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Teacher turnover: Effects, mechanisms and organisational responses

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ABSTRACT

This paper contributes to the understanding of the causal relationship between teacher turnover and student performance. We extend this research by examining the mechanisms through which turnover affects student learning, and by providing evidence on how schools respond to mitigate the disruptive effects of turnover. Using administrative data covering all state-school, age-16 students and their teachers in England, we find that a higher teacher entry rate has a small but significant negative effect on students' final qualifications from compulsory-age schooling. This is the first study to document that the lack of school-specific human capital in incoming teachers is the main mechanism through which turnover disrupts student performance. We also find evidence that schools mitigate the effects of turnover by assigning new teachers away from high-risk student grades.

1. Introduction

Recent research has established that teachers matter for student achievements (Rivkin et al. 2005, Rothstein 2010, Chetty et al. 2014a, Chetty et al. 2014b, etc.). On the basis of this evidence, policy in the US has, sometimes controversially, moved towards hiring and firing teachers on the basis of measurable impacts on student test scores (see for example, discussion in Hanushek 2009, Thomsen 2014, Rothstein 2015, Adnot et al. 2017). Teacher turnover has potential benefits (e.g. James and Wyckoff 2020) because it is the mechanism by which teachers gain a variety of experience, new ideas and talents are brought into schools, and productive teacher-school matches are formed. However, there are also potential costs for students and schools when teachers move: leavers take school-specific knowledge and experience with them, new arrivals may need extra training, they take time to assimilate and gain much needed school-specific human capital, and there are also administrative costs imposed by turnover. The overall presumption amongst policymakers is that teacher turnover has, on average, adverse impacts on student performance. Turnover of teachers is also a perennial concern for parents, particularly when it occurs during the period when students are studying for important exams. However, despite the popular importance of this issue, there are relatively very few quality studies that investigate it empirically, the recent exceptions being: Ronfeldt et al. (2013), Hanushek et al. (2016), Atteberry et al. (2017). There are even fewer studies that investigate the potential channels through which turnover may be disruptive or examine organisational responses to mitigate potential negative effects of turnover. The lack of quality data has made the task of investigating turnover and performance in education, and more generally in the public sector, challenging.

Our analysis of teacher turnover is based on a unique dataset that links the teacher workforce in England to students' achievement records, by school and teaching subject categories, over five cohorts. Using these data, we investigate the effects of teacher entry into schools on the final qualifications of students in the subjects taught by those teachers. The paper contributes to the literature in a number of ways: we improve on the rather limited existing international evidence on the causal impact of teacher turnover, investigate potential mechanisms through which turnover can affect student performance, and provide evidence on how schools respond to mitigate the disruption effects of turnover.

Our first key finding is that students experiencing high teacher turnover do less well in their end-of-school exams. The effects are small, though non-negligible relative to other factors that have been found to affect student achievement. A 10 percentage points increase in teacher annual entry rate reduces student point scores in their GCSE exam (the standardized test at the end of secondary school) by around 0.5% of one standard deviation. Hence, a standard deviation change in entry rate (14%) leads to a standardised effect size of 0.8% of a standard deviation. This result is similar to that found in studies of teacher turnover in the US (e.g. Ronfeldt et al. 2013, Hanushek et al. 2016). Students in the middle of the ability distribution, proxied by primary school grades,

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are the ones most affected by turnover.[1] Examining potential mechanisms through which turnover affects achievement, we show that it is new teachers' lack of school-specific human capital that matters. General teaching experience does not play a role (in contrast to the findings in Hanushek et al. 2016). Other channels, such as changes in teacher quality, or other teacher characteristics, do not seem to play a role either. We also find that schools do respond to mitigate the negative effects of turnover: new teachers, particularly if they are new to the profession, are less likely to teach in high stakes grades. Our main estimates are, thus, a lower bound on the causal impacts of randomly assigning new teachers to students.[2]

The rest of the paper is structured as follows: the next section explains how our paper contributes to the literature on teacher mobility; Section 3 outlines our empirical strategy; Section 4 describes the education institutional setting in the UK and the dataset; Section 5 presents our main regression results, with Section 5.2 investigating the robustness of the analysis; Section 5.3 presents results on the potential channels that drive the negative impact of turnover and examines the actions schools take to mitigate these disruptive effects; Section 6 concludes.

2. Contribution relative to previous literature

Identifying the causal impact of teacher turnover is a difficult task. The main threat to a causal interpretation of the association between teacher entry rates and student performance is, of course, the self-selection or assignment of incoming teachers to student groups that are already lower or higher performing. To address this concern, we focus on the 'intent to treat' effect of teacher entry into subject groups, across all grades in a school in a given year, on the final school qualifications of students taking their exams in that subject in that year, while controlling for time varying school and subject specific shocks in a fixed effects regression design. There is an advantage of this approach, over, say comparing the performance of students in a year when they are allocated a new teacher with those who are not (Atteberry et al. 2017), or comparing the performance of students experiencing different rates of teacher entry in specific grades (Ronfeldt et al. 2013). The advantage is that it is hard to reallocate specialised secondary school teachers across subjects, mitigating concerns about selective allocation of new teachers to lower or higher performing students or student groups within a school. The improvement over using a single subject (Hanushek et al. 2016), is that we can control more effectively for school-by-year shocks using fixed effects estimation. Thus, our regression methods identify the causal impacts from the variation in entry rates in school-subject year groups (akin to school departments), conditional on combinations of fixed effects at school-by-year, school-by-subject, subject-by-year level, and finally, fixed effects at student level. The identifying assumption is that turnover between subjects within schools, or over time in school-by-subject groups is likely driven by random shocks, or by exits of teachers based on personal preferences, rather than any factors directly linked to poor student performance. An array of robustness checks strongly supports our findings: we demonstrate through a range of placebo, balancing, and other tests that we can treat turnover as random, conditional on these fixed effects.

A further advantage of our work over existing studies that analyse the effects of grade-specific variation in turnover is that, in these studies, students move between grades, typically experiencing a change in teachers every year, regardless of levels of turnover. Therefore, any estimates of turnover based on this type of design will omit effects due to disruption in the continuity of teaching experienced by students, which appears to be playing an important role, as shown in Henry and Redding (2020). Our study, in contrast, looks at turnover in subject groups during a two-year period where students are preparing for their crucial end of school exams, and where disruption is often thought to be particularly important. Usually, students are taught by the same teachers over this period.

The second important contribution of our study is to look at various potential mechanisms through which teacher turnover can affect student learning. A likely reason why entry of teachers affects student achievement is that incoming teachers lack specific knowledge about the school and its students i.e. they lack school-specific human capital. But these teachers may also lack general teaching experience if they are new to teaching, i.e. industry specific human capital, or lack general experience in the labour market. We investigate these channels by comparing the effects from entry of experienced and less experienced teachers (measured by years of teaching experience), and by comparing the effects of length of school tenure, age and experience amongst teaching staff.[3] Although the importance of general and specific forms of human capital has been examined widely in labour economics since the seminal work of Becker (1962), we have little evidence in relation to teaching. An exception is Ost (2014) who finds that grade-specific and general human capital do matter for teacher productivity. Like Ost (2014), our data set linking student performance to the characteristics of their teachers provides an opportunity to investigate these questions with direct measures of teachers' success in improving student achievement. These metrics are better than wages for measuring teacher productivity, because wages in the state-sector teaching professions - like those in the public sector generally - are carefully regulated. We also provide important insights on some other potential channels that might drive the disruptive impact of turnover such as teacher quality and workload.

To examine how schools respond to mitigate the impacts of turnover, we use information on the grade allocation of teachers to show to what extent schools/departments assign incoming teachers away from the critical final year of compulsory schooling (Year 11). If schools take direct actions to mitigate the disruption effect of turnover, then our 'intent to treat' estimates based on school-subject-year turnover may understate the impacts of teacher entry, if new teachers are assigned to students in grades other than that for which we measure student outcomes (i.e. there is non-compliance with the treatment). This in itself is very important as it sheds light on the extent to which re-organisation may lead to underestimation of the impact of many types of interventions or shocks in schools, or more widely in the public sector. This is a pervasive concern throughout public policy evaluation as it implies that estimates of policy interventions on school performance, or other public sector institutions, might be lower than what policy makers and researchers might expect unless they allow for this kind of organizational re-adjustment.[4]

3. Empirical strategy

3.1. Estimating the causal effects of turnover

Our first aim is to estimate the average causal impact that teacher turnover has on the academic achievement of their students. Conceptually, the idea is to understand the impact of randomly increasing the rate at which teachers enter or leave a school, holding other characteristics of the workforce, school, and student body, constant.

There are several basic empirical issues we face: firstly, there are various ways to define and measure turnover. In line with previous work on

[1] This effect is smaller than the effect of turnover in other dimensions of the educational system that have been investigated such as the externalities from the turnover of students in schools (Gibbons and Telhaj 2011; Hanushek et al. 2004) and slightly larger than the effects of turnover of students in neighbourhoods (Gibbons et al. 2017).

[2] However, further analysis using information on the grade in which a teacher teaches suggests the downward bias is not large.

[3] We explain in detail how we make use of these measures later.

[4] Our research also adds to a broader literature on teacher turnover, most of which looks into the factors that cause teachers to enter and leave schools and investigating the consequences of sorting for the composition of the teaching workforce. (e.g. Allen et al. 2018; Elacqua et al. 2019; Ost and Schiman 2015; Hanushek and Rivkin 2010; Ingersoll 2001; Dolton and Newson 2003).

student and teacher mobility (Hanushek et al. 2004, Gibbons and Telhaj 2011, Ronfeldt et al. 2013, Hanushek et al. 2016), we focus on the entry rate - in our case, the share of new teachers in a school-subject-year group - to represent turnover.[5] The reasons for focusing on entry are elaborated at the end of this section. Secondly, there are obvious potential endogeneity problems. Entry rates (and other measures of turnover) will be, in part, determined by the characteristics of the school, its students and the characteristics of stock of teachers, since these factors will affect the exit rate (and hence the number of vacancies), and how attractive a school is to potential applicants. Moreover, sorting implies that teachers entering a school, the teachers in the stock, and the teachers leaving a school are not likely to be identical, so entry and exit rates can change the composition of the school workforce. All of these factors may have direct effects on achievement and are only partially observed. We address these endogeneity issues using a fixed effects regression design with a rich set of school and teacher characteristics, in which we regress student exam outcomes in the final year of compulsory schooling (Year 11, age 16) on teacher entry rates at school-by-subject-by-year level i.e. measuring the entry rate for teachers in a school, teaching a particular subject, in a given year, for all grades. Our preferred specification, thus, is:

$$\widetilde{Score}_{ijst} = \alpha + \beta mob_{jst} + x'_{it}\gamma + z'_{jst}\lambda + \eta_{js} + \zeta_{jt} + \theta_{st} + \varepsilon_{ijst} \quad (1)$$

Where $\widetilde{Score}_{ijst}$ is an index of individual i achievement in age-16 qualifications in school j, subject s, and year t; mob_{jst} is the entry rate in each school-subject-year group (defined later in the section where we describe the data), and β, our coefficient of interest, is the expected change in student test scores associated with an increase in turnover in the year in which a student takes his/her age-16 exams; x_i is a vector of student characteristics which includes gender, an indicator of economic background (eligibility for free school meals), prior achievement (primary school test scores, KS2), and ethnicity; and z_{jst} are school/department characteristics. These include school characteristics in terms of the overall student composition for the school (gender, free school meal eligibility, and ethnicity of students), but also characteristics of the teaching workforce such as the pupil-teacher ratio, the number of teachers in the current and previous year, share of women, average age, and experience among current teachers. This rich set of control variables allows us to net out time-varying confounders correlated with turnover, and to account for the effects of turnover-related sorting on the composition of the workforce. Finally, we control for a wide range of fixed effects which allow us to partial out permanent unobserved differences across: school-subject groups (η_{js}); school-by-year (ζ_{jt}); and subject-by-year (θ_{st}).[6] We cluster standard errors at school level to allow for serial correlation in unobservables over time, and heteroscedasticity at school level. Summing up, identification in our preferred regression specification comes from year-to-year changes in entry rates within school-subject categories, partialling out school-by-year and subject-by-year fixed effects.

In a variation to this design, we run a specification with student fixed effects, so identification in this case comes, purely, from variation in entry rates across subjects experienced by a student in a given school and year. The resulting equation is:

$$\widetilde{Score}_{ijst} = \alpha + \beta mob_{jst} + x'_{it}\gamma + z'_{jst}\lambda + \eta_{js} + \xi_i + \varepsilon_{ijst} \quad (2)$$

In other words, we examine whether students who face higher teacher mobility in, say, mathematics than in English have lower academic performance in mathematics rather than in English.[7] The key difference between the strategies in Eqs. (1) and (2) is that the latter allows to account for unobserved student ability, and it provides a useful robustness test for our main results.

The identifying assumption underlying these strategies is that teacher entry into a school-subject-year group is determined by the choices of teachers outside the school with only limited information about the characteristics of the students and other staff in a specific school-subject-year group. This is especially true because teachers almost always join at the beginning of the school year, when they would have little information about the future performance of the student-subject group they are joining. As we discuss in Section 4, information on age-16 qualifications is publicly available so teachers would have annual information about the school and how students in previous cohorts had performed. However, these performance tables do not have information about the current cohort new entrants will be required to teach when they join the new school, nor about performance in specific subjects. Teachers' choices of school are, therefore, largely informed by persistent school level factors (and job availability), so school-subject-year specific entry rates can be rendered plausibly exogenous by appropriate conditioning on fixed effects and observable school and department characteristics (as we demonstrate, through various robustness and placebo checks).

The above considerations suggest that entry rates are better measures of teacher turnover than exit rates. End-of-year exit rates from a school-subject-year group are determined by the choices of teachers inside the school, with good information about the cohort of students they have been teaching. General school cohort quality shocks are taken care of by our school-year fixed effects. However, it is likely that subject-year exit rates, either during year t or $t-1$ are related to unobserved (to us) student-teacher match quality and, hence, to student attainment in year t. A teacher exit in a specific subject within a school-year group could signal adverse teacher-student match quality that is unobserved to us but observed by the incumbent teacher. The exit of a poorly matched teacher will, in turn, induce the entry of another teacher. However, there is no reason to believe that this incoming teacher will share the same characteristics that make the outgoing teacher a poor match for the current student cohort. The entry rate is therefore less likely to be correlated with unobserved student cohort characteristics than the exit rate.

One related situation which might raise concerns is if a shock to a department in year $t-1$ leads to exits in year $t-1$, consequent entry in year t, and poor performance in year t. In this case, entry rates in year t are negatively correlated with performance in year t, through the exit rates in $t-1$. Given a shock to a department in year $t-1$ would likely cause a fall in performance in year $t-1$, we would therefore also expect entry rates in year t correlated with performance in year $t-1$. However, we will show through a 'placebo' test that this is not the case. In any case, as we show in Table A5, exit rates do not have a strong effect on performance, conditional on entry rates.

3.2. Teaching reorganisation

The last part of our empirical analysis looks at whether schools reorganise teaching in response to teacher turnover, to minimise the effect it has on student learning and final qualifications. The GCSE exam results mark the end of compulsory schooling in England, thus represent a crucial test not only from the students' and parents' perspective, but also for schools. Secondary schools' national performance ranking is based on GCSE results and is widely published, so there is pressure on managers for students in their school to do well on these tests. They, therefore, have incentives to take action to improve students' performance, one of which may be to limit the negative impact of student exposure to new teachers.[8]

[5] Our design, based on year-to-year shocks to turnover, necessitates short term turnover indicators, rather than long term measures of turnover, churn and instability discussed in Holme et al. (2018).

[6] We follow the numerical procedure of Correia (2014) as implemented in the command reghdfe in Stata.

[7] This between-subject, within-student design has featured in several previous papers (e.g. Dee 2005, Slater et al. 2012, Nicoletti and Rabe 2018, etc).

[8] This is in line with evidence from other settings where schools change teacher allocation in response to high stakes exams, such as Elacqua et al. (2016).

Our analysis explores how schools respond to the entry of new teachers by looking at the distribution of teaching workload and allocation of teachers in different grades. We investigate the teaching allocation for new teachers, and how incumbent teachers are affected by incoming teachers. To perform this analysis, we build a teacher-year level panel dataset for the 2011–2013 period, and estimate the following equation:

$$HoursYG11_{ijst} = \alpha + \beta NewEntrant_{ijst} + X_{it}\gamma + Z_{jst}\delta + \eta_{js} + \zeta_{jt} + \theta_{st} + \varepsilon_{ijst} \tag{3}$$

where the dependent variable is the number of hours per week taught by teacher i in Year Group 11; $NewEntrant_{ijst}$ is a dummy taking the value of one if teacher i entered school j, department s in the current year t; X_{it} includes a set of individual characteristics, and Z_{jst} is a set of department level controls. Individual level controls include: an age squared polynomial, a gender dummy, and a set of experience dummies; while department level controls include: number of teachers in the department, number of teachers in the school, and the pupil-teacher ratio. We also include fixed effects at the school-subject (η_{js}), school-year (ζ_{jt}), and subject-year level (θ_{st}). The coefficient β tells us how much incoming teachers teach in Year 11 with respect to incumbent teachers.

We also look at the effect of entry on incumbent teacher workload, by estimating a variation of Eq. (3) in which we restrict the sample to incumbent teachers, and replace $NewEntrant_{ijst}$ with the number of new teachers in the school-subject-year group.

4. Institutional setting and data

Compulsory education in state schools[9] in England is organised into five 'Key Stages'. The Primary phase, from ages 4–11, spans the Foundation Stage to Key Stage 2 (Years 1–6, where Years are the English terminology for Grades). At the end of Key Stage 2, when pupils are aged 10/11, children leave the Primary phase, and go on to Secondary school from ages 11–16. This is divided in Key Stage 3 (Years 7–9) and Key Stage 4 (Year 10–11). At the end of each Key Stage, prior to age-16, pupils are assessed on the basis of standard national tests (though the Key Stage 3 test was discontinued in 2008).

We consider secondary school students in their last year of compulsory schooling (Year 11), and teachers in state-maintained secondary schools in England. During Key Stage 4 (comprising Years 10 and 11), students study a range of subjects, which are assessed in their final examination. The most common qualification is the General Certificate of Secondary Education (GCSE). We focus on these GCSE educational outcomes of students by subject. The GCSE is a particularly salient exam in the UK system: previous research has shown that performing poorly in this exam has long lasting consequences on students' career (Machin et al. 2020), both in terms of further education and in early job outcomes. Students are expected to take between four and nine subjects, with five being a common choice. They choose their subjects at the beginning of Year 10, and study them for two years. In some instances, it might be possible for students to switch or drop subjects, but this is not generally allowed, and it often requires discussion with school officials.

GCSE examination is also highly relevant from schools' perspective. Since 1994, every year each school exam results are made public by the government through the publication of School Performance Tables,[10] and students' performance is a widespread reason of anxiety for headteachers.[11] Both the curriculum and the exam content are set by external exam boards, which also grade the students' scripts. Exam boards also provide some broad teaching material, but the lesson plan and class details are left to the discretion of the teacher.[12]

The empirical strategy, described in Section 3, requires data on student performance on each subject, and on teachers' career histories. Our main sources are student-level data from the Department for Education's National Pupil Database (NPD), and teacher records from the School Workforce Census (SWC), supplemented with the Database of Teacher Records (DTR). The NPD data contains information on students' socioeconomic characteristics, and attainment scores in the Key Stage national tests. Data on student demographics come from school returns made in January each year. Student GCSE exam point scores (the standardized test at the end of secondary school) at Key Stage 4, our main outcome measure, are taken from the NPD, along with scores for the Key Stage 2 primary school exam as a measure of prior achievement. The NPD also reports information on student characteristics such as age, gender, free school meal eligibility (FSM), and ethnicity, which we also employ for this study.

The School Workforce Census has run since 2010/11 academic year, and is based on returns from schools, providing information on teachers, their qualifications, salaries, contract type, number of hours taught, subjects they teach, and other characteristics. We use SWC data up to 2012/13, and supplement it with information from the DTR to extend the data back to 2008/9. As the GCSE structure was subject to relevant changes over the years after 2013, we restrict our attention to a period ensuring a stable and common framework for the exam. The DTR is used in the administration of the national teachers' pension system, and also provides a range of information on teachers, their salaries, and their qualification. We also employ data from Office for Standards in Education, Children's Services and Skills (OFSTED) on school inspections, which provide information on school quality.

Schools are identified as individual entities that are consistent over time from the 'Edubase' dataset, which holds information on basic school characteristics like school phase, type, and location. Starting from the universe of secondary schools in UK, we exclude independent (private) and special schools (for children with special needs). We construct unique school identifiers with information available on the Edubase database concerning school conversions. Schools formed from the merger of two or more schools, or schools resulting from the division of a school are treated as new schools.

Our data does not permit us to link each teacher individually to each student. However, we are able to link students to teachers by the subjects the student takes in a school at Key Stage 4 (Years 10 and 11), and the subjects a teacher in that school is teaching. The SWC dataset also provides information on the hours taught by teachers in each subject. There are originally 114 original subject codes, which we group in 18 subject groups that are equivalent to teaching school departments: Mathematics; English; Science; History; Modern Foreign Languages; Sports; Biology; Chemistry; Physics; Art; IT; Social Science; Design; Business and Economics; Home Economics; Media and Humanities and Engineering. These groups tend to be rather homogeneous and, although teachers can be assigned to various subjects at once, most of them (about 75%) teach all their hours in a single department, with 20% teaching in two departments. We assign teachers to their main department for the main part of our analysis. In the DTR data this information is unavailable, and we infer their main subject from subjects the teach in the later SWC years, and teachers' degree qualification.[13]

Note that this aggregation at the department level does not imply we are introducing measurement error in terms of the entry rates and other measures of mobility: we are aggregating our explanatory variable, not

[9] State schools in England account for around 93 percent of the population of students.

[10] https://www.gov.uk/school-performance-tables.

[11] See, for example, "Secret headteacher: After Thursday's GCSE results, will I still have a job?"', The Guardian, 08/23/2016.

[12] We do not have access to data on which exam board a school subscribes to.

[13] A comparison of the subject taught and teacher qualification, when both are available, show a high level of concordance (more than 90%), which suggests that this imputation should induce, at most, only a small measurement error. In addition, results are consistent if we restrict the analysis to periods fully covered only by the SWC, as we show in Table A5. This imputation appears sensible, and it does not drive our results. If a teacher does not teach in any department, we assign the department based on the department in which the teacher teaches in the same school in other years.

Table 1
The Impact of Teacher Entry on Standardised Test Scores.

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Entry rate	-0.098***	-0.229***	-0.032***	-0.054***	-0.030***	-0.048***
	(0.015)	(0.018)	(0.008)	(0.010)	(0.010)	(0.011)
Observations	12,699,846	12,699,846	12,699,846	12,699,846	12,699,846	12,699,846
Year FE	Y	Y	Y	Y	Y	Y
Controls	N	Y	N	Y	N	Y
SchoolXSubj FE	N	N	Y	Y	Y	Y
SchoolXYear FE	N	N	Y	Y	N	N
SubjectXYear FE	N	N	Y	Y	N	N
Student FE	N	N	N	N	Y	Y

Note: OLS regressions at student level. The dependent variable is the average standardized test score in the KS4 exam by student, subject, and year. Entry rate is defined as the share of teachers in year t who were not present in the school in year t-1. Controls include teacher, student, and school characteristics. Teacher characteristics include: average age of teacher in the department; average experience; share of female. Student characteristics include: normalized prior test scores; Free School Meal (FSM) eligibility; gender; ethnicity (white/others). School characteristics include: pupil teacher ratio at department-school-year level; proportion of female students in the department; proportion of FSM eligible in the department; proportion of white students in the department; number of teacher in current and past academic year in the department. Standard errors clustered at school level. Level of significance: *** p<0.01, ** p<0.05, * p<0.1.

introducing noise. Aggregation at department level allows us to overcome several issues: it accounts for possible spillovers from within department disruption due to the entry of a new teacher, and it overcomes issues related to selective assignment of teachers to specific students, subjects, or grades. Hence, our estimates will have an 'intention-to-treat' interpretation.

As discussed in Section 3, we use teacher entry rates as the main measure of turnover. Entry rates are constructed on school-by-subject-by-year groups, and also broken down by teacher characteristics (e.g. gender and age). We also determine whether a teacher is moving from one school to another, or appears as a new entrant into the system, or whether they are leaving the system (based on whether we observed them in previous or subsequent years).[14] The entry rate in a school-subject-year group is computed as the share of teachers present in the school-subject group during the current academic year (t), who were not present in that school-subject group in the previous year ($t-1$). In part of our analysis, we also use a refined measure of teacher entry which distinguishes between the entry of new teachers teaching in Year 11, which is the year of students' final qualification exams, and entry in Year 10, the first year of the Key Stage 4 curriculum phase. We do this based on information on hours taught by teachers in these two grades. This allows us to investigate the importance of the timing of teacher entry relative to the timing of student assessments. Although the information on hours taught for each subject is only collected for the later years of the sample for which Census data are available, thus reducing our sample size, it is also very useful in providing insights on the mechanisms through which turnover affects attainment and on how schools respond to mitigate the disruption caused by teacher mobility.

Ultimately, we end up with data on teachers, their characteristics and the turnover variables aggregated to school by subject group by year cells. These school-subject-year variables are then merged with student-level data from the NPD. After cleaning and matching, the final sample spans 5 years, and it covers 18 subject groups, approximately 2,750 schools, and 2,305,500 students, with a total of about 12,700,000 student-subject observations.

Descriptive statistics for the sample used for student level regressions are presented in Appendix A, Table A1. Annual entry rates are slightly higher (14%) than exit rates (10%).[15] Around 32% of the entry is due to teachers new to the profession (or entering from outside the English state school system), and the rest due to movement between schools. As table shows, there are more female teachers (around 62%) than male teachers, teachers' average age is 40 years, and their average tenure in the same school is 7 years. In terms of student characteristics, half of the students in the sample are female, about 80% are white, and 13% come from an economically disadvantaged background and are eligible for free school meals. Table A2 reports, instead, summary statistics for regressions at teacher level. These regressions exploit only data from 2011 to 2013, for which hours taught by teachers are available. Teachers are, on average, 40 years of age and more than half of them are women. They spent about 10.6 years in the teaching profession.[16] Teachers spend, on average, 15 hours teaching per week with about 2.8 hours in Year Group 11. The share of new teachers per year is close to 15%.

5. Results

5.1. Turnover and performance: main regressions

To begin the empirical analysis of teacher turnover on students' KS4 (Year 11) attainment, Table 1 reports the coefficients and standard errors from baseline regression estimates of Eqs. (1) and (2), with overall entry rates as turnover measure. As we move from left to right across the table, the specifications control for fixed effects at finer levels of granularity: Column 1 controlling only for year dummies and Column 2 adding student, subject and school time-varying controls; Columns 3 and 4 controlling for subject-school fixed effects; and Columns 5 and 6 controlling for student fixed effects. In order to test for the relevance of compositional changes and control for other possible confounding factors, we also estimate our fixed effect specifications with and without additional time-varying control variables, which are included in Columns 2, 4, and 6. Estimates are stable to the addition of control variables in specifications that control for school-subject specific unobservables, time varying school and subject specific shocks, or student specific unobservables.

In all specifications in Table 1, higher entry rates are associated with lower KS4 scores. With no control variables or fixed effects in Column

[14] To simplify our methodology and decrease the effect of possible misreporting, we do not consider entry from the profession if the teacher is not observed in the data for a few years but eventually is reported again.

[15] Exit is defined as the share of teachers who were present in the school in year ($t-1$) and are no longer present in year (t).

[16] Experience is censored at 21 years in the profession as we can access data at most up to 1993.

1, the coefficient of 0.10 implies that a 10 percentage-point increase in entry rate (about 60% of a standard deviation) is associated with a 1% of one standard deviation reduction in KS4 scores. When we add in controls for observable student, teacher and school attributes in Column 2, the coefficient becomes larger in absolute value. It is the inclusion of variables describing the existing teacher stock that leads to this change. However, when we control for unobserved confounders with fixed effects at school-by-subject level in Column 3 and Column 4, the coefficient is halved, to -0.05 (Column 4, which includes controls). The magnitude remains relatively stable with the inclusion of student fixed effects presented in Column 5 and Column 6. Here identification comes from variation across subjects taken by each student. Note that school-by-year fixed effects are not identified within student and so are omitted.

Taken together, the estimates in Table 1 suggest that an increase in the entry rate of 10 percentage points reduces attainment by around 0.4–0.5% of one standard deviation, with our preferred estimate in Column 4 at 0.5% of one standard deviation. This implies that a standard deviation increase in entry rates (16.7 percentage points) in the year of preparation for end of school qualifications reduces attainment by around 0.8% of a standard deviation. This is not a huge effect, but it is non-negligible compared to many school interventions and the magnitude is similar to the effects of other turnover-related externalities in schools. The magnitude is smaller than the effect of turnover of students in schools (Gibbons and Telhaj 2011; Hanushek et al. 2004), and slightly larger than the effects of turnover of students in neighbourhoods (Gibbons et al. 2017). In the remainder of the empirical analysis, we focus on the most conservative estimates based on year to year shocks to mobility in the specification of Column 4.

5.2. *Turnover and performance: robustness checks*

The estimates of our effect of interest in Table 1 appeared robust to the inclusion of a wide range of controls and fixed effects. However, it is still possible that some unobserved student, department/school pre-existing trends or time varying contemporaneous (to entry) shocks are driving our results. To test for this, Tables 2 and A3 present the results of a number of checks related to these threats to identification, including placebo' estimations. As a point of comparison, Table 2 Column 1 reports the coefficient for our preferred baseline specification with school-by-subject, school-by-year, and subject-by-year fixed effects from Table 1, Column 4.

To check for unobserved trends in the school or department, Table 2 Column 2 includes one-year ($t+1$) and two-year ($t+2$) leads of the measure of entry. In the presence of unobserved trends in performance and turnover, we would expect to see an association between current (t) achievement and turnover in the future. As the regression results show, the inclusion of this measure of future entry does not have any impact on students' attainment in the current year, and our coefficient of interest (entry in period t) is largely unaffected. Column 3 further explores this temporal pattern, by looking at the performance of students in departments who experienced turnover in the past years, ($t-1$) and ($t-2$). Here too, we find that past teacher turnover measures do not have an impact on students' current attainment, and our main coefficient of interest is, again, unaffected by the inclusion of lagged values of turnover. This finding also suggests that the detrimental effects of turnover are short lived, which makes it unlikely that they are driven by permanent changes in teacher characteristics or quality. The short term impact of turnover could also be driven by high turnover of low quality teachers, who might be more likely to leave the school once their quality is revealed. However, below we show that our results are robust to selective attrition.

Next, Column 4 controls for school-subject group specific linear trends to partial out trends in mobility and performance in these groups. Again, this very demanding specification makes little difference to the estimates of the effects of entry rates. In Column 5, we implement another 'placebo' test for unobserved school shocks by looking at the effect of entry by teachers into GCSE subject areas that were not taken by the student in the school in the same year. Reassuringly, entry into subjects not studied by a student has no effect on their achievement. As a further check for trends, Column 6 includes lagged school-by-subject KS4/GCSE achievement. Doing so, again, makes little difference to the magnitude or statistical significance of the effect of teacher entry.

Another potential concern is that less effective teachers tend to move schools more often, so when entry rates are high, there are more low quality teachers in the department. Column 3 in Table 2, discussed above, implies that the effects of entry in a given year are not persistent, suggesting it is unlikely that unobserved teacher quality lies behind the effect of entry rates on achievement (assuming teachers stay in the same school more than one year). As a further check, in Table 2 Column 7, we decompose the entry rate at time t based on what happens to the incoming teachers in time ($t+1$), after their performance is revealed in their first teaching year in the school. If poor quality teachers drive the results on entry rates, we would expect to see entry of those retained to teach in the critical final exam grade (Year 11) at t + 1 being less disruptive than those moved to a different grade, or leaving the school. However, the results in Column 7 show that the coefficients on entry across these different groups are similar in magnitude, suggesting that unobserved teacher quality differences do not explain the effects of entry rates on achievement.

Our main measure of teacher entry captures entry into school departments as a whole, rather than into the year groups (10 and 11) specifically relevant for KS4 study. This avoids endogeneity issues posed by strategic selection of teachers into 'low-risk' year groups, but masks potentially informative patterns related to timing of entry. Column 8 of Table 2 uses a more refined measure of turnover (discussed in Section 4) in which we define entry rates by the share of incoming teachers who teach in different year groups (Year 10 or Year 11). We report three different entry effects based on this grade entry rate definition: the effects of new teachers who teach only in Year 11 (Entry rate: teaching YG11) on the current Year 11 cohort's GCSE results; the effects of the new teachers who teach in both Year 10 and Year 11 (Entry rate: teaching YG10 and YG11) on the current Year 11 cohort's GCSE results; and the effects of new teachers who teach only in Year 10 (Entry rate: teaching YG10) on the current Year 11 cohort's GCSE results. As results of Column 8 show,[17] what matters in these specifications is entry rates in Year 11, when students are in their final examination year: the coefficient is negative and statistically significant. The zero-insignificant coefficient on Year 10 entry rates reinforces the findings of other 'placebo' tests presented in this table: new teachers entering in a given academic year have no effect on GCSE results if they are not actually teaching the students taking these exams. This result also suggests that there is little loss from using department-wide entry rates, and, if anything, our main results are overly conservative.[18]

A correlation between entry rates and student achievement might also arise because of a correlation between entry and student characteristics, either because of selection of new teachers into school-subject-year groups according to student quality, or because students select out of school-subject-year groups with new teachers e.g. by changing subjects. To test for this, we estimate 'balancing' regressions in which we regress the entry rate on mean student characteristics and number of students in school-subject-year cells. Once we account for school-

[17] Note that the sample for the last two columns is restricted for years in which we have direct information on hours taught by teachers so the sample includes only years between 2011 and 2013.

[18] We also present our main results by directly using the share of hours taught by new teachers in Year 11 in Table A4, and results are comparable to our main estimates. Although the share of hours taught by new teachers is likely to be endogenous to school choices, the use of this measure allows us to relate more directly the level of interaction between new teachers and students. In this context, the similarity of the results with these two different measures strengthens the support of our main finding on the magnitude of our effect of interest.

Table 2
The Impact of Teacher Entry on Standardised Test Scores: Robustness Tests.

	(1) Score	(2) Leads	(3) Lags	(4) Department Trends	(5) Other Dep: not seated	(6) Past Quality	(7) Mobility	(8) Year Groups
Entry rate	-0.054***	-0.039***	-0.076***	-0.049***	-0.055***	-0.047***		
	(0.010)	(0.014)	(0.015)	(0.010)	(0.010)	(0.010)		
Entry Rate (t+1)		-0.008						
		(0.015)						
Entry Rate (t+2)		-0.012						
		(0.013)						
Entry Rate (t-1)			-0.016					
			(0.015)					
Entry Rate (t-2)			-0.017					
			(0.012)					
Entry rate: subjected not seated					-0.006			
					(0.009)			
Past Score						0.217***		
						(0.007)		
Entry Rate: Teach Year 11 in year (t) and exit in (t+1)							-0.071**	
							(0.036)	
Entry Rate: Teach Year 11 in year (t) and change Grade in (t+1)							-0.066	
							(0.047)	
Entry Rate: Teach Year 11 in year (t) and same Grade in (t+1)							-0.054***	
							(0.017)	
Entry rate: teaching YG11								-0.086**
								(0.038)
Entry rate: teaching YG10								-0.024
								(0.027)
Entry rate: teaching YG10 and YG11								-0.056***
								(0.016)
Observations	12,699,846	7,465,581	7,147,922	12,699,846	12,698,725	12,280,190	6,511,047	7,447,428
R-squared	0.465	0.514	0.472	0.512	0.465	0.467	0.475	0.476
Year FE	Y	Y	Y	Y	Y	Y	N	Y
Controls	Y	Y	Y	Y	Y	Y	Y	Y
SchoolXSubj FE	Y	Y	Y	Y	Y	Y	Y	Y
SchoolXYear FE	Y	Y	Y	Y	Y	Y	Y	Y
SubjectXYear FE	Y	Y	Y	Y	Y	Y	Y	Y
Student FE	N	N	N	N	N	N	N	N
SchoolXSubject Trends	N	N	N	Y	N	N	N	N

Note: OLS regressions at student level. The dependent variable is the average standardized test score in the KS4 exam by student, subject, and year. Entry rate is defined as the share of teachers in year t who were not present in the school in year t-1. Controls include teacher, student, and school characteristics. Teacher characteristics include: average age of teacher in the department; average experience; share of female. Student characteristics include: normalized prior test scores; Free School Meal (FSM) eligibility; gender; ethnicity (white/others). School characteristics include: pupil teacher ratio at department-school-year level; proportion of female students in the department; proportion of FSM eligible in the department; proportion of white students in the department; number of teacher in current and past academic year in the department. Department X Subject trends are linear trends at school and department level. Column 2 considers entry rate for future years (leads of entry rate; t + 1 and t + 2). Column 3 considers entry rate for past years (lags of entry rate; t-1 and t-2). Column 4 includes school by department linear time trends. Column 5 provides a placebo test with teacher entry rate for subjects not seated by the student. Column 6 includes the average grade for KS4 for students in the same School and Department in the previous year (t-1). Column 7 decomposes the entry rate for new teachers who teach Year 11 according to what they do in the following year (t + 1). We divide the entry rate in three groups: those who enter the school in year (t) and are moved to another Year in year (t + 1); those who enter the school in year (t) and remain in the same Year in year (t + 1); those who enter the school in year (t) and leave the school in the following year (t + 1). Finally, Column 8 decomposes entry rate by the Year in which new entrants are teaching. We consider three groups of teachers: those who teach only in Year 11; those who only teach in Year 10; those who teach in both Year 10 and Year 11. The sample includes only years for which the number of hours taught is reported (2011–2013). Standard errors clustered at school level. Level of significance: *** p<0.01, ** p<0.05, * p<0.1.

by-subject, subject-by-year and school-by-year fixed effects (as in our main regressions), we find no statistical nor quantitatively relevant relationship between entry and the characteristics of students taking the GCSE exam in the current academic year. Results,reported in Table A3, demonstrate that the entry rates are uncorrelated with these student characteristics, either through teacher entry, or because students are selectively sorting across subjects based on entry.

5.3. Turnover and performance: mechanisms

So far, we have shown that teacher turnover reduces student attainment and that the results are robust to a wide range of identification checks. In this section we shed light on the potential mechanisms through which turnover can be detrimental for student performance.

We employ information from the school workforce census such as hours taught by teachers, date they join the school, information about departments they join/leave and whether/what administrative roles they play, plus the information we have on students and schools, to examine potential channels through which turnover may be disruptive for students.

5.3.1. General, industry and school-specific human capital

Hanushek et al. (2016) suggest that a lack of teaching experience by entrants (and loss of grade-specific experience through re-allocation of teachers within schools) is the main cause of disruption from turnover. However, incoming teachers also have zero tenure, implying no school-specific experience and may also have less general labour market experience, so there are other potential underlying causes than simply lack

Table 3
The Impact of Teacher Entry on Standardised Test Scores: General and Specific Human Capital.

	(1) Tenure	(2) Entry by Experience	(3) Entry by Origin
Share of Teachers by tenure: <1 year	-0.043**		
	(0.017)		
Share of Teachers by tenure: 1–4 years	0.007		
	(0.015)		
Share of Teachers by tenure: 5–8 years	0.004		
	(0.012)		
Share of Teachers with Experience: <1 year	0.028		
	(0.022)		
Share of Teachers with Experience: 1–4 years	0.016		
	(0.017)		
Share of Teachers with Experience: 5–8 years	-0.009		
	(0.013)		
Age Group 20–29	-0.014		
	(0.020)		
Age Group 30–39	0.010		
	(0.015)		
Age Group 40–49	-0.006		
	(0.013)		
Entry rate by experience: <1 year		-0.039**	
		(0.019)	
Entry rate by experience: 1–4 years		-0.041**	
		(0.021)	
Entry rate by experience: 5–8 years		-0.056**	
		(0.023)	
Entry rate by experience: 9 years or more		-0.070***	
		(0.015)	
Share of Incumbents by experience: 1–4 years		0.007	
		(0.016)	
Share of Incumbents by experience: 5–8 years		-0.011	
		(0.013)	
Entry rate: Other Schools			-0.056***
			(0.0110)
Entry rate: Elsewhere			-0.051***
			(0.0152)
Observations	12,699,846	12,699,846	12,699,846
R-squared	0.465	0.465	0.465
Year FE	N	N	Y
Controls	Y	Y	Y
SchoolXYear FE	Y	Y	Y
SubjectXYear FE	Y	Y	Y
SchoolXSubj FE	Y	Y	Y
Student FE	N	N	N
F test Joint sig. (p-value)		0.000	
F test equality (p-value)		0.529	

Note: OLS regressions at student level. The dependent variable is the average standardized test score in the KS4 exam by student, subject, and year. Entry rate is defined as the share of teachers in year t who were not present in the school in year t-1. Controls include teacher, student, and school characteristics. Teacher characteristics include: average age of teacher in the department; average experience; share of female. Student characteristics include: normalized prior test scores; Free School Meal (FSM) eligibility; gender; ethnicity (white/others). School characteristics include: pupil teacher ratio at department-school-year level; proportion of female students in the department; proportion of FSM eligible in the department; proportion of white students in the department; number of teacher in current and past academic year in the department. Column 1 includes the share of teachers by years of tenure and experience as well as age group categories. Column 2 reports entry rate by experience of teachers and share of incumbent teachers by years of experience. P-Values reported at bottom of the table report show results for an F-test for joint significance of entry rates and for an F-test for equality of coefficients of entry rates by experience. Column 3 decomposes the entry rate by the origin of the incoming teachers depending on whether they come from other schools or outside the profession. Standard errors clustered at school level. Level of significance: *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

of teaching experience. As briefly discussed earlier, the relationship between a teacher and a student is interrupted when a new teacher joins the school and replaces an existing teacher in the student's classroom. It takes time for a new teacher to acquire school-specific human capital (i.e. to adjust to the new school practices, policies and environment; to get to know students and their academic background, etc.). This lack of knowledge, specific to the school, could disrupt student learning, at least in the short term.

We disentangle the relative contributions of school-specific and more general human capital in two ways. First, we show the effects of tenure, teaching experience and age in the teaching staff, with entry rates reframed as the share of teachers with less than a year of tenure. Secondly, we look at the differential effects from entry of teachers with different levels of teaching experience. Table 3 presents these results.

Column 1 shows the results from re-estimation of our preferred specification, replacing the entry rate variable with categories of teacher tenure, experience, and age. These are shares of teachers in the department in a given year, including entrants and incumbents. The share of teachers with tenure less than one year, is equivalent to our entry rate variable, but here it is conditional on the categories of experience and age. Note that interpretation of the experience variables requires some care: teachers with less than one year of teaching experience necessarily have less than one year of tenure at the school, so the effect of teachers with less than one year of experience in Column 1 is the sum of the coefficients on one year of experience and one year of tenure. The coefficient on one year of tenure, on the other hand, is identified by entry of teachers with more than one year of experience. The baseline category for tenure and experience is nine years or more, and for age, 50 and over.

The results from Column 1 show clearly that tenure, experience and age are not, in general, important factors affecting student achievement (in line with the abundant literature showing a limited role for observable teacher characteristics). The only significant factor is the proportion of teachers with less than 1 year of tenure in the school, i.e. the entry rate. We interpret this to mean that it is a short run lack of school specific experience amongst incoming teachers that causes turnover to reduce student achievement. Once teachers have been in a school for an academic year, teachers have acquired a sufficient amount of school-specific human capital for these effects to dissipate. Note that results presented in Column 7 of Table 2 provide evidence that negative effects of low tenure are not driven by survival bias: we find that the negative effects on the first year of tenure are present regardless of whether the teacher stays in the school in the following year. Indeed, these effects are not limited only to teachers who will leave the school, or to teachers moving to another grade within the school in the following year. The magnitude of the effect is also very similar across groups of teachers based on what they do in the year following their entry in the school.

We further unpick the role of general experience in incoming teachers in Column 2, which splits experience amongst teaching staff into the experience amongst incomers and the experience amongst incumbents.[19] Evidently, from these results, experience amongst incumbents matters very little and the coefficients are all small and statistically insignificant (note, these coefficients are identified from exits of incumbent teachers from year-to-year). In contrast, entry of teachers has an adverse impact on achievement, regardless of their experience. The point estimates suggest that teachers with less experience tend to be less disruptive - perhaps because they are more adaptable - though the F-test (at the bottom of the table) for the equality of the entry coefficients across experience groups 'F-test equality') does not reject the null hypothesis of equality of coefficients ($p = 0.529$).

Lastly, we look at an alternative indicator of experience in Column 3 of Table 3, and split entry rates based on whether teachers are moving from other schools in our data, or are coming from elsewhere – which would usually mean they are new to the profession. The results here are broadly in line with those in Column 2.

Other measures of human capital, such as grade or subject specific experience, which has been shown to play a relevant role Ost (2014) might potentially be an additional important channel, but we cannot explicitly investigate them due to data limitations.[20] Finally, as Jackson (2013) shows, teacher effectiveness is increased due to teachers' move because of better matching. If that is the case, our estimates may be considered as a lower bound of the magnitude of the negative effect of entry.

5.3.2. Alternative mechanisms

We have argued that the effect of turnover on student achievement is driven by short run lack of school specific experience in incoming teachers - school specific human capital. There are, of course, other competing or complementary explanations, which would imply different policy responses. Here we discuss three alternatives.

Firstly, it is plausible that students take time to adapt to a new teacher, rather than the teacher who takes time to adapt to a new school. However, further analysis suggests this is not the case. If students take time to adapt to a new teacher, we would expect to see achievement affected when they were assigned a new teacher who is already in the school and has experience of teaching at the relevant school grades (Year 10 and 11). Unfortunately, our data does not reveal this information on teacher re-allocations within grades, but we can infer something by looking at exit rates of GCSE teachers.[21] In a year in which GCSE teachers leave and none join, incumbent teachers will need to be reallocated to cover the teaching gaps, implying that some students will get a different teacher. However, re-estimating our regression to look at the effect of teacher exit rates, either in periods with zero teacher entry, or controlling for teacher entry, reveals no impact of exit rates and their consequent internal organisation disruption on achievement. The results are shown in Appendix Table A5, Columns 3 and 4.

A second potential channel is an increased teaching workload on incumbent teachers in response to turnover, reducing their effectiveness. Teacher surveys often point to the teaching workload as being one of the main reasons for teachers to take time off teaching or quit. According to the Teacher Workload Survey 2019 (Walker et al. 2019), in England 37% of secondary school teachers reported that workload was a very serious problem. We investigated this issue, by controlling flexibly for average teaching hours in each subject-year group, but found this made little difference to our estimates of the effects of teacher turnover. The related results are shown in Appendix Table A5, Column 5.

Lastly, we considered whether teachers moving to the school might simply face external challenges from the relocation, which have little to do with lack of school specific knowledge. If this was the case, then we would expect teachers facing bigger geographical moves to be more affected. However, splitting entry rates according to whether moves are between or within cities reveals no difference in terms of effects on achievement, so relocation costs do not seem to be an important factor. Again, Appendix Table A5, Column 6 shows the corresponding estimates.

5.4. Organisational responses and teacher reallocation

Results related to estimation of the models of teacher workload allocation discussed in Section 3.2 are reported in Table 4. Panel A presents the results of estimating Eq. (3). It examines how many hours per week incoming teachers teach in Year Group 11 relative to other teachers in the school. Results, from Column 1 through to Column 5, show a clear pattern: new teachers teach fewer hours per week in Year Group 11 than incumbent teachers (about 0.75 hours less). This difference corresponds to about 20% of the average number of hours taught by incumbent teachers. As the Table shows, the magnitude of the coefficient is stable across different specifications, and it persists even after controlling for individual fixed effects, which also account for unobserved differences in teacher 'quality'. Results suggest that schools tend to keep new teachers away from teaching in 'high-risk' grades, which is in line with the findings of 'staffing to the test policies' studies (Cohen-Vogel 2011; Grissom et al. 2017). This pattern could also be related to teachers' preferences, as more tenured teachers are more likely to have a higher lobbying power within the school to be assigned their desired

[19] We also estimate this specification by excluding students in departments where the entry rate was 100% (no incumbents). Results are very similar to Column 2 reported in the main Table.

[20] Information on grade or subject taught are available only for three year in our data and this makes it difficult to separately disentangle these elements.

[21] The share of teachers who were in the department and teaching Year 10 or Year 11 in the previous year ($t-1$), but are no longer in the school in the current academic year (t).

Table 4
Teacher Entry and Department Organization: Hours Taught by New Entrants and Incumbents.

Panel A: Difference in hours taught between New Entrants and Incumbents						
	(1) Hours Y11	(2) Hours Y11	(3) Hours Y11	(4) Hours Y11	(5) Hours Y11	(6) Hours
New Entrant	-0.700***	-0.698***	-0.729***	-0.751***	-0.611***	-1.102***
	(0.016)	(0.016)	(0.015)	(0.013)	(0.027)	(0.049)
Observations	409,865	409,865	409,865	409,865	409,865	409,865
Average Dependent	2.894	2.894	2.894	2.894	2.894	14.553
Controls	NO	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
SchoolXSubject	NO	NO	YES	YES	YES	YES
SchoolXYear	NO	NO	NO	YES	NO	NO
SubjectXYear	NO	NO	NO	YES	NO	NO
Teacher FE	NO	NO	NO	NO	YES	NO
Panel B: Impact of New Entrants on Hours taught by Incumbent						
	(1) Hours Y11	(2) Hours Y11	(3) Hours Y11	(4) Hours Y11	(5) Hours Y11	(6) Hours
Number of new teachers in department	0.071***	0.059***	0.035***	0.026***	0.026***	-0.141***
	(0.007)	(0.007)	(0.007)	(0.004)	(0.009)	(0.030)
Observations	349,038	349,038	349,038	349,038	349,038	349,038
Average Dependent	2.894	2.894	2.894	2.894	2.894	14.553
Controls	NO	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
SchoolXSubject	NO	NO	YES	YES	YES	YES
SchoolXYear	NO	NO	NO	YES	NO	NO
SubjectXYear	NO	NO	NO	YES	NO	NO
Teacher FE	NO	NO	NO	NO	YES	NO

Note: OLS regressions at teacher level for the 2011–2013 period. Dependent variable is the number of weekly hours taught in Year 11 for Columns from 1 to 5 and weekly hours taught in the school in Column 6. Panel A covers regressions for the whole school workforce, and it compares new entrants and incumbents. Panel B restricts the sample to incumbent teachers and the regression computes the impact of the number of new entrants on the number of hours taught by incumbents. Controls include: a squared polynomial in age, dummy for women; dummies for experience groups (2–5 years, 5–10 years, more than 10 years); Quartile of the school in the GCSE distribution; log number of teachers in the department; log of pupil-teacher ratio in the department; a dummy for academy schools. Standard errors clustered at school level. Level of significance: *** p<0.01, ** p<0.05, * p<0.1.

task (Loeb et al., 2012). In our setting, survey evidence suggests that exams and pressure to improve scores are one of the major stress cause for teachers[22] which makes it less likely that teachers' preferences are the driving factor behind the observed assignment pattern. The lower amount of hours taught by new teachers comes from two components: first, new teachers are less likely to teach in general - they are 13 percentage points less likely to teach in Year Group 11 compared to incumbent teachers (baseline probability for incumbent teachers is 75%); second, even when they teach, newcomers have lower teaching load and spend fewer hours teaching Year 11 students than incumbents - with about 0.402 fewer hours per week than incumbents, the baseline for incumbents is 3.9 hours per week).[23] Finally, Column 6 shows that new teachers also teach fewer hours per week overall (that is accounting for teaching in all grades): about 1.102 hours less per week with respect to incumbents who spend about 14.5 hours teaching per week in the classroom. Overall, these findings suggest that schools not only keep new teachers away from teaching students on their final compulsory school year, but they are also given a lower teaching workload than incumbent teachers. This may be to give new teachers time to adapt to the new school environment, and acquire the school specific human capital that is important for school performance.

If new teachers spend fewer hours in the classroom, this may have implications for other teachers in the school: they may have to teach more, which in turn may affect their productivity and harm student learning. Panel B investigates this aspect by assessing the impact of number of new teachers on incumbent teachers teaching workload. Columns 1–5 explore the extent to which incumbent teachers get increased teaching workload in Year Group 11, as a result of the entry of new teachers. We find that a higher number of new teachers in the department is associated with more hours taught by incumbent teachers - about 0.03 hours per additional teacher in the most comprehensive specification (Column 4). This corresponds to about 1% of the hours taught per week in Grade 11. Column 6 finally shows that the entry of new teachers also leads to a small reduction in total hours taught by incumbent teachers.

We also explore other ways schools may respond to teacher turnover by examining several heterogeneity margins. Results are reported in the Appendix, Section Appendix A. We find that schools that are classified as 'good quality', by OFSTED inspections, and especially those with 'very good managers' (Columns 46) are less likely to make newcomers teach (Panel A) and their students are less affected by turnover (Panel B). This suggests that good schools have plans in place to respond better to disruptive effect of turnover. In addition, we find that newcomers in schools with higher proportion of minority students are more likely to teach in their first year of joining the school. However, this coefficient is very small: a 10 percentage points increase in the share of non-white students leads to an increase in the probability of teaching by 0.3 percentage points. In Panel B, Column 7, we show that turnover has no differential effect on students' performance regardless of the school student ethnic composition. More details on this are shown in Table A7.

Looking at teacher characteristics, we compare the characteristics of new entrants and incumbents in Table A8, and highlight that new entrants differ along several dimensions compared to incumbents (in terms of age, experience and type of contract). We find that new entrants are younger, less experienced, and more likely to be on temporary contracts. The share of women is similar across the two groups. We also find that schools are more likely to keep younger and less experienced teachers

[22] See for example: "Exam stress - teachers feel it too", educationsupport.org ; "Tackling stress", National Education Union.
[23] The corresponding regressions are reported in Appendix in Table A6.

away from teaching Year 11 in their first year of joining the school, but we do not see differences in school responses by other teacher characteristics such as gender. Results are presented in Table A9.

Finally, examining whether schools respond differently to different types of students to mitigate negative effects of turnover, we find that teacher turnover appears to be less disruptive for disadvantaged students in the school - about one fourth lower, as Table A10 results show. This suggests that schools may take actions to mitigate the disruptive effects for disadvantaged students by keeping newcomers away from this type of students. In addition, the negative effects of turnover seem to be larger for students in the middle of the ability distribution, proxied by their grade in the KS2 examination.

6. Conclusions

Our study investigates the impact of teacher entry rates at school-subject-year level on student achievement in England using fixed effects regression designs, which control carefully for unobserved school-by-year, subject-by-year shocks, and school-by-subject or student unobservables. Importantly, we also examine potential mechanisms through which turnover may be disruptive for student learning and look at how schools respond to mitigate these negative effects of turnover. The key finding is that students in the final year of their compulsory secondary school score less well in their final assessments if they are exposed to higher rates of teacher entry in the subjects they are studying. Entry in the final year in which students take their final GCSE assessments seems crucially important. The magnitudes are modest, with a 10-percentage point increase in entry rates reducing scores in final qualifications by 0.5 percent of a standard deviation.

This figure is almost exactly the same as that found for entry of teachers in schools in the US (e.g. Ronfeldt et al. 2013, Hanushek et al. 2016), suggesting that effects are quite generalisable. One caveat here, is that the English system is one with a standardised National Curriculum, which may make it easier for teachers to switch schools, and dampen the disruptive effects of turnover relative to a system where the syllabus is school specific. Then again, there are multiple exam boards (OCR, Edexcel, WJEC, AQA) which set assessments and define the exact syllabus. Different schools will often use different exam boards for different subjects, so teachers will still need to adapt to the specific syllabus they are required to teach, as well as adapt to the school-specific working environment.[24]

The size of this impact is economically meaningful compared to other education inputs. For instance, the literature on teacher quality suggests that a one standard deviation increase in overall teacher quality where quality' means everything about teachers that is correlated with persistently higher value-added scores raises individual student achievement by around 0.11 standard deviations (see for example Hanushek 2009). Our standardised effect is about 0.008 standard deviations in final year grade from a one standard deviation increase in entry rates, so considerably smaller.

Examining potential channels through which turnover can be harmful for student learning, our findings suggest that it is the lack of the school-specific human capital the main mechanism through which turnover affects student performance. We find that new teachers are disruptive only in their first year in the new school and that this negative effect disappears after the first year. The adverse effects of entry do not appear to be driven by changes in workforce composition or the overall teacher experience. Evidently, schools are able to partly mitigate the impact of turnover by the way they organise teaching, implying that our estimates potentially underestimate (in absolute value) the causal impact in a situation where new teachers were randomly assigned to students. Investigating on whether/how school respond to mitigate disruptive effects of turnover, we find that schools tend to keep new teachers away from teaching Year 11 students, but also give them lower teaching workload than the incumbent teachers, maybe to give them time to adapt to the school and gain the much needed school-specific human capital. Even so, turnover of teachers matters regardless of these organisational responses suggesting that our key results are likely driven by unavoidable general disruption as a result of the lack of school specific human capital due to new teacher entry.

These findings have relevant policy implications for the education sector, but also the public sector organisations generally. Our results show that schools can effectively reduce the impact of turnover , through strategic reassignment of teachers, keeping new teachers away from teaching high-stakes grades in their first year of joining the school, to allow time to adapt and acquire school-specific human capital. These findings might be useful for other public sector institutions, where turnover is pervasive.

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Appendix A. Heterogenous effects

Average effects might mask substantial heterogeneity across different groups of teachers, students, and institutions. In this section of the appendix we examine school responses given different characteristics of schools, teachers, and students.

A1. School characteristics

We examine, in Table A7, whether schools with different characteristics respond differently to rates of turnover. Panel A considers the probability of teaching in Year 11 for a teacher who just arrived in the school with respect to other teachers, for different types of schools. Column 1 reports our baseline result. Column 2 looks at school academies. Academies are state schools in England, but they enjoy more freedom in terms of managerial decisions, hiring, and firing. Results show that for academy schools the impact of entry is similarly disruptive to other schools. Column 3 considers differences between small and large schools. Small schools are expected to have less room for teacher grade re-assignment. These schools, defined as those with a number of teachers below the median, show a larger negative effect, possibly due to less margins to strategically allocate teachers to grades. Columns from 4 to 6 consider several dimensions of school quality, as assessed by OFSTED inspections. We look at the inspection overall grade in Column 4; the quality of management in Column 5; and the quality of teaching in Column 6, the latter measure also includes training provided to faculty members. We find that schools which are considered of high quality by OFSTED inspection are less likely to assign new teachers to salient grades, thus being less affected by turnover. To summarize, turnover has more detrimental effects on student performance for small schools (Column 3), but it affects less schools of high quality (Columns from 4 to 6). The role of management appears to be particularly important (Column

[24] These exam boards define the syllabus, set the assessments, provide texts, example teaching materials, lessons and assessments. However, they do not provide comprehensive lesson plans, or a complete course package.

Table A1
Summary statistics.

Variable	Mean	Std. Dev.	Min	Max
Turnover measures at school-subject-year level				
Entry Overall	0.14	0.165	0	1
Exit Overall	0.105	0.151	0	1
Entry School	0.085	0.133	0	1
Exit School	0.077	0.132	0	1
Entry Profession	0.055	0.102	0	1
Exit Profession	0.028	0.078	0	1
Teacher characteristics				
Female	0.622	0.262	0	1
Age	39.902	5.701	20.75	72
Tenure School	6.953	2.846	1	20
Experience	10.427	3.251	1	21
Student characteristics				
KS4 Standardized Score	0.01	0.988	-1.693	10.123
KS2 Standardized Score	0.002	0.999	-4.33	2.204
% FSM students	0.109	0.311	0	1
% Female students	0.506	0.5	0	1
% white students	0.831	0.375	0	1
School/subject group variables				
# Teachers	7.19	4.399	1	66
Pupil Teacher Ratio	27.297	25.206	0.024	446
Number of observations	12,699,846			

Note: Summary statistics for the regression sample at student level.

Table A2
Summary statistics at teacher level.

Variable	Mean	Std. Dev.	Min	Max
Age	39.515	10.859	19	85
Female	0.623	0.485	0	1
Experience	10.634	6.591	1	21
Total Hours Year Group 11	2.789	2.324	0	9.330
Total Hours Taught	14.565	7.420	0	26
New Teacher	0.148	0.356	0	1
Observations	409,865			

Note: Summary statistics for regressions at teacher level. Hours taught in Year Group 11 and overall are winsored at 1%.

5), although other estimates of school quality (Column 4 and Column 6) are reasonably close, though less precise.

A2. Teacher characteristics

Results so far showed that new entrants tend to be, at least temporarily, kept away from teaching Year Group 11, and this is partly offset by increasing teaching hours for incumbent teachers. This strategic reassignment depends crucially on the observed characteristics of new entrants. To explore new teachers' likelihood to teach students in their last year of compulsory schooling, we group teachers based on their individual characteristics and estimate Eq. (3), where the dependent variable is a dummy taking the value of one if a new teacher teaches in Year 11 and 0 otherwise. Results are presented in Table A9, Panel A. Column 1 decomposes the entry rate by teacher age group and it highlights a non-linear pattern in the likelihood that a new entrant teaches Year 11. As results show, young (20–29 year old) entrants are those with the largest difference in the probability of teaching in Year 11 in their first year with respect to incumbents. This difference declines for teachers aged between 30–39, but then again increases for the other older age groups of 40–49 and 50 +. This appears reasonable as young teachers are the most inexperienced ones and schools might want to provide them with extra time and training before letting them teach in high-stake grades, while older teachers might be given other administrative tasks, which could move them away from teaching. Column 2 looks at the role of experience. The coefficients follow a pattern consistent with the age profile shown in Column 1: more inexperienced teachers show the largest differences with respect to incumbents in their probability of teaching Year 11; the difference declines with experience, but then increases again for the most experienced teachers (with more than 10 years in the education system). Results do not show marked differences along gender dimension, reported in Column 3: new entrants are less likely to teach in Year 11 with respect to incumbents regardless of whether they are male or female. Column 4 shows that teachers coming from outside the profession are much less likely to teach than new teachers coming from other

Table A3
Balancing Tests: Correlation of Entry Rates with Student Characteristics.

	No Fixed Effects			Full Set of Fixed Effects		
	(1)	(2)	(3)	(4)	(5)	(6)
Variable	Coefficient	Se	T-Stat	Coefficient	Se	T-Stat
Number of Students	26.052	2.042	12.757	0.755	0.636	1.187
Female	0.007	0.006	1.120	-0.001	0.001	-0.824
Fsm Eligible	0.028	0.004	7.871	0.000	0.000	0.931
White	-0.084	0.008	-10.493	-0.001	0.001	-1.389
Score KS2	-0.101	0.013	-8.085	-0.002	0.003	-0.604

Note: Regression at student level between student characteristics and entry rate in the department. Entry rate is defined as the share of teachers in year t who were not present in the school in year t-1. Column 1 includes only the entry rate, while Column 4 includes fixed effects at school-by-subject, school-by-year, and subject-by-year level. Standard errors clustered at school level. Level of significance: *** p<0.01, ** p<0.05, * p<0.1.

Table A4
Impact of Share of Hours Taught by New Entrants on Standardised Test Scores.

	(1)	(2)	(3)	(4)	(5)	(6)
Share of hours taught in Year 11	-0.072***	-0.138***	-0.048***	-0.054***	-0.044***	-0.052***
	(0.020)	(0.020)	(0.012)	(0.012)	(0.013)	(0.014)
Observations	6,585,701	6,585,701	6,585,701	6,585,701	6,585,701	6,585,701
Year FE	Y	Y	Y	Y	Y	Y
Controls	N	Y	N	Y	N	Y
SchoolXSubj FE	N	N	Y	Y	Y	Y
SchoolXYear FE	N	N	Y	Y	N	N
SubjectXYear FE	N	N	Y	Y	N	N
Student FE	N	N	N	N	Y	Y

Note: OLS regressions at student level. The dependent variable is the average standardized test score in the KS4 exam by student, subject, and year. Share of hours by new teachers in Year 11 is defined as the share of new hours taught by teachers who are present in the school in year t but were not present in the school in year t-1. Teacher characteristics include: average age of teacher in the department; average experience; share of female. Student characteristics include: normalized prior test scores; Free School Meal (FSM) eligibility; gender; ethnicity (white/others). School characteristics include: pupil teacher ratio at department-school-year level; proportion of female students in the department; proportion of FSM eligible in the department; proportion of white students in the department; number of teacher in current and past academic year in the department. Standard errors clustered at school level. Level of significance: *** p<0.01, ** p<0.05, * p<0.1.

Table A5
The Impact of Teacher Entry on Standardised Test Scores: Additional Mechanisms.

	(1) Score	(2) Score	(3) Exit (no entry)	(4) Exit	(5) Hours	(6) Mobility
Entry rate	-0.054***	-0.062***			-0.060***	
	(0.010)	(0.014)			(0.014)	
Exit rate			0.026			
			(0.032)			
Share of new teachers in Year 11				-0.063***		
				(0.023)		
Exit rate from Year 10 and Year 11				-0.011		
				(0.021)		
Entry rate: outside profession						-0.064***
						(0.021)
Entry rate: from another town						-0.061***
						(0.020)
Entry rate: from the same town						-0.073**
						(0.029)
Entry rate: from not specified town						-0.031
						(0.036)
Observations	12,699,846	6,585,701	2,641,874	4,369,550	6,578,205	6,585,701
Controls	Y	Y	Y	Y	Y	Y
SchoolXYear FE	Y	Y	Y	Y	Y	Y
SubjectXYear FE	Y	Y	Y	Y	Y	Y
SchoolXSubj FE	Y	Y	Y	Y	Y	Y
Student FE	N	N	N	N	N	N

Note: OLS regressions at student level. The dependent variable is the average standardized test score in the KS4 exam by student, subject, and year. Entry rate is defined as the share of teachers in year t who were not present in the school in year t-1. Controls include teacher, student, and school characteristics. Teacher characteristics include: average age of teacher in the department; average experience; share of female. Student characteristics include: normalized prior test scores; Free School Meal (FSM) eligibility; gender; ethnicity (white/others). School characteristics include: pupil teacher ratio at department-school-year level; proportion of female students in the department; proportion of FSM eligible in the department; proportion of white students in the department; number of teacher in current and past academic year in the department. Column 2 restricts the sample to the years for which hours and Year taught are available (2011–2013). Column 3 includes Exit rates (share of teachers who were present in the school in year t-1 but are no longer present in year t) and restricts the sample to the period in which hours are available and to department years experiencing no entry. Column 4 includes entry rates of teachers in Year Group 11 and Exit rates (share of teachers who were present in the school in year t-1 but are no longer present in year t) for teachers who taught in Year 10 and/or Year 11. Column 5 includes the share of teachers by number of hours taught in the department. Column 6 decomposes entry rate for teachers coming from other school based on whether the past school was in the same town or not. If the last school was observed before 2008, then we group entrants in the category 'from not specified town'. Standard errors clustered at school level. Standard errors clustered at school level. Level of significance: *** p<0.01, ** p<0.05, * p<0.1.

Table A6
Teaching by New Entrant Teachers: Extensive (Teaching) and Intensive (Hours) margin.

Panel A: Difference in probability of Teaching between New Entrants and Incumbents

VARIABLES	(1) Teaching 11	(2) Teaching 11	(3) Teaching 11	(4) Teaching 11	(5) Teaching 11	(6) Teaching
New Entrant	-0.130***	-0.125***	-0.127***	-0.130***	-0.104***	-0.018***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.006)	(0.002)
Observations	409,865	409,865	409,865	409,865	409,865	409,865
Average Dependent	0.746	0.746	0.746	0.746	0.746	0.87
Controls	NO	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
SchoolXSubject	NO	NO	YES	YES	YES	YES
SchoolXYear	NO	NO	NO	YES	NO	NO
SubjectXYear	NO	NO	NO	YES	NO	NO
Teacher FE	NO	NO	NO	NO	YES	NO

Panel B: Difference in hours taught conditioning on positive hours between New Entrants and Incumbents

VARIABLES	(1) Hours Y11	(2) Hours Y11	(3) Hours Y11	(4) Hours Y11	(5) Hours Y11	(6) Hours
New Entrant	-0.318***	-0.343***	-0.389***	-0.402***	-0.381***	-0.923***
	(0.013)	(0.013)	(0.011)	(0.011)	(0.025)	(0.030)
Observations	297,645	297,645	297,645	297,645	297,645	355,907
Average Dependent	3.88	3.88	3.88	3.88	3.88	16.725
Controls	NO	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
SchoolXSubject	NO	NO	YES	YES	YES	YES
SchoolXYear	NO	NO	NO	YES	NO	NO
SubjectXYear	NO	NO	NO	YES	NO	NO
Teacher FE	NO	NO	NO	NO	YES	NO

Note: OLS regressions at teacher level for years between 2011 and 2013. In Panel A the dependent variable is a dummy for teaching positive hours (linear probability model) in Year 11 for Columns from 1 to 5 and in Column 6. In Panel B the dependent variable is the number of hours taught in YG11 in Colums from 1 to 5 and in the school in Column 6. Panel A covers regressions for the whole school workforce, while Panel B restricts the sample to teachers with positive hours. Controls include: a squared polynomial in age, dummy for women; dummies for experience (2–5 years, 5–10 years, more than 10 years); Quartile of the school in the GCSE distribution; log number of teachers in the department; log of pupil-teacher ratio in the department; academy dummy. Standard errors clustered at school level. Level of significance: *** p<0.01, ** p<0.05, * p<0.1.

schools. Finally, Column 5 shows that a similar pattern is present for teachers on temporary contracts. While all new teachers are less likely to teach, those hired on temporary contracts show an even lower probability of teaching in Yaer 11 in their first year.

Panel B looks at the effect of entry of different groups of teachers on students' scores in their final exam, as in Eq. (1). Results show some interesting patterns. As Column 1 shows, the negative effect of entry is more marked for older teachers and lower for younger teachers. This is in line with younger teachers being less likely to teach to students in Year 11, while the higher effect for more experienced teachers could be explained with the fact that they could be more likely to have been allocated administrative roles in the department, which, as we showed before, tend to be associated with more pronounced negative effects. A similar pattern can be seen for experience in Column 2. Column 3 examines the gender dimension, and it shows that male teachers seem to have a more negative impact. Column 4 looks at the origin of incoming teachers and it appears that teachers from other schools have a large negative impact with respect to those coming from elsewhere. This could be rationalized with the pattern observed in Panel A, where selection into teaching in Year 11 is much more marked for teachers coming from elsewhere rather than from those coming from other schools. Finally, entry of teachers with temporary contracts seem to have a slightly larger negative effect.

A3. Student characteristics

Finally, student characteristics might also play a role in how schools respond to mitigate the negative impact of turnover. Turnover might impact different type of students differently. For example, low ability students might be affected more than others. We investigate this in our usual regression framework by interacting the entry rate with student characteristics and re-estimate our main regression. Results for students are reported in Table A10. Interestingly, the negative effect of turnover appears to be about one fourth lower for more disadvantaged students (Column 1), while no statistically significant differences appear between male and female (Column 2), or White and Non White students (Column 3). Finally, we look at the effect of entry across the quality distribution of students. We proxy it by using their prior attainment in primary school (KS2). We divide this measure of ability in quartiles and interact the resulting dummies with our measure of entry. The effect of the interaction term of entry with ability quartiles follows a U-shaped pattern. Although it is negative for all groups, students in the middle part of the ability distribution seem to be the most affected, while students at the top of the ability distribution are the least affected. This appears reasonable: while students at the top of the ability distribution can rely less on teachers than their peers, those at lower levels of the ability distribution need more support from teachers.

Table A7
New Entrants: Probability of Teaching for New Entrants with respect to Incumbents by School Characteristics and Effect on Standardised Test Scores.

Panel A: Probability of Teaching of New Entrants with respect to Incumbents by School Characteristics

	(1) Baseline	(2) Academies	(3) Small Schools	(4) Overall Evaluation	(5) Management	(6) Quality	(7) Ethnicity
New Entrant	-0.130***	-0.128***	-0.140***	-0.124***	-0.121***	-0.126***	-0.136***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.004)
New EntrantXAcademy		-0.007					
		(0.006)					
New Entrant X Small School			0.031***				
			(0.006)				
New EntrantXOfsted very good Quality				-0.029***			
				(0.007)			
New EntrantXOfsted very good Management					-0.028***		
					(0.007)		
New EntrantXOfsted very good Quality						-0.023**	
						(0.009)	
New Entrant X Proportion Non-White St.							0.030***
							(0.011)
Observations	409,011	409,011	409,011	387,502	366,527	366,527	407,927
Average Dependent	0.726	0.726	0.726	0.726	0.726	0.726	0.726

Panel B: Impact of Entry Rate of Teachers by School Characteristics on Students' Performance.

	(1) Baseline	(2) Academies	(3) Small Schools	(4) Overall Evaluation	(5) Management	(6) Quality	(7) Ethnicity
Entry Rate	-0.054***	-0.049***	-0.042***	-0.064***	-0.069***	-0.063***	-0.056***
	(0.010)	(0.011)	(0.013)	(0.012)	(0.012)	(0.012)	(0.012)
Entry Rate X Academy		-0.032					
		(0.023)					
Entry Rate X Small School			-0.029*				
			(0.017)				
Entry Rate X Ofsted very good Grade				0.033			
				(0.020)			
Entry Rate X Ofsted very good Management					0.049**		
					(0.022)		
Entry Rate X Ofsted very good Quality of Teaching						0.040	
						(0.026)	
Entry Rate X Proportion Non-White St.							0.005
							(0.036)
Observations	12,699,846	12,699,846	12,699,846	11,794,607	10,887,592	10,887,592	12,699,846
Teacher char	Y	Y	Y	Y	Y	Y	Y
Student char	Y	Y	Y	Y	Y	Y	Y
School char	Y	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y	Y
School-by-Year FE	Y	Y	Y	Y	Y	Y	Y
Subject-by-Year FE	Y	Y	Y	Y	Y	Y	Y
Subject-by-School FE	Y	Y	Y	Y	Y	Y	Y
Student FE	N	N	N	N	N	N	N

Note: OLS regressions at teacher (Panel A) and student (Panel B) level. Panel A reports regressions for the probability of teacher in Year 11 for new teachers. Panel B reports regressions at student level for the effect of the share of incoming teachers on GCSE exams. Panel A reports results from Eq. 3 while Panel B reports results from Eq. 1. See main text for a discussion of controls and fixed effects. Column 2 includes an interaction with a dummy for academy, Column 3 includes an interaction with a dummy for small schools, defined as schools with less than the median number of teachers, Column 4, Column 5, and Column 6 include interactions with school characteristics based on OFSTED reports. Column 4 includes an interaction with a very high Overall OFSTED inspection grade, Column 5 includes an interaction with a very high Management score, and Column 6 includes an interaction with a very high Teacher Quality Score. Column 7 includes interaction between a dummy for being a new entrant and the proportion of non-white student in the school. Standard Errors clustered at school level. Level of significance: *** p<0.01, ** p<0.05, * p<0.1.

Table A8
Average Characteristics for New Entrants and Incumbents Teachers.

Variable	(1) Overall	(2) New Entrants	(3) Incumbents
Age	39.515	32.866	40.674
Female	0.623	0.647	0.619
Permanent Contract	0.924	0.698	0.964
Experience	10.634	5.488	11.528
Observations	409,865	60,827	349,038

Note: Summary statistics for teachers between 2011 and 2014. Column 1 reports the average for all teachers, Column 2 reports averages for new entrants, and Column 3 reports averages for incumbent teachers.

Table A9
New Entrants: Probability of Teaching in Year 11 with respect to Incumbents and Effect on Standardised Test Scores.

Panel A: Probability of Teaching in Year 11 of New Entrants with respect to Incumbents by Teacher Characteristics

(1) Age		(2) Experience		(3) Gender		(4) Origin		(5) Contract	
20–29	-0.118***	<2	-0.219***	Female	-0.122***	Outside Profession	-0.219***	Permanent	-0.095***
	(0.007)		(0.004)		(0.003)		(0.004)		(0.003)
30–39	-0.032***	2–4	-0.096***	Male	-0.146***	Other School	-0.099***	Temporary	-0.135***
	(0.006)		(0.005)		(0.004)		(0.003)		(0.006)
40–49	-0.072***	5–10	-0.058***						
	(0.007)		(0.005)						
50+	-0.081***	>10	-0.115***						
	(0.009)		(0.005)						
Observations	409,865		409,865		409,865		409,865		409,865
Avg. Dependent	0.746		0.746		0.746		0.746		0.746

Panel B: Impact of Entry Rate of Teachers by Teacher Characteristics on Students' Performance.

(1) Age		(2) Experience		(3) Gender		(4) Origin		(5) Contract	
20–29	-0.049***	<2	-0.049***	Female	-0.043***	Outside Profession	-0.051***	Permanent	-0.053***
	(0.015)		(0.014)		(0.012)		(0.015)		(0.014)
30–39	-0.047***	2–4	-0.047**	Male	-0.074***	Other School	-0.056***	Temporary	-0.081***
	(0.015)		(0.021)		(0.016)		(0.011)		(0.022)
40–49	-0.063***	5–10	-0.058***						
	(0.018)		(0.019)						
50+	-0.079***	>10	-0.065***						
	(0.025)		(0.016)						
Observations	12,699,846		12,699,846		12,699,846		12,699,846		7,447,428

Note: OLS regressions at teacher (Panel A) and student (Panel B) level. Panel A reports regressions for the probability of teacher in Year 11 for new teachers. Panel B reports regressions at student level for the effect of the share of incoming teachers on GCSE exams. Panel A reports results from Eq. 3 while Panel B reports results from Eq. 1. Entry rate for each category computed as the number of new teachers for that category divided by the total number of teachers in the department. See main text for a discussion of controls and fixed effects. Each column is a regression which decomposes the effect of interest in its components by age (Column 1), by experience (Column 2), by gender (Column 3), by origin of the incoming teacher (Column 4), and by Contract type (Column 5). Standard Errors clustered at school level. Level of significance: *** p<0.01, ** p<0.05, * p<0.1.

Table A10
The Impact of Teacher Entry on Standardised Test Scores: Student Characteristics.

	(1) FSM	(2) Gender	(3) Ethnicity	(4) Previous Grade
Entry Rate	-0.056***	-0.070***	-0.056***	-0.044***
	(0.010)	(0.021)	(0.010)	(0.011)
Entry Rate X FSM eligible	0.014*			
	(0.008)			
Entry Rate X Female		0.025		
		(0.029)		
Entry Rate X Non White St.			0.008	
			(0.010)	
Entry Rate X Second Quart				-0.012**
				(0.006)
Entry Rate X Third Quart				-0.020**
				(0.009)
Entry Rate X Bottom Quart				-0.011
				(0.013)
Observations	12,699,846	12,699,846	12,699,846	12,699,846
Year FE	Y	Y	Y	Y
SchoolXYear FE	Y	Y	Y	Y
SubjectXYear FE	Y	Y	Y	Y
SubjectXSchool FE	Y	Y	Y	Y
Student FE	N	N	N	N

Note: OLS regressions at student level. The dependent variable is the average standardized test score in the KS4 exam by student, subject, and year. Entry rate is defined as the share of teachers in year t who were not present in the school in year t-1. Controls include teacher, student, and school characteristics. Teacher characteristics include: average age of teacher in the department; average experience; share of female. Student characteristics include: normalized prior test scores; Free School Meal (FSM) eligibility; gender; ethnicity (white/others). School characteristics include: pupil teacher ratio at department-school-year level; proportion of female students in the department; proportion of FSM eligible in the department; proportion of white students in the department; number of teacher in current and past academic year in the department. Standard errors clustered at school level. Level of significance: *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

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