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Spatial Variations in the Impact of Covid-19 on the Educational Gender Gap in English Secondary Schools

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Spatial Variations in the Impact of Covid-19 on the Educational Gender Gap in English Secondary Schools

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Abstract

We investigate the effects of Covid-19 on spatial variations in gender differences in educational attainment in English secondary schools. Spatial variations in various measures of Covid-19 incidence rates at the Travel-to-Work-Areas are explored. Since all parts of the UK were affected by Covid-19, spatial variations in Covid-19 are regarded as variations in the 'dose' of the virus - the higher the dose the greater the impact. Employing a Difference-in-Differences (DiD) framework with fixed effects for year, school and TTWA, and controlling for selection effects, we estimate the causal effect on the gender gap in high school test scores at age 16. We find that, when comparing schools in TTWAs in the treatment to their counterparts in the control group, there is a statistically significant and positve effect on the educational gender gap in favor of females of between 0.3 and 0.6 points. Girls at the upper end of the attainment distribution achieved much better scores. Robustness checks show that school composition and area effects are important. We explore the implications for education policy.

JEL Classification: I2, I24, I19

Keywords: Covid-19; Educational Gender Gap; School Performance.

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1 Introduction

The COVID-19 pandemic created substantial global disruptions, including within the educational sector, serving to exacerbate existing inequalities whilst also introducing new challenges. In the education context these challenges have included significant interruptions to classroom education, the introduction of online provision with attendant problems of IT access, especially for pupils from disadvantaged backgrounds, and significant changes in methods of assessment and grading of exams. There has also been an increase in mental health challenges faced by young people and parents caused in part by the social isolation arising from the responses to the Covid-19 pandemic and the financial difficulties faced by households. The responses by the British Government ranged from complete lock-downs to a tiered approach to restrictions based on the geographical incidence and severity of the pandemic. We document these responses to Covid-19 in some detail below. Geographical variations in the incidence and severity of Covid-19, and the associated government responses, has also led to geographical variations in its effects on schooling and learning. Furthermore, pupils entered the Covid-19 pandemic from different starting points in terms of their educational attainment and attitudes to schooling. For instance, previous research on the educational gender gap has revealed that girls perform better in high stakes secondary school exams when compared to boys. Andrews et al. (2006) document the evolution of the educational gender gap for England between 1985 and 2003, and show that the gap widened even after controlling for determinants of that gap. As we will show this gap has persisted beyond 2003. Research also shows that there are diverse factors which affect this educational gender gap, including motivation and attitudes to school and study. In view of the spatial disparities in Covid-19 and the consequent responses, as well as the different starting points between girls and boys, it is possible that the Covid-19 pandemic exacerbated this pre-existing educational gender gap.

In this paper we investigate the impact of the Covid-19 pandemic on the educational gender gap at secondary level for schools in England, and do so in a novel way by exploiting spatial variations in the incidence of Covid-19. Specifically, we investigate spatial variations in Covid-19 at the TTWA level and employ a Difference-in-Differences (DiD) framework whilst also controlling for pre-sample selection by adopting Propensity Score Matching (PSM) techniques. We think of spatial variations in the incidence rates of the pandemic as variations in the 'dose' of the pandemic - the higher the dose the greater the health effects and the greater the impact in terms of lockdown and restrictions on teaching and learning. By adopting this empirical approach we seek to estimate the causal effect of the Covid-19 pandemic on the gender gap in high school test scores at age 16 - that is, Key Stage 4 (KS4).

Our results show that there were significant disparities in COVID-19 incidence rates between local areas, which exacerbated existing disparities in the educational gender gap in favour of girls. Specifically, when we estimate models using the median COVID-19 incidence rate, we reveal a moderate increase in the gender gap, whereas the analysis using the standard deviation in the incidence rate pointed to a stronger, more consistent, exacerbation of the educational gender gap, perhaps because this greater variability in the virus led to greater variation in the incidence and timing of lockdown restrictions. These effects were greater at the upper end of the educational gender gap distribution, suggesting that high achieving girls did much better than high achieving boys, and these effects were quite long-lasting, persisting through 2022 to 2023. Collectively, these findings highlight the pandemic's role in widening educational inequalities between genders, especially in areas facing severe Covid-19 outbreaks. Where the school is located also matters and so too does the socio-economic and ethnic make-up of the school. We show that schools with a higher proportion of pupils from ethnic and disadvantaged social backgrounds had more substantial gender gaps after Covid-19. Schools with a larger SEN population also witnessed a widening of the gender gap. Schools in areas with higher unemployment and economic inactivity rates, and those with larger populations of ethnic minority groups and white immigrants witnessed larger increases in the educational gender gap.

From a policy perspective, these findings underpin the need for targeted interventions - particular schools in particular areas and for particular sub-groups - boys, but perhaps low achieving boys in particular.

The remainder of this paper is structured as follows. In section 2 we review the timeline of government responses to the Covid-19 pandemic, followed in section 3 by a review of the existing literature on the educational gender gap with a specific focus on the on the impact of Covid-19. Section 4 describes the data and introduces our measures of the incidence of Covid-19, followed by a discussion of some descriptive statistics. In section 5 we explain our empirical approach, which is then followed by a discussion of our results and conclusions.

2 Government responses to Covid-19

The timeline of Covid-19 lockdown and other restrictions in England took place between March 2020 and December 2021. Two waves of Covid-19 have been identified: Wave 1 occurred between 24th January 2020 and 31st August 2020, and the second Wave began on the 1st September 2020 and the 28th December 2020 (Nafilyn et al., 2021), however the Government responses to Covid-19 overlapped these waves.

The initial response to wave one of the Covid-19 pandemic came on the 16th March 2020 when the Prime Minister announced a lockdown with all but essential workers told to cease non-essential contact and travel. This included schools and led to an abrupt shift to online learning from home. Children of key workers, such as doctors and nurses were permitted to continue going to school but attendance was variable. Restrictions were eased on the 10th May and schools re-opened in a phased way from the 1st June with an instruction of social distancing to two metres between all individuals. To stimulate economic activity and support the hospitality sector the Government introduced the 'Eat Out to Help Out' scheme in early August, with a further relaxation of restrictions in mid-August where people were allowed to mix in groups of to six. The upshot of the relaxation of restrictions was an increase in the spread and incidence of the Covid-19 virus (the second wave).

In response to the second wave, the Government announced a set of new restrictions on 22nd September. By mid-October a three tier system of geographically based restrictions had been introduced, only to be replaced by a further national lockdown on the 5th November. As the second wave subsided the Government announced the end of the second lockdown on the 2nd December but did introduce a stricter three tier system on the 19th December and a fourth tier was added just over a week later requiring people in London and the South East to stay at home. As Covid-19 surged in a locality then more areas were added to the tier four category of restrictions. Schools re-opened in early January 2021 but a third national lockdown was announced on the 6th January. Two months later (8th March) primary and secondary schools were permitted to re-open , otherwise social mixing rules and the stay at home instruction remained in place. From the end of March onwards there was a gradual relaxation of restrictions and by December 2021 the vaccination programme had begun, in addition to a requirement for people to wear face masks and use an NHS Covid pass for access to events.

This brief overview of government responses to Covid-19 in England clearly shows the length of the disruption to schooling covering two school years, and it emphasises the spatially differentiated responsesto the waves of the Covid-19 pandemic. Anders et al. (2022) document the impact of the lock-downs and restrictions on learning and teaching, showing clear disparities between different types of schools during the second period of school closures. For instance, pupils in grammar schools (96%) and pupils in 'more affluent' comprehensive schools (95%) caught up with the curriculum, but for pupils in in more deprived schools and area catch-up was much less (80%). They also show that pupils in these schools struggled with remote learning because of a lack of IT equipment, quiet spaces to learn and a lack of support from teachers in terms of live sessions, and parental support for their children's learning. A further study by Anders et al. (2021) showed that boys were less engaged with home learning, completing less schoolwork during school closures. Green (2020) analysed the impact of the start of the Covid-19 pandemic, showing spatial disparities in offline schoolwork - lowest in the Northeast of England, where only 9% of pupils recieved 4 or more assignments compared to a national average of 20%. In contrast, 28% of pupils in schools in the Southeast region received four or more pieces of offline schoolwork per day.

3 Literature review

3.1 The determinants of the educational gender gap

The educational gender gap, which can be characterised as the under-achievement of boys and/or the superior performance of girls is a persistent issue at school level in many countries. However, it is important to note that there is also lower rates of participation of girls in

STEM (Science, Technology, Engineering, and Mathematics) subjects has also been identified (Lundberg, 2020), suggesting that the educational gender gap is complex.

The mechanisms that determine the educational gender gap are multifaceted and deeply ingrained in societal, cultural, and economic structures. Comparative studies by Borgonovi et al. (2018) across OECD countries shows that boys generally exhibit lower academic attainment than girls, emphasising the role of policies and teaching practices in mitigating these gender disparities. Hermann and Kopasz (2019) also examine the impact of specific educational policies on the gender gap in test scores, finding that early tracking and student-oriented teaching practices tend to benefit girls, thereby influencing gender disparities. Aucejo (2013) highlights the significance of non-cognitive skills in explaining the educational gender gap, particularly among African Americans, pointing to the distribution of these skills as a disadvantage for males in terms of their educational attainment. Social exclusion has also emerged as a key explanation for the educational gender gap. Conversely, ethno-linguistic heterogeneity within countries can trigger economic and psycho-social mechanisms that limit girls' schooling (Lewis and Lockheed, 2008).

The above factors are compounded by factors such as private education, mother's education, and the gender composition of school peer groups, suggesting that changes in school characteristic, for instance, can help reduce the educational gender gaps. Single-sex schooling has been considered as a potential mitigating measure for male disadvantages in educational achievement compared to co-educational schools, where a significant gender gap favoring females is evident (Gibb et al., 2008).

In England, Andrews et al. (2006) attributed part of the educational gender gap to educational practices in schools and policy changes. They review the evidence on a number of school practices, such as the tendency for teachers to submit girls for higher tier 'exams' in subjects, and to place them in higher sets (classes), both of which lead girls to get better results when compared to boys. One change associated with the switch from the General Certificate of Education (GCE) to the General Certificate of Secondary Education (GCSE) relates to teaching practices. The GCSE led to a narrative approach to subjects and, in view of the superior linguistic skills of girls, this also led to girls achieving higher grades relative to boys. Andrews et al. (2006) also review some of the findings from economists who showed there was a clear improvement in the educational attainment of girls relative to boys due to the shift from GCEs to GCSEs.

Public high schools have been identified as contributors to gender disparities in college enrollment among Black and Hispanic students, further highlighting the complex nature of the educational gender gap (Conger and Long, 2013). The closing of the gender literacy gap from 1992 to 2003, attributed to a significant increase in women's participation in higher education, demonstrates the potential for bridging gender disparities through improved educational opportunities for women (Cohen et al., 2012). In-depth exploration of mechanisms underlying the educational gender gap in UK secondary schools acknowledges a complex interplay of socio-cultural norms, policy frameworks, and school practices. Research by Lim et al. (2020) highlights structural gender differences in the use of ICT. In their study of college students in South Korea, male students tended to use a Learning Management System (LMS) system more actively than female students, particularly in areas such as studying, task performance, and academic interactions. Even in technologically advanced environments, male students may derive more benefits from e-learning platforms, which could contribute to the broader educational gender gap. The study also found that while both genders use LMS for instructional information similarly, female students are less likely to engage in collaborative and interactive activities through these platforms. Other studies show that boys tend to use technology more for gaming and recreational purposes, while girls use it more for communication and academic tasks. For instance, girls reported higher levels of engagement and perceived support in digital learning environments compared to boys during the COVID-19 pandemic. The findings overall suggest that there is a gender digital divide even in technologically advanced environments. These pre-existing usage patterns likely gave girls an advantage when education shifted online, as they were already familiar with using technology for learning purposes (Korlat et al., 2021).

In terms of policies to reduce educational gender gaps, it has been found that the establishment of a school management committee in rural areas was associated with lower dropout rates for both genders, suggesting that school governance could play a role in addressing the educational gender gap (Nishimura, 2017). DiPrete and Buchmann (2013) suggests that the growing female advantage in educational attainment can be attributed to male over-representation among secondary school dropouts and female over-representation among tertiary education students and graduates. These trends are influenced by increasing returns to education and lower effort costs for females (Pekkarinen, 2012). Other research suggests a need for embracing gender-relational policies, which transcend traditional educational aspirations and expectations, thus fundamentally challenging entrenched disparities (Younger and Warrington, 2007).

In Germany, for example, the rising share of single-parent households detrimentally affected boys' attainment in upper secondary education, while the development of class sizes and social norms played a significant role in influencing the gender gap in tertiary education (Riphahn and Schwientek, 2015).

3.2 Covid-19 and the educational gender gap

There is limited research on the impact of the Covid-19 pandemic on the educational gender gap.[1] Those studies that do focus on the educational gender gap emphasise the complex interplay between gender, education, and the economic impacts of the Covid-19 pandemic. They highlight the resilience of female students in some contexts, the exacerbation of existing inequalities, and the emergence of new challenges that require targeted interventions to support male pupils,especially in areas and schools, where they are most disadvantaged. We classify existing research into one of two approaches - those focusing on the direct effects of the pandemic due to lockdown, and those focusing on the indirect effects via broader economic and mental health problems arising from the pandemic.

In terms of direct effects, a study by Bratti and Lippo (2023) found that the gender gap in university student performance was not significantly affected by the Covid-19 pandemic, except for some college majors where female students did relatively better as reflected by their GPA scores. Bertoletti et al. (2023) conducted a cross-country analysis revealing that girls tended to perceive changes in their learning less favorably than boys during school closures, with physical activity, psychological distress, and family environment being key drivers of this gender gap. This suggests that the pandemic's impact on education extends

[1] A more substantial literature exists on the effects of Covid-19 on educational outcomes more generally. See, for example, Gambi and De Witte (2024), Werner and Woessman (2023).

beyond academic performance to affect students' well-being and perception of learning.

A study by Castano et al. (2022) highlights the mental health deterioration among university students due to the pandemic, with female students experiencing greater levels of anxiety, depression, and post-traumatic stress disorder. Their research explored undergraduate learning performance during the first semester of the 2020/21 academic year. Their findings revealed a significant drop in performance among low-achieving students, with female students performing slightly better than their male counterparts despite the overall decline. This suggests that while the Covid-19 pandemic did negatively impact student performance, the effects are not uniform across genders.

With respect to the indirect effects of Covid-19, Risse (2023) explored the economic impacts of the pandemic in Australia, noting a widening gender gap in earnings and a larger decline in women's educational participation during the pandemic. This economic dimension is crucial for understanding the broader consequences of the pandemic on gender disparities in education. More specifically, the shift to online learning has had mixed impacts. For instance, in Spain, Castellanos-Serrano et al. (2022) found that the gender gap in economics was influenced by factors such as age, work-life balance, as well as COVID-19. Women under-performed in education due to family tasks, and this finding was particularly marked for those aged 30-45 with young children. The pandemic initially narrowed the educational gender gap during lockdown but worsened women's results post-lockdown due to increased caring responsibilities.

What these findings suggest is that there are various mechanisms through which the Covid-19 pandemic could have affected educational attainment and the educational gender gap in particular.

4 Data

4.1 Data source

The analysis focuses on Travel-to-Work-Areas (TTWA) as the primary spatial unit and these data were obtained from the Office for National Statistics (ONS) in the UK. They periodically update TTWA boundaries, based on census data, reflecting changes in commuting patterns, employment, and urban development, ensuring that TTWAs accurately represent current labor market areas. A TTWA is typically defined where at least 75% of an area's resident workforce works within the area, and also, at least 75% of the jobs are filled by residents. This creates a measure of self-containment for both workers and jobs. TTWAs do vary significantly in size, often encompassing multiple towns or parts of cities.[2] However, the size of a TTWA is determined more by commuting patterns rather than the magnitude of the population. Nevertheless, to the extent that individuals in a TTWA mix for work, schooling and for social reasons, it is likely to drive the spread of the Covid-19 virus. Based on the 2011 census, there are 228 Travel to Work Areas (TTWAs) in the UK: 149 in England, 45 in Scotland, 18 in Wales, and 10 in Northern Ireland, with 6 cross-border TTWAs. In our analyisis we restrict only to English and cross-border TTWAs.

The COVID-19 data were collected at the level of Middle Layer Super Output Areas (MSOA).[3]

Our analysis begins by using the dataset that includes TTWAs and postal codes from the 2011 census. By combining the TTWA and MSOA datasets, using postal codes as the key for merging we create a linkage between the two spatial units through common postal codes. This allows us to map the Covid-19 data collected at the MSOA level from 2020 to 2023 to corresponding TTWAs. We then calculated the count of Covid-19 cases for each MSOA and merged the Covid-19 data with the TTWA-MSOA dataset, creating a combined dataset that links COVID-19 cases to specific geographic areas. This combined dataset allows us to analyze the spread of Covid-19 between different Travel-to-Work-Areas.

Based on the data presented in Figure 1 the 'high Covid-19' period can be defined by observing the months with the highest mean number of cases across the four years depicted. In 2021 there is a noticeable increase in the mean number of cases starting from around July

[2]A number of studies have identified the importance of geography for COVID-19 incidence and excess deaths. Rodriguez-Pose and Burlina (2021) note that the UK had one of the highest Covid-19 incidence rates in the first 6 months of the pandemic and areas with large 'connected' and dense populations suffered more. See also Khan et al. (2023).

[3]Middle Layer Super Output Areas MSOAs) are geographical areas designed by the UK's Office for National Statistics. Each MSOA typically represents a population of about 7,200 to 10,000 people. This makes them smaller than TTWAs but larger than the more granular Lower Layer Super Output Areas (LSOAs). A TTWA may therefore contain more than one MSOA.

and extending through to April 2022, with peaks in December 2021 and January 2022.

We calculated the variation in cases within this period and classified the TTWAs based on their response to COVID-19. The essence of this analysis is not only to quantify the Covid-19 cases but also to contextualise them in relation to the population sizes of each TTWA, thereby enabling a more in-depth understanding of the Covid-19 pandemic's impact. Indeed, the calculation of COVID-19 cases per capita for each TTWA offers a more accurate representation of the pandemic's intensity enabling comparison between TTWAs of varying population sizes.

Our methodology distinguish between TTWAs, separating areas with sparse Covid-19 cases from those with dense outbreaks, employing a standardised measure, the *incidence rate*, to facilitate a uniform comparison between TTWAs. We calculate this rate monthly as the number of new COVID-19 cases per 100 people. This standardised approach allows for a consistent, comparative analysis of the pandemic's 'local' effects. The incidence rate can be calculated as follows:

$$\text{Incidence Rate} = \left(\frac{\text{Number of New Cases in a Month}}{\text{Population of TTWA}} \right)$$

To accurately evaluate the progression of COVID-19 between different TTTWAs, we summarise the monthly incidence rates from January 2020 to August 2023. This aggregation helps us understand the pandemic's temporal dynamics and its varied impact on each area.

We apply multiple metrics for this categorization, including the mean, median, standard deviation, cumulative incidence, and normalized range. Each metric uses specific thresholds to identify significant differences in the Covid-19 pandemic's impact, ensuring a detailed analysis of its effects on local communities. The *mean incidence rate* is the average monthly incidence rate for each TTWA over the entire period. By providing a central measure of tendency, this average helps us grasp what a 'typical' month looked like in terms of COVID-19 spread within each area. The *median incidence rate* is particularly valuable in the presence of outliers or non-normal distributions, as it remains robust against extreme values, presenting a more stable measure of the central trend. We also compute the *standard deviation of incidence rates* for each TTWA to measure the range of variation. A higher standard deviation signifies greater fluctuations in Covid-19 incidence rates over time, indicating that the impact of the pandemic, and associated policy responses, became more variable in those areas. Two further measures of the incidence rate are calculated: the *cumulative incidence rate* which is the total number of new COVID-19 cases per 100 people in each TTWA over the period from July 2021 to April 2022, and the *normalized range of incidence rates.* This latter measure adjusts the incidence rates to a common scale enabling a direct comparison between TTWAs, irrespective of their size or population. By normalizing the range of incidence rates, we can more accurately assess relative variations and spikes in Covid-19 cases over time, ensuring that comparisons are fair and not skewed by external factors, such as population density. The normalized range is calculated as the difference between the maximum and minimum incidence rates within a given period, divided by the maximum incidence rate.

4.2 Definition of Treatments Groups and school data

To analyze the impact of the Covid-19 across different areas, we employ a threshold approach to categorize the TTWAs into 'treated' and 'control' groups, based on predetermined percentile benchmarks (50th, 40th, and 30th percentiles) of the incidence rates. Specifically, an observation is classified as 'treated' if the value of the used definition of incidence rate surpasses the designated upper threshold. Conversely, it is considered 'control' if the metric is below the lower threshold. After defining the treatment groups at TTWAs level, we merge the school data for the time period 2016 to 2023. Furthermore, our study delineates a distinct 'post-treatment' period, starting from the year 2022. This allows us to conduct a longitudinal analysis at school level, tracking trends and evaluating outcomes after key interventions have been implemented.

Table 1 presents for each definition of incidence rate and each percentile threshold the corresponding average value in the treated and control TTWAs, and the number of schools in each group. Overall, we always observe higher values of the incidence rate in the treated groups, and for lower percentiles the values in the control group are decreasing. We are aware that all the TTWAs are affected by Covid-19, hence we try to consider control groups with the smallest possible incidence rate.

4.3 Educational gender gap

The data source for the school performance measures comes from the Department for Education in the UK. These data are collected and published to provide insights into the performance of pupils in public exams in a range of subjects at different (key) stages of education. We focus on Key Stage 4 (KS4), a performance metric used to evaluate the achievements and progress of students between the ages of 14 to 16, typically in Years 10 and 11 of secondary education.

During KS4, students work toward completing their GCSE that cover a wide range of subjects, including mathematics, science, humanities, languages, and the arts. Pupil performance in the GCSEs play a significant role in determining their future educational and labour market outcomes. The subjects a student takes can vary, but there is usually a core set of subjects that includes English, mathematics, and science. At the end of KS4, students receive their GCSE results, which are graded on a scale from A* (highest) to U (ungraded). Depending on their GCSE results and career aspirations, students may choose to continue their education in KS5 or pursue vocational training or employment opportunities. KS4 and KS5 performance is used by universities to determine whether to enrol an applicant or not. School performance at KS4 is often assessed based on various factors, including student coursework achievements and exams. The key measures used to evaluate school performance at this stage include the 'Attainment 8' score which is used to calculate the educational gender gap. Specifically, this is an average score calculated based on the results of pupils' GCSE examinations across eight subjects. Pupil-level scores are not publicly available, however, they are available for a school year group and averaged to produce a school's overall score. Each subject grade is converted into a point score. The scores from these eight subjects are then added together to produce the school's 'Attainment 8 Score'.

Finally, to calculate the educational gender gap we subtract the boys' score from the girls' score (Att8 girls - Att8 boys). Figure 2 presents a boxplot representation of Attainment 8 scores for girls and boys from 2016 to 2023. It is important to note that the data for the years 2020 and 2021 have been excluded from this analysis due to the significant disruptions caused by the COVID-19 pandemic described above. The plot shows the inter-quartile range, with the horizontal line inside the box denoting the median Att8 score. For both girls and boys, the median appears to be relatively stable over the years, however, the girls score shows that post-pandemic (2022) they did increase the educational gap returning to trend in 2023. The 'whiskers' of the boxplot also show that it was girls at the upper end of the attainment distribution who did particularly well in 2022.

Table 2 shows some summary statistics of the educational gender gap over a period from 2016 to 2023, including the number of secondary schools for each year. The mean gender gap fluctuated over the observed period, peaking in 2018 where girls achieved 4.407 points more in the GCSEs when compared to boys, falling back to 3.502 by 2023. This suggests that the educational gender gap narrowed following the pandemic. This is, of course, before we control for observable and unobservable differences between boys and girls. Figures 3 and 4 map the educational gender gaps in each TTWA in England in 2023, and identify the treatment and control areas for the median Covid-19 incidence rate (40:40 split) and the standard deviation of the incidence rate. The gender gaps are almost entirely positive regardless of whether the area is in the treatment or control group, although there is variance in the size of the gender gaps in each group. The maps differ between the two measures of the Covid-19 incidence rate, although there is overlap in terms of which TTWAs fall in the treatment and control groups. Figure 4 which uses the standard deviation measure of the incidence rate shows a clearer north-south divide between treatment and control groups.

Table 3 provides descriptive statistics for school-level characteristics, reflecting the pupil and teacher composition of the school. It is worth noting the variable referring to the percentage of pupils on free school meals because this is a measure of the socio-economic backgrounds of pupils in the school. Similarly, pupils with a statement of special education needs refers to pupils with mental, educational and physical disabilities. The variables in Table 3 are used in our PSM models and in our robustness checks.

5 Empirical Methodologies

Following the work of Todd and Wolpin (2003, 2006) we adopt the conceptual framework of the education production function, where educational attainment is a function of contemporaneous and past inputs. The standard specification considers the effect of personal, family or home inputs, school inputs and unobservable factors, such as non-cognitive skills like motivation to learn and other personality traits (Cunha and Heckman, 2006)[4]

We use a Difference-in-Differences (DiD) approach with multiple time periods, extending beyond traditional two-period comparisons to analyse treatment effects across the pre- and post-treatment years. This approach allows for a nuanced assessment because it captures temporal variations in the impact of the Covid-19 pandemic. Our model specification includes time varying characteristics of the school (X_{it}), year (T_t), as well as school (θ_{sch}) and TTWA (η_{ttwa}) fixed effects, which control for unobserved heterogeneity and time invariant characteristics. This approach ensures a more robust estimation of the treatment effect on the educational gender gap. Our model specification is:

$$Y_{st} = \beta_0 + \eta_{ttwa} + \theta_{sch} + T_t + \beta_2 D_s \times Post_t + \beta_4 X_{it} + \epsilon_{st} \tag{1}$$

where: Y_{st} is the educational gender gap in school s at time t. D_s is a dummy variable which equals 1 if a school is treated, zero otherwise. $Post_t$ is also a dummy variable equal to 1 for the years 2022 and 2023 and 0 otherwise. We first estimate Equation 1 using the full sample, and then we use propensity score matching to select a balanced sample of treated and control schools based on their propensity scores. This ensures that the treated and control groups are comparable in terms of observed covariates (measured prior to the Covid-19 pandemic), reducing the risk of selection bias.

We estimate our main models using different definitions of the treatment and control groups based on a choice of the incidence rates.We also estimate simple 2×2 DiD, restricting on 1 year before Covid and 1 year after. A series of robustness checks are undertaken to understand whether there is heterogeneity in our main results. For instance, we consider a quantile difference-in-differences model to estimate the treatment effects at different points (top 20th versus the bottom 20th percentiles) of the gender gap distribution. While the standard DiD estimates the average treatment effect, quantile DiD allows for a more nuanced analysis by examining how the treatment impacts the distribution of the educational gender

[4]Note that (Cunha and Heckman, 2006) show that non-cognitive skills affect cognitive skills, reflected in test scores, but cognitive skills do not affect non-cognitive skills.

gap. We also evaluate whether there is heterogeneity of the Covid-19 effect according to different characteristics of schools and TTWAs which are explained below.

However, given that our focus is on the gap in achievement between boys and girls, it is necessary to address the underlying mechanisms driving the educational gender gap, or more specifically how the covariates in equation vary in in their effect for boys versus girls. In terms of home inputs, it is unlikely that there were gender differences in the availability of IT equipment with which to undertake online learning during lock-downs, however, 15-16 year old girls are more likely than their male counterparts to undertake household duties, including caring for younger siblings. This would have the effect of reducing effort with respect to online study, and hence potentially reducing the educational attainment of girls relative to boys. In terms of personal characteristics, there are gender differences in the propensity to truant from normal schooling, with low achieving boys being more likely (Bradley and Crouchley, 2019). In those areas with higher incidence rates of Covid-19, and hence a greater likelihood of school closure or restricted access to school, boys may have become more disaffected with learning when compared to girls. As a result boys test score attainment at age 16 may have been relatively lower than that for girls. With respect to school practices, Section 3.2 has already highlighted how methods of teaching, streaming of pupils and differences in tiering of pupils for GCSEs can lead to better educational attainment for girls versus boys. In sum, the net effect of these differences in inputs between boys and girls could have led to the widening of the educational gender gap.

In terms of schools we investigate two aspects - the socio-economic composition and the ethnic composition of the school. To investigate socio-economic background we compute the distribution of pupils on free school meals in all schools in 2016, and then select two separate sub-samples, one with schools in the top 20 percentile (a high percentage of pupils on free school meals) and the other with schools in the bottom 20 percentile. We then track the same schools, in each sub-sample, from 2016 to 2023, and we re-estimate our DiD models. We repeat a similar analysis by computing the percentile distribution of immigrant pupils in all schools in 2016, measured by the percentage of pupils in a school for whom English is not their first language, and select only those schools in the top 20 percentile.

With regard to heterogeneity at the TTWA level, we investigate several variables which proxy for levels of poverty in the area and the population characteristics in the area, all measured in 2016. One proxy for poverty is the percentage of the population of working age who are either economically inactive or registered unemployed. Using the median and standard deviation incidence rates, we include in the treatment group the TTWAs that are in the top 40 percentiles of the incidence rate distribution and contrast this with those TTWAs in the top 30 percentile of the unemployment/inactivity distribution. Conversely, two control groups are created - TTWAs in the bottom 40 percentile of the incidence rate and those in the bottom 50 percentile of unemployment/inactivity rates. A further measure of poverty in a TTWA is the percentage of the employed (aged 16-64) with no qualifications who more likely to be amongst the low paid. We repeat the same approach for several measures of the local population - the percentage of the population who are from minority ethnic groups, the percentage of white immigrants.

Our final robustness check is based on a 2×2 rank-rank regression. We define the dependent variable as the difference in deciles of educational gender gap post-Covid minus deciles of education gender gap pre-Covid. We then estimate the effect of deciles of incidence rates on the dependent variable for each year before and after Covid.

5.0.1 Parallel Trends Assumption

A critical assumption of the DiD method is that, in the absence of the intervention, the outcomes of the treatment and control groups would follow parallel trends over time. This means that the groups would experience similar changes in educational outcomes even without the intervention.

In Figure 5, using a median incidence rate we observe that both treated and control groups show similar trends between 2016 and 2019, with the gender gap increasing until 2018 and then decreasing slightly in 2019. Similar trends are observed in Fgure 6 when using a standard deviation definition of the incidence rate. This parallel pre-treatment trend is reassuring, adding validity to our Difference-in-Differences (DiD) approach, suggesting that, in the absence of treatment, the treated and control groups would in fact have followed similar paths.

6 Results

6.1 Choosing the Treatment selection

Table 4 reports the effect of Covid-19 on the education gender gap for different levels (doeses) of the treatment (see Panels 1-4), based on six definitions of the Covid incidence rate described in Section 3.2. All models are esitmated using fixed effects and exclude time varying school covariates. We report the estimated effects for the $treat \times post$ interaction term. In Panel 1 we split TTWAs into the top 50% in terms of Covid-19 incidence (the treatment areas) and the bottom 50% (the controls). The effect of the treatment effect is positive and statistically significant but only for the standard deviation incidence rate, which shows that Covid-19 increased the educational gender gap in favour of girls by 0.42 points. In Panel 2 we refine the treatment and control groups (a 40-40 split of TTWAs), and here both the median and the standard deviation incidence rates show statistically significant effects, and the gender gap increases by between 0.3 and 0.4 points, respectively. A further refinement is reported in Panel 3 where TTWAs are split into the top 30% in terms of Covid incidence and the bottom 30%, and statistically significant effects remain for both the median and standard deviation incidence rates. The estimated effects are similar to those in Panel 2, but slightly smaller in magnitude, possibly because there are fewer schools as we refine the treatment and control areas. Given this preliminary analysis, the remainder of the paper adopts a 40:40 split of the TTWAs for the treatment and control groups using the median and standard deviation incidence rates to capture the effect of the Covid-19 pandemic. A number of robustness checks are made which relax this definition of treatment and control areas.

6.2 Main models

Table 5 examines the impact of the treatment on the gender gap and is organized into two panels, for both the DiD estimates using the full sample (Panel 1) and the matched sample of schools using PSM (Panel 2). The results are displayed for four models, where we incrementally add more time varying school and school workforce covariates (see Table

A.3 for details). The Propensity Score Models include a number of covariates that are expected to determine pupil outcomes, such as the number of teachers, and staff and school characteristics. Figures A.1 and A.2 report the balancing tests for the median and the standard deviation incidence rates, which suggest that the matching process is effective in creating balanced samples.

In Panel 1, using a median incidence rate for the treatment, we observe a positive effect on the gender gap, with coefficients ranging from 0.289 to 0.304 points in favour of girls. The effects are statistically significant at the 5% level, except for model 4 which is only significant at the 10% level. Similar effects are observed for the matched sample using PSM, although the estimated effects are slightly smaller in magnitude. Panel 2 reports the estimated effects using the standard deviation incidence rate of Covid-19, which shows that the effects are larger and suggest that the gender gap widens by between 0.43 to 0.51 points in favour of girls. These estimates are all highly statistically significant. The same pattern of results are confirmed in the matched sample. In summary, the estimated effects in Panels 1 and 2 indicate that in the post-Covid period , the gender gap increased more in schools located in high Covid-19 incidence areas compared to those located in low incidence areas. Girls test scores improved relative to those of boys, and this is especially the case in those areas where the incidence of Covid-19 was not only relatively higher but also more variable. The inclusion of time varying school characteristics does not change the pattern of estimated effects, implying that they had little effect on changes in the educational gender gap during the period of the Covid-19 pandemic.[5]

7 Robustness checks

In Table 6 we change the definition of treatment and control groups, comparing TTWAs in the top 50% of incidence rates versus the control group in the bottom 30%. There are positive but statistically insignificant results when we use the median incidence rate. However, for the standard deviation incidence rate in Panel 2, the treatment effect maintains a high

[5]However, this is not to deny the importance of these factors more generally. The relatively narrow time frame of our analysis and the inclusion of school fixed effects is likely to have reduced their statistical significance.

level of statistical significance across all models, similar to the main model in Table 5. The coefficients range from 0.417 to 0.431, demonstrating a strong effect on increasing the variability of the gender gap.

Table 7 presents the 2 × 2 DiD estimates, where we use only a single year as the pre-treatment period and only one year as post-treatment period. We report all the possible combinations in the time frame 2016-2023. There are four years before the Covid-19 pandemic (2016-2019) and two years in the post-pandemic period (2022 and 2023). Table 7 is structured into two panels: the median and the standard deviation of the incidence rate and using the 40:40 split of the incidence rates within TTWAs for the treatment and control groups.

The effect of Covid-19, as indicated by the $treat \times post$ coefficients, shows that there is greater variability in the size and statistical significance of the estimated effects for different years. For instance, in the median incidence rate analysis, a statistically significant effect on the gender gap is observed in the model comparing 2016 vs 2022 (0.52) and in that for 2016 vs 2023 (0.5), suggesting that the treatment effect is relatively constant over time. In the standard deviation analysis, the treatment's effect is again stronger than the effect using the median incidence rate. This is the case for the post-pandemic years of 2022 and 2023, however, in this analysis the effect for 2016 is positive but statistically insignificant. In summary, the estimated effects in Table 7 are consistent with our main effects in Table 5.

7.1 School-level quantile difference-in-differences estimates

Table 8 presents the Quantile DiD results. We replicate the same structure of the 2 × 2 DiD, however the treatment effects are reported only for two groups of *schools* - those at upper end (80th percentile and above) and the lower end (20th percentile and below) of the educational gender gap distribution in the pre-Covid period (2016).

For the median incidence rate, there are very few statistically significant effects, except for 2016 versus both post-Covid periods, and there is no difference in the estimates which range from 0.6 (in 2022) to 0.7 (2023) points. However, when using the standard deviation of the incidence rate, there is a clear pattern to the estimated effects. In general, for schools at the upper end of the gender gap distribution, the estimates range from 0.58 in 2022 to 0.87

points in 2023 in favour of girls. As with the median incidence rates, there is very little in terms of a systematic effect at the lower end of the gender gap distribution. These findings suggest that the pandemic widened pre-existing educational gender gaps at the school level and clearly favoured girls.

7.2 A rank-rank regression approach

Comparing two groups of schools at the upper and lower end of the gender gap distribution is a fairly crude analysis. In this section we take a different approach by looking at the percentile distribution of schools with respect to the gender gap and the percentile distribution of Covid-19 incidence rates. The estimate effects show whether a percentile change in Covid-19 incidence rates 'causes' a change in the percentile rank of schools in terms of their educational gender gap.

The estimates from the rank-rank regression analysis are reported in Table **??** showing positive effects of the Covid-19 pandemic on the percentile ranking of schools' gender gap. Specifically, the analysis indicates that an increase in the percentile Covid-19 incidence rate is associated with a corresponding increase in the percentile ranking of the educational gender gap. This relationship is statistically significant for the standard deviation of Covid-19 incidence rates, suggesting that areas with higher variability in Covid-19 cases experienced a widening of the educational gender gap post-pandemic. The results show that for both post-pandemic years (2022 and 2023), the estimated effects range from 0.04 to 0.06 and are statistically significant at the 10% level. These effects are quite small implying around a half a percentile increase in the educational gender gap in favour of girls, which is consistent with our previous findings.

7.3 Is there hetereogeneity in the effect of Covid-19 by TTWA?

In this section we investigate how the impact of the Covid-19 pandemic varies with the characteristics of the local area, and how its impact varies with the pupil composition of the school. For each TTWA we first compute separately the percentile distribution of four characteristics - the percentage of the workforce aged 16-64 who are either economically inactive or unemployment, the percentage of individuals from a minority ethnic background in the area, the percentage of immigrants (non-UK white nationals), and finally the percentage of the employed aged 16-64 with no qualifications.[6] Each of these measures can be regarded as proxies for either low incomes or poverty, or in the case of ethnicity for vulnerability to the virus. Using the median and standard deviation percentile incidence rates, we then define the treatment and control groups for each characteristic by TTWAs with a 40:40 split, respectively.

Table 10 shows the results for our analysis. Using the median incidence rate the estimated effects are all positive, however, all but the percentage employees with no qualifications are statistically insignificant. In this case, we find that schools in TTWAs with a high percentage have a positive increase in the educational gender gap in favour of girls by around 0.4 points. Using the standard deviation of Covid-19 incidence shows that all four characetristics of the TTWAs are associated with a positive and statistically significant increase in the educational gender gap, suggesting that a higher variability in the pandemic is more important than the level of incidence. Those areas with a higher percentage of ethnic minorities (model C, Panel 2) and those areas with a higher percentage of white immigrants (model B) experience an increase in the educational gender gap at school level by around 0.6 points.

The characteristics of an area clearly also matter for the educational gender gap probably because of the association between the incidence and severity of Covid-19 and low incomes and population characteristics.

7.4 Is there hetereogeneity in the effect of Covid-19 by pupil composition of schools?

We investigate the effect whether the effect of Covid-19 varied with respect to the socio-economic status of pupils in a school, proxied by the the percentage of students on free school meals, reflective of low incomes and/or poverty, the percentage of pupils in the school

[6] Nafilyan et al (2021) investigate mortality rates for the 1st and 2nd waves of the Covid-19 pandemic with a particular focus on the association with ethnic minority groups. They find that all ethnic minority groups had a higher risk of Covid-related deaths compared to the white group in the first wave whereas for the second wave only Pakistani and Bangladeshi groups had a higher risk. Geography explained around half of the variation between groups in the first wave.

from a minority ethnic background, reflecting their vulnerability to the pandemic and the percentage of students in the school with a statement of special educational need. These pupils are required extra support to help them with their education even before the Covid-19 pandemic struck. We focus only on those schools where the percentage of pupils for each characteristics was in the top 30%. Using the median and standard deviation percentile incidence rates, we then define the treatment and control groups for each characteristic of the school with a 40:40 split, respectively. Conditioning on the top 30% of schools allows us to assess whether schools in areas with higher incidence rates of Covid-19 fared worse than their counterparts in areas with lower Covid-19 rates.

Table 9 reports the results of this analysis. Using the median incidence rate (Panel 1) we show that schools in the treatment group with a high percentage of pupils on free school meals experienced a 0.7 point increase in the gender gap in favour of girls. This effect is even higher when we use the standard deviation of incidence rates insofar as it increases the gender gap by over 1 point. There are small and statistically insignificant effects (not reported) in those schools in treated areas with a low percentage of pupils on free school means. Thus, low incomes and poverty do matter for the performance of boys and girls from these backgrounds perhaps of resource constraints at home, such as quiet space to study or access to ICT. The effect of the Covid-19 pandemic is even greater in those schools with a higher percentage of pupils from minority ethnic backgrounds, regardless of whether we use the median or the standard deviation of incidence rates. In these schools girls increase their test score relative to boys by 1 to 1.2 points. This finding is consistent with the area effects discussed in the previous section. Finally, schools with a higher percentage of pupils with a statement of educational need experience a positive and statistically significant increase in the gender gap, ranging from 0.6 to 0.8 points. This could be because girls are more likely to be statemented or school resources are stretched in order to support SEN pupils and girls cope better in such circumstances.

8 Conclusions and Policy Implications

This paper investigates the effects of the Covid-19 pandemic's on the educational gender gap at secondary school level by exploiting spatial variations in the incidence of the pandemic at Travel-to-Work Area level. We use a difference-in-differences (DiD) framework, complemented by propensity score matching to control for pre-Covid selection effects. We assign those areas (and associated schools), with high incidence rates to the treatment group and conversely those areas (and associated schools) with low incidence rates to the control group. Our main findings are as follows:

- The pandemic exacerbated the educational gender gap, raising the performance of girls relative to boys.
- The effect ranged from around 0.3 points in favour of girls if we use the level of incidence of the Covid-19 rate at its median to 0.5 if we use the standard deviation of incidence rates in an area. The variability of the incidence of Covid-19 matters.
- Girls at the upper end of the attainment distribution fared much better through the pandemic when compared to boys. The educational gender gap at the top end of the attainment distribution increased by 0.6 to 0.8 points
- Schools in treatment areas with larger numbers of pupils from poorer backgrounds, minority ethnic backgrounds and those with statements of special education needs witnessed larger increases in the educational gender gap. This ranged from 0.6 to 1.2 for the free school meals, ethnicity and special educational needs variables.
- There is a spatial pattern to the incidence rates of the pandemic, and our analysis indicates that the characteristics of the area do effect the educational gender gap in schools. Areas with a higher percentage of immigrants, ethnic minorities, low or unskilled workers and higher inactivity and unemployment rates experienced significant increases in the educational gender gap in associated schools.
- The effect of the Covid pandemic on the educational gender gap is also persistent over time insofar as it continues to impact pupils in 2022 *and* 2023.

Our main finding is in line with the existing literature, which finds that the pandemic had a differential impact on boys and girls, and exacerbated the educational gender gap in favour of girls. In terms of the underlying mechanisms that drive these results, studies have shown that girls generally reported higher levels of engagement with digital learning environments, and demonstrated greater resilience in the face of educational disruptions (Bertoletti et al., 2023) (Korlat et al., 2021). Non-cognitive skills are likely to be very important as discussed in Literature Review section. School practices in terms of streaming for Key Stage 4 GCSEs subjects, for instance, are also likely to be important determinants of the educational gender gap. The economic and demographic context in which a school is located are also important insofar as the Covid-19 pandemic was more prevalent in those areas. The consequence was that these areas were often subjected to more, and possibly longer, local lockdowns and restrictions in an attempt to contain the spread.

For educational policymakers and local government officials, understanding these spatial disparities can aid in the targeted allocation of resources and support, particularly in those areas identified as high-risk in terms of educational disparities being boys and girls. For instance, ensuring equitable access to digital learning resources, providing targeted psychological and academic support, and developing strategies to engage disaffected boys more effectively in remote learning environments are essential steps to mitigate the further widening of the educational gender gap.

Table 1: Average incidence rate by treatment and control TTWAs

	50-50			***40-40***			***30-30***		
Incidence Rate									
	T	C	all	T	C	all	T	C	all
Mean TTWA	0.97	0.79	0.88	0.98	0.77	0.88	1.00	0.73	0.87
N_{sch}	1992	1384	3376	1653	1113	2766	1151	504	1655
Median TTWA	0.33	0.24	0.29	0.34	0.23	0.29	0.35	0.22	0.29
N_{sch}	1668	1709	3377	1466	1474	2940	1194	1182	2376
Std TTWA	4.87	3.86	4.36	4.95	3.74	4.35	5.04	3.62	4.34
N_{sch}	1880	1497	3377	1661	1160	2821	1415	897	2312
Cum TTWA	39.27	30.83	35.03	39.79	29.53	34.70	40.41	27.99	34.26
N_{sch}	2051	1326	3377	1794	611	2405	1443	320	1763
Norm range TTWA	0.99	0.99	0.999	0.999	0.998	0.999	0.999	0.998	0.999
N_{sch}	2288	1089	3377	1939	788	2727	1596	393	1989
N_{TTWA}	78	77	155	50.40	49.60	125	50.53	49.47	95

Table 2: Descriptive Statistics of educational Gender Gap

Year	Mean	Std. Dev.	Min	Max	N
2016	3.611	2.986	-8.7	15.9	2752
2017	4.334	3.363	-13.4	16.9	2733
2018	4.407	3.664	-12.4	19.2	2759
2019	4.286	3.540	-14.3	16.9	2788
2022	3.961	3.583	-15.1	16.8	2869
2023	3.502	3.512	-16.4	15.8	2894

N refers to the number of schools for the period 2016-2023 (excluding 2020-2021).
The average score calculated based on the results of students' GCSE results in eight subjects.

Table 3: Descriptive Statistics of School charateristics

Variable	Mean	Std. Dev.	Min	Max	N×T
Total number of pupils on roll	881.57	499.37	3	3001	20258
Percentage of SEN pupils with a statement or EHC plan	17.80	35.68	0	100	20258
Perc of eligible pupils with SEN support	10.46	6.91	0	52.7	20258
Perc of pupils with English not as first language	15.18	18.48	0	100	20257
Perc of pupils where first language is unclassified	0.37	1.60	0	95.7	20257
Number of girls on roll	424.73	254.73	0	1561	20258
Number of boys on roll	456.84	251.77	0	1560	20258
Number of teacher	68.04	29.53	42	234	16382
Number of teacher full time	62.91	27.07	64	213	16382
Number of staff	26.15	13.55	69	203	16374
Number of staff full time	22.16	11.24	40	212	16374
Pupil teacher ratio	16.39	3.58	25	93	16363
Salary	40277.3	3884.41	10065	68817	16358
Perc of pupils eligible for free school meals	21.62	15.30	0	92.5	16846

N×T refers to the number of schools in each TTWA (155) across the period 2016-2023 (excluding 2020-2021).

Table 4: The effect of Covid-19 incidence rates on the educational gender gap: Selecting the treatment and control groups

Dependent variable:	$(ATT8_{girls} - ATT8_{boys})$				
	(1)	(2)	(3)	(4)	(5)
Incidence Rate:	***Mean***	***Median***	***Std Dev***	***Cumu***	***Norm***
Panel 1 - 50-50%					
treat×post	0.034	0.181	0.417***	-0.029	-0.027
	(0.114)	(0.112)	(0.113)	(0.115)	(0.120)
N	16480	16480	16480	16480	16480
Panel 2 - 40-40%					
treat×post	-0.013	0.292**	0.436***	-0.199	0.014
	(0.128)	(0.121)	(0.124)	(0.154)	(0.137)
N	13444	14285	13718	11815	13298
Panel 3 - 30-30%					
treat×post	-0.274	0.277**	0.352**	-0.237	0.072
	(0.178)	(0.134)	(0.138)	(0.202)	(0.179)
N	8102	11539	11258	8681	9656
Panel 4 - 50-30%					
treat×post	0.037	0.184	0.420***	-0.026	-0.028
	(0.115)	(0.113)	(0.113)	(0.116)	(0.121)
N	16415	16415	16415	16415	16415
School FE	✓	✓	✓	✓	✓
TTWA FE	✓	✓	✓	✓	✓
Year FE	✓	✓	✓	✓	✓

Significance levels: *** 1% ** 5% * 10%.

Table 5: The effect of Covid-19 on educational gender gap - main models

Dependent variable:	$(ATT8_{girls} - ATT8_{boys})$			
	(1)	(2)	(3)	(4)
Panel 1 - Median 40-40%				
treat×post	0.292**	0.298**	0.303**	0.293**
	(0.121)	(0.122)	(0.122)	(0.124)
N	14285	14285	14285	13510
treat×post PS	0.256**	0.261**	0.261**	0.256*
	(0.130)	(0.131)	(0.132)	(0.132)
N	11855	11855	11855	11855
Panel 2 - Std Dev 40-40%				
treat×post	0.436***	0.431***	0.430***	0.425***
	(0.124)	(0.126)	(0.126)	(0.128)
N	13718	13718	13718	12943
treat×post PS	0.461***	0.477***	0.466***	0.457***
	(0.134)	(0.136)	(0.137)	(0.137)
N	11234	11234	11234	11234
FE (School, TTWAE, Year)	✓	✓	✓	✓
School char 1		✓		
School char 2			✓	
School char 2 + School Workforce				✓

Note: School characteristics in (1) are: total number of pupils on roll, total number of pupils on roll square, percentage of SEN pupils, percentage of eligible pupils with SEN support, percentage of pupils with English not as first language, percentage of pupils where first language is unclassified, percentage of pupils eligible for Free School Meals (FSM), percentage of pupils no british.
School characteristics in (2) are: number of girls on roll, number of boys on roll.
School workforce variables are: number of teacher, number of teacher full time, number of staff, number of staff full time, pupil teacher ratio, salary, percentage of pupils eligible for FSM, percentage of pupils no british

Significance levels: *** 1% ** 5% * 10%.

Table 6: Varying the TTWAs in the treatment and control groups

Dependent variable:	$(ATT8_{girls} - ATT8_{boys})$			
	(1)	(2)	(3)	(4)
Panel 1 - Median inc rate 50-30%				
treat×post	0.181	0.185	0.187*	0.180
	(0.112)	(0.113)	(0.113)	(0.115)
N	16480	16480	16480	15547
Panel 2 - Std Dev inc rate 50-30%				
treat×post	0.417***	0.427***	0.430***	0.431***
	(0.113)	(0.114)	(0.114)	(0.116)
N	16480	16480	16480	15547
FE (School, TTWAE, Year)	✓	✓	✓	✓
School char 1		✓		
School char 2			✓	
School char 2 + School Workforce				✓

Note: School characteristics in (1) are: total number of pupils on roll, percentage of SEN pupils with a statement or plan, percentage of eligible pupils with SEN support, percentage of pupils where English is not the first language, percentage of pupils where first language is unclassified.
School characteristics in (2) are: the number of girls on roll, number of boys on roll.
Workforce variables are: the number of teachers, the number of full time teachers, the number of staff, number of full time staff, the pupil teacher ratio, average teacher salaries, the percentage of pupils eligible for FSM.

Significance levels: *** 1% ** 5% * 10%.

Table 7: A linear 2×2 Difference-in-Differences model of the effect of Covid-19

	$ATT8_{girls} - ATT8_{boys}$			
	2016	2017	2018	2019
2022				
treat^a×post	0.517**	0.342	0.382*	0.249
	(0.211)	(0.215)	(0.223)	(0.213)
N	4,530	4,515	4,545	4,562
2023				
treat^a×post	0.496***	0.322	0.359*	0.227
	(0.188)	(0.204)	(0.212)	(0.190)
N	4,512	4,497	4,527	4,544
2022				
treat^b×post	0.379	0.584***	0.626***	0.487**
	(0.234)	(0.209)	(0.207)	(0.201)
N	4,343	4,318	4,347	4,368
2023				
treat^b×post	0.284	0.483**	0.532**	0.383**
	(0.206)	(0.214)	(0.211)	(0.177)
N	4,333	4,308	4,337	4,358

Clustered Standard errors at TTWA level.

Significance levels: *** 1% ** 5% * 10%.

[a]Median Incidence Rate percentiles 40-40.

[b]Standard deviation Incidence Rate percentiles 40-40.

Table 8: A quantile Difference-in-Differences model

	$ATT8_{girls} - ATT8_{boys}$			
	2016	2017	2018	2019
Treatment: Median Incidence Rate 40-40%				
2022				
treat×post 80%				
	0.621***	0.318	0.228	0.332
	(0.237)	(0.258)	(0.321)	(0.283)
treat×post 20%				
	0.566*	0.461	0.399	0.509**
	(0.292)	(0.295)	(0.262)	(0.253)
N	4,530	4,515	4,545	4,562
2023				
treat×post 80%				
	0.673**	0.358	0.356	0.346
	(0.267)	(0.281)	(0.320)	(0.299)
treat×post 20%				
	0.327	0.047	0.240	0.155
	(0.268)	(0.264)	(0.264)	(0.257)
N	4,512	4,497	4,527	4,544
Treatment: Standard Dev Incidence Rate 40-40%				
2022				
treat×post 80%				
	0.613**	0.661**	0.716**	0.581*
	(0.288)	(0.293)	(0.307)	(0.340)
treat×post 20%				
	0.471	0.661**	0.317	0.702***
	(0.289)	(0.279)	(0.256)	(0.264)
N	4,343	4,318	4,347	4,368
2023				
treat×post 80%				
	0.630**	0.752***	0.865***	0.655**
	(0.264)	(0.281)	(0.314)	(0.274)
N	4,333	4,310	4,339	4,361
treat×post 20%				
	-0.123	0.163	0.029	0.177
	(0.268)	(0.292)	(0.263)	(0.281)
N	4,333	4,308	4,337	4,358

Significance levels: *** 1% ** 5% * 10%.

Table 9: A rank-rank model of the effect of Covid-19

Dependent variable:	$(PercentileEdGap_{post} - PercentileEDGap_{pre})$			
pre-Covid :	2016	2017	2018	2019
post: 2022				
Median rate	0.014	0.013	0.010	0.009
	(0.018)	(0.018)	(0.018)	(0.018)
N	2642	2650	2666	2694
post: 2023				
Median rate	0.034*	0.027	0.032*	0.028
	(0.018)	(0.018)	(0.018)	(0.018)
N	2664	2674	2688	2696
post: 2022				
Standard deviation of rate	0.036*	0.044**	0.042**	0.037*
	(0.020)	(0.020)	(0.020)	(0.020)
N	2642	2650	2666	2694
post: 2023				
Standard deviation of rate	0.049**	0.049**	0.055***	0.049**
	(0.020)	(0.020)	(0.020)	(0.020)
N	2664	2674	2688	2696

Table 10: Heterogeneous effects of Travel-to-Work Areas

Dependent variable:	$(ATT8_{girls} - ATT8_{boys})$			
	(1)	(2)	(3)	(4)
Panel 1 - Median rate 40-40%				
treat(A)×post	0.236	0.237	0.233	0.209
	(0.146)	(0.147)	(0.147)	(0.149)
N	9864	9864	9864	9318
treat(B)×post	0.244	0.317	0.323	0.319
	(0.217)	(0.219)	(0.220)	(0.223)
N	4465	4465	4465	4241
treat(C)×post	0.240	0.216	0.214	0.208
	(0.224)	(0.226)	(0.226)	(0.229)
N	6312	6312	6312	5950
treat(D)×post	0.432***	0.432***	0.439***	0.457***
	(0.150)	(0.152)	(0.152)	(0.156)
N	9116	9116	9116	8633
Panel 2 - SD of rate: 40-40%				
treat(A)×post	0.368**	0.369**	0.373**	0.366**
	(0.150)	(0.152)	(0.153)	(0.155)
N	9371	9371	9371	8835
treat(B)×post	0.625***	0.615***	0.646***	0.662***
	(0.234)	(0.236)	(0.236)	(0.240)
N	4242	4242	4242	4012
treat(C)×post	0.591***	0.579***	0.586***	0.588***
	(0.214)	(0.216)	(0.216)	(0.221)
N	7685	7685	7685	7215
treat(D)×post	0.489***	0.498***	0.505***	0.522***
	(0.145)	(0.147)	(0.148)	(0.150)
N	9850	9850	9850	9278
FE (School, TTWA, Year)	yes	yes	yes	yes
School char 1		yes		
School char 2			yes	
School Workforce			yes	yes

Note: (A) conditional on bottom 50 and top 30% of unemployment and inactivity rates
(B) conditional on 50:30% white non-UK nationals
(C) conditional on 50:30% non-white UK nationals
(D) conditional on 50:30% employed with no qualifications.
School characteristics in (1) are: total number of pupils on roll (and its square), the percentage of SEN pupils, percentage of eligible pupils with SEN support, percentage of pupils for whom English is not their first language, percentage of pupils where first language is unclassified, percentage of pupils eligible for FSM, percentage of pupils no british.
School characteristics in (2) are: number of girls on roll, number of boys on roll.
Worforce variables are: number of teachers, number of full-time teachers, the number of staff, number of full-time staff, pupil teacher ratio, average teacher salaries, percentage of pupils eligible for FSM, percentage of pupils no british.

Table 11: Heterogeneity analysis of school composition

Dependent variable:	$(ATT8_{girls} - ATT8_{boys})$			
	(1)	(2)	(3)	(4)
Panel 1 - Median 40-40%				
High FSM				
treat×post	0.661*	0.675*	0.683*	0.761
	(0.395)	(0.401)	(0.401)	(0.471)
N	1517	1517	1517	1213
Non-white				
treat×post	0.949***	0.953***	0.939***	0.972***
	(0.232)	(0.236)	(0.236)	(0.243)
N	3940	3940	3940	3801
SEN - top 30%				
treat×post	0.717**	0.722**	0.764**	0.829**
	(0.317)	(0.322)	(0.324)	(0.366)
N	2373	2373	2373	1987
Panel 2 - SD of rate: 40-40%				
High FSM				
treat×post	1.090***	1.075***	1.088***	1.223***
	(0.389)	(0.403)	(0.403)	(0.469)
N	1588	1588	1588	1275
Non-white				
treat×post	1.172***	1.191***	1.163***	1.207***
	(0.227)	(0.231)	(0.233)	(0.239)
N	3546	3546	3546	3421
SEN - top 30%				
treat×post	0.632*	0.680**	0.709**	0.842**
	(0.334)	(0.340)	(0.343)	(0.397)
N	2118	2118	2118	1724
FE (School, TTWA, Year)	yes	yes	yes	yes
School char 1		yes		
School char 2			yes	
School Workforce			yes	yes

See tables notes for Table 10. height

Table A.1: Effect of the median incidence rate 40-40 on gender gap(full cov)

Dependent variable:	$(ATT8_{girls} - ATT8_{boys})$			
	(1)	(2)	(3)	(4)
Panel 1 - Median rate 40-40%				
treat×post	0.289**	0.300**	0.304**	0.304**
	(0.120)	(0.121)	(0.122)	(0.124)
Total number of pupils on roll		0.002*		
		(0.001)		
		(0.000)		
Percentage of SEN pupils with a statement or plan		0.044	0.046	0.051
		(0.045)	(0.045)	(0.048)
Percentage of eligible pupils with SEN support		-0.005	-0.005	-0.005
		(0.010)	(0.010)	(0.010)
Percentage of pupils with English not as first language		-0.013	-0.013	-0.014
		(0.009)	(0.009)	(0.009)
Percentage of pupils where first language is unclassified		0.025	0.025	0.033
		(0.027)	(0.027)	(0.028)
Number of girls on roll			0.004	0.003
			(0.003)	(0.003)
			(0.000)	(0.000)
Number of boys on roll			-0.001	0.001
			(0.003)	(0.003)
			(0.000)	(0.000)
Number of teacher				0.005
				(0.012)
Number of teacher full time				-0.009
				(0.013)
Number of staff				0.003
				(0.012)
Number of staff full time				-0.013
				(0.014)
Pupil teacher ratio				-0.021
				(0.014)
Salary				0.000
				(0.000)
Percentage of pupils eligible for free school meals				
const	3.975***	2.762***	2.738***	3.619***
	(0.034)	(0.656)	(0.657)	(0.878)
N	14343	14343	14343	13517
FE (School, TTWAE, Year)	✓	✓	✓	✓
School char 1		✓		
School char 2			✓	
School char 2 + School Workforce				✓

Significance levels: *** 1% ** 5% * 10%.
Mod1: no covariates, Mod2: school covariates

Table A.2: Effect of the std dev incidence rate 40-40 on gender gap (full cov)

Dependent variable:	$(ATT8_{girls} - ATT8_{boys})$			
	(1)	(2)	(3)	(4)
Panel 2 - SD of rate: 40-40%				
treat×post	0.433***	0.443***	0.440***	0.449***
	(0.124)	(0.125)	(0.125)	(0.128)
Total number of pupils on roll		0.001		
		(0.001)		
		(0.000)		
Percentage of SEN pupils with a statement or plan		0.003	0.005	0.003
		(0.044)	(0.044)	(0.047)
Percentage of eligible pupils with SEN support		-0.015	-0.014	-0.015
		(0.010)	(0.010)	(0.010)
Percentage of pupils with English not as first language		-0.009	-0.010	-0.010
		(0.010)	(0.010)	(0.010)
Percentage of pupils where first language is unclassified		0.031	0.031	0.043
		(0.034)	(0.034)	(0.035)
Number of girls on roll			0.001	0.000
			(0.003)	(0.003)
			(0.000)	(0.000)
Number of boys on roll			0.001	0.002
			(0.003)	(0.003)
			(0.000)	(0.000)
Number of teacher				0.004
				(0.012)
Number of teacher full time				-0.006
				(0.013)
Number of staff				-0.006
				(0.011)
Number of staff full time				-0.002
				(0.014)
Pupil teacher ratio				-0.006
				(0.014)
Salary				0.000
				(0.000)
Percentage of pupils eligible for free school meals				
const	3.943***	3.161***	3.138***	3.616***
	(0.037)	(0.668)	(0.669)	(0.905)
N	13774	13774	13774	12951
FE (School, TTWAE, Year)	✓	✓	✓	✓
School char 1		✓		
School char 2			✓	
School char 2 + School Workforce				✓

Significance levels: *** 1% ** 5% * 10%.
Mod1: no covariates, Mod2: school covariates

Table A.3: Propensity score matching

Incidence Rate:	***Median 40***	***Std Dev 40***
number of teacher	-0.007	-0.027***
	(0.006)	(0.007)
number of teacher full time	0.007	0.028***
	(0.007)	(0.008)
number of staff	-0.020**	-0.023***
	(0.008)	(0.009)
number of staff full time	0.015	0.022**
	(0.010)	(0.011)
pupil teacher ratio	0.005	0.013
	(0.008)	(0.009)
salary	-0.000***	-0.000***
	(0.000)	(0.000)
type	0.045**	0.018
	(0.020)	(0.021)
religion	-0.052	-0.124***
	(0.036)	(0.038)
const	3.257***	3.323***
	(0.355)	(0.393)
N	2442	2339

Robust Standard errors. Significance levels: *** 1% ** 5% * 10%.
Note: The propensity score matching is calculated at pre-treatment period 2016.

Figure 1: The spread of Covid-19 cases across 2020-2023

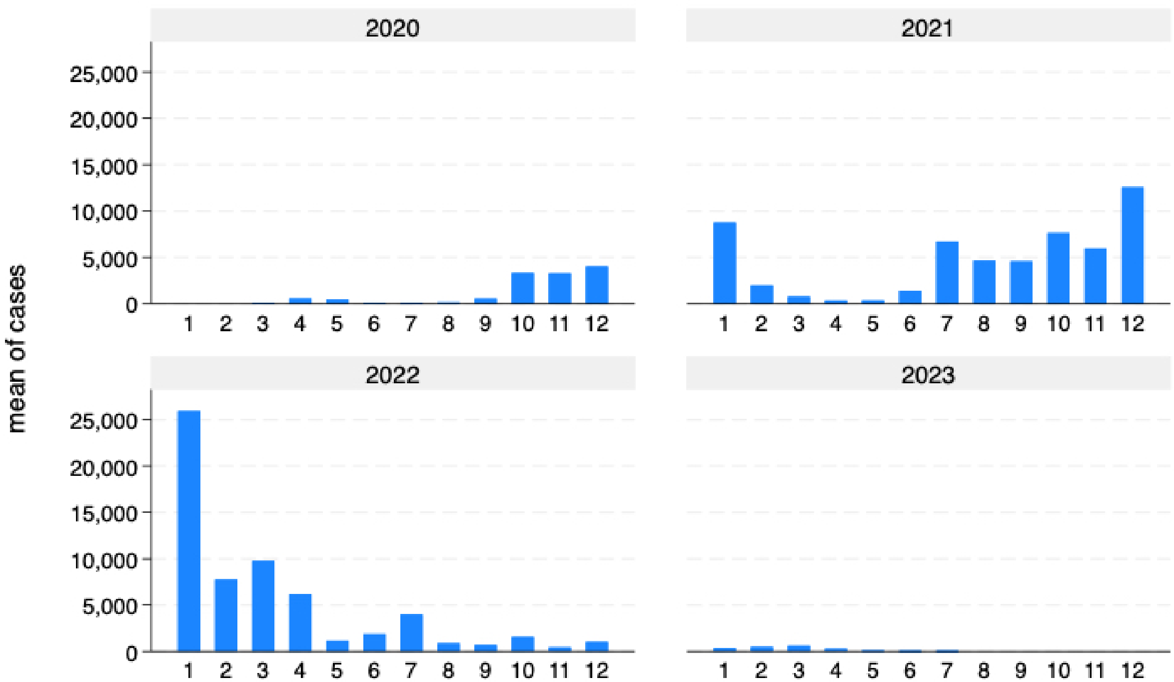


Figure 2: Att8 score for boys and girls over years

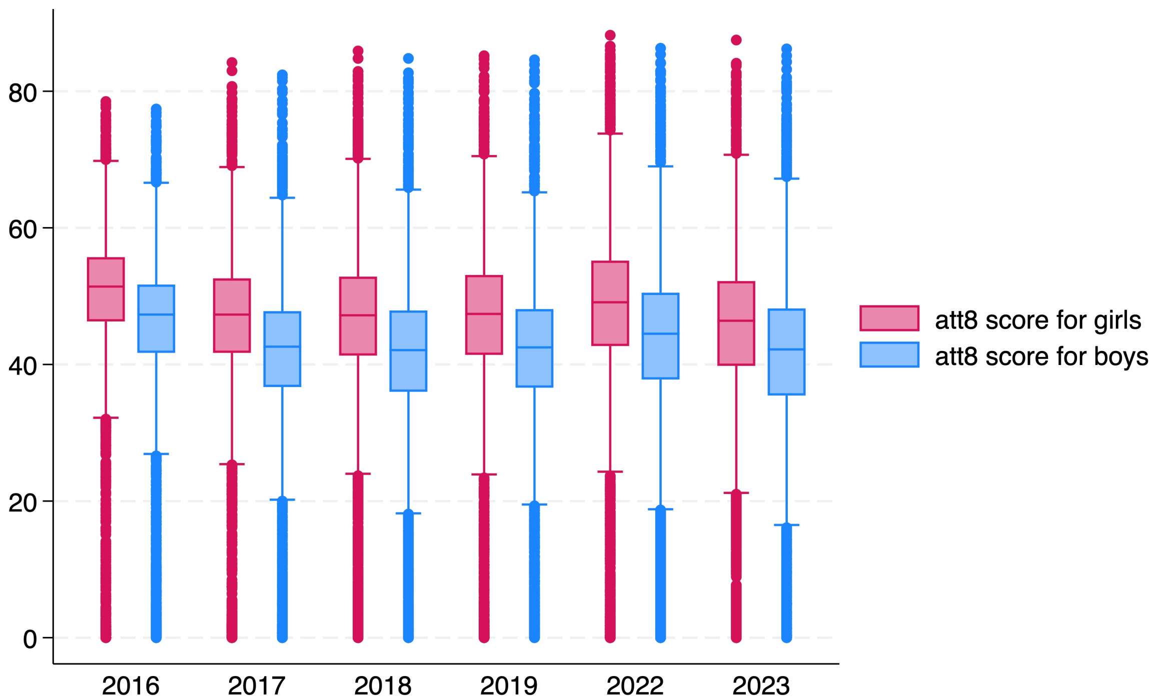


Figure 3: Educational Gender Gap - Median Incidence Rate 2023

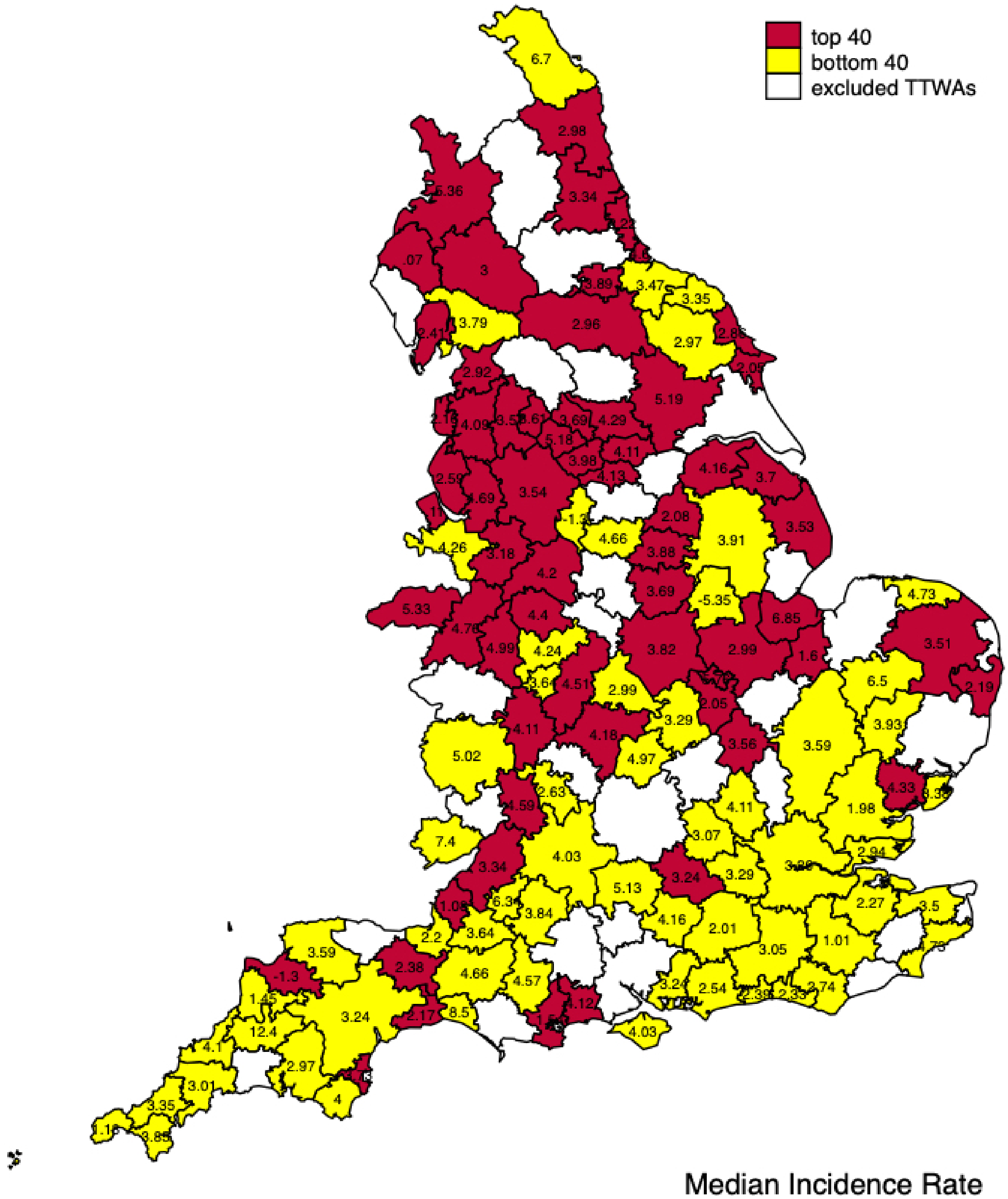


Figure 4: Educational Gender Gap - Standard Deviation Incidence Rate 2023

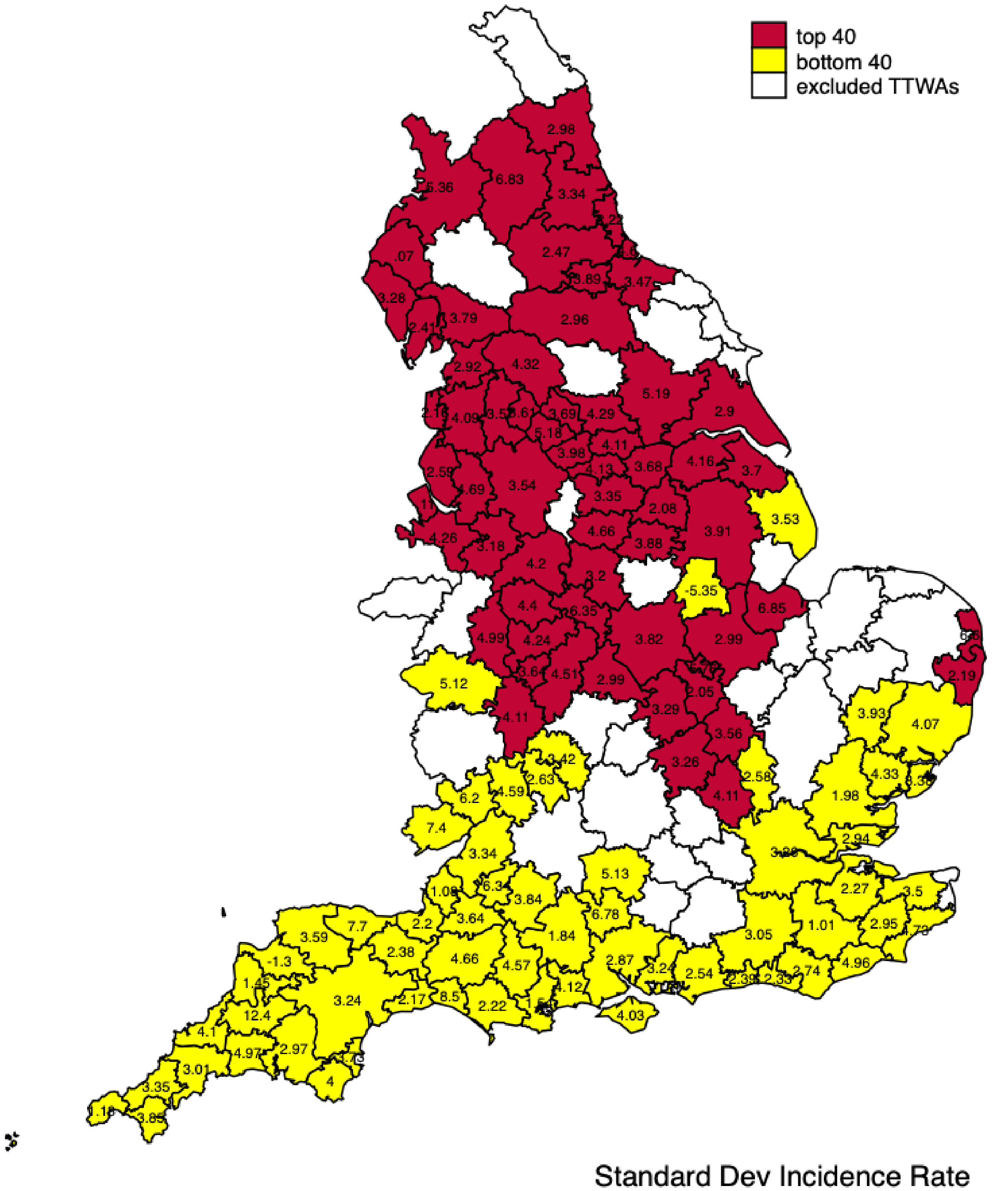


Figure 5: Education Gender Gap - Median Incidence Rate Top 40 vs Bottom 40

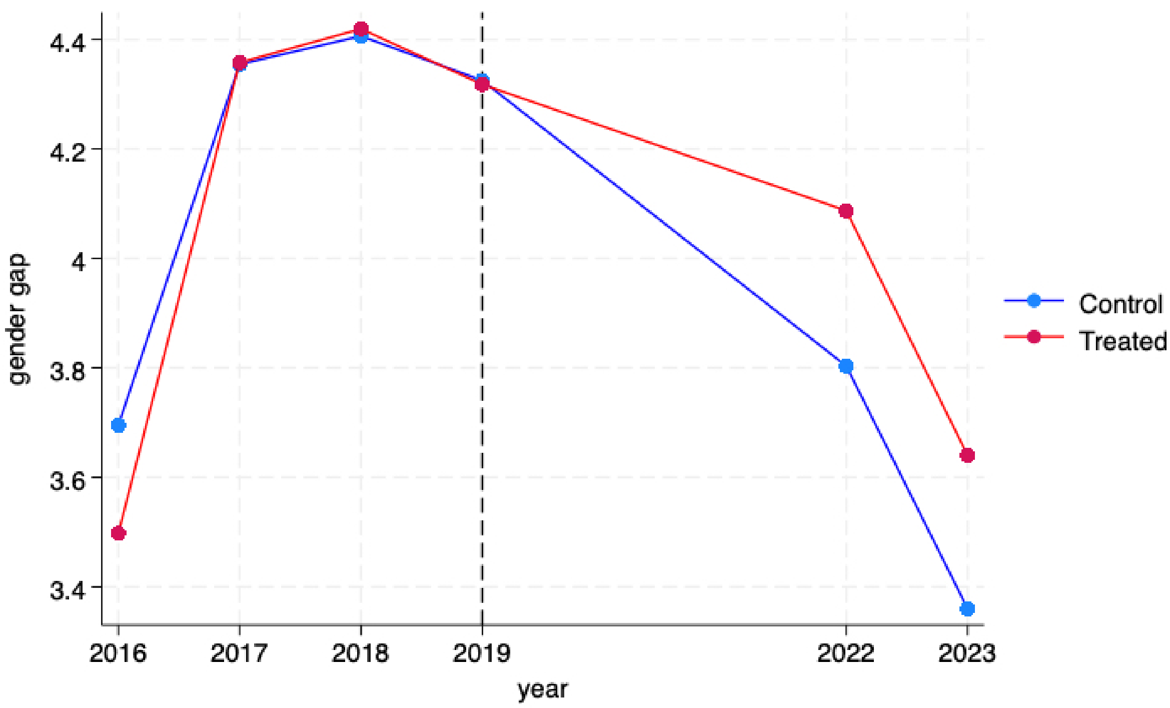


Figure 6: Education Gender Gap - Std. Dev. Incidence Rate Top 40 vs Bottom 40

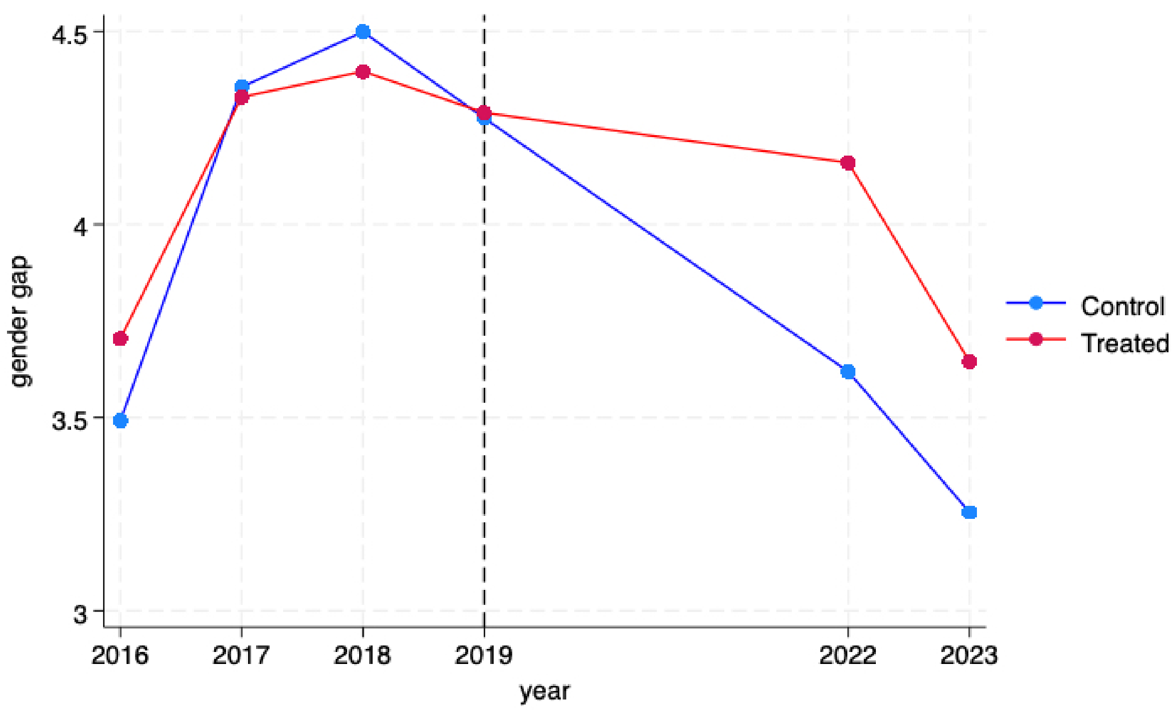


Figure A.1: Balancing test Median Incidence Rate

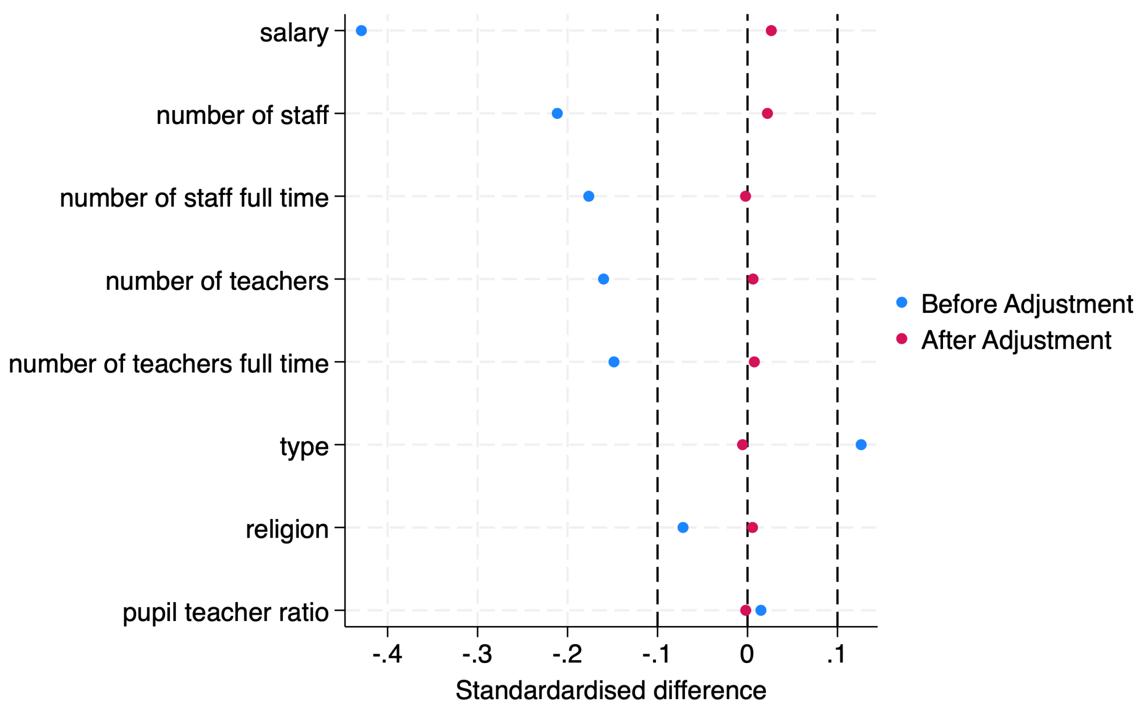
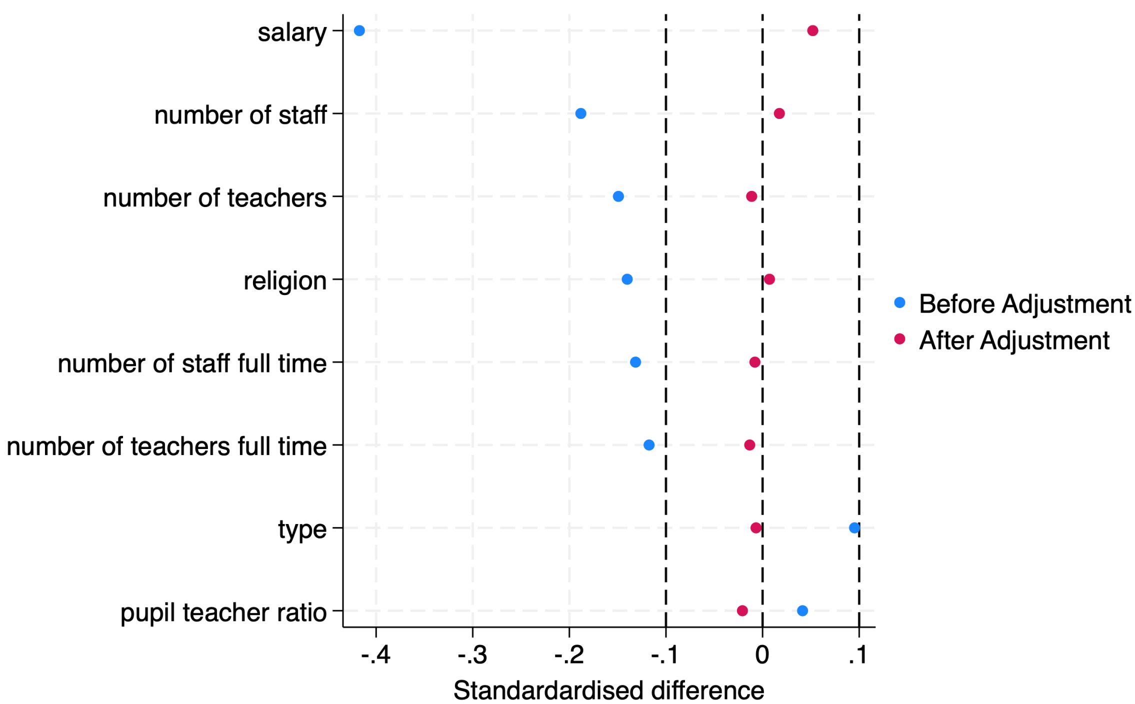


Figure A.2: Balancing test Std Incidence Rate



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