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Heterogeneous Effects of High School Peers on Educational Outcomes

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Abstract

We investigate peer ability effects on high powered test scores at ages 16 and 18, and on the probability of university attendance. To account for endogeneity in peer ability, we instrument average peer ability with the average ability of the primary school peers of one's high school peers. Our results show that peers have a moderately positive effect on test scores, and that being in a school with a large proportion of low-quality peers can have a significantly detrimental effect on achievements. Furthermore, peer ability seems to have a stronger effect on students at the bottom of the grade distribution, especially at age 16.

Keywords: peer effects, instrumental variables, test scores

JEL codes: I20, J24

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1. Introduction

The aim of the present paper is to investigate the relationship between peer ability and individual attainment in high-stakes educational tests at the end of compulsory schooling at age 16 and at the end of high school at age 18, using a large, rich, and recent dataset of English teenagers.

The analysis of peer effects in education has received increasing attention among economists and applied social scientists in recent years (see, for example, the recent review by Sacerdote, 2011). A number of studies (Angrist and Lang, 2004; Lavy et al., 2012; and Gibbons and Telhaj, 2015, among others) typically find statistically significant but modest peer effects on individual test scores. There is also evidence that heterogeneous peer effects exist. In particular, Burke and Sass (2013) and Ding and Lehrer (2007) find that high-ability students benefit from other high-ability students while Imberman et al. (2012) find that good peers have positive effects which are greatest for low-achieving students. Lavy et al. (2012) estimate a significantly negative effect from bad peers using British data, and positive effects from academically bright peers, but only for girls.

Establishing the presence and estimating the size of peer effects is important because they imply that educational interventions may have multiplier effects (Glaeser, Sacerdote, and Scheinkman 2003), i.e., that the impact of an educational intervention on an individual may self-propagate within a wider group of students. In addition, where there is heterogeneity in peer effects across the ability distribution, this provides a rationale for the efficient mixing of pupils in a school or in a classroom. An optimal student mix may raise the average attainment of a group in ways which other educational interventions may not be able to achieve.

Identifying the effect of peer ability on individual achievements is particularly complicated for several reasons pertaining to the endogeneity of the peer ability measure (Angrist, 2014). Measures of peer ability are likely to be endogenous because of non-random sorting.

For example, children attending the same school are likely to have some common unobserved characteristics related to the area in which they live and their families' socioeconomic backgrounds. The correlation between these factors and both the educational outcomes and the nature of the peer group may lead to an overestimation of the effect of peer ability because of positive selection bias. Our strategy to estimate the effect of average peer ability is to instrument it with average peer ability of the peers of students' peers who have not shared an educational institution with those specific students. That is we exploit our ability to identify the peers of peers.

Moreover, individuals also affect their own peer group as much as the peer group affects them (the so-called 'reflection' problem coined by Manski, 1993).[1] As a result, peer achievements are not exogenous with respect to individual educational outcomes, especially when pupils have been exposed to each other for some years. Student learning is affected by direct classroom contact and more general social interaction, and individual achievements are likely to be correlated with those of other students in the same class or school. If this reflection issue is not taken into account, estimates of peer effects will be biased upwards.

We use information on the primary school peers of an individual's high school peers who satisfy two conditions: first, they must have attended a *different* primary school from the student of interest; and, second, they *must not be in the same high school* as the student of interest. This information is used as an instrument for an individual's average peer ability in high school. We believe our analysis is the first study to adopt this strategy of excluding peers of peers who have been one's own peers, now or in the past. By instrumenting average

[1] Manski (1993) distinguishes between the three non-exclusive channels through which individuals may have characteristics and outcomes similar to their peer group: via the endogenous effect, via exogenous effects (also called contextual effects), and via correlated effects. In our context, an endogenous effect arises if the individual's achievement varies with the average achievement of the peer group; an exogenous effect arises if the individual's achievement varies with the observable socioeconomic characteristics of the peer group; and correlated effects arise if the individual has similar achievements as her peers because they are subject to similar unobservables.

peer ability with the average outcome of the peers of one's peers, i.e., those children who never shared the same school with the individual concerned, but who did share the same primary school as the individual's current schoolmates, we overcome the reflection problem and mitigate the impact of selection bias. The exclusion restriction is based on the idea that these peers could never have had a direct effect on the student's outcomes because they had never been in the same classroom or, indeed, the same school. While other studies have also used peers of peers as an identification strategy we believe our analysis is the first to be able to impose the constraint that the peers of peers could not generate reflection.

Much of the existing literature is based on large administrative datasets. Such data is usually not very rich – they typically contain rather few covariates. For example, the existing literature in the UK mostly relies on the National Pupil Database (NPD), which has a very limited set of background characteristics that are typically thought of as important determinants of academic outcomes. We use data from the Longitudinal Study of Young People in England (LSYPE), which includes a wide variety of information on the child, the family, and the school.

When we exploit the richness of LSYPE and control for a much wider set of covariates than previous studies, average peer ability has no significant impact on test scores at age 16, but it has some significant effects on performance at age 18 test scores. We do not find that that peers significantly affect the likelihood of attending university. The number of weak peers also has an effect on average outcomes at age 18, but not earlier. However, average peer ability seems to have a stronger beneficial effect on students at the bottom of the grade distribution, especially at age 16. Finally, when we analyse the effect of the presence of weak peers on age 16 test scores across the ability distribution, we find some evidence that the effect of weak peers is more detrimental to weak students than to stronger ones.

We contribute to the existing literature on peer effects in education in three main ways. First, we provide evidence based on this rich dataset of English teenagers, and we focus our attention on high-stakes educational outcomes at the end of high school at age 18. The existing literature based on British data mostly analyse the impact of peers on junior high school achievement at age 14 (Lavy et al., 2012; Gibbons and Telhaj, 2015). Thus, our first contribution is that we show that the existing findings in the literature do not 'fade' – at least, they do not fade into statistical insignificance. Second, we provide statistically significant evidence for the existence of heterogeneous peer effects across the grade distribution. Finally, we further contribute to the literature by introducing a novel identification strategy to overcome the reflection problem as well as the biases resulting from unobserved heterogeneity and non-random sorting.

The rest of this paper is organised as follows. In Section 2, we provide a brief overview of the existing literature. We present the data and explain the peer-ability indicators and outcomes in Section 3. In Sections 4 and 5, we discuss the estimation methods and the results, respectively. Finally, we conclude in Section 6 with a discussion of policy implications.

2. Overview of the existing literature

Researchers have been interested in the analysis of peer effects on a variety of outcomes, including risky health behaviours (McVicar and Polanski, 2014; and Trogdon et al., 2008), and on a number of academic and educational outcomes (Zimmerman, 2003; Hanushek et al., 2003; Carrell, 2009; Duflo et al., 2011; Lavy et al., 2012; and Gibbons and Telhaj, 2015). Most relevant to our work are those studies that analyse the effect of peer ability on educational achievements in school. Most studies have looked at low stakes outcomes for children in primary school environments and have exploited several different strategies to analyse the impact of peers in early ages (e.g., Hoxby, 2000; Hanushek et al., 2003; Angrist and Lang, 2004; Lefgren, 2004; Ammermueller and Pischke, 2006; Vigdor and Nexhyba, 2007; and Goux and Maurin, 2007; Landini et al., 2016).

Hanushek et al. (2003) use data from the Texas Assessment of Academic Skills (for students in grade three through to eight) and control for fixed school, individual, and school-by-grade effects to show that peer achievements have a positive effect on individual grades, and that this effect is constant across quartiles of the grade distribution. Similarly, Lefgren (2004) uses data from Chicago public elementary schools and examine peer effects using school tracking policies. The author shows that peer effects are quite small but generally positive and significant. Angrist and Lang (2004) analyse the results of the METCO program in Boston, which sends black disadvantaged students to public primary schools in high-socioeconomic-status areas, and they indicate that there is limited evidence of statistically significant effects.

A distinct strand of the literature examines peer effects in middle and secondary schools. Several studies show, mostly small but nonetheless often statistically significant, peer effects (e.g., Kang, 2007; Lavy et al., 2007; Schindler Rangvid, 2008; and Calvo-Armengol et al., 2009). In the UK, Bradley and Taylor (2008) estimate peer effects using information on pupils changing schools in the last two years of their compulsory education. They show that peer effects exist and are stronger for low-ability students and non-white children. However, pupils who change schools may be systematically different from those who do not change, especially when the reasons for the change can be related to school achievements. In addition, Atkinson et al. (2008) use a panel of school children from the southwest of England to look at the effect of the introduction of teacher performance-related pay in England, and show significant and non-trivial peer effects while conditioning for school and teacher fixed effects.

The studies that are closest to ours are Lavy et al. (2012) and Gibbons and Telhaj (2015). Both papers exploit the change in peers from primary to high school and use the National Pupil Database (NPD) to analyse the effect of peer ability measured at the end of primary school through Key Stage 2 examinations (at age 11) and on achievements at the beginning of high school, measured through Key Stage 3 exams (at age 14).[2] Lavy et al. (2012) use within-pupil and cross-subject regressions, and exploit the variation in achievements by subject to show negative effects arising from bad peers. They estimate little effect of the average peer quality on the good peers. Gibbons and Telhaj (2015) exploit year-to-year changes in secondary school peer group, and account for fixed effects for both primary and high school attended. Their work shows small and significant peer effects as well as complementarities between peers with different ability levels.

These studies analyse the impact of peer ability at the beginning of high school (age 14). Our work naturally complements them by estimating peer effects on high-stakes outcomes at the end of high school and before entering tertiary education. Furthermore, both Lavy et al. (2012) and Gibbons and Telhaj (2015) use the Pupil Level Annual School Census (PLASC) and the National Pupil Database (NPD), which has a very limited set of family characteristics, and, in particular, do not include the detailed set of parental socioeconomic-background variables which are available in LSYPE.[3] Lastly, we believe our alternative identification strategy is also compelling since it relies on 'peers of peers' who never had any contact with the individual, thereby allowing us to account for both non-random sorting and the reflection problem.

[2] Key Stages are discussed in more detail in Sec. 3.1.

[3] The only proxy for family income available in NPD is free school meal status eligibility. We tested our analysis using this variable and have found that it does not capture the effect of other important variables, such as a local deprivation index, and parental education and employment.

3. Data

3.1 Institutional background

Education in England is organised in ‘Key Stages’ (KS). Children enter primary school at 4–5 years old, and move to Key Stage 1 (at age 6–7). Key Stage 2 starts at age 7–8, and lasts until age 10–11 (Year 6) when children leave primary education and enter secondary school. At this point, Key Stage 3 starts (age 11–14), followed by Key Stage 4 (age 14–16). At the end of Key Stage 4, students take the General Certificate of Secondary Education (GCSE), which coincides with the end of compulsory schooling.

After this, students may decide to pursue further studies from age 16–18 (sometimes in a different school if their own school caters just for age 11–16, or otherwise in a ‘Sixth Form College’ that caters only for this older age group). In this Key Stage 5 (age 17–18), children specialise and study more challenging subjects in preparation for their General Certificate of Education (GCE) Advanced Level examinations (the so-called ‘A-levels’). Usually three or four subjects are studied at A-level over a two-year period, which are examined at the end of each year. Students usually select subjects that depend on their academic preferences and intentions toward further education.

Local Educational Authorities (LEA) are responsible for organising the admission policies for their primary and secondary schools.[4] Publicly-funded schools cannot select students on the basis of their ability, although some studies have suggested that schools find ways to select students on the basis of parental characteristics that might be correlated with ability (West and Hind, 2003). Our sample includes over 640 high schools and over 82 percent of them are government ‘comprehensive’ schools, while voluntary-aided and con-

[4] Recent policy in England (Wales, Scotland and Northern Ireland, who are not in LSYPE, have long had separate control over the shape of their education systems) have led to a more diversified population of schools with the conversion of an increasing number of publically funded comprehensive secondary schools becoming ‘Academy’ schools with greater independence from both central and local government control.

trolled schools (usually those schools with a religious denomination), who obtain the vast majority of their funding from the public purse, provide high school education for about 15 percent of children.

Children within a given area will often attend one of a small number of primary schools, and neighbouring children will often move on to one of several high schools. Parents are free to choose any secondary school they prefer, but when schools have a number of applicants which is higher than the available places, they allocate places according to some published criteria. Usually, looked-after children and children with special needs have priority, followed by children who have siblings in the same school, and then children living in the area, with proximity used as the tie-breaker.

In secondary schools, students are often grouped with different peers for different subjects, so they do not have a unique ‘class’ for all subjects. Furthermore, students are sometimes taught in groups of similar ability (determined after an initial observation period) for some subjects, although not all schools ‘set’ by ability, and this varies by subject, with a higher prevalence of ability setting for Mathematics and Science and a lower incidence for English (Kutnick et al., 2006). Indeed, some GCSE examinations, at age 16, are organised in ‘tiers’, whereby different students sit a different test depending on their ability group, so that the maximum grade that they can achieve depends on their allocated tier. As noted in Lavy et al. (2012), a high level of ability setting might affect measures of peer quality and might lead to downward bias in estimates of peer effects. However, our identification strategy relies on peers of peers’ ability in primary schools, where a low degree of ability setting is expected.

3.2 Dataset

The LSYPE dataset is managed by the UK Department of Education and covers a wide range of topics, including family relationships, attitudes toward school, family and labour market, and some more sensitive or challenging issues, such as risky health behaviours, and personal relationships. Young people included in LSYPE were selected to be representative of all young people in England but, at the same time, the survey oversampled specific groups (and, in particular, young people from a low socioeconomic background). The survey started when these adolescents were in Year 9 in 2004 at the age of 14. In the first wave of LSYPE, around 15,000 young people were interviewed across more than 700 high schools. On average, data were collected for 27 students in each school. In the first four waves, parents (or guardians) were also interviewed.

The records of LSYPE children can be linked to the NPD, a pupil-level administrative database of all English pupils including detailed information on pupil test scores and achievements, as well as school characteristics. We use this data to collect information about LSYPE children's results in test scores at ages 11, 14, and 16, which is the minimum school-leaving age for this cohort. This occurs at the end of a stage of Key Stage 4, and culminates in the GCSEs exams. LSYPE also includes information on Key Stage 5 exams, with detailed grades by subject studied. Beyond this, the LSYPE dataset records intention to participate in higher education at a university and actual attendance.

Our final sample includes 9,213 observations of children with non-missing information on test scores at ages 11, 14 and 16, peer test scores, and other essential information on the child's family background, coming from 640 high schools and 4,126 primary schools. When we estimate the impact of peers' ability on test scores at age 17-18, the sample becomes smaller because we only include individuals who remain in education at age 17 (Wave 4 of LSYPE). The selected observations were not significantly different from the original data in terms of their observable characteristics.

3.3 Outcomes

Our interest is in analysing the effect of peer ability on academic outcomes at the end of high school and on the chances that a young person will take further studies after compulsory education. We analyse peer effects on GCSE examinations score performance at age 15–16, A-level attainments (at age 17–18), the likelihood of attending university, and of being admitted to a prestigious institution.

Our dependent variables include the number of subjects with ‘pass’ grades (A*–C) in GCSE exams; and a binary variable equal to 1 if the child has five GCSE passes including Mathematics and English, which is the ‘gold standard’ that is usually required for students to follow an academic track for progression beyond 16 into senior high school and beyond. Table 1, which provides the descriptive statistics for our outcome variables, shows that more than half of the adolescents in the sample achieved five or more GCSE exams with a passing grade between A* and C, and 42 percent take A-level examinations two years later. Of those who stay in education after 16, 35 percent attend university and, within this subsample, 23 percent attend an institution that is part of the Russell Group of institutions that is regarded as being elite.[5] Figures 1 and 2 show the distribution of the number of GCSEs obtained at passing grades, and cumulated A-level points scores, respectively.[6]

We also explore the impact of peer ability on student performance in Mathematics and Science at A-levels. As noted in Mendolia and Walker (2014), the determinants of performance in a particular subject are very hard to disentangle from overall school performance. It is particularly interesting to analyse peer effects in performance in these STEM (Science, Technology, Engineering, and Math) subjects, as the UK ranking of 15-year-old pupils in Mathematics and Science in the OECD’s PISA tests has been consistently falling from 2000 to 2009. Furthermore, the UK has one of the lowest shares of 15-year olds intend-

[5] The Russell Group consists of the following 24 institutions: Birmingham, Bristol, Cambridge, Cardiff, Durham, Edinburgh, Exeter, Glasgow, Imperial College, King's College London, Leeds, Liverpool, London Scholl of Economics, Manchester, Newcastle, Nottingham, Oxford, Queen Mary College London, Queen’s Belfast, Sheffield, Southampton, University College London, Warwick, and York.

[6] The LSYPE data accurately reflect the population average numbers of passes at GCSE (approximately 60 percent in this cohort), and the distribution of A-levels, where around 10 percent of an A-level cohort would achieve 4 (and sometimes more) straight A’s . The note to Table 1 explains how A-level grades in each subject are converted to points and aggregated.

ing to pursue a STEM career among the OECD countries, and particularly lags behind in women's aspirations to study a STEM subject and engage in a STEM career (OECD, 2012).

Finally, we analyse the effect of peer ability on the probability of being enrolled at university at age 19–20 (close to 30 percent of an age cohort), and on the probability of attending a Russel Group institution (which is close to 25 percent of all university entrants).

3.4 Other independent variables

We exploit the richness of the LSYPE data and estimate three versions of our model, progressively expanding the set of covariates. Below, we present estimates for a model which controls for a basic set of individual and family characteristics, including child's sex and achievement in the KS2 test (age 11); maternal education and marital status; employment status of both parents (Wave 4 – age 17); and, additionally, the Index of Multiple Deprivation (IMD) score, which is a measure derived from area level income, employment, health and disability, education, housing, crime, and living environment.[7] Table 2 records the descriptive statistics for a number of the independent variables included in the analysis.

We also estimate results which exclude the IMD score; and results which extend the controls to embrace individual ethnic background and for some school characteristics, such as government region, number of students, religious denomination, and the gender mix of the school. These results are presented in the Appendix.

3.5 Peer ability

The principal explanatory variable, average peer ability, is measured through achievements in KS3 tests (age 14) for children who attended the same high school of each LSYPE child. Our

[7] In the Appendix, we present results which exclude this latter variable; and results which extend the controls to embrace individual ethnic background and for some school characteristics, such as government region, number of students, religious denomination, and the gender mix of the school.

instrumental variable, the average peers-of-peers ability, is measured through achievements in KS2 tests taken at the end of primary school at age 10.

We investigate the effect of low-achieving peers in high school in order to analyse whether a large fraction of 'bad peers' is detrimental to student learning. To do so, we use the information on the percentage of students not achieving the basic standard (called Level 5) in KS3 Mathematics. Figure 3 presents the distribution of this variable. The majority of schools in the estimation sample have a percentage of students not achieving basic standards in Maths below 30 percent and, as expected, there are very few schools where more than 50 percent of students are in this category.

Our analysis is limited to children who are in LSYPE, and, consequently, we do not have a complete overview of all students in a particular primary or high school, and our estimates could potentially be affected by measurement error for this reason. However, the LSYPE sample was designed to be representative of various subgroups of the student population in England, and using students in LSYPE allows us to access to all the available information on their families and backgrounds, which are not included in NPD but could be relevant in explaining academic outcomes.

On average, LSYPE children have a high school peer group of 15 students (in LSYPE) who come from many different primary schools (from two to 23 primary schools). The vast majority of high schools (around 80 percent) draw their students from a group of 8 to 14 primary schools. Table 3 shows that over 70 percent of children have a peers-of-peers group that contains three or more students. In our sample, the size of the peers-of-peers group varies from one to 97 children.

4 Estimation

We begin our analysis by estimating a linear-in-means model of peer effects:

$$Y_{ihp} = \bar{A}_{ih}\alpha + \mathbf{X}_i'\boldsymbol{\gamma} + \epsilon_i, \tag{1}$$

where Y_{ihp} represents a particular academic outcome for individual i who is attending high school h and who attended primary school p. We define i's high school peers as those currently attend high school h, and they could have attended a variety of primary schools apart from school p. The variable $\bar{A}_{ih}$ is the average ability (measured by KS3 score) for LSYPE children attending high school h excluding the individual (the 'leave-one-out' mean), and $\mathbf{X}_i$ is a vector of child and family characteristics and a constant, the inclusion of which would likely increase the precision of the OLS estimator while simultaneously reducing the impact of potential selection bias.

The parameter of interest is α, which captures the relationship between average peer ability, $\bar{A}_{ih}$, and individual achievements, Y_{ihp}, at the end of junior high school and beyond. This represents the endogenous effect in the terminology of Manski (1993) and, if significant, it is this that generates the social multiplier effect.

To account for the endogeneity of average peer ability in Equation (1), we use instrumental-variable estimation, with peers-of-peers ability in primary school (measured as KS2 achievements – age 11) as an instrument for the average high school peer ability (measured as KS3 achievements – age 14). Our first-stage equation is

$$\bar{A}_{ih} = \bar{B}_{zt}\beta + \mathbf{X}_i'\boldsymbol{\pi} + \nu_i, \tag{2}$$

where the average high school peer ability $\bar{A}_{ih}$ depends on the peers-of-peers average performance $\bar{B}_{zt}$ in primary school of those who attended primary schools z, where $z \neq p$, and currently attending high school t, where $t \neq h$.

The exclusion restriction essentially states that the ability of the high school students' peers-of-peers in primary school did not affect the high schools' student achievements directly except through its impact on the student's current peers in high school. Note that there is no reason for our measure of ability to be restricted to KS3 performance because not only have individuals in our sample never met their peers of peers in primary school, these peers-of-peers children have also gone to different high schools. Therefore, the reflection problem does not arise. We also present results throughout which, instead, we measure peer ability using peers' KS2 and GCSE instrumented by their peers of peers score at KS2 level.

One natural concern in the estimation of this model is that selection of secondary schools on the basis of unobservable characteristics could be driving the main findings. Parents choose the school for their children (or at least the area where they live) and, thus, individuals who attend the same high school are likely to have some common background characteristics. Our instrument relies on peers of peers who do not attend the same high school as the individual *and* did not attend the same primary school. Around 80 percent of high schools in the estimation sample have more than eight primary feeder schools, and, therefore, the peers of peers (who now attend a different high school) are likely to have come from an area with different socioeconomic characteristics. Therefore, given the considerable number of primary and high schools in the data, there is no reason to believe that these differences are systematic and peers of peers are a selected group.[8]

As noted in Gibbons et al. (2013), most households can choose between more than one school from their area of residence and, on average, students in the same cohort living in the same neighbourhood attend just one of a handful of different local secondary schools. Furthermore, a typical English secondary school is attended by pupils living in more than 60 Output Areas, the smallest proxy for neighbourhood (Gibbons et al., 2013). However, neighbourhood composition has a very limited effect on test scores once one controls for family

[8] We might expect the peers of peers to be more likely to have correlated effects with the high school peers in the data the fewer the high schools are typically attended in a given area. For example, this might be the case with rural schools where choices may be geographically limited. It may also be the case in large high schools. We show that our headline results are robust to differentiating between rural and urban high schools, and those coming from small or large high schools (where small high schools are defined as those with less than 1000 students, which is about the median high school size in our data).

socioeconomic characteristics (Gibbons et al., 2013), and we believe that our rich data allow us to take into consideration a wide set of these factors.

Thus far, we have assumed that peer effects are homogeneous in the sense that the relationship between peer ability and individual achievements is the same for each student. However, peer effects are likely to be heterogeneous and vary according to the individual ability of students. For example, peer ability might have stronger effects on weak students than on strong students or vice versa; or the presence of a group of weak students might have different effects on weak students than on strong ones (see, e.g., Kong 2007).

We use quantile regression to examine the potential heterogeneous effects of peer ability at different points of the achievement distributions. We estimate the effect of the average peer ability for students at different quantiles of the GCSE and A-level score distributions. In order to deal with the endogeneity of peer ability in high school, we use IV quantile regression (Chernozhukov et al., 2010; Chernozhukov et al., 2015; Lee, 2007) which has been used in a similar context in Kong (2007).[9]

A parametric version of the estimator proposed by Lee (2007) is used in the estimation. In particular, following Lee (2007), the following model is estimated:

$$Q_{Y_{ihp}|A,\mathbf{X}} = \bar{A}_h\alpha + \mathbf{X}_i'\boldsymbol{\gamma} + \varepsilon_i, \tag{3}$$

where $Q_{Y_{ihp}|A,\mathbf{X}}$ is the quantile distribution of Y. The first-step linear quantile regression is modelled as

$$Q_{\bar{A}_h|Z} = \bar{B}_{zt}\beta + \mathbf{X}_i'\boldsymbol{\pi} + \nu_j, \tag{4}$$

where $Q_{\bar{A}_h|Z}$ is the quantile distribution of peer ability $\bar{A}_h$, and β and $\boldsymbol{\pi}$ can be estimated by a quantile regression of Y on $\bar{A}$ and Z.

[9] The analysis is performed using the Stata routine cqiv with the uncensored option (Chernozhukov et al., 2011).

Furthermore, we follow Lavy et al. (2012) and estimate the effect of having low-ability peers in high school. To do so, we use the information on the percentage of students not achieving the basic standard (called Level 5) in KS3 (or KS2) Mathematics, which is available in the LSYPE dataset for each high school. In order to deal with the potential endogeneity of this variable, we apply the same strategy as in the previous model and instrument it with a variable indicating the percentage of students not achieving basic standards in KS2 Mathematics in peers-of-peers primary schools.

5 Results

The main results are presented in Table 4, where the regressions control for individual and family characteristics, including the Index of Multiple Deprivation score. Each row is separate outcome variable; adjacent columns compares OLS and IV; the three super columns refer to different ways of measuring peer ability – peers KS2 age 10 score, or their KS3 age 14 score, or the number GCSE passes at age 16.[10]

Despite the long vector of control variables, the results from least-squares estimation are still likely to be biased estimates of the true peer effect. It could be biased upward because peers are endogenous, but it could also be biased downward because we measure peer performance with error. Our information on peers is limited to students being in the same school, but we cannot actually observe whether two pupils have had direct interaction with each other. Moreover, we are measuring the average performance of peers using a subsample of individuals who are in the same high school, but went to a different primary school, and are also interviewed in LSYPE. Thus, our average measure of peer ability is likely to have more

[10] Results for less and more parsimonious specifications are provides in the Appendix, Tables A4 and A5. It is important to show the stability of our main results when controlling for the IMD variable, as it is well-known that family socioeconomic status is a strong predictor of educational achievements later in life. The Appendix results show similar patterns as Table 4. We also tested our main results by including an additional indicator of economic disadvantage of the primary school attended (percentage of students eligible for free school meal). The substantive results were unaffected. First-stage regression results from 2SLS are presented in the Appendix as well (Table A6).

measurement error than is usually the case when all peers are included in the data. Therefore, we cannot *a priori* sign the direction of bias in OLS.

Unsurprisingly, the OLS results presented in Table 4 are consistently highly significant and suggest that improving peer ability has a positive effect on individual achievements at age 16–17 (GCSE exams) and at age 17–18 (A-level exams); and the sizes of the effect are nontrivial. For example, a one standard deviation increase in average peer KS3 score increases an individual's chances of having five or more GCSE with A*–C by 4.5 percent (and the mean of this variable is 52 percent).

A number of statistically significant coefficients lose their significance once we account for potential endogeneity with IV estimation. However, the OLS results for performance in test scores at age 17–18 (A-levels) carry over into IV, although most of the estimated coefficients are now larger, which suggests that there could be substantial attenuation bias in OLS estimation due to measurement error. Interestingly, when we use IV estimation, we do not find any significant effect of peer ability on the chances of attending university, nor to gaining admission to an elite higher education institution.

The IV results show that a one-standard-deviation increase in the average KS3 score of the peers increases the probability of taking A-levels by about 13 percent (the average of this variable is 42 percent in the estimation sample); and the effect on average A-level score increases by 39.815 points, which is equivalent to 28 percent of a standard deviation. Peer ability also significantly increases performance in A-level Mathematics by 21.35 points (38 percent of a standard deviation). These results are broadly consistent in terms of size and significance whether use peer KS2, KS3 or GSCE as the measure of average peer ability.

Table 5 presents estimation results for the effect of having low-achieving peers. Each row is a different outcome, and again we compare OLS and IV results across columns; and we measure peer ability by KS2 and KS3 scores. The IV results indicate that being in a school with a 10-percent larger proportion of peers who do not achieve basic standards in Mathematics significantly decreases performance in test scores at age 14 (KS3) by about 0.20 to 0.30 points (equivalent to 3 to 5 percent of a standard deviation). While low-quality peers do not seem to affect GCSE performance, the results suggest that they do decrease A-level results (–14 to –18 points or 10–13 percent of a standard deviation), as well as the probability of taking A-levels in Maths and Sciences and results in A-level Maths.[11] These results are similar to the corresponding effect in Lavy et al. (2012), who show that a 10-percent decrease in the proportion of 'bad' peers at school is associated with an improvement of approximately 10–11 percent of a standard deviation of the within-pupil KS3 distribution for students.

Both Tables 4 and 5 suggest that peer ability does not significantly affect performance at GCSE level (age 16–17). However, this could simply be due to the fact that the effect of peer ability on individual achievements is heterogeneous, i.e., that peer ability matters a lot for students at a particular point of the grade distribution, and very little for others. For example, it is possible that some students suffer (or benefit) more from their peers' ability and in particular, it is possible that weaker students are more heavily influenced by their peers' behaviour and achievements in class. For this reason, we follow Kang (2007) and use quantile regressions in order to analyse the potential heterogeneity of peer interactions.

Results from the estimation using quantile regression are summarised in Table 6, and in Figures 4 and 5, using the benchmark specification where average peer KS3 performance is used as a measure of peer ability. Our results confirm the main findings in the previous literature (e.g., Kang, 2007 and Carrell et al., 2009), which indicate that peer effects are stronger at the bottom of the grade distribution. For example, Figure 4 shows that a one-standard-deviation increase in average peer KS3 score increases the number of GCSEs with Grades

[11] We explore the sensitivity of these results to school size and urban/rural in the Appendix (see Tables A1 and A2) which shows that small and large schools have insignificantly different IV results (although the *F*-statistic indicates a weakness in the instrument in the case of large schools), as do urban and rural schools.

A*–C by about 0.75 for students in the 20th quantile while the effect vanishes for students in the top half of the grade distribution. Similarly, Figure 5 shows that increased peer ability improve the score in A level exams by over 50 points for students in the bottom quintile of the grade distribution, while the effect is much smaller for students at the top.

Results from the estimation of quantile regression on the effect of low-ability peers are presented in Figure 6 and 7 and strongly confirm that increasing the percentage of low-ability peers is significantly detrimental for students at the bottom of the GCSE grade distribution. 10 percent more high school peers who do not achieve basic standards in Mathematics decrease the number of GCSEs at passing A*–C grades by about 0.3 for students in the 20th percentile of the grade distribution, while the effect is significantly smaller and then vanishes for top students. Figure 7 shows effects of low-quality peers on A-level points which are generally negative. A 10-percent increase in the proportion of peers who do not achieve basic standards in Mathematics has a negative effect that ranges from 19 (10th percentile of A-level distribution) to 12 points (80th percentile) in the individual A-level score.

The potential endogeneity of peer ability is taken into account using quantile instrumental variable regression, and the results are presented in Tables 7–10.[12] Average peer effects are generally insignificant across the GCSE distribution. In the case of the effect of low-quality peers, the results presented in Table 8 suggest that the effect of low-quality peers on GCSE results is especially relevant at the bottom of the distribution. The results also confirm that peer effects on A-level performance are significant across the grade distribution, especially when we look at the impact of low-quality peers in Table 10.

This difference with respect to GCSE results might be partially due to the fact that students who undertake A-levels will usually study in a different school (often a Sixth Form

[12] We estimate this model using the Stata user-written cqiv command with the uncensored option (Chernozhukov et al., 2012).

College) from the one they attended in the junior high years, so this model is actually estimating the effect of 'past peers', as we rely on peers at the *beginning* of junior high school. Furthermore, A-level exams require a higher level of preparation than GCSEs, and it is possible that the quality of high school peers has a stronger effect on the students' preparation at this higher level.

We test our main results using three sensitivity analyses. First, we re-estimate the model comparing schools with less than 1000 students to those with more than 1000 students enrolled.[13] Large schools will typically draw from a larger number of junior schools and are more likely to implement setting by ability groups in some subjects. For this reason, we expect peer effects to be stronger in small schools, where there are a limited number of peers with which to interact. Similarly, Lavy et al. (2012) address the ability-tracking problem by restricting their estimation to the smallest 50 percent of secondary schools in England. The results are fairly similar across different school sizes with respect to the impact of low-quality peers, and do indeed seem stronger in small schools, especially when we look at the impact on the performance in A-level in Mathematics (see Appendix Table A1).

Second, we re-estimate results comparing high schools that are in regions that are largely rural with high schools in urban areas.[14] In rural areas, school choice is likely to be limited, and the student population is more likely to be homogeneous. Peer effects from low-quality peers are very similar across the two sub-samples, but the effect from average peer quality is stronger in non-rural schools (see Appendix Table A2).

[13] We also re-estimate the model limiting the sample to students who have at least ten peers from the same high school in LSYPE. The substantive results are unchanged.
[14] We adopt the definition of rural areas used in the Family Resource Survey data. The complete list of rural areas is Berkshire, Bournemouth, Dorset and Poole, Cambridgeshire, Cheshire and Warrington, County Durham, Cumbria, Derbyshire, Devon and Cornwall, Essex, Gloucestershire, Hampshire and Isle of Wight, Herefordshire and Worcestershire, Hertfordshire, Humberside, Kent and Medway, Lancashire, Leicestershire, Lincolnshire and Rutland, Norfolk, North Yorkshire, Northumberland, Shropshire, Somerset, Staffordshire, Suffolk, Sussex, West Yorkshire, West of England, Wiltshire and Swindon.

As a final sensitivity test, we estimate a model with primary-school fixed effects in order to take into consideration the common unobserved characteristics of children who attended the same primary school (see Appendix Table A3). Unfortunately, our data do not allow estimating a model with high-school fixed effects, as we only have one observation of average peer KS3 score for all children attending the same high school, and this would be perfectly collinear with the fixed effect. The results are consistent with the previous findings from the OLS and IV estimates. Interestingly, in the fixed-effects model, peer ability has a significant effect on the probability of attending university.[15]

6. Conclusion

We estimated the effect of peer ability in English high schools using data from the Longitudinal Study of Young People in England (LSYPE). As a measure of peer ability, we used primarily the pupil's Key Stage 2 test score at age 10. While we focused our attention on the effect of average peer ability, we also considered the effect of being in a school with a high proportion of low-achieving peers. Moreover, we have investigated the effect of peer ability across the grade distribution using quantile-regression methods.

The main contributions of the work are that we analyse peer effects on high-stakes outcomes at the end of high school using a very rich and recent dataset. We also propose and use a novel identification strategy based on the peers of peers who have had no direct interaction with the student of interest. These peers of peers are primary school peers of an individual's high school peers who attended both different primary and high schools from the individual, and we use information pertaining to them as an instrument for high school average peer ability. The maintained assumption is that, since these peers of peers have never been in

[15] The results for other independent variables are reported in Appendix Table A7. Not surprisingly, individual ability (measured through the KS2 score) and family socioeconomic status (and, in particular, maternal education) are strong determinant of academic achievements.

school with the individual, they could never have had a direct effect on her or his achievements.

Our findings show that average peer ability has a moderate effect on performance in GCSE exams at age 16, and most of the effect is found for students at the bottom of the grade distribution. In particular, being in a school with a high proportion of low-achieving peers is particularly detrimental for the achievements of students in the bottom quartile of the GCSE distribution.

Results for A-levels are less heterogeneous and show that increased peer quality is significantly beneficial for all students across the grade distribution. Our results are stable to the introduction of a more detailed set of independent variables, including individual, family and school characteristics, and robust as well to IV regression and primary-school fixed effects. Our results are broadly consistent with previous findings from the literature and in particular with Gibbons and Telhaj (2015) and Lavy et al. (2012).

Our results imply that there are some indications of complementarities between students of different abilities. Even if it is particularly complex to draw clear policy implications related to students' ability mixing, we believe that these results show the detrimental effect of grouping low-ability students with peers from similar ability levels.

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Table 1 Descriptive Statistics of Outcome Variables

Educational Outcomes	Mean (Std. Dev.)
Key Stage 3 Score	34.661 (6.42)
Has 5 or more GCSE with A*–C incl. English and Maths	52.34%
Number of GCSEs with A*–C	6.46 (4.17)
Has A levels	42.30%
A-levels points | Has A levels	242.56 (137.43)
Has A level in Maths	9%
A-level points in Maths | A level in Maths	113.8 (53.88)
Has A level in Science	12%
A-level points in Science | A level in Science	134.22 (75.36)
Attending university	29.8%
Attending a Russell Group university | conditional on attending university	23%

Note.—A-level points are counted as 100 for Grade A, 80 for B, 60 for C, 40 for D, and 20 for E.

Table 2 Descriptive Statistics of independent variables

Variable	Mean (Stand. Dev)
Key Stage 2 Score	27.341(3.93)
IMD score	24.273 (17.44)
Male	0.504
Maternal age	44.952 (5.44)
Maternal education	
Degree	0.112
HE below degree level	0.135
A-level	0.128
GCSE A*-C	0.279
Below GCSE	0.337
Marital status	
Mother is married	0.758
Mother is divorced	0.131
Mother is widow	0.018
Maternal employment status	
Mother is employed or self-employed	0.762
Mother is unemployed	0.017
Mother is out of the labour force	0.282

Table 3 Peer of Peers Group Size

Number of Peers	Percent of LSYPE Children
1 peer of peers	10
2 peers of peers	18
3–4 peers of peers	10
5–7 peers of peers	10
8–10 peers of peers	12
11–15 peers of peers	12
15+ peers of peers	28

Table 4 OLS and IV Estimates of the Impact of Average Peers' Quality on Academic Achievement

	Effect of peers' KS2			**Effect of peers' KS3**			**Effect of peers' GCSE**		
Outcomes	**OLS**	**IV**	**F**	**OLS**	**IV**	**F**	**OLS**	**IV**	**F**
KS3 points	0.507	0.735	29.58	1.356	0.837	20.53	n.a	n.a	n.a
	(0.112)***	(0.566)		(0.0985)***	(0.574)				
N	9,213	7,997		9,213	9,213				
# GCSE A*–C	-0.153	0.287	29.28	0.286	0.376	20.53	0.7398	0.197	13.45
	(0.103)	(0.618)		(0.106)***	(0.698)		(0.059)***	(0.391)	
N	9,280	8,050		9,213	7,997		9,280	8,050	
5+ GCSE A*–C	-0.0168	0.088	29.28	0.045	0.108	20.53	0.0421	0.060	13.45
	(0.013)	(0.067)		(0.012)**	(0.075)		(0.006)***	(0.042)	
N	9,280	8,050		9,213	7,997		9,280	8,050	
Having A levels	**0.0254**	**0.108**	33.05	**0.057**	**0.133**	20.19	**0.039**	**0.077**	13.94
	(0.013)**	**(0.064)***		**(0.011)*****	**(0.076)***		**(0.006)*****	**(0.043)***	
N	7,133	6,247		**7,098**	**6,220**		7,133	6,247	
A-level Points	34.028	35.020	23.54	**43.124**	**39.815**	14.06	**18.583**	**25.624**	10.36
	(5.016)	(22.538)		**(4.039)*****	**(23.903)***		**(2.472)*****	**(15.583)***	
N	3,960	3,506		3,948	3,497		3,960	3,506	
A levels in Maths	0.032	0.109	23.54	0.053	0.120	14.06	0.026	0.079	10.36
	(0.018)*	(0.080)		(0.016)***	(0.089)		(0.008)***	(0.059)	
N	3,960	3,506		3,948	3,497		3,960	3,506	
A level points in Maths	**6.273**	**19.290**	23.54	**8.974**	**21.350**	14.06	**4.156**	**14.114**	10.36
	(2.451)**	**(9.491)****		**(2.219)*****	**(10.481)****		**(1.100)*****	**(7.170)****	
N	3,960	3,506		3,948	3,497		3,960	3,506	
A levels in Science	0.055	0.0330	23.54	0.070	0.039	14.06	0.0329	0.0241	10.36
	(0.018)**	(0.078)		(0.016)***	(0.087)		(0.008)***	(0.056)	
N	3,960	3,506		3,948	3,497		3,960	3,506	
A level points in Science	9.3788	-0.313	23.54	12.356	0.228	14.06	5.417	-0.229	10.36
	(3.059)***	(12.697)		(2.536)***	(14.14)		(1.318)***	(9.304)	
N	3,960	3,506		3,948	3,948		3,960	3,506	
Attend any university	0.029	-0.092	33.55	0.059	-0.102	20.19	0.038	-0.065	14.09
	(0.013)**	(0.073)		(0.013)***	(0.088)		(0.007)***	90.056)	
N	6,337	5,545		6,309	5,524		6,337	5,545	
Russell university	0.055	0.131	25.05	0.081	0.126	18.75	0.034	0.075	14.66
	(0.020)	(0.101)		(0.017)***	(0.096)		(0.009)***	(0.058)	
N	2,738	2,401		2,734	2,399		2,738	2,401	

Note: Std errors are in brackets. * indicates that the underlying coefficient is significant at 10% level, ** at 5% and ***1%. Additional variables included are listed at p.14-15. Sample size, N, is different between IV and OLS because all students whose peers come from 1 primary school only do not have "peers of peers" and are excluded. F is the Stock and Yogo test that suggests that, as a rule of thumb, one might consider instruments that result in an F below 10 as weak.

Table 5 OLS and IV estimates of the impact of % of students not achieving basic standards in Mathematics on academic achievements

	Effect at KS2[1] level			Effect at KS3[2] level		
Outcomes	**OLS**	**IV**	**F**	**OLS**	**IV**	**F**
KS3 points	-0.040 (0.054)	**-0.211 (0.118)****	126.42	-0.422 (0.046)***	**-0.305 (0.135)****	70.96
N	8,907	7,752		9,104	7,898	
# GCSE A*–C	0.0825 (0.062)	-0.123 (0.122)	126.42	-0.082 (0.046)*	-0.176 (0.148)	71.33
N	8,907	7,752		9,168	7,947	
5+ GCSE A*–C	0.0003 (0.006)	-0.0180 (0.013)	126.42	-0.012 (0.0057)**	-0.023 (0.016)	71.33
N	8,907	7,752		9,168	7,947	
Having A levels	-0.0048 (0.007)	-0.0176 (0.015)	125.38	-0.0168 (0.005)***	-0.019 (0.018)	71.35
N	6,857	6,026		7,039	6,163	
A levels Points	**-9.263 (2.712)*****	**-14.25 (5.366)*****	113.38	**-17.004 (1.910)*****	**-18.274 (5.918)*****	64.74
N	3,796	3,376		**3,900**	**3,459**	
A levels in Maths	0.001(0.008)	-0.024 (0.017)	113.38	**-0.015 (0.006)*****	**-0.035 (0.019)***	64.74
N	3,796	3,376		**3,900**	**3,459**	
A level points in Maths	-0.104 (1.080)	-3.094 (2.112)	113.38	**-2.698 (0.856)*****	**-4.867 (2.528)*****	64.74
N	3,796	3,376		**3,900**	**3,459**	
A levels in Science	-0.0205 (0.009)	**-0.036 (0.018)****	113.38	**-0.029 (0.007)*****	**-0.0459 (0.020)****	64.74
N	3,796	**3,376**		3,900	3,459	
A level points in Science	-2.826 (1.428)**	-3.963 (2.804)	113.38	-4.695 (1.091)***	-5.322 (3.098)*	64.74
N	3,796	3,376		3,900	3,459	
Attend any univ.	-0.023 (0.008)**	-0.002 (0.016)	121.56	-0.020 (0.005)***	-0.005 (0.018)	71.85
N	6,090	5,349		6,250	5,470	
Attend Russell univ.	-0.012 (0.010)	-0.021 (0.023)	96.06	-0.030 (0.007)***	-0.030 (0.027)	63.29
N	2,624	2,315		2,697	1,976	

Note: Std errors are in brackets. * indicates that the underlying coefficient is significant at 10% level, ** at 5% and ***1%. Additional variables included are listed at p.14-15. IV Sample size, N, is different between IV and OLS because all students whose peers come from 1 primary school only do not have “peers of peers and are excluded. F is the Stock and Yogo test that suggests that, as a rule of thumb, one might consider instruments that result in an F below 10 as weak.

[1] Effect of a 10% increase in the percentage of students who did not achieve basic standards in Mathematics in KS2 (age 11) in the primary school of the individual’s high school peers.
[2] Effect of a 10% increase in the percentage of students who did not achieve basic standards in Mathematics in KS3 (age 14) in the individual’s high school.

Table 6 *Quantile Regression of the impact of peers' quality on GCSE passes*

	Effect of peers' KS3 on # GCSE A*-C		Effect of peers' KS3 on A level points	
Percentile	**Average peers quality**	**% Low quality peers**	**Average peers quality**	**% Low quality peers**
P10	0.935	-0.285	54.544	-18.787
	(0.209)***	(0.048)***	(6.719)***	(2.632)***
P20	0.764	-0.299	53.045	-18.692
	(0.178)***	(0.047)***	(6.800)***	(2.741)***
P30	0.461	-0.173	48.610	-20.224
	(0.113)***	(0.061)***	(5.638)***	(2.569)***
P40	0.378	-0.155	47.814	-19.527
	(0.107)*	(0.053)***	(5.496)***	(2.287)***
P50	0.205	-0.078	45.354	-18.274
	(0.116)	(0.061)	(4.836)***	(2.450)***
P60	0.128	-0.030	41.207	-15.949
	(0.117)	(0.061)	(4.692)***	(2.366)***
P70	0.016	0.001	36.867	-13.730
	(0.084)	(0.033)	(4.721)***	(2.335)***
P80	-0.041	-0.008	31.785	-11.900
	(0.104)	(0.037)	(4.090)***	(2.579)***
P90	-0.331	0.043	27.300	-10.235
	(0.206)	(0.084)	(5.037)***	(2.040)***
N	9,213	9,168	3,948	3,900

Note: Std errors are in brackets. * indicates that the underlying coefficient is significant at 10% level, ** at 5% and ***1%. Additional variables included are listed at p.14-15.

Table 7 IV Quantile Regression of the impact of average peers' quality on GCSE passes (Effect of Peers' KS3)

# GCSE A*–C	**P10**	**P20**	**P30**	**P40**	**P50**	**P60**	**P70**	**P80**	**P90**
_b	0.668	1.613	0.234	0.189	0.092	0.435	-0.111	-0.114	0.435
Mean	0.842	1.458	0.494	0.309	0.029	0.454	-0.003	-0.272	0.454
Lower bound	-0.432	-0.203	-0.687	-0.692	-0.792	-0.376	-1.039	-1.133	-0.376
Upper bound	2.366	3.171	1.666	1.338	0.870	1.379	0.996	0.681	1.379

Note: Confidence intervals are reported. Results have been estimated with Stata routine cqiv with uncensored option and 50 bootstrap replications.

Table 8 IV Quantile Regression of the impact of % low ability peers on GCSE passes (Effect of peers'KS3)

# GCSE A*–C	**P10**	**P20**	**P30**	**P40**	**P50**	**P60**	**P70**	**P80**	**P90**
_b	-0.441	-0.443	-0.210	-0.184	-0.151	-0.347	-0.252	-0.088	-1.448
Mean	-0.420	-0.384	-0.238	-0.212	-0.170	-0.321	-0.256	-0.087	-1.164
Lower bound	**-0.646**	**-0.629**	-0.531	-0.431	-0.423	**-0.538**	-0.426	-0.287	-3.122
Upper bound	**-0.087**	**-0.092**	0.060	0.095	0.069	**-0.088**	0.016	0.170	0.593

Note: Confidence intervals are reported. Results have been estimated with Stata routine cqiv with uncensored option and 50 bootstrap replications.

Table 9 *IV Quantile Regression of the impact of average peers' quality on A level points* – Effect of peers' KS3

A level points	P10	P20	P30	P40	P50	P60	P70	P80	P90
_b	46.92728	37.61557	4.898	4.898241	5.62693	14.66731	**40.002**	32.643	11.752
Mean	51.33338	35.56376	18.618	18.61795	12.12015	21.97272	**49.004**	37.477	44.712
Lower bound	-16.7845	-38.9555	-30.743	-30.7431	-57.7063	-41.402	**11.234**	-19.417	-13.628
Upper bound	112.7472	120.8973	85.156	85.15649	87.29702	84.02908	**97.631**	99.380	138.942

Note: Confidence intervals are reported. Results have been estimated with Stata routine cqiv with uncensored option and 50 bootstrap replications.

Table 10 *IV Quantile Regression of the impact of % low quality peers on A level results*– Effect of peers' KS3

A level points	P10	P20	P30	P40	P50	P60	P70	P80	P90
_b	-10.2379	-13.4252	-19.182	-20.487	-20.3744	-25.7201	-20.9793	-15.924	-15.515
Mean	-10.2687	-13.9594	-18.745	-20.7811	-23.0012	-25.1854	-21.4499	-18.254	-19.033
Lower bound	-28.5673	-26.4512	**-34.772**	**-37.2917**	**-40.5129**	**-41.2162**	**-36.8531**	-34.526	-37.214
Upper bound	8.389135	1.492725	**-4.763**	**-6.75027**	**-7.59995**	**-11.0534**	**-8.77824**	2.472	-0.514

Note: Confidence intervals are reported. Results have been estimated with Stata routine cqiv with uncensored option and 50 bootstrap replications

Figure 1 Distribution of Number of GCSEs with Grade A–C*

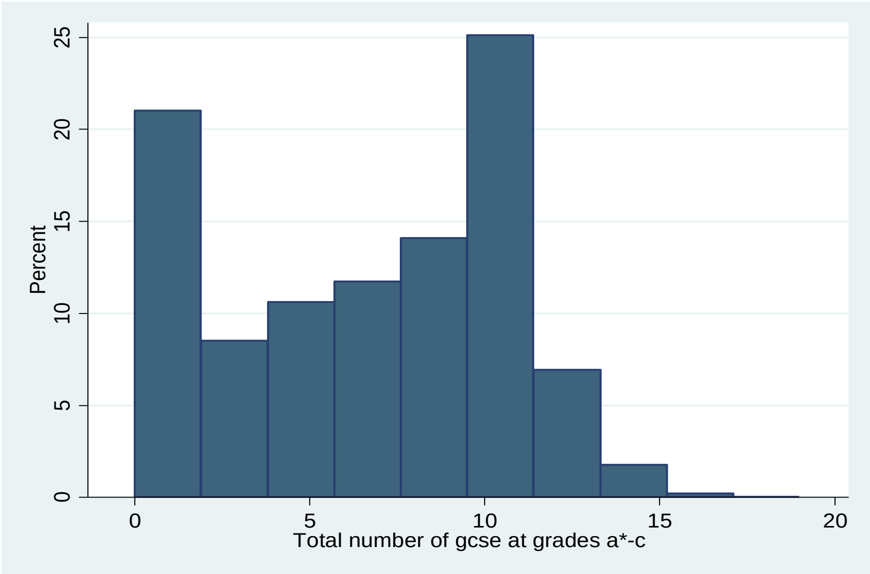


Figure 2 Distribution of A-Level points scores

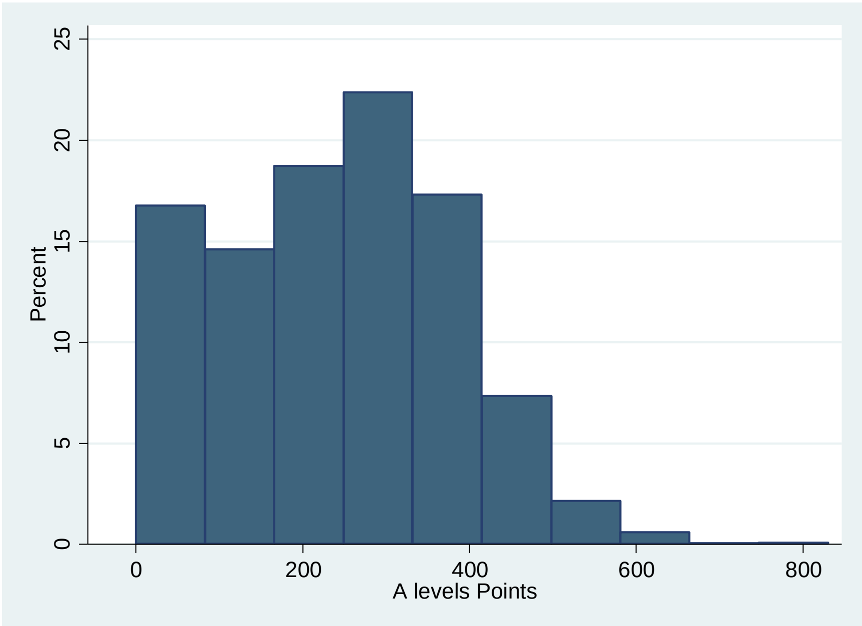


Figure 3 Distribution of Percentage of Students Not Achieving Basic Standard Mathematics

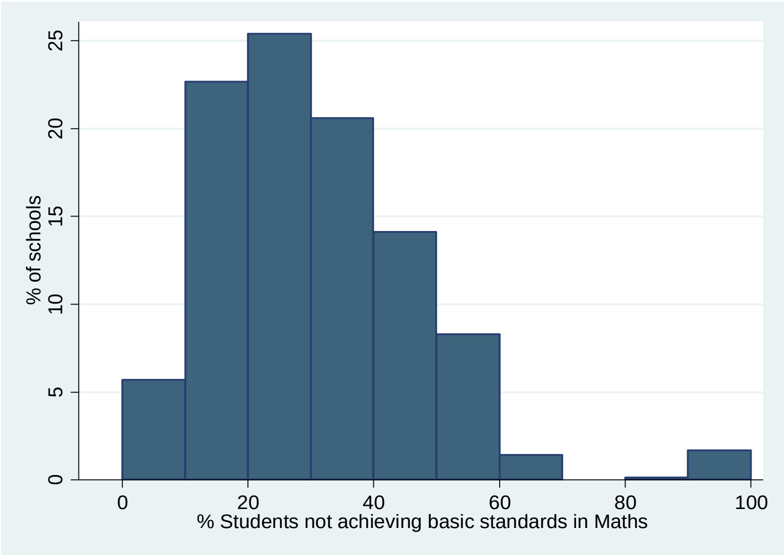


Figure 4 Estimated effects of average KS3 peers' score across deciles of #GCSE A-C*

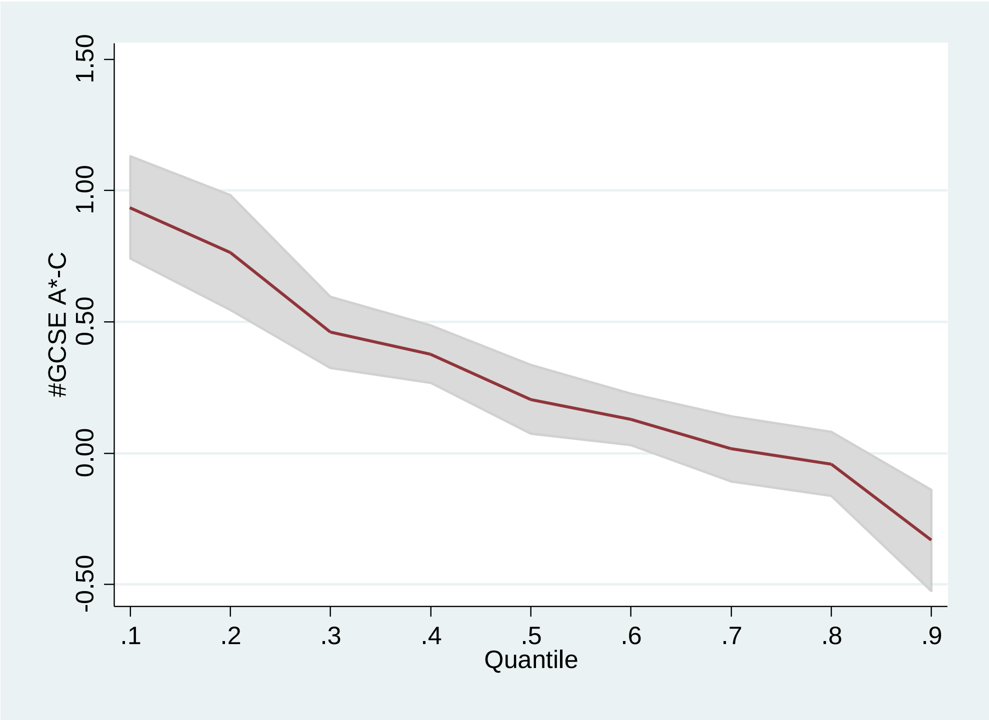


Figure 5 Estimated effects of average KS3 peers' score across deciles of A-level points

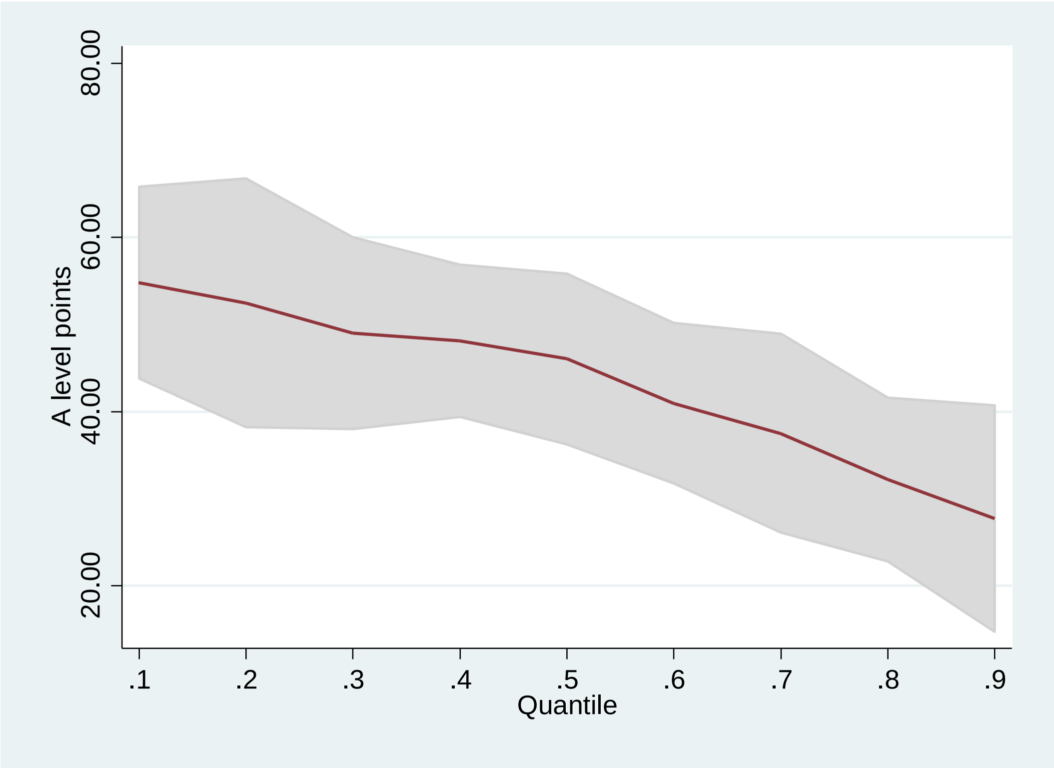


Figure 6 Estimated effects of low quality peers across deciles of #GCSE A-C*

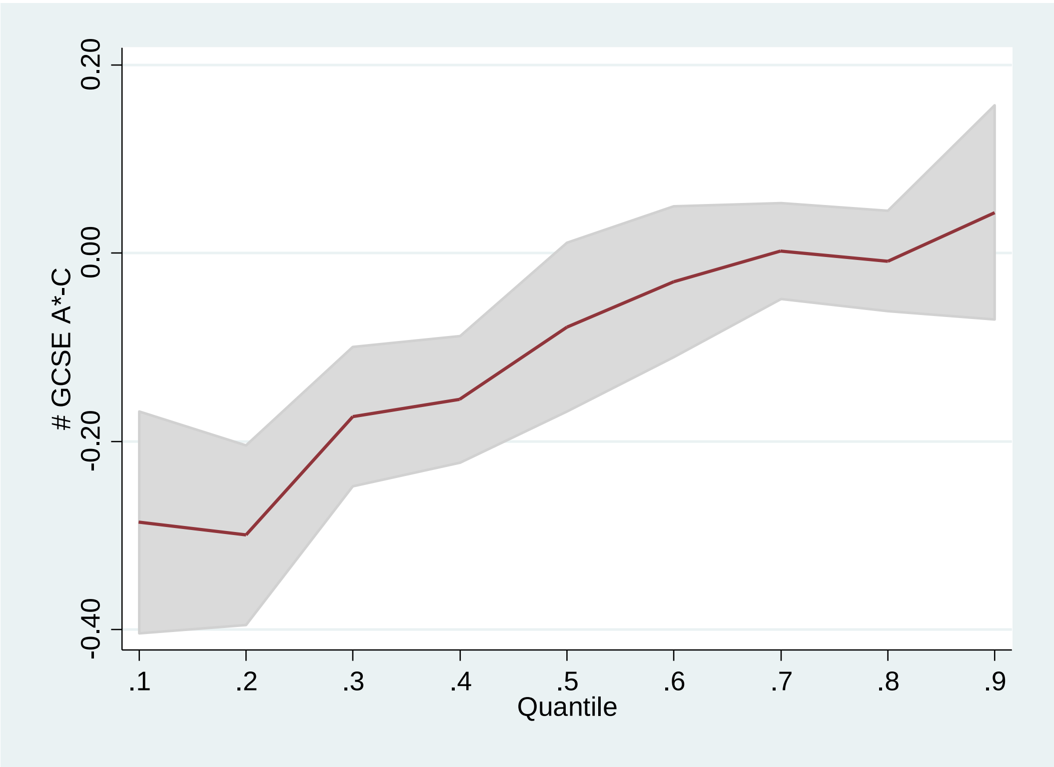
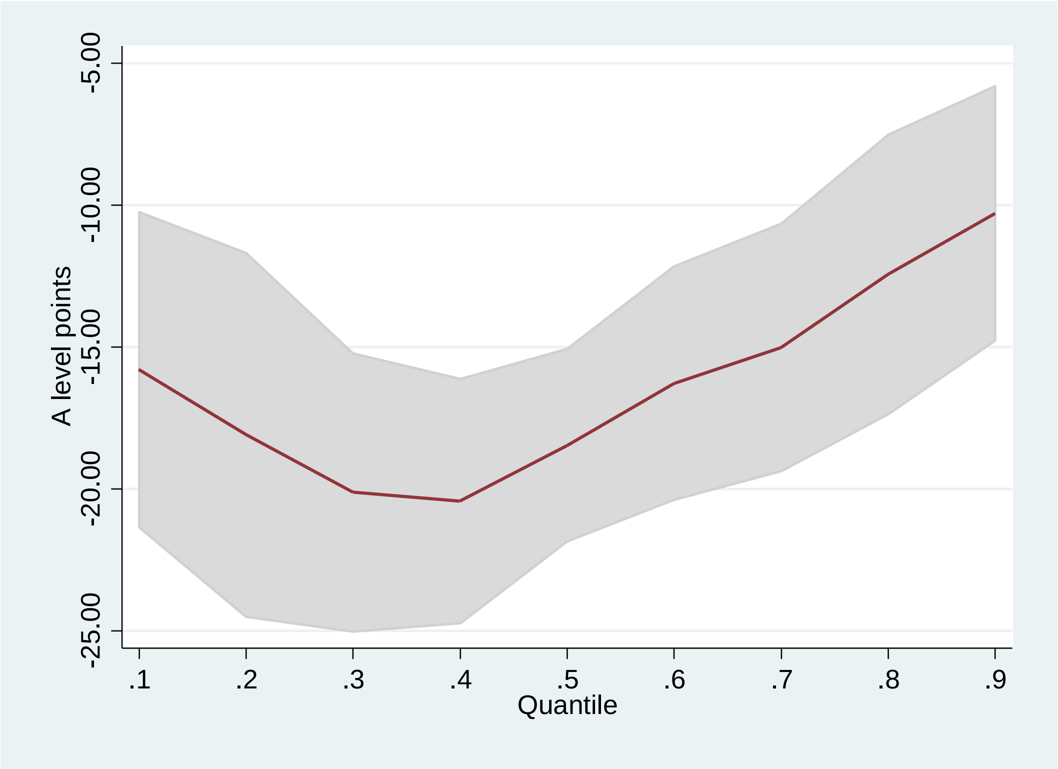


Figure 7 Estimated effects of low quality peers across deciles of A-level points



Appendix

Table A1 *Sensitivity to compare students from small and big high schools (<1000 and >1000 students) Model* 2

	Average peers quality						% Low quality peers					
	Small schools			Big schools			Small schools			Big schools		
Outcomes	OLS	IV	F	OLS	IV	F	OLS	IV	F	OLS	IV	F
Having A levels	**0.034** **(0.017)****	**0.190** **(0.100)****	9.87	0.084 (0.017)***	0.007 (0.139)	8.96	-.005 (0.007)	-0.035 (0.037)	17.46	-0.030 (0.007)	-0.014 (0.020)	53.66
A levels Points	42.79 (5.784)***	29.053 (22.173)	12.09	45.151 (5.756)***	66.898 (62.543)	3.14	**-18.653** **(2.811)*****	**-19.492** **(9.946)****	19.74	**-15.63** **(2.610)*****	**-17.543** **(7.326)*****	43.04
Having A levels in Maths	**0.110** **(0.023)*****	**0.213** **(0.085)****	12.09	0.0058 (0.019)	-0.082 (0.222)	3.14	**-0.034** **(0.011)*****	**-0.067** **(0.034)*****	19.74	0.0009 (0.0077)	-0.018 (0.024)	43.04
A levels Points in Maths	**14.914** **(3.042)*****	**30.911** **(9.757)*****	12.09	3.967 (3.107)	0.8148 (24.480)	3.14	**-4.685** **(1.305)*****	**-7.014** **(4.181)*****	19.74	-1.180 (1.061)	-3.708 (3.117)	43.04

Note: Std errors are in brackets. * indicates that the underlying coefficient is significant at 10% level, ** at 5% and ***1%. Additional variables included are listed at p.14-15.

Table A2 Sensitivity to compare students from rural and non-rural areas

	Average peers quality						% Low quality peers					
	Rural schools			Non rural schools			Rural schools			Non rural schools		
Outcomes	OLS	IV	F	OLS	IV	F	OLS	IV	F	OLS	IV	F
Having A levels	0.058 (0.018)***	0.018 (0.143)	5.20	**0.056** **(0.016)****	**0.219** **(0.081)****	24.55	-.015 (0.007)**	-.007 (0.029)	25.59	-0.018 (0.007)**	-0.033 (0.020)	58.41
A levels Points	46.141 (5.398)**	43.961 (48.071)	3.63	**40.729** **(6.075)*****	**44.395** **(22.855)****	16.35	**-19.819** **(2.788)*****	**-24.090** **(9.650)*****	23.17	**-14.743** **(2.620)*****	**-14.336** **(6.763)*****	63.00
Having A levels in Maths	0.040 (0.023)*	0.122 (0.184)	3.63	0.064 (0.019)**	0.099 (0.082)	16.35	-0.012 (0.010)	-0.024 (0.033)	23.17	-0.019 (0.008)**	-0.031 (0.022)	63.00
A levels Points in Maths	6.027 (3.013)***	27.931 (21.270)	3.63	**11.432** **(3.181)*****	**16.027** **(9.772)***	16.35	-2.029 (1.232)	-3.3740 (3.975)	23.17	**-3.363** **(1.167)*****	**-5.274** **(3.093)***	63.00

Note: Std errors are in brackets. * indicates that the underlying coefficient is significant at 10% level, ** at 5% and ***1%. Additional variables included are listed at p.14-15.

Table A3 Primary school fixed effects estimates of the effect of peers' ability on academic achievements

Outcomes	**Average peers quality**	**% Low quality peers**
# GCSE A*–C	-0.032 (0.153)	-0.176 (0.063)***
5+ GCSE A*–C	0.00096 (0.021)	-0.017 (0.008)**
Having A levels	0.065 (0.027)***	-0.041 (0.011)***
A levels Points	34.051 (11.293)***	-23.284 (5.102)***
Having A levels in Maths	0.045 (0.039)	-0.039 (0.017)***
A level points in Maths	7.484 (4.687)	-5.530 (2.099)***
Having A levels in Science	0.084 (0.042)**	-0.045 (0.019)***
A level points in Science	13.130 (6.605)**	-6.149 (2.970)**
Attended University	0.0612 (0.032)*	-0.045 (0.013)***
Russell University	-0.046 (0.056)	-0.0052 (0.026)

Note: Std errors are in brackets. * indicates that the underlying coefficient is significant at 10% level, ** at 5% and ***1%. Additional variables included are listed at p.14-15.
All models include primary schools FE (at KS2 level). Models with A levels as main outcomes control from GCSE past performance and models with university outcomes control for A levels.

Table A4 –Results from alternative (more parsimonious) model – Impact of average peers' ability (Key Stage 3 score)

	Effect of peers' average KS3		**Effect of % low ability peers**	
Outcomes	**OLS**	**IV**	**OLS**	**IV**
KS3 points	1.473 (0.089)***	1.410 (0.425)***	-0.495 (0.041)***	-0.415 (0.104)**
# GCSE A*–C	0.327 (0.099)***	0.576 (0.539)***	-0.107 (0.041)***	-0.190 (0.115)*
5+ GCSE A*–C	0.057 (0.012)***	0.134 (0.058)***	-0.018(0.005)***	-0.029 (0.012)***
Having A levels	0.069 (0.011)***	0.147 (0.060)**	-0.024 (0.005)***	-0.028 (0.014)***
A-level Points	42.912 (3.773)***	43.962 (19.024)**	-16.500 (1.727)***	-17.723 (4.849)***
A levels in Maths	0.055 (0.015)***	0.104 (0.070)	-0.016 (0.006)***	-0.0313 (0.016)*
A level points in Maths	9.249 (2.076)***	18.874 (8.158)**	-2.899 (0.767)***	-4.648 (2.045)***
A levels in Science	0.067 (0.015)***	0.048 (0.067)	-0.0261 (0.006)***	-0.036 (0.017)***
A level points in Science	11.994 (2.362)***	3.868 (10.681)	-4.277 (0.983)***	-4.655 (2.523)***
Attend any university	0.057 (0.012)***	-0.056 (0.066)	-0.0195 (0.005)***	-0.0101 (0.014)
Russell university	0.083 (0.016)***	0.125 (0.181)	-0.030 (0.007)***	-0.031 (0.021)

Independent variables: gender, Key Stage 2, maternal education and marital status, parental employment, maternal age

Table A5 –Results from alternative (less parsimonious) model – Impact of average peers' ability (Key Stage 3 score)

	Effect of peers' average KS3		**Effect of % low ability peers**	
Outcomes	**OLS**	**IV**	**OLS**	**IV**
KS3 points	1.238 (0.097)***	0.663 (0.654)	-0.421 (0.048)***	-0.323 (0.148)**
# GCSE A*–C	0.258 (0.117)**	0.454 (0.756)	-0.083 (0.049)*	-0.187 (0.163)
5+ GCSE A*–C	0.0395 (0.013)***	0.151 (0.086)*	-0.012 (0.006)***	-0.028 (0.018)
Having A levels	0.042 (0.013)***	0.158 (0.089)*	-0.0126 (0.005)***	-0.0301 (0.019)
A-level Points	35.959 (4.653)***	37.054 (27.997)	-15.913 (2.001)***	-16.357 (6.672)**
A levels in Maths	0.048 (0.018)***	0.141 (0.097)	-0.015 (0.007)***	-0.037 (0.022)***
A level points in Maths	8.221 (2.396)***	26.180 (11.312)**	-2.557 (0.869)***	-5.587 (2.895)*
A levels in Science	0.068 (0.017)***	0.115 (0.099)	-0.029 (0.007)***	-0.064 (0.024)***
A level points in Science	10.606 (2.666)***	11.276 (16.096)	-4.485 (1.078)***	-7.479 (3.752)***
Attend any university	0.054 (0.013)****	-0.005 (0.089)	-0.0175 (0.005)***	-0.001 (0.022)
Russell university	0.066 (0.019)***	0 .152 (0.111)	-0.026 (0.007)**	-0.046 (0.029)

Independent variables: gender, imd score, Key Stage 2, maternal education and marital status, parental employment, maternal age, school characteristics (Government Office Region, religious school, total number of students), ethnicity

Table A6 - First stage results – Endogenous variable: average peers' quality (KS3 score) (selected outcomes)–

	5+ GCSE A*-C		**# GCSE A*-C**		**Having A levels**		**A level Points**		**Attend university**		**Russell university**	
Male	-0.007	(0.023)	-0.007	(0.023)	-0.007	(0.023)	0.014	(0.042)	0.001	(0.030)	0.025	(0.046)
Imd score (stan.)	-0.176	(0.012)***	-0.176	(0.012)***	-0.176	(0.012)***	-0.196	(0.000)***	-0.196	(0.202)***	-0.197	(0.021)***
KS2 score	0.140	(0.018) ***	0.140	(0.018) ***	0.140	(0.018)***	0.183	(0.028)***	0.163	(0.021)***	0.177	(0.028)***
Maternal Uni degree	0.200	(0.033) ***	0.200	(0.033) ***	0.200	(0.033)***	0.189	(0.042)***	0.177	(0.036)***	0.165	(0.042)***
Other HE qual	0.095	(0.023) ***	0.095	(0.023) ***	0.095	(0.023)***	0.125	(0.035)***	0.089	(0.026)***	0.110	(0.039)***
Senior high school graduate	0.065	(0.023)***	0.065	(0.023)***	0.065	(0.023)***	0.079	(0.039)***	0.068	(0.022)***	0.080	(0.044)***
Junior high school graduate	0.014	(0.018)	0.014	(0.018)	0.014	(0.018)	0.007	(0.030)	-0.004	(0.022)	-0.014	(0.037)
Level 1 or below	0.011	(0.022)	0.011	(0.022)	0.011	(0.022)	0.013	(0.043)	-0.012	(0.031)	0.001	(0.052)
Other qual	0.040	(0.033)	0.040	(0.033)	0.040	(0.033)	0.127	(0.062)**	0.048	(0.042)	0.117	(0.076)
Mother self-emp	0.028	(0.026)	0.028	(0.026)	0.028	(0.026)	0.020	(0.042)	0.023	(0.031)	0.067	(0.049)
Mother unemp	-0.047	(0.039)	-0.047	(0.039)	-0.047	(0.039)	-0.077	(0.072)	-0.110	(0.051)**	-0.025	(0.090)
Mother out of labour force	-0.041	(0.016)**	-0.041	(0.016)**	-0.041	(0.016)***	-0.030	(0.024)	-0.040	(0.020)***	-0.031	(0.029)
Father self-emp	0.036	(0.016)**	0.036	(0.016)**	0.036	(0.016)**	0.044	(0.026)*	0.033	(0.020)	-0.001	(0.030)
Father unemp	0.016	(0.033)	0.016	(0.033)	0.016	(0.033)	-0.004	(0.057)	0.047	(0.042)	0.018	(0.081)
Father out of labour force	-0.009	(0.016)	-0.009	(0.016)	-0.009	(0.016)	-0.009	(0.027)	-0.015	(0.021)	-0.075	(0.032)**
Mother divorced	0.017	(0.019)	0.017	(0.019)	0.017	(0.019)	0.032	(0.040)	0.031	(0.026)	0.084	(0.044)*
Mother widow	0.016	(0.039)	0.016	(0.039)	0.016	(0.039)	0.096	(0.059)	0.026	(0.052)	-0.009	(0.079)
Maternal age	0.004	(0.001)***	0.004	(0.001)***	0.004	(0.001)	0.003	(0.002)*	0.004	(0.001)***	0.005	(0.002)***
Peers of peers average KS2	0.125	(0.028)***	0.125	(0.028)***	0.137	(0.030)***	0.150	(0.040)***	0.141	(0.031)***	0.179	(0.041)***
F stat	20.53		20.53		20.19		14.06		20.19		18.75	

Note: standard errors are in brackets. * indicates that the underlying coefficient is significant at 10% level, ** at 5% and ***1%.
Results from the estimation of peer effects on A levels in Maths and Science are available on request.

Table A7 – Results from OLS regression for the effect of other independent variables (selected outcomes)-

	KS3 Points	5+ GCSE A*-C	#GCSE A*-C	Having A levels	A level Points	Attend university	Russell university
Male	-0.302	-0.061	-0.832	-0.066	-25.008	-0.052	-0.005
	(0.061)***	(0.008)***	(0.069)***	(0.011)***	(3.892)***	(0.012)***	(0.016)
Imd score	-0.282	-0.029	-0.131	-0.023	-2.146	-0.004	0.001
	(0.046)***	(0.006)***	(0.053)**	(0.007)***	(2.638)	(0.008)	(0.010)
KS2 score	5.145	0.287	2.663	0.209	86.507	0.162	0.142
	(0.043)***	(0.005)***	(0.037)***	(0.006)***	(3.004)***	(0.007)***	(0.012)***
Maternal uni degree	1.059	0.078	0.515	0.060	17.764	-0.015	0.102
	(0.124)***	(0.016)***	(0.129)***	(0.021)***	(6.750)***	(0.023)	(0.031)***
Other higher education	0.452	0.025	0.170	0.028	-9.078	-0.038	-0.002
	(0.115)***	(0.015)	(0.123)	(0.020)	(7.197)	(0.022)*	(0.030)
Senior high school grad	-0.005	0.004	-0.041	-0.024	-19.152	-0.061	-0.062
	(0.109)	(0.016)	(0.127)	(0.020)	(6.604)***	(0.022)***	(0.031)**
Junior high school grad	-0.086	-0.033	-0.314	-0.023	-24.025	-0.086	-0.109
	(0.097)	(0.012)***	(0.107)***	(0.017)	(6.146)***	(0.018)***	(0.025)***
Level 1 or below	-0.368	-0.056	-0.608	-0.096	-44.053	-0.094	-0.086
	(0.120)***	(0.017)***	(0.147)***	(0.022)***	(9.321)***	(0.026)***	(0.034)**
Other qualification	-0.024	-0.070	-0.285	-0.014	-8.883	-0.039	-0.088
	(0.178)	(0.026)***	(0.205)	(0.034)	(12.110)	(0.037)	(0.042)**
Mother self-employed	0.096	-0.006	-0.066	-0.015	2.947	-0.019	0.022
	(0.119)	(0.017)	(0.128)	(0.022)	(7.430)	(0.026)	(0.034)
Mother unemployed	-0.369	-0.027	-0.322	-0.037	1.869	-0.045	-0.039
	(0.252)	(0.030)	(0.232)	(0.042)	(16.116)	(0.044)	(0.057)
Mother out of labour force	0.141	0.026	0.190	0.043	16.224	0.014	-0.003
	(0.081)*	(0.011)**	(0.085)**	(0.013)***	(5.002)***	(0.015)	(0.020)
Father self-employed	-0.049	0.006	0.052	-0.002	-1.779	-0.006	0.004
	(0.076)	(0.011)	(0.084)	(0.015)	(4.409)	(0.017)	(0.022)
Father unemployed	-0.173	-0.026	0.234	-0.002	4.426	-0.087	-0.011
	(0.169)	(0.023)	(0.214)	(0.033)	(11.846)	(0.033)***	(0.050)
Father out of labour force	-0.641	-0.052	-0.733	-0.072	-20.800	-0.059	-0.030
	(0.092)***	(0.012)***	(0.097)***	(0.015)***	(5.582)***	(0.017)***	(0.025)
Mother is divorced	-0.071	-0.025	-0.180	-0.046	-7.385	-0.033	0.018
	(0.114)	(0.015)*	(0.117)	(0.019)**	(7.346)	(0.020)	(0.029)
Mother is a widow	-0.429	0.023	0.307	0.043	-2.029	-0.013	0.070

	(0.287)	(0.031)	(0.268)	(0.041)	(12.375)	(0.045)	(0.062)
Maternal age	0.029	0.004	0.039	0.006	1.601	0.002	0.001
	(0.006)***	(0.001)***	(0.006)***	(0.001)***	(0.345)***	(0.001)	(0.002)
N	9,213	9,213	9,213	7,098	3,948	6,309	2,734

Note: standard errors are in brackets. * indicates that the underlying coefficient is significant at 10% level, ** at 5% and ***1%.
Results from the estimation of peer effects on A levels in Maths and Science are available on request.