world-wide. Given the high human capital costs of school closures, our results should be taken seriously in considerations of re-opening schools. Moving back to on-site schooling requires careful designs of hygiene measures, but blueprints are readily available (Levinson et al., 2020; Leopoldina, 2020; Stephenson, 2020).

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A Appendix

A.1 Robustness Checks

Heterogeneous dynamic treatment effects. Several recent contributions have demonstrated that difference-in-differences approaches with staggered introductions of treatments might provide biased estimates if treatment effects change over time dynamically (Goodman-Bacon, 2018; Callaway and Sant'Anna, 2019; de Chaisemartin and D'Haultfoeuille, 2020). The intuition behind this empirical problem is that estimates partly rely on problematic comparisons of newly treated observations ("switchers") with already treated units. These already treated units display a problematic control group if treatment not only leads to a level change, but rather leads to dynamic changes in the outcome.

This problem can be circumvented by focusing on unproblematic comparisons only, which compare switchers with not yet treated observations (de Chaisemartin and D'Haultfoeuille, 2020).[13] Estimates based on their approach are summarized in Figure A.1. Despite the fact that daily effects are identified by ever-smaller numbers of observations with increasing time since treatment, the found pattern is very similar to our main results based on simple event studies without adjustment (Figure 3). We conclude from this similarity that the negative slope in cases after the end of summer breaks is no artifact of heterogeneous dynamic treatment effects.

Subgroup analyses. We explore in how far the evolution of cases in single states is driving our results. To do this, we run our main specification 16 times, excluding each state one by one. The results are summarized in Figures A.2–A.5. Patterns remain almost identical when single states are excluded, providing support for homogeneous treatment effects over states. No single state appears to drive our result as an outlier.

We further estimate Equation (1) for systematic distinctions of states into subgroups. We first estimate effects separately among states with early and late summer breaks (Figure A.6–A.9). Average results are mainly driven by early states. States with late summer breaks show a similar post-treatment pattern as states with early summer breaks. Yet, they display a slight negative pre-trend indicating that late re-opening states already experienced decreasing case numbers before the summer break. Accordingly, the trend break surrounding the school re-opening is less distinct.

We further run subgroup analyses separately for East and West Germany. East German counties, which constitute just 19 percent of the sample, were later and far less severely hit by the pandemic. In addition, East German states are characterized by a lower level of urbanization and population density. Up to late summer, cases remained below West German levels. In line with low case numbers, separate regressions show that results are entirely driven by West German states.

Overall, we conclude from the robustness checks and subgroup analyses that the found pattern is primarily driven by West German states and states with early summer breaks. No robustness check or subgroup analysis points to any positive effect of the end of school breaks and associated school re-openings on the number of confirmed cases.

Travel returnees. During the summer, Germany had comparably low infection numbers (see Figure 1). Travel returnees from abroad were among the main sources of new infections at the end of summer breaks. During July, about one third of all new cases had been infected abroad

[13] Note that this necessarily excludes the last treated federal state of Baden-Wuerttemberg from our estimation.

(Robert Koch Institute, 2020). Mandatory testing of travel returnees from at-risk areas was in place at all major airports in Germany. Returnees from at-risk areas were quarantined on a mandatory basis for 14 days. Higher case numbers among travel returnees are a potential alternative mechanism of how the end of summer breaks could affect case numbers independently from school re-openings.

There are four pieces of evidence that make us confident that our pattern is not driven by travel returnees. First, travel returnees with school-aged children tend to return gradually over the holiday season, not necessarily concentrated at the end of the school holidays. The observed gradually changing mobility patterns (see Figures A.10 and A.11) corroborate this gradual return of returnees. Thus, the estimated effect of the end of school breaks is unlikely driven by a coinciding spike of holiday returnees before the end of summer breaks. Second, flat pre-trends depicted in Figure 3 show that control and treatment states experienced similar developments in case numbers before the summer break. Increasing numbers of positively-tested holiday returnees towards the end of summer breaks would instead imply increasing pre-trends. Third, holiday returnees before school start would not be able to explain the gradual decrease in cases we observe for younger age groups, but would indicate a sudden reduction in levels of new cases after school re-openings. Finally, our results are also insensitive to the inclusion of mobility controls. Existing variation in mobility measures, even if driven by holiday returnees, does not explain the observed pattern of flat pre-trends followed by a decrease in case numbers. Taken together, we are confident that our results are not driven by travel returnees.

Supplementary Figures

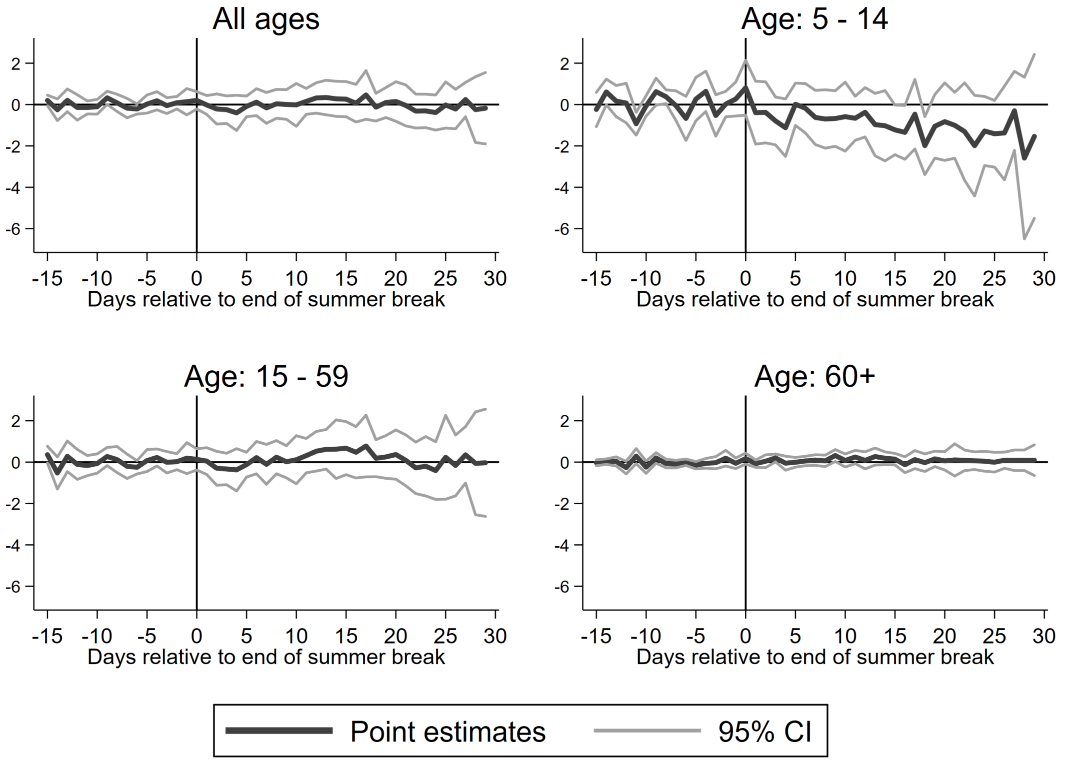

Figure A.1: Accounting for Heterogeneous Treatment Effects

Note: This graph plots the point estimates ($\hat{\beta_\tau}, \tau \in [-15, 29]$) and corresponding 95% percent confidence intervals of the event study model as defined in Equation (1) adjusted for heterogeneous treatment effects following de Chaisemartin and D'Haultfoeuille (2020). The dependent variable is always the daily count of confirmed cases per 100K population per county and age group. The vertical line at $\tau = 0$ indicates the school opening. The regressions include fixed effects on the county and day level. Permutation-based standard errors based on 100 repetitions.

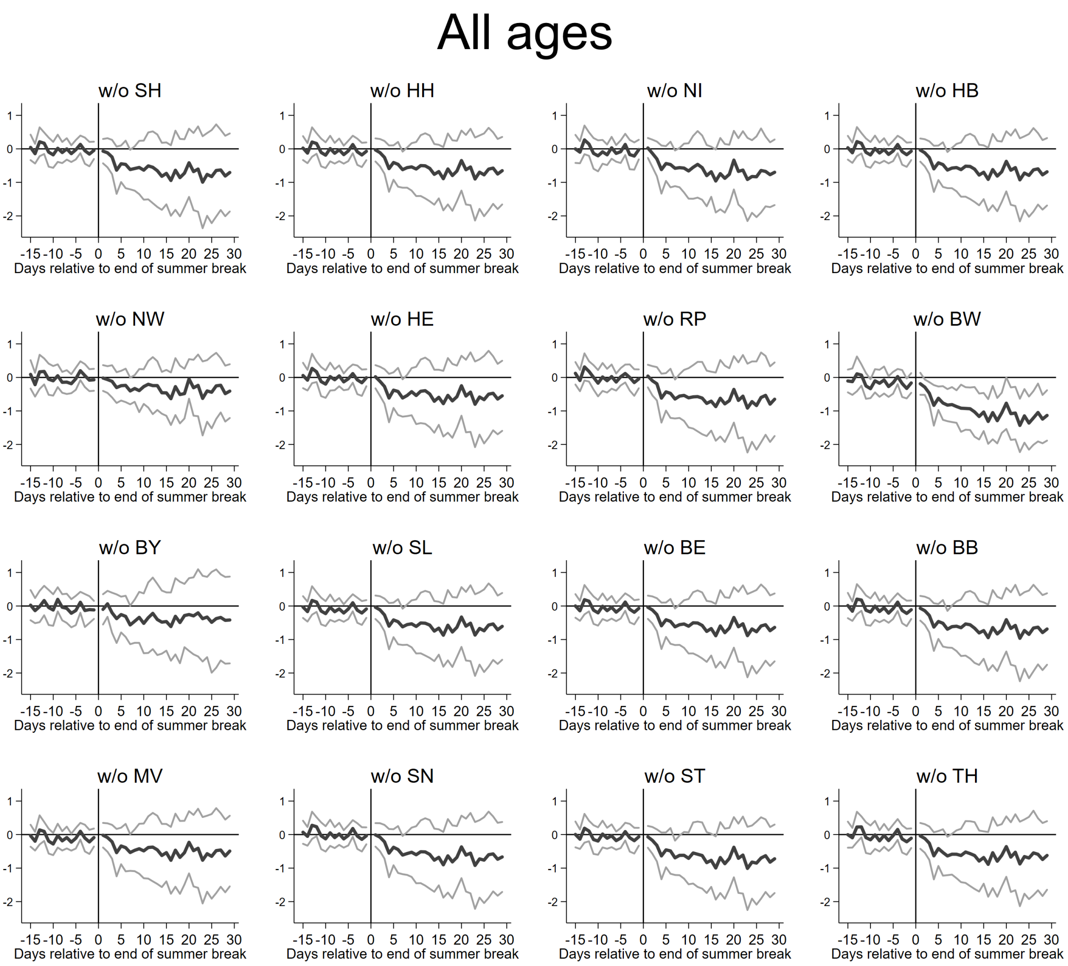

Figure A.2: The Effect of the End of Summer Breaks on Confirmed Cases Leaving One State Out

Note: This graph plots the point estimates ($\hat{\beta_\tau}, \tau \in [-15, 29]$) and corresponding 95% percent confidence intervals of the event study model as defined in Equation (1). The dependent variable is always the daily count of confirmed cases per 100K population per county and age group. The vertical line at $\tau = 0$ indicates the school opening. The regressions include fixed effects on the county and day level. Standard errors are clustered at the federal state level.

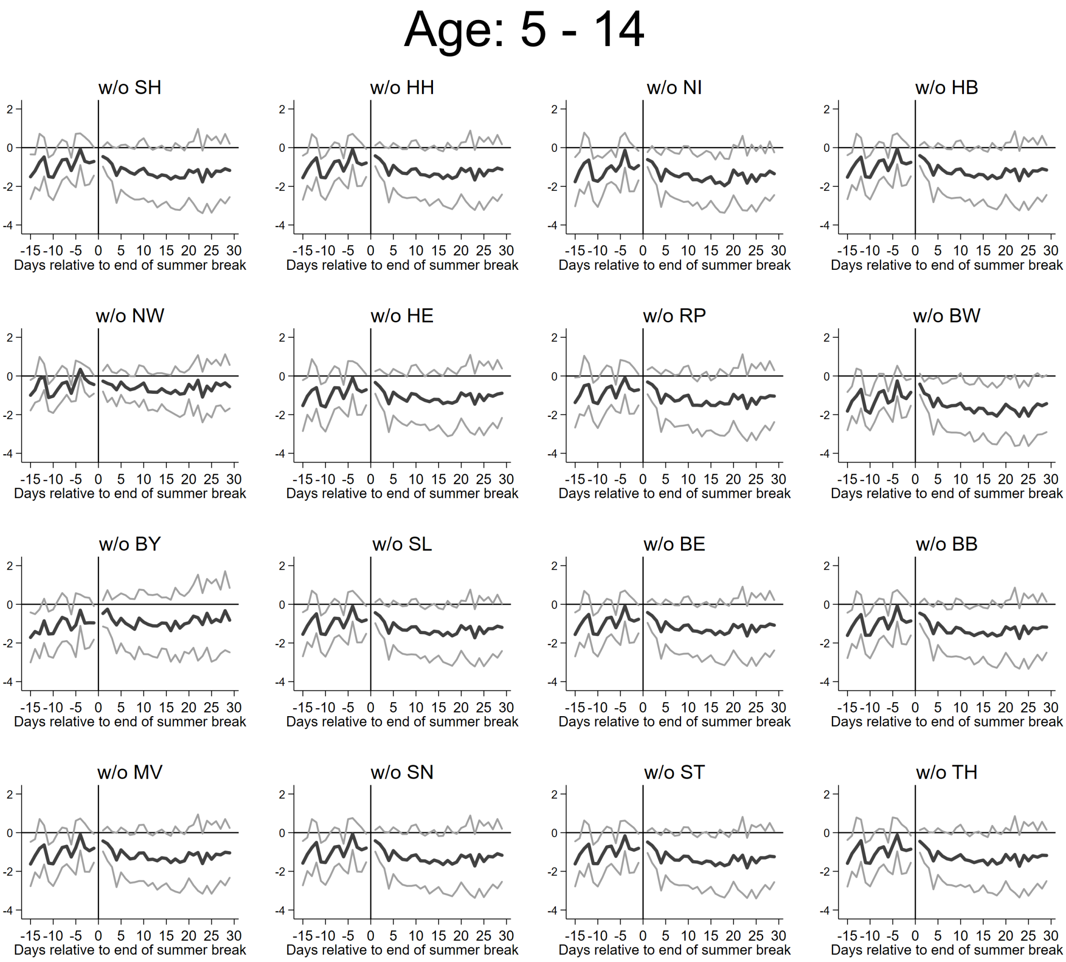

Figure A.3: The Effect of the End of Summer Breaks on Confirmed Cases Leaving One State Out

Note: This graph plots the point estimates ($\hat{\beta}_\tau, \tau \in [-15, 29]$) and corresponding 95% percent confidence intervals of the event study model as defined in Equation (1). The dependent variable is always the daily count of confirmed cases per 100K population per county and age group. The vertical line at $\tau = 0$ indicates the school opening. The regressions include fixed effects on the county and day level. Standard errors are clustered at the federal state level.

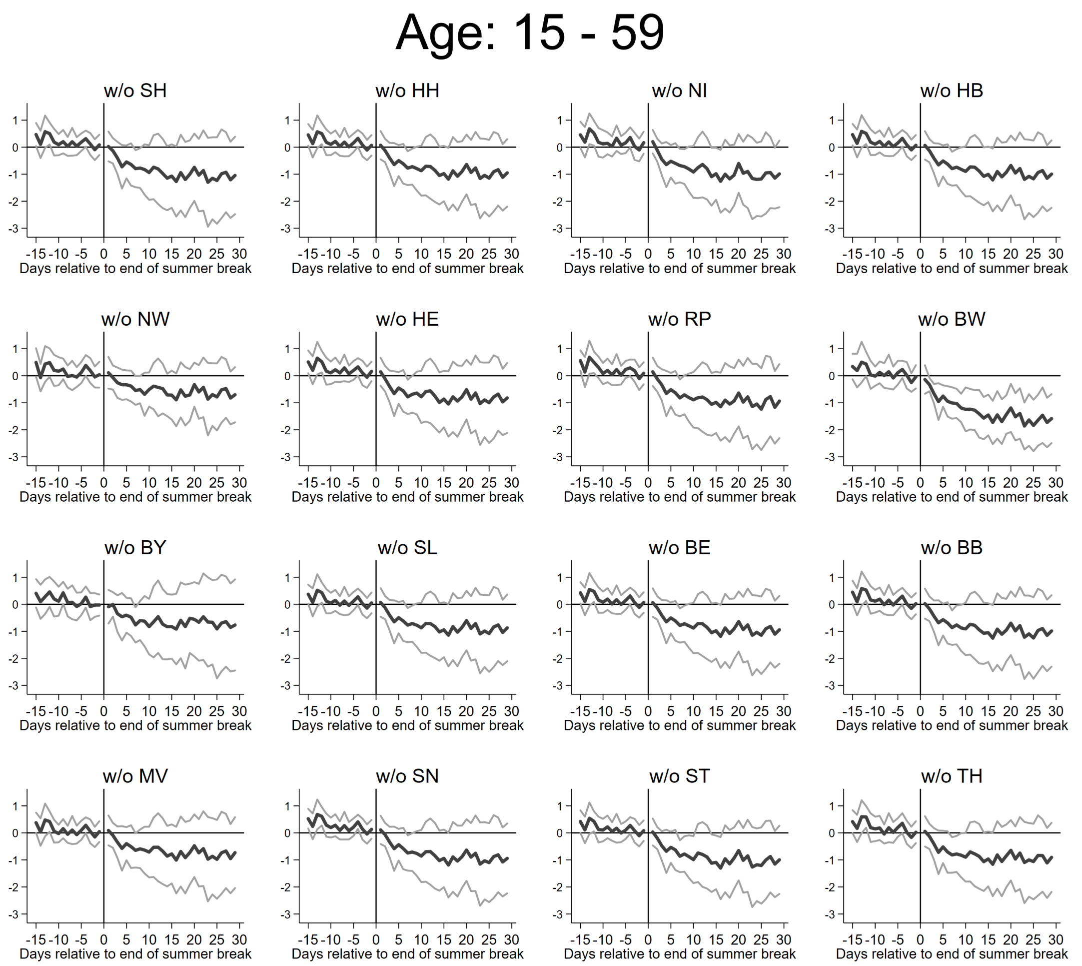

Figure A.4: The Effect of the End of Summer Breaks on Confirmed Cases Leaving One State Out

Note: This graph plots the point estimates ($\hat{\beta_\tau}, \tau \in [-15, 29]$) and corresponding 95% percent confidence intervals of the event study model as defined in Equation (1). The dependent variable is always the daily count of confirmed cases per 100K population per county and age group. The vertical line at $\tau = 0$ indicates the school opening. The regressions include fixed effects on the county and day level. Standard errors are clustered at the federal state level.

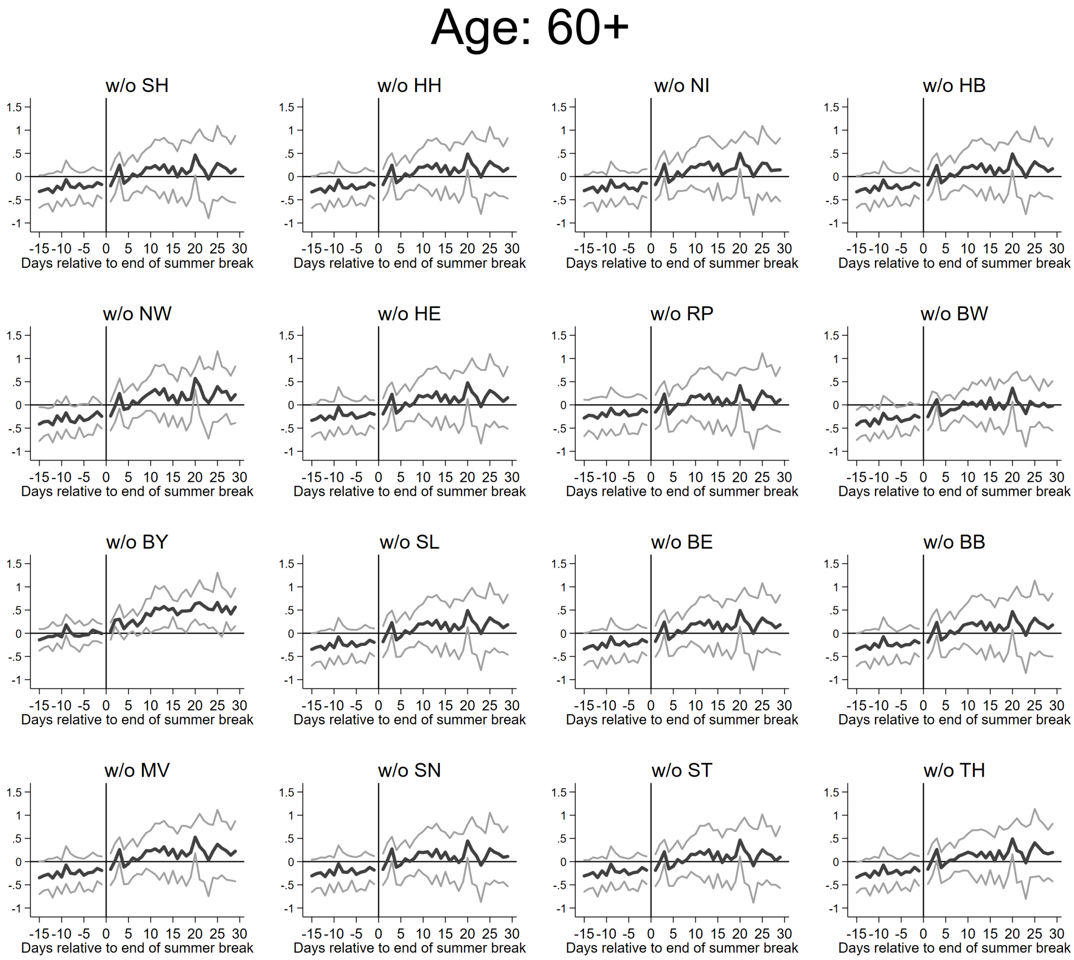

Figure A.5: The Effect of the End of Summer Breaks on Confirmed Cases Leaving One State Out

Note: This graph plots the point estimates ($\hat{\beta}_\tau, \tau \in [-15, 29]$) and corresponding 95% percent confidence intervals of the event study model as defined in Equation (1). The dependent variable is always the daily count of confirmed cases per 100K population per county and age group. The vertical line at $\tau = 0$ indicates the school opening. The regressions include fixed effects on the county and day level. Standard errors are clustered at the federal state level.

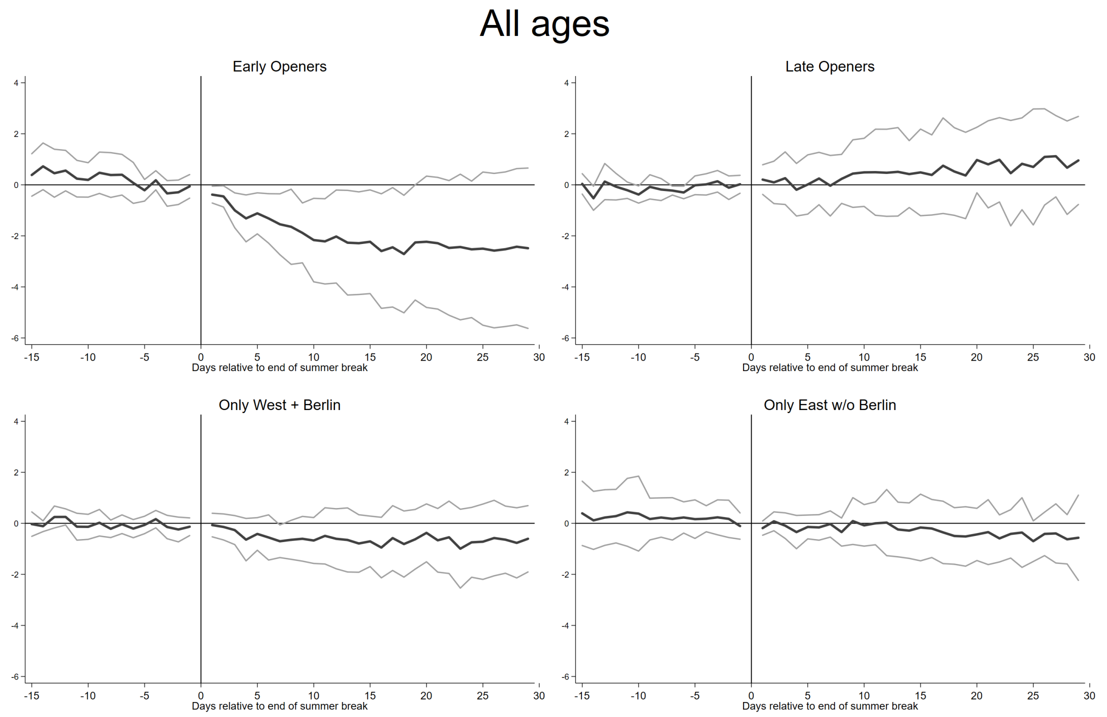

Figure A.6: The Effect of the End of Summer Breaks on Confirmed Cases by Subgroups of States

Note: This graph plots the point estimates ($\hat{\beta_\tau}, \tau \in [-15, 29]$) and corresponding 95% percent confidence intervals of the event study model as defined in Equation (1). The dependent variable is always the daily count of confirmed cases per 100K population per county and age group. The vertical line at $\tau = 0$ indicates the school opening. The regressions include fixed effects on the county and day level. Standard errors are clustered at the federal state level.

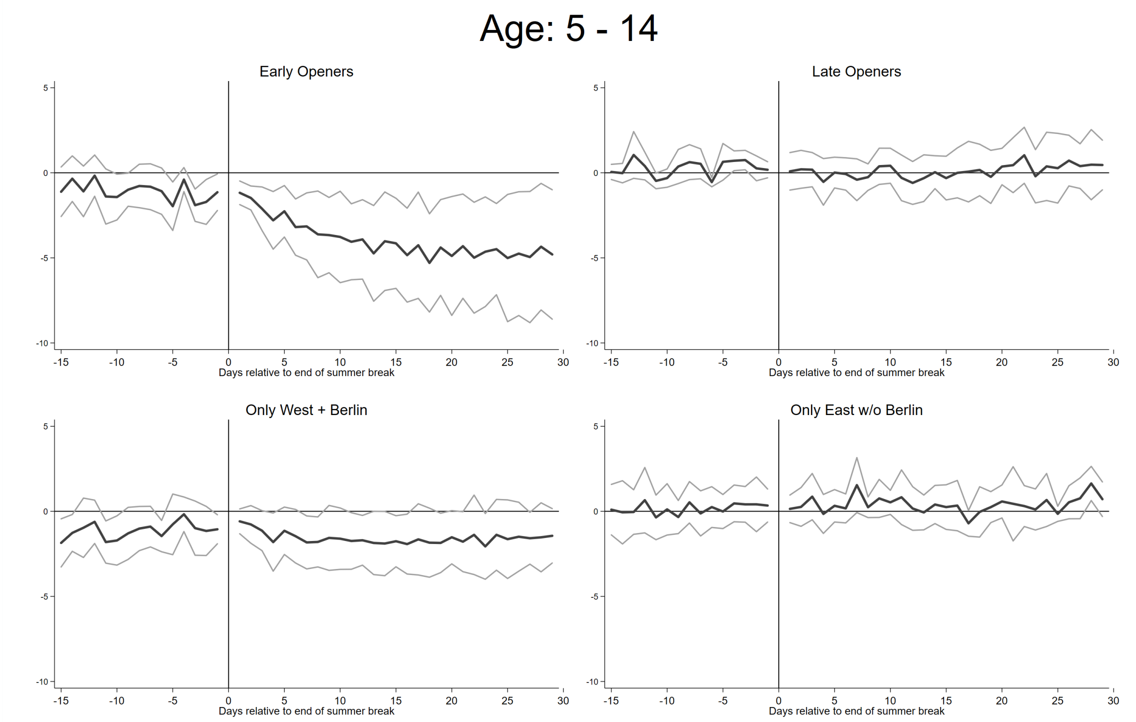

Figure A.7: The Effect of the End of Summer Breaks on Confirmed Cases by Subgroups of States

Note: This graph plots the point estimates ($\hat{\beta}_\tau, \tau \in [-15, 29]$) and corresponding 95% percent confidence intervals of the event study model as defined in Equation (1). The dependent variable is always the daily count of confirmed cases per 100K population per county and age group. The vertical line at $\tau = 0$ indicates the school opening. The regressions include fixed effects on the county and day level. Standard errors are clustered at the federal state level.

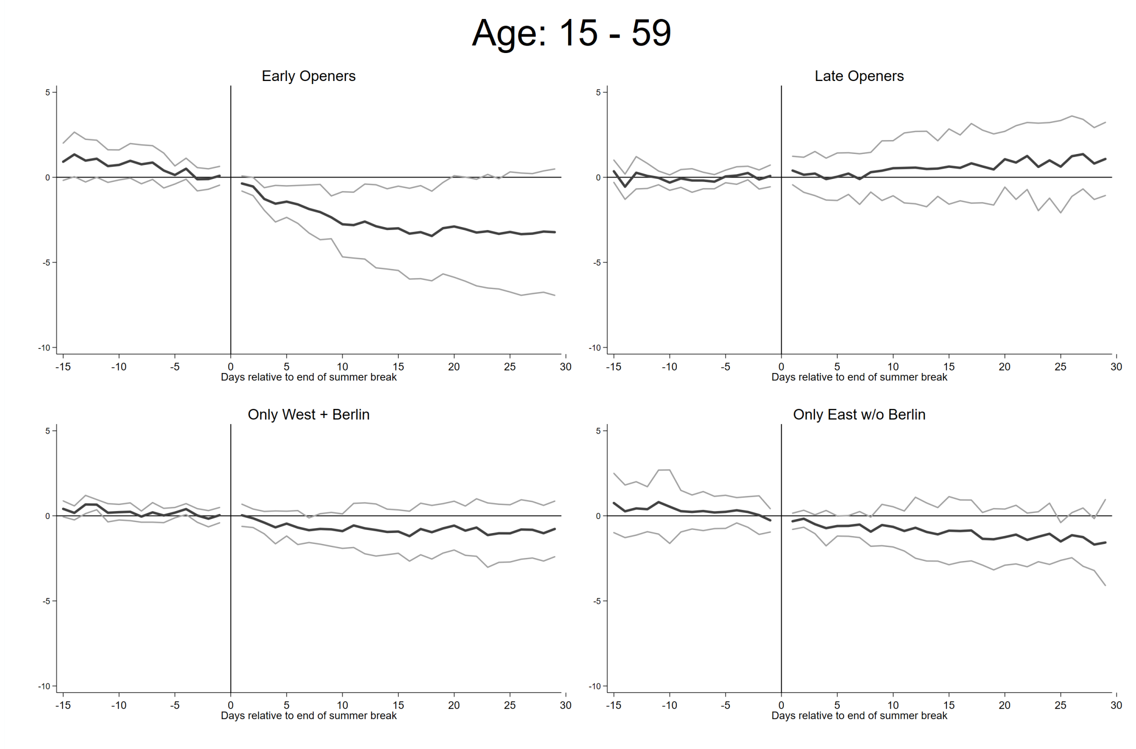

Figure A.8: The Effect of the End of Summer Breaks on Confirmed Cases by Subgroups of States

Note: This graph plots the point estimates ($\hat{\beta_\tau}, \tau \in [-15, 29]$) and corresponding 95% percent confidence intervals of the event study model as defined in Equation (1). The dependent variable is always the daily count of confirmed cases per 100K population per county and age group. The vertical line at $\tau = 0$ indicates the school opening. The regressions include fixed effects on the county and day level. Standard errors are clustered at the federal state level.

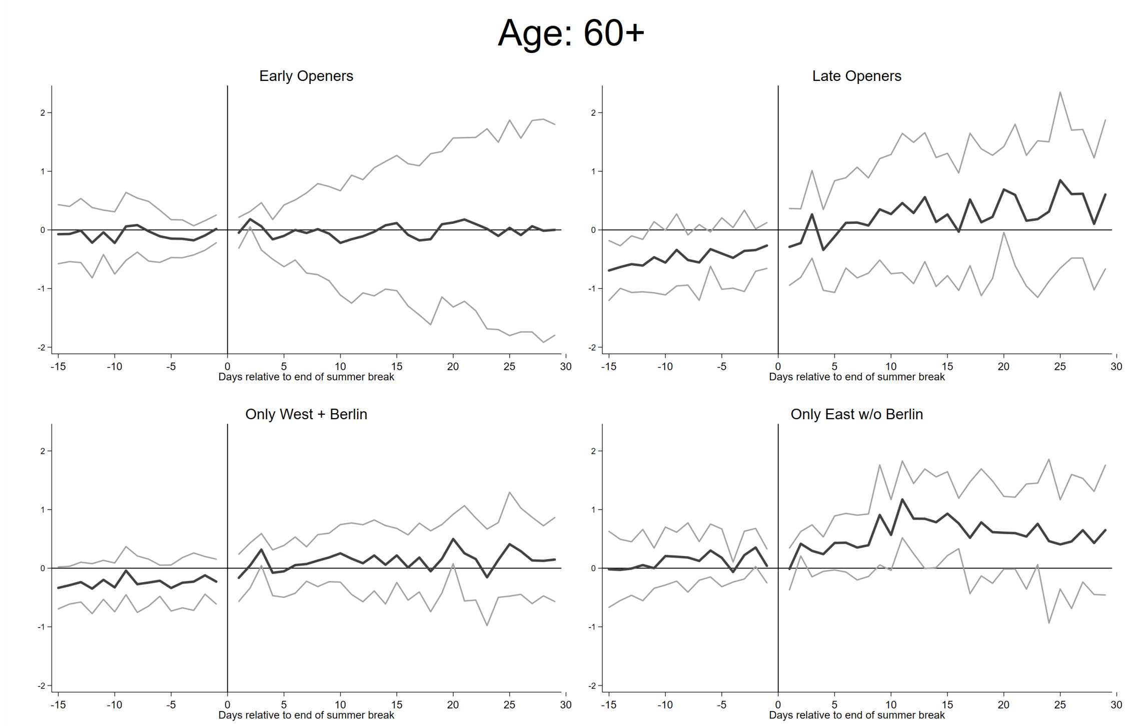

Figure A.9: The Effect of the End of Summer Breaks on Confirmed Cases by Subgroups of States

Note: This graph plots the point estimates ($\hat{\beta_\tau}, \tau \in [-15, 29]$) and corresponding 95% percent confidence intervals of the event study model as defined in Equation (1). The dependent variable is always the daily count of confirmed cases per 100K population per county and age group. The vertical line at $\tau = 0$ indicates the school opening. The regressions include fixed effects on the county and day level. Standard errors are clustered at the federal state level.

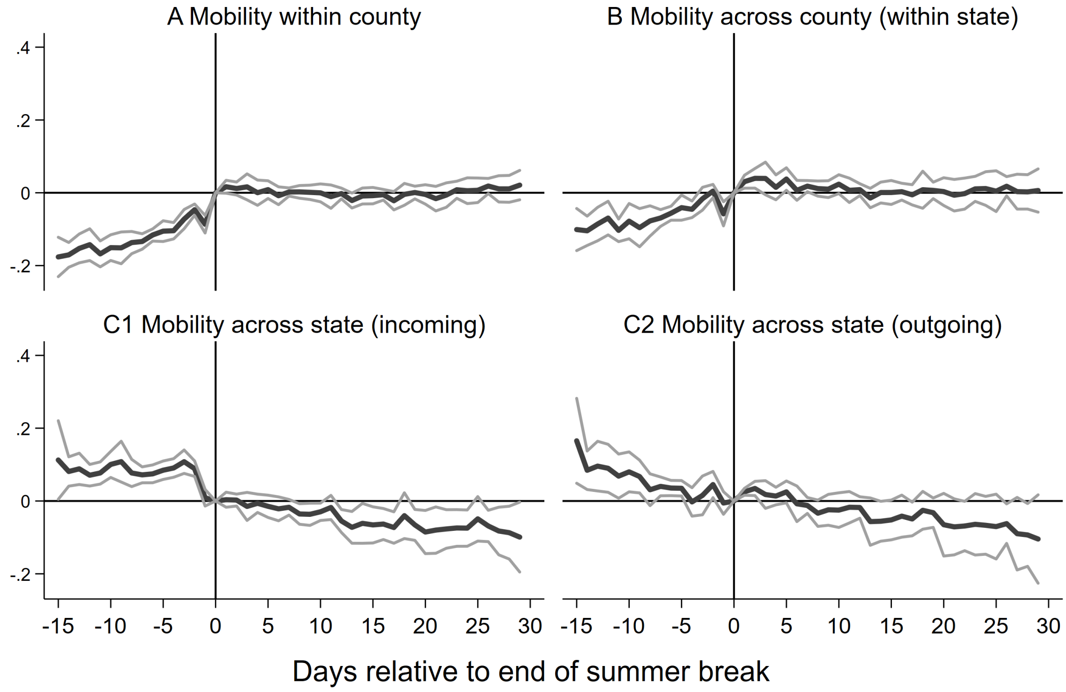

Figure A.10: The Effect of the End of Summer Breaks on Mobility Patterns I

Note: This graph plots the point estimates ($\hat{\beta_\tau}, \tau \in [-15, 29]$) and corresponding 95% percent confidence intervals of the event study model as defined in Equation (1). The dependent variables are the number of daily trips (in logs) within and across county and state borders. Mobility is measured by mobile phone movements, based on commercial data by *Teralytics*. The vertical line at $\tau = 0$ indicates the school opening. The regressions include fixed effects on the county and day level as well as state-specific day-of-the-week fixed effects. Standard errors are clustered at the federal state level.

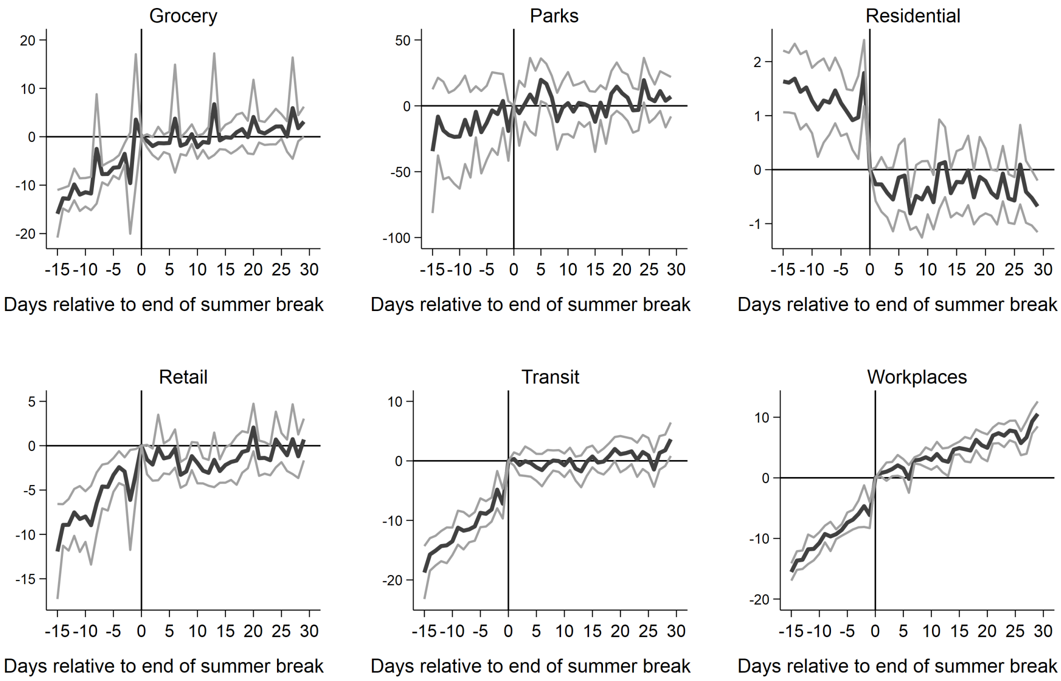

Figure A.11: The Effect of the End of Summer Breaks on Mobility Patterns II

Note: This graph plots the point estimates ($\hat{\beta}_\tau, \tau \in [-15, 29]$) and corresponding 95% percent confidence intervals of the event study model as defined in Equation (1). The dependent variables is the percentage change in mobility compared to a baseline period. Mobility measures are based on *Google Mobility Reports*. The vertical line at $\tau = 0$ indicates the school opening. The regressions include fixed effects on the state by day-of-the-week and day level. Standard errors are clustered at the federal state level.