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University of Kent

Doctoral Thesis

Essays in Economics of Education

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Declaration of Authorship

I, Francesca FOLIANO, declare that this thesis titled, 'Essays in Economics of Education' and the work presented in it are my own. I confirm that:

- This work was done wholly or mainly while in candidature for a research degree at this University.
- Chapter 1 "Away from Home, Better at School" is conjoint work with Francis Green and Marcello Sartarelli. The results of this chapter are included in the working paper titled "Can Talented Pupils with Low Socio-economic Status Shine? Evidence from a Boarding School", IVIE WP-AD 2017-05, which is currently submitted to a peer-reviewed journal. Together with the co-authors I have contributed to the paper in the following aspects: development of research question and methodological approach, data construction, statistical analysis using STATA, conceptual framework and robustness checks.
- Where I have consulted the published work of others, this is always clearly attributed.
- Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work.
- I have acknowledged all main sources of help.

Signed:

Date:

In memory of my beloved grandparents whom I miss dearly

Abstract

This thesis is an examination of how aspects of the English secondary school system affect attainment of pupils, particularly those who are disadvantaged. The analysis is based on administrative data for all pupils enrolled in state schools in England. The thesis includes three self-contained chapters. In the first chapter we study whether substituting family with school inputs in the education production function of high ability pupils with low socio-economic status has an impact on their achievement in the exams at the end of compulsory education. We consider a selective, well-resourced boarding school admitting an unusually high share of talented pupils from disadvantaged backgrounds and we estimate the effect of attending it with propensity score matching to obtain comparable control groups in selective day schools. Our main finding is that the probability of being in the top decile of achievement in the exams increases by about 17 percentage points compared to the baseline of 59% for controls.

The second chapter investigates whether gender segregation in secondary schools affects achievement and subject choice in non-selective schools in England. The empirical analysis is based on a value added model for achievement and a linear probability model for subject choice, both of which incorporate neighbourhood fixed effects. A robustness check based on a reasonable assumption about the relationship between the selection on observables and unobservables reveals that gender segregation has no effect on achievement of girls and a small effect on achievement of boys in english; in addition it does affect the probability of taking advanced science subjects at A-level for girls. My main finding is that girls from disadvantaged background who attend single sex schools are 2.6 percentage points more likely to choose an advanced science subject at A-level compared to a baseline of 7.3% in co-ed schools. Using a survey of students in England I find that girls and boys in single sex schools have less gender-stereotyped tastes and self-assessment of their abilities. These results support the hypothesis that girls in same-gender classes are less exposed to gender stereotypes, therefore more confident in their abilities in science and maths and more motivated to study these subjects.

The third chapter explores the effects of school competition on the academic performance of pupils. In the early 2000s the Labour government introduced academies, a new type of state-run school managed by a team of private co-sponsors. This reform broadened the choice of schools available to pupils and their parents increasing competitive pressure in the education sector. I use administrative pupil-level data to evaluate whether pupils in traditional secondary schools located near academies were affected by this new competition in the education market. Credible causal estimates of the short term impact of academies on neighbouring state schools are obtained by exploiting variation in both the timing and the number of academy entries. I find small positive effects on achievement in schools located within three miles from an academy: this finding suggests that increasing competition in the education market in England does not affect negatively the academic performance in less popular traditional schools and instead results in modest benefits particularly for more disadvantaged pupils.

Acknowledgements

The PhD is a long and lonely journey. For me that was particularly true and it would not have been possible without the support of my fantastic husband Huw and the patience of my wonderful daughters Bianca e Ludovica. To my parents who helped me and stood by me when I most needed them I can only say thank you, for everything and more. During these years studying, teaching and working I have met many people that were happy to help me, teach me and share their knowledge with me: I am particularly grateful to Saul Estrin, Cheti Nicoletti, Michael Gasiorek, Marcello Sartarelli, Giuseppe Migali and Rebecca Riley. I also would like to thank Peter Backus for the time he spent with me looking at data while holding my screaming baby daughter. I have been lucky enough to meet some amazing colleagues and friends over the last few years who have inspired me and pushed me to do better and not to give up: Giuseppe Ilardi, Katerina Raoukka, Alessandro Cusimano, Ana Rincon-Aznar and Lucy Stoke. My Italian friends in London, Carlo, Lucia, Antonella, Serena, Marco, Gabriella, Francesca and Chiara were my home away from home and now that some of them have moved away I miss them very much. Finally I would like to thank Dr. Sylvain Barde for his help and time, and Dr. Amanda Gosling and Prof. Yu Zhu. ESRC PhD funding is gratefully aknowledged.

”Just like the films
There’s no reason
To feel all the hard times
To lay down the hard lines
It’s absolutely true
Nothing much could happen
Nothing we can’t shake
Oh, we’re absolute beginners”

(*Absolute Beginners*, David Bowie)

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Abbreviations

ATT	Average Treatment Effect on the Treated
CA	Carchment Area
CIA	Conditional Independence Assumption
CH	Christ Hospital
CS	Common Support
CTC	City Technology College
EAL	English Additional Language
FSM	Free School Meal
GB	Government Body
GCSE	General Certificate of Secondary Education
IDACI	Income Deprivation Affecting Children Index
ITT	Intention-to-treat
LA	Local Authority
LATE	Local Average Treatment Effect
LEASIS	Local Education Authority School Information Service
LSOA	Lower Super Output Area
LSYPE	Longitudinal Survey of Young People in England
NPD	National Pupil Database
OFTED	Office for Standards in Education
OLS	Ordinary Least Squares
PLASC	Pupil Level Annual School Census
PPE	Per-pupil expenditure
SEN	Special Education Needs
SES	Socio-economic status
VA	Voluntary Aided

Introduction

The aim of this thesis is to investigate the role of secondary schools in shaping the attainment of pupils in England, with a particular focus on those coming from a disadvantaged background. Secondary education represents an important moment in the formation of cognitive and non-cognitive skills of young people as it prepares them for adult life and the labour market; its function is potentially vital at the national level for fostering economic growth through the increase of individual's productivity. Statistics in England however show that a significant number of children leave school without basic qualifications. In 2016 37% of 16 year olds did not attain any qualification in both English and Maths and 15% had no level 2 qualifications at all. Those most likely to be in this group are boys, pupils in receipt of free school meals, and pupils from traveler families (Department for Education, 2016a). At the other end of the scale, high achieving boys do better than girls in maths (Department for Education, 2011) and only a small percentage of graduates in STEM subjects are girls.[1] Existing research suggests that ability and parental resources are the main determinants of a young person's trajectory in education and the labour market.[2] It is essential to evaluate whether schools can have a role in changing these trajectories at all. Additionally it is important to investigate whether educational policies aimed at raising standards of schools have any beneficial effect on pupil achievement or whether they are in fact ineffective or even detrimental.

The effect of secondary schools on the attainment of disadvantaged pupils is central to the empirical analysis of this thesis. In the first chapter my coauthors and I focus on high ability pupils from a low socio-economic background. These pupils are mostly failed by secondary state schools and end up achieving on average less than welthier peers with lower ability. We then study whether full boarding in a selective school would help them

[1] Statistics on gender and subjects breakdown in higher education are produced by the Higher Education Statistics Agency and available here: https://www.hesa.ac.uk/data-and-analysis/students/what-study (accessed: March 15, 2018).

[2] See Heckman (2008) for findings in the US and Chowdry, Crawford, Dearden, Goodman, and Vignoles (2013) for findings with data for England.

maintain the achievement trajectories they were on during primary school. In the second chapter I investigate whether studying with same-gender peers boosts achievement and whether it affects the probability of girls studying science and maths at the age of 16. Disadvantaged girls are one of the least likely subgroups of the population of students in England to choose science and maths for their post-compulsory education: I then test whether an all-girl environment has a different effect on their probability to choose maths and science. I study the indirect effects of an education policy, i.e. the creation of academy schools, in the third chapter. Academy schools replaced failing schools in deprived neighbourhoods and succeeded in raising the achievement of their pupils. In my research I investigate whether academies had an impact on schools located nearby through the competitive pressure they exerted on the local education market. I also carry out an analysis of the heterogeneous effects of competition on different subgroups of pupils and schools including pupils with low socio-economic status and more deprived schools.

I use two large administrative datasets of pupil records, the National Pupil Database (NPD) and the Pupil Level Annual School Census (PLASC) to retrieve reliable estimates for subgroups of the population, such as disadvantaged pupils or pupils attending schools in well defined geographical areas. England is one of few countries where administrative records of all pupils enrolled in state schools are systematically collected by the Department for Education. These records include information on the school attended by each pupil, her socio-economic characteristics and a detailed history of exclusions and absences and test scores from Year 2 (Key Stage 1) to Year 13 (Key Stage 5) and subjects chosen after Year 9 (Key Stage 3).[3] Individual-level characteristics and exclusion records for all pupils in state primary and secondary schools were collected from the academic year 2002/03, data on absences from the academic year 2005/06 whereas data on tests scores and subject choice were collected since the late 1990s. Additionally records of school level enrolment and workforce characteristics were collected since 1992. Each pupil that enters the state school system is assigned a unique identifier and for each year in the data there is also a record for the identifier of the school she attended. The access to this large longitudinal dataset covering several cohorts has therefore allowed me to obtain precise estimates based on very specific samples: all pupils in a

[3] For pupils in independent schools, 7% of all pupils enrolled in schools in England, the NPD includes only records of test scores at Key Stage 4

specific boarding school and their counterfactual matches; disadvantaged girls in non-selective single-sex schools; disadvantaged pupil and low achievers attending schools in the vicinity of academies.

The findings of my analysis contribute to the rich literature on schools and attainment. In particular the first and second chapters contribute to the literature on school choice by suggesting that currently available alternatives to standard schooling options may help increase academic outcomes of pupils, particularly those with a low socio-economic background. The third chapter contributes to the literature on school choice and competition by evaluating the effect of an unexpected shock that changed the supply of schools in some local education markets and showing that competition in education can have a positive effects on everyone involved.

Chapter 1

Away from home, better at school: the case of a boarding school in England[1]

1.1 Introduction

Gaps in achievement by socio-economic status (SES) are a policy challenge worldwide (see for a review Sirin, 2005; Reardon, 2011). In England these gaps are observed as early as primary education and they usually do not change over time or tend to increase with age (Dearden, Sibieta, and Sylva, 2011). While gaps by SES tend to be concentrated among pupils who are initially low achievers, they have also been found among high achievers (Crawford, Macmillan, and Vignoles, 2014; Jerrim, 2017). This may have potentially high opportunity costs if pupils who have the potential to perform well at school, which is a good predictor of success in the labour market, are held back or slowed down by the environment where they grow up.

Most of the policies that have been designed to counteract the influence of deprivation on pupil achievement are based on the assumption that increasing school inputs boosts academic outcomes. However the effect of these policies may be confounded by parental responses to the change in school inputs (Todd and Wolpin, 2003, 2007): family inputs may reinforce the role of school policies if parents respond by putting more effort into their children's development or dilute it if they put less.[2]

[1]This chapter is joint work with Francis Green (UCL) and Marcello Sartarelli (Univeristy of Alicante).

[2]Recent examples of school policies are the introduction of sponsored Academy schools in disadvantaged areas in the UK (Eyles, Hupkau, and Machin, 2016) and of Charter schools in the US (see a review

Boarding schools offer a suitable example of substantial substitution of family inputs for school inputs, i.e. they reduce the role of family inputs for all pupils, since they offer education during the day and lodging at night in the week. However, obtaining clean estimates of the effect of attending a boarding school on, for example, pupil achievement is an empirical challenge as it may be confounded by a selection effect if boarding school pupils and pupils in other schools differ substantially in ability or family resources.

Lotteries granting random admission to oversubscribed boarding schools have been used to obtain clean estimates of the effect of boarding education. Randomly admitted pupils obtain substantially higher tests scores than non-admitted ones in boarding schools in poor neighbourhoods in the US (Curto and Fryer Jr, 2014). Related research exploiting random admission in an elite school in France obtains similar results (Behaghel, de Chaisemartin, and Gurgand, 2017). Lotteries offer the advantage that admitted pupils have similar characteristics to those not admitted. However, the estimated effect may be biased upward since oversubscribed schools, the only ones in which lotteries are run, may be on higher demand than other schools because they are of higher quality (Eyles and Machin, 2015a). In addition, the low number of observations in these studies limits the possibility of studying the impact of boarding for specific subgroups of the population, such as high achievers from disadvantaged backgrounds.

This paper is the first to test the hypothesis that offering high achievers with low SES admission at a truly selective boarding school, Christ's Hospital (CH hereafter), leads to higher achievement (H_1). We base our analysis on rich administrative data of pupils in England and measures of achievement at age 7, 11 (Key Stage 1 and 2) and in the compulsory school final exams at age 16 (General Certificate of Secondary Education, GCSE hereafter) for five consecutive cohorts of pupils. The aim of our research design is to find, for each pupil at CH, a pupil in a selective day school who is as similar as possible in observable characteristics by using propensity score matching. We use the following two measures of SES: the income deprivation affecting children index (IDACI), measuring the share of children in low income households by local area, and, whether pupils' parents obtain income support from the government, proxied by whether pupils are eligible for Free School Meals (FSM).

We also test whether there is heterogeneity in the impact of CH on achievement as a related hypothesis (H_2). We study whether it differs for pupils with very low SES,

in Epple, Romano, and Zimmer, 2016), as well as more narrowly targeted interventions in urban schools in the UK, such as Excellence in the Cities (Machin, McNally, and Meghir, 2004).

proxied by an IDACI greater than the median value, to assess if they are the ones who benefit most from CH as their learning environment is the one improving the most upon admission. In addition, we examine the effects of CH separately for girls and boys given that the home environment's contribution to academic achievement may be gendered and in light of the widely documented achievement gap in favour of girls in England (Machin and McNally, 2005).

CH is an outlier in English private education, as it admits a very high share of high achievers with low SES. Its especially wealthy foundation enables it to admit the majority of its pupils with low or no fees through means-tested bursaries. Since it is selective and boarding, we compare its pupils with those in the following two types of selective day schools, i.e. our *control groups*. The first are pupils in grammar schools, that are highly selective state schools with substantially fewer resources than CH. The second group are pupils in independent schools, that are also well-resourced like CH, although they tend to be less selective based on academic merit. In addition, in our control groups we only selected pupils from primary schools located in the same local authority (LA) as those attended by pupils who then went to CH. This ensures that the school and non-school environment that a pupil at CH and a very similar pupil in a selective day school experienced before secondary school is also comparable.

We find that pupil achievement at CH is significantly higher than for control pupils (H_1). The probability of at least five GCSE exams (GCSEs hereafter) at A-A*, i.e. of being in the top decile in the distribution of the number of GCSEs at A-A*, is significantly higher at CH by 17.4 and 12.6 percentage points, i.e. a 20-29% increase with respect to 59-64% for matched pupils in grammar and independent day schools respectively. When we assess whether there is heterogeneity in our main results (H_2), we find that they tend to be driven by higher point estimates for pupils from poorer areas, proxied by an IDACI level above the median, and by girls. Crucially, predetermined characteristics for pupils at CH and for controls in grammar and independent schools are balanced and our main results are robust to a set of sensitivity checks.

To the best of our knowledge, our results are the first to show that a boarding school admitting high ability and low SES pupils significantly improves their achievement (H_1). These results contribute to the school choice literature by suggesting that currently available alternatives to standard schooling options may help reversing the achievement gap for these pupils. Finding that the impact is higher for poor pupils (H_2) also contributes to studies on children's educational production function by suggesting that the substitutability between the inputs that these pupils obtain from parents and from the school is not substantially diluted by economic, cognitive or psychological disadvantages associated with low SES. Our related finding on the greater effect for girls is also relevant for an understanding of the gender achievement gap for high ability pupils in England. Finally, our results contribute to the recent policy debate over the use of boarding schools for disadvantaged children in England (Department for Education, 2014, 2016b) that so far has not been informed by a quantitative economic analysis.

The rest of the paper is structured as follows: section 1.2 reviews the relevant literature; section 1.3 describes the institutional setting of compulsory education in England and the data that we use in the empirical analysis; section 1.4 outlines the econometric strategy; section 1.5 describes the main results; section 1.6 reports the results of a sensitivity analysis and, finally, section 1.7 discusses and concludes.

1.2 Literature review

In this section, we consider what existing studies around the world find about the effects of boarding on academic and non-academic outcomes. Boarding secondary schools for bright pupils with low SES have been introduced in recent years in the US. SEED schools in Washington and Baltimore are the only urban public schools that combine the charter school model with a 5-day-a-week boarding program in poor neighbourhoods. Curto and Fryer Jr (2014) estimate the impact of attending a SEED school in Washington on achievement by exploiting lottery-driven admission that is used when a school is oversubscribed. By comparing achievement of students admitted and of those turned down by the lottery, they find that SEED increases achievement by about 20% of a standard deviation in reading and in math, with results being mainly driven by females.

In France public 'boarding schools of excellence' for poor and high achieving pupils have been opened in deprived suburbs of large French cities. Behaghel, de Chaisemartin, and Gurgand (2017) exploit an admission lottery to study the effect of attending one such school in the suburbs of Paris. They find that by the end of the first year, achievement in French and in maths is lower (by 8.5% and 4.5% of a standard deviation) although these differences are not significant. A subjective measure of well-being, obtained by way of a survey, is also weakly significantly lower (29.8% of a standard deviation) and is driven by frictions in adapting to the boarding environment. In contrast, after the second year maths scores are significantly higher (21.3%) while they are lower in French (8.7%) although the difference is not significant. Well-being is also significantly higher than in the first year (11.8%), driven by significantly higher scores to the question on whether children feel at home. Improvement in maths is driven by those students who were in the top three deciles of the distribution of maths scores when they enrolled. While it is argued that clean estimates are obtained by using this quasi-experimental setting, there are at least two main drawbacks of lotteries. First is that since oversubscribed schools are in higher demand than others that are not oversubscribed, their quality is higher, e.g. they may have more resources and more motivated or more qualified teachers, and since quality tends to be unobserved, estimates of the boarding school effect obtained by exploiting lotteries may be upward biased. The second is that the number of observations tends to be small, e.g. about 400 in total in each of these studies, as only very few schools are oversubscribed. This number may not be big enough to estimate the parameter of interest separately for a subgroup of pupils by ability and SES.

In a related study based instead on observational data **?** study the effect of boarding primary education in a rural Swedish county in the 1940s. Pupils living far away from primary schools were allowed to board in accommodations where they were given food and lodge and the out-of-school time was dedicated to work, tidiness and obedience. These pupils were more likely to come from a less advantageous background than the rest of pupils enrolled in local primary schools. **?** find that boarding has a positive effect on achievement at the end of primary school and this effect increases monotonously with the number of semesters pupils had boarded. However they find no effects of boarding on a set of mid to long-term outcomes such as years of education and earnings. **?**Curto and Fryer Jr (2014); Behaghel, de Chaisemartin, and Gurgand (2017) are the only studies in economics, to the best of our knowledge, that investigate the effects of boarding education.

Excellence in the Cities is an example of a policy intervention designed to improve school inputs in urban day schools in poor neighbourhoods in England, that targets talented pupils as part of its third core strand. Its main effect is an increase in maths achievement (2.5-5% relative to the mean value for children in control schools), with this result being driven by children in disadvantaged schools and particularly by those with ability above average in these schools (Machin, McNally, and Meghir, 2004).[3]

[3] Kirabo Jackson (2010) exploits exogenous variation arising from secondary school choice conditional on merit-based rules assigning pupils to schools in Trinidad and Tobago to study the effect of attending

Related policies have focused on giving schools greater autonomy over, for example, hiring teachers and using those teaching methods that are most suitable to children's learning needs in neighbourhoods with different socio-demographic characteristics. In the early 1990s Charter Schools were introduced in the US 'as laboratories for educational innovation' (Epple, Romano, and Zimmer, 2016). They led to a highly significant increase mainly in math (on average 5-10% relative to children in other schools or 25-40% of a standard deviation), while the improvement in English (3-6% or 20% of a standard deviation) is smaller, less precise and not always significant (see for a review Epple, Romano, and Zimmer, 2016). Similarly, in the early 2000s Academies were introduced in the UK to improve standards of low performing schools and they were more frequently located in poorer neighbourhoods. Overall these schools led to a significant increase in achievement in the compulsory school final exams (7% of a standard deviation in GCSE points score) and in the probability of degree completion (10% relative to mean value), driven by children with low SES (see for a review Eyles and Machin, 2015a; Eyles, Hupkau, and Machin, 2016).

The main assumption behind these interventions for children with low SES is that the potentially negative impact of the home environment can be offset either by offering children better school inputs in the case of school-based policies or by substituting family inputs with a better learning environment, in the case of boarding schools such as CH. If cognitive outcomes are the results of an education production function as the one described in Todd and Wolpin (2003, 2007), then introducing a better school input such as a more learning-oriented environment, would result in more desirable outcomes for children. However the effect of better school inputs may be confounded by parental responses to the intervention as simultaneous changes in family inputs are not fully accounted for.

Boarding schools have been studied in psychological research with a focus on their consequences on pupil well-being. Results obtained either using simple differences in means or OLS regressions are mixed. Lester, Mander, and Cross (2015) show using data on 150 boarders in the US that they experience significantly higher bullying when their boarding experience starts. Wires, Barocas, and Hollenbeck (1994) show using data on 197 boarders in the US that the development of their identity improves with age although it is lower for those with adolescent behavioural problems. Fisher, Frazer,

better schools, i.e. those with a pool of higher ability pupils and with better resources. Results show that attending a better school significantly increases exams performance at the end of secondary school, with the effect being larger for girls.

and Murray (1986) show using data on 115 boarders in the UK that their initially high level of homesickness decreases over time.

In partial contrast, Martin, Papworth, Ginns, and Liem (2014) find no significant differences in boarders' subjective well-being or in their academic achievement using data on 2,002 school children in Australia, 30% of whom are boarders. In related work, Hodges, Sheffield, and Ralph (2016) show using survey data on 415 boarders in Australia that they perceive the boarding environment more negatively than the school staff does, in line with research on children in day schools.[4]

Recent studies on boarding in rural China, whose institutions differ markedly from the Anglo-Saxon ones show mixed results. Shu and Tong (2015) use about 2,000 observations from the 2010 wave of the survey of Chinese households and, by using propensity score matching and school fixed effects regressions, find that boarders do significantly better in tests although they also have higher depression scores. In related research Wang, Medina, Luo, Shi, and Yue (2016) use data from surveys they conducted on about 5,000 children in the period 2008-2013 to study the effect of a boarding program introduced in 2001 and find that boarders' academic achievement is, instead, significantly lower.

Overall, the evidence summarised in this section from studies in different disciplines in social science shows that pupils in boarding schools tend to have higher achievement and that this seems to be driven by higher motivation and study effort. Although this evidence expands our knowledge on the role played by boarding schools, to the best of our knowledge no study has tested whether a conducive boarding environment can compensate, through substitution of family and school inputs, for high ability children with a low SES.

1.3 Institutions and data

In this section we describe the institutional setting of compulsory education in England, along with the main characteristics of CH, grammar and independent schools in section 1.3.1. We then describe the data we use in the empirical analysis in section 1.3.2.

[4] Schaverien (2004, 2011) present qualitative evidence on the interplay between emotional deprivation and social success. However, it is based on 2-3 case studies per study, i.e very few observations to draw any conclusion based on them.

1.3.1 Institutional setting

The state school system in England entails 11 years of compulsory education divided into two phases, primary and secondary, and 4 Key Stages: this is summarised in table 1.1. Primary school starts with Key Stage 1 (age 5 to 7) and it is followed by Key Stage 2 (age 7-11), whereas secondary school starts with Key Stage 3 (age 11 to 14) followed by Key Stage 4 (age 15-16). All Key Stages end with a national standardised assessment, either carried out internally by teachers or externally, and the Department for Education sets a level or target that pupils are expected to achieve in compulsory tests in English, Math and Science.

CH is an independent selective and boarding-only mixed school that funds over 80% of the costs of its pupils education. It is a Christian institution dedicated to providing a stable background and boarding education of high standard to 830 boys and girls each year, particularly for children of those families in social, financial or other particular need, as set out in its mission statement. It is located in West Sussex in South-East England, and anecdotal evidence suggests that it relies mainly on word of mouth by its alumni for publicity.

Applicants to CH have to meet its academic standards and also be judged suitable to board. They are expected to be working towards level 5 at Key Stage 2 in English, Maths and Science. After a first selection based on school reports, successful applicants are invited in for an initial assessment in English and Maths. Those who pass it will be asked in for a second assessment stage consisting in additional English and Maths tests a few months later and also to stay in the school overnight: this will help the school to assess their suitability to board. Calculations from CH show that each assessment stage screens approximately 50% of all applicants. Achievement at Key Stage 2, SES and suitability to board are CH admission criteria.

Mixed grammar schools, our first control group, are highly selective, academically-oriented for historical reasons and include different school types. In our data about 54% are Foundation and 24% are Voluntary Aided or Voluntary Controlled, which are types of schools that enjoy some degree of independence from LAs, The remaining 22% are Community grammars, which are not independent of control from LAs.

Our second control group are independent schools, which are generally fee-paying private schools that are attended by about 7% of pupils either as day pupils or as boarders. The schools for pupils up to ages 11 or 13 are typically referred to as preparatory schools and from age 11 or 13 they can attend senior or high school. Some independent schools cover the full age range from age 3 to 18. Since CH is Christian, we restrict our attention to Christian independent day schools to study boarding effects. Independent schools set their own examinations at the end of each year and the only national assessment their pupils sit during compulsory schooling is GCSE. Independent schools admit small number of pupils on means tested bursaries; among those pupils we expect to find our matched controls. [5]

Grammar schools are funded by the government as they are state schools. Independent schools receive no direct government funding, though about 80% of them are constituted as charities (Independent Schools Council, 2014) and therefore receive important tax exemptions. They receive most of their income in the form of fees. Table 1.2 shows proxies of schools' teaching resources separately for CH, for our control groups and for state schools. Information on school resources were obtained from the School Workforce Census 2011 published by the Department for Education. The teaching resources of CH are quite close to those of independent schools. However relative to grammar schools, CH has a substantially lower pupil/teacher ratio and a higher number of qualified teachers per pupil. Both CH and independent schools have higher resources relative to other schools while grammars have similar ones to other state schools. Finally independent schools also devote substantially more than state schools to non-teaching resources which may have spillover benefits for academic outcomes (Davies and Davies, 2014).

1.3.2 Data

Our analysis is based on individual-level administrative records on pupils in England, the NPD and the PLASC. The final dataset, with about 2 million pupils, contains information on five cohorts who attended primary state schools and sat their Key Stage 2 tests in years 2002-2006 and accordingly sat GCSEs at the end of Key Stage 4 in years 2007-2011.

Out of all pupils in the data, 429 went to CH after completing primary education in state schools, an average of 86 pupils each year. About 70,000 went to secondary

[5] The percentage of pupils attending independent schools varies between about 5% for pupils aged 5-10, 8% for those aged 11 to 15, and 18% for those aged 16 to 18. About 13.5% of pupils are boarders in independent schools and only 1% of all independent schools has only boarding pupils. The average termly boarding fee is 8,780 pounds while the average termly day fee is 3,903 pounds. Bursaries, scholarships and discounts are available: around 8% of pupils have received means-tested bursaries and 1% of all pupils paid no fees at all (Independent Schools Council, 2014).

grammar schools and about 80,000 to independent ones. These pupils are our control groups and we describe in detail the criteria we use to select these subsamples for the empirical analysis in the remaining part of this section.[6]

Figure 1.1 shows the number of CH pupils by LA where they went to primary school as well as CH location marked by a black triangle towards the lower part of the map. LAs from which no pupil goes to CH after completing primary school are not shown. The figure shows that the majority of CH pupils come from LAs not very far away from CH, indicated using darker colours, and that a small number of pupils who went to primary school further away also attends CH.

Two additional pieces of information are shown in figure 1.1 to illustrate the reason for choosing selective day schools, i.e. grammar and independent schools, as our control groups in estimating the effect of boarding at CH. The first is the set of all grammar and independent secondary schools attended by pupils who were in a primary school located in the same LA as those attended by CH pupils, marked using squares and with 'g' and 'i' respectively in the figure. The fact that these schools are located either in the same LA or in adjacent ones shows that pupils may not choose the closest secondary school in the LA in which they attended primary school. The second and related piece of information is the set of schools actually chosen by pupils similar to those at CH, i.e. matched using the propensity score that will be defined in section 1.4. They are marked as black squares while white squares indicate schools attended by pupils not similar enough to CH ones, according to the propensity score, and show heterogeneity in pupils' characteristics even between selective day schools.

Pupils who attended grammar secondary schools are the first control group that we use to obtain an estimate of the effect of attending CH. In common with CH they are academically selective however they differ by not offering boarding and having substantially fewer resources. The second control group consists of pupils who attended independent Christian day schools after state primary. They are also academically selective to varying degrees and deploy far more resources than state schools (Green, Machin, Murphy, and Zhu, 2012). Like CH, the independent schools in our data have a Christian foundation, either Church of England or Roman Catholic.

We restrict our analysis to pupils in grammar and in independent schools who went

[6] The name of Christ Hospital School is used in the empirical analysis in our paper in compliance with guidelines on disclosure control that can be found in point 9.5 in the National Pupil Database Agreement for the supply of data and after obtaining written approval from the Department for Education.

to a primary school in the same LAs as those attended by pupils at CH. This is approximately 10% of all pupils in grammar and in independent schools. This restriction ensures that CH pupils and those in the control groups face the same choice set of secondary schools, live in the same geographical area and are covered by the same local government.

Figure 1.2 shows scatterplots of the percentage of pupils eligible for FSM, measured on the vertical axis, and the percentage of pupils that obtained the top level in Key Stage 2 tests, i.e. 5, in all three subjects, measured on the horizontal axis, by using school-level data. CH is marked in the figure using a black triangle while the black squares show the grammar and independent schools chosen by pupils who are very similar to those at CH, i.e. matched using the propensity score.

The grammar and independent schools shown in figure 1.2 have been selected as some of their pupils are very similar, i.e. matched, to those at CH and we also notice that a high percentage of their pupils obtain level 5 in all Key Stage 2, particularly for independent schools. However CH stands out with a percentage of admitted pupils that are eligible for FSM twice or three times higher than in the grammar and independent schools shown in the figure.[7]

Figure 1.3 shows histograms of achievement at Key Stage 1, 2 and 4 using our full dataset with 2 million pupils to help us defining meaningful achievement measures for the pupils in selective schools in our empirical analysis. The central panel shows that the percentage of pupils obtaining in individual tests a level greater than 4 in Key stage 2 varies between 40 and 50% and coincides with the modal frequency. The percentage obtaining 5 in all tests at Key Stage 2, a measure that was used in figure 1.2 as an indicator of high achievement is typically lower. Figure 1.3 also shows in the top panel histograms of achievement levels at Key Stage 1, in which the expected level is 2 and it coincides with the modal frequency. Therefore in the empirical analysis we will use as predetermined measures of achievement a dummy equal to 1 if a pupil obtains a level greater than 2 by subject at Key Stage 1 and a dummy equal to 1 if a level greater than 4 by subject is obtained at Key Stage 2, in addition to using Key Stage 2 tests scores.

We chose three binary indicators as outcomes. The first one is equal to 1 if a pupil obtains at least one GCSE at A and 0 otherwise. The histogram on the left-hand side in the bottom panel in figure 1.3 shows that only pupils who are approximately in the top four deciles of the distribution of the number of GCSEs at A obtain this qualification.

[7] Additional information about how pupils are matched is found in section 1.4.

The second indicator is equal to 1 if the pupil obtains at least one GCSE at A* and 0 otherwise, with only 10-15% of pupils obtaining this grade, as shown by the histogram of the number of GCSEs at A* in the centre in the bottom panel in figure 1.3. Finally the third indicator is equal to 1 if 5 or more GCSEs are at A or A*, with only pupils in the top two deciles achieving this, as shown by the histogram of the number of GCSEs at A-A* on the right-hand side in the bottom panel in figure 1.3. These outcomes are typically good predictors of the decision to enrol in post-compulsory education (Chowdry, Crawford, Dearden, Goodman, and Vignoles, 2013).[8]

As far as possible we try to match pupils at CH with pupils in grammar or independent schools according to additional predetermined characteristics. These include socio-demographics, such as gender, ethnicity, quarter of birth and two proxies for SES. The first is the IDACI, measuring the share of children in low income households in an area of about 40 households and 100 persons called super output areas (the smallest unit used for census purposes). The second is a dummy equal to 1 if a pupil is eligible for FSM as her parents receive some form of income support. Extra dummies are used to measure if a pupil takes English as an additional language (EAL) where it is not her native language and whether a pupil has special education needs (SEN), both being assessed case-by-case by educational specialists in schools.

Table 1.3 shows descriptive statistics of predetermined characteristics separately for pupils at CH and in control schools. There are sizeable differences between the socio-demographic characteristics and achievement of pupils at CH and pupils in the other control groups. In particular pupils at CH are more likely to be non-white, EAL, eligible for FSM, to have attended and faith primary school and to have achieved the highest levels in KS1 and KS2. The differences become small and mostly not significant when instead we consider the subsamples of matched pupils in grammar and independent schools.

[8]In choosing our outcomes of interest we focused on the highest grades in GCSEs, i.e. A or A*, since all secondary schools we consider are selective and its pupils tend to achieve towards the high end of the distribution of grades in GCSEs. We did not choose the probability of achieving five or more GCSEs at A*-C, a lower grade, as it is about 98% in selective schools and, similarly, the mean number of GCSEs taken by pupils in these schools is 10 and shows little variation across schools. Achievement in English and Maths at GCSE are not used as outcomes as this information is not available for CH and for independent schools in NPD data.

1.4 Econometric strategy

We estimate the effect of going to CH on achievement in the compulsory school leaving exams and whether this effect differs by SES and gender using propensity score (pscore) matching, an econometric strategy based on selection on observables. This is possible thanks to the unique admission criteria based jointly on merit and on SES and to the rich set of pupils' observable characteristics in the administrative data.

$$\Delta^{ATT} = E[A(1) - A(0) \mid D = 1] \tag{1.1}$$

Let D be a dummy indicating whether pupils go to CH, with $D = 1$ for pupils at CH (treatment) and $D = 0$ for those in a selective day school (controls). Let $A(1)$ and $A(0)$ be the potential outcome, i.e. achievement, for treated and for controls. Finally, let X be a set of predetermined observable characteristics for pupils. Our parameter of interest is the average treatment on the treated (ATT) which we denote Δ^{ATT} and define in our setting as the mean effect of attending CH, i.e. the treatment group, rather than a selective day school, i.e. the control group, as shown in equation (1.1).

To recover the unobservable term $E[E[A(0) \mid D = 0] \mid D = 1]$ in equation (1.1) via the law of iterated expectations we rely on the assumption that admission to CH depends only on observables: this assumption is also known as selection on observables or the Conditional Independence Assumption (CIA). Under this assumption assignment to the treatment or to the control group is independent of the potential outcome in the untreated case conditional on the set of observables X, formally $A(1), A(0) \perp D \mid X$. However, when the number of observable characteristics in the vector X is high, it may not be possible to find an exact match in control groups for some pupils at CH. This problem, known as the curse of dimensionality, is solved by using the probability of going to CH given observable characteristics X or pscore, i.e. $P(D = 1 \mid X)$.

In addition we ensure that for each pupil at CH there is one or more with very similar observables in the control group by imposing the common support (CS) condition, i.e. $0 < P(D = 1 \mid X) < 1$. Finally, after estimating the pscore with a logit model, we match treated pupils with very similar pupils from the control group by using nearest neighbour matching method. We obtain two sets of estimates by using two different control groups (grammar and independent schools). While in our preferred specification we use the nearest neighbour method to match pupils, we also assess the sensitivity of our results to using different matching methods based on the pscore.[9]

The assumption we make in our analysis so far is that the choice faced by talented pupils was binary: either CH or another type of selective school, for example an independent school. However at the end of primary school a talented pupil may have been granted admission to CH, as well as to a grammar and an independent secondary school. This can be accounted for by extending the binary propensity score matching framework to the case of multiple treatments thanks to the matching estimator proposed in Lechner (2002). By allowing multiple treatments, the treatment variable D in our setup is no longer binary and can take multiple values. In our setup of secondary school choice, D is equal to 0 if a pupil chooses an independent school, which we set as the baseline (although this choice does not affect results), to 1 if the choice is a grammar and to 2 for CH.

First, a multinomial logit model of school choice is estimated using as covariates the set of observables X used in the logit model. Secondly, we compute the predicted probabilities $\hat{P}^j(X) = \hat{P}(D = j \mid X)$ of attending an independent school ($j = 0$), a grammar school ($j = 1$) or CH ($j = 2$). To estimate the effect of attending CH relative to, for example, an independent school, we compute the conditional probability $\hat{P}^{2|2,0}(X) = \frac{\hat{P}^2(X)}{\hat{P}^2(X)+\hat{P}^0(X)}$. Finally, the estimated conditional probability is used in Lechner (2002) as a balancing score in a matching estimator setting with multiple treatments to estimate the unobserved term $E[E[A(0) \mid D = 0, P^{2|2,0}] \mid D = 2]$, i.e. to match pupils at CH ($D = 2$) and pupils in independent schools ($D = 0$) with very similar values of the conditional probability $P^{2|2,0}$. Analogously, the procedure is repeated to estimate the effect of attending CH relative to a grammar school.[10]

1.5 Results

We start this section by showing estimates of the pscore and means of predetermined characteristics separately for pupils at CH and for those in the control groups in subsection 1.5.1. Then, we show propensity score matching estimates of the effect of going to

[9] ATT estimation with binary treatment was conducted using the software routines described in Becker and Ichino (2002); Leuven and Sianesi (2015).

[10] ATT estimation with multiple treatments was conducted by implementing the algorithms proposed in Gerfin and Lechner (2002); Lechner (2002); Frölich, Heshmati, and Lechner (2004).

CH on achievement in the compulsory school final exam in subsection 1.5.2. A sensitivity analysis is then presented in section 1.6.

1.5.1 Propensity score and balance of predetermined characteristics

We estimate the propensity score by using a logit model and the following socio-demographic characteristics: gender, ethnicity dummies, a dummy equal to 1 if primary school was a faith school, a dummy for FSM, a dummy equal to 1 if IDACI is above the median or a dummy equal to 1 if it is in the top quartile of its distribution. We also use scores in Key Stage 2 tests by subject and dummies for whether the level obtained by the pupil was greater than the expected level 4. Thus the predetermined characteristics chosen for the propensity score matching fall into two main categories: detailed previous achievement and socio-demographic characteristics. Following the literature on value added models for achievement we match pupils on previous test scores, as measures of ability and past inputs, and socio-demographics as controls for the remaining observable characteristics. Achievement and SES characteristics are also criteria used for the selection into CH. The advantage of using five cohorts of data in the empirical analysis is that larger samples improve the quality of the matching between CH pupils and pupils with very similar observable characteristics in the control groups.

Figure 1.4 shows the estimated propensity score distribution for CH pupils and for matched pupils in each of the two control groups. The *common support*, measured on the horizontal axis, is the interval of propensity score values over which the probability of observing pupils, measured on the vertical axis, is positive both for the control and for the treatment group. This varies from 0 to about 0.6 and to 0.9 for grammar and independent schools respectively.

By following Black and Smith (2004), we also use a more conservative definition of support, called *thick support*, that consists in using only data on pupils in the 'thick' region of the pscore distribution for treated and for controls, and is a subset of the common support. Guided by the pscore empirical distribution in Figure 1.4, we chose the interval between 0 and 0.2 as thick support and an even smaller interval, 0-0.1, i.e. we drop observations for pupils with pscores in the right tail of the distribution. Estimates obtained after excluding pupils outside the thick support region are helpful in assessing whether those obtained under the common support are potentially biased due to self-selection into or out of CH, since it is more likely for pupils in the tails rather than in the middle of the pscore distribution.

Descriptive statistics of pupil predetermined characteristics at the time they started secondary education are shown in Figure 1.5. These are used to assess the balancing property after estimating the propensity score. The vertical axis on the left-hand side measures the difference between pupils at CH and controls in, for example, the relative frequency of females in the top left of the figure, separately for pscore blocks measured along the horizontal axis. After estimating the pscore, the blocks are defined along the pscore support to ensure that predetermined characteristics are balanced. Pscore estimation using pupils in grammar schools as controls required splitting the data sample into 7 different blocks according to pupil estimated pscore while 9 blocks were used when the control group were pupils in independent schools. In addition, the vertical axis on the right-hand side measures p-values of t-tests of the null hypothesis of no difference in the mean value between treated and controls by block.

The plot on the top left in Figure 1.5 shows that the difference in the relative frequency of females by pscore block in CH relative to grammar schools, reported using a continuous line marked by diamonds, is either slightly positive or zero. P-values, reported using a scatterplot of diamonds, are greater than the 5% conventional level. The difference in the frequency of females by pscore block at CH relative to independent schools is reported using a dotted line marked by circles and its p-values, reported using a scatterplot of circles, are also greater than 5%. Overall figure 1.5 shows that predetermined characteristics are balanced, except for p-values close to 5% for some pscore blocks of Key Stage 2 scores. This suggests that the propensity score is helpful in choosing those pupils at grammar and independent schools who are most similar to pupils at CH in terms of observables.[11]

1.5.2 The effect of CH on achievement

In this section, we report ATT estimates of the impact on achievement in the compulsory school final exam of attending CH, rather than a day grammar or independent school. This is to test our first hypothesis that offering a better learning and non-school environment to high ability pupils with low SES increases their achievement (H_1). Overall, the positive and significant ATT estimates in table 1.4 support our hypothesis.

[11] Since in figure 1.5 the difference in the relative frequency of pupils with an IDACI above the median or an IDACI in the top quartile is zero in some blocks, corresponding p-values are not reported.

To match controls to treated we used as our preferred method nearest neighbour matching with replacement and set to 0.01 the maximum distance in pscore that is allowed to perform a match. The estimates in table 1.4, obtained using the common support, show that the probability of obtaining at least 1 (1+ hereafter) GCSEs with A is 4.4 and 10 percentage points higher relative to grammar and independent schools respectively, with ATT estimates being significant. This is 5% and 12% higher relative to the value for matched controls, which is also shown in the table. Differences in the probability of obtaining 1+ GCSEs with A* are also significant and show that the point estimate is 17 and 8.4 percentage points higher or about 26% and 11% relative to grammar and independent schools. Finally the probability of obtaining 5+ GCSEs with A-A* is 17.4 and 12.6 percentage points higher or about 29% and 20% relative to the control groups respectively. Overall, the point estimates are higher when using as outcome the dummy equal to 1 if pupils obtain 1+ GCSEs with A* or 5+ GCSEs with A-A*, who are approximately in the top two deciles of the distribution of achievement in GCSE exams among all pupils in the administrative data, as shown in figure 1.3.[12]

In addition to ATT estimates and mean values of outcomes for matched controls, table 1.4 shows mean values for all controls to compare our ATT estimates with naive estimates obtained as the difference in mean achievement between CH pupils and all pupils in grammar and in independent schools respectively. Naive estimates have the same sign as our ATT estimates but their magnitude is greater since the mean value of the outcomes for all pupils in the control groups is smaller than for matched controls. Under our untestable identifying assumption of selection on observables naive estimates are then biased upwards relative to our ATT estimates. This comparison also suggests that had pupils at CH instead gone to grammar or independent day schools, they would have obtained higher scores than the average in those schools.

Finally, table 1.4 shows that the ATT for the probability of obtaining 1+ GCSEs at A, i.e. of being a moderately high achiever at GCSE, is higher at CH when controls are pupils from independent schools, while the probability of obtaining 1+ GCSEs at A* or 5+ GCSEs at A-A*, i.e. of being a very high achiever, tends to be higher when controls are from grammar schools. However, the significance of the difference is not

[12] Results for the estimates of the ATT do not change much if additional predetermined characteristics are used, such as achievement in all tests at Key Stage 1, the type of school at Key Stage 2 and the distance to the closest secondary schools. However, since we used as criterion to choose the predetermined characteristics that are used as covariates in estimating the pscore the results of covariates balancing analysis that is described in section 1.5.1, we did not use these additional covariates as they were slightly unbalanced.

testable with our econometric strategy based on selection on observables without making additional assumptions.

Table 1.5 reports additional ATT estimates of the impact of attending CH relative to control schools for pupils whose pscore is in a 'thick' region of the pscore distribution, following Black and Smith (2004). We define pscore values in the range 0-0.2 as thick support as well as a more narrow range: 0-0.1. Table 1.5 shows overall that our main results are robust to using only pupils in the thick support when considering the sign of the point estimates, as well as their size and significance. However slight differences emerge across control groups. Thick support estimates when pupils in grammar schools are the controls are slightly greater than those obtained on the common support, with the greatest differences being for the probability of obtaining 1+ GCSEs at A. When looking at thick support estimates obtained with pupils in independent schools as controls, table 1.5 shows that they are very similar to common support ones.[13]

ATT estimates for subsamples of pupils by gender and by SES are shown in table 1.6. Results by gender are in line with common support estimates except the very small and negative effect of obtaining 1+ GCSE at A for females, suggesting some heterogeneity by gender for those pupils who are not among top achievers at CH since the result for males is positive. Heterogeneity by gender also seems to be present among top achievers, i.e. pupils with 5+ GCSE at A-A*, as it is shown by greater point estimates for females.

We examined subsamples by SES in two alternative ways. First, we obtained estimates for pupils who live in an area with an IDACI value above the median of the distribution, i.e. poor areas, and contrast these with estimates for those with an IDACI value below the median, i.e. a more affluent areas. Second, we compared estimates for pupils according to whether or not they were on FSM. When we look at results separately by whether IDACI is low or high, we find that achievement gains arising from attending CH tend to be higher for pupils with a high IDACI. Results by FSM are similar although when the controls are pupils in grammars their precision is lower due to the low number of matched controls. However, we cannot fully test these differences in a selection on observables framework without additional assumptions.

To summarise, ATT point estimates of the effect of attending CH are greater when using as outcome proxies for high achievers at GCSE, i.e. 1+ GCSEs at A* or 5+ GCSEs with A-A*, who are among the top 10-15% in the distribution of achievement

[13] In choosing the pscore intervals defining the thick support regions, we use as guidance the empirical distribution of pscores in figure 1.4.

at GCSE. For these same variables, estimates of the CH effect obtained using grammar school pupils as controls tend to be greater than those obtained using independent school pupils. When we consider only those pupils in the thick support region, we find that point estimates are very similar to those obtained using the common support. This similarity suggests that estimates are driven by pupils in the middle of the pscore distribution rather than by those in the tails and hence that they are little confounded by self-selection in the right tail of the propensity score distribution. Finally, we find that the effect is greater and tends to be more precise for females and for pupils in poorer households.

1.6 Sensitivity analysis

In this section we perform a sensitivity analysis of our main results. Firstly, we compare them with matching estimates obtained by allowing for multiple treatments, i.e. CH, grammar or independent schools, rather than a binary one, following Lechner (2002). Table 1.7 shows matching estimates that were obtained considering different types of selective schools as multiple treatments. The sign and size of the two sets of point estimates, as well as their significance, are in line with our main results in table 1.4, which are obtained by assuming a binary treatment. Overall, this suggests that relaxing the assumption of modelling choice of CH relative to a different selective secondary school as a binary treatment does not substantially alter our main results. The only difference is that the estimate of the probability of obtaining 1+ GCSE at A with pupils in grammar schools as controls is smaller and no longer significant. This may be due to the lower number of matched controls in grammar schools and may lead to a poorer match relative to our main results, particularly when looking at the probability of obtaining 1+ GCSE at A, as grammar school pupils tend to be very high ability pupils achieving top grades at Key Stage 2 and at GCSE.

Secondly, we compare our main results, obtained by using nearest neighbour matching, with results obtained using different matching methods, as one of the limitations of nearest neighbour is finding a match for all CH pupils and not controlling for the 'quality' of the matching, i.e. how similar to pupils at CH are pupils in control schools in terms of their predetermined characteristics. Instead with kernel and radius matching a pupil at CH can be matched with more than one pupil in the control group and the estimated counterfactual outcome for that pupil at CH is a weighted average of the outcome values for matched pupils in the control group, with the weight increasing with the quality of the matching. In kernel matching a CH pupil is matched with all pupils in the control group and the weight is inversely proportional to the distance between the propensity score value for that CH pupil and for controls.

In radius matching, only control group pupils whose value of the propensity score is within a fixed radius from the one of a given CH pupil are matched with her/him. The weight is equal to the inverse of the number of matched pupils, which is the same for all controls matched to the same pupil at CH. Finally, instead of relying on the propensity score as a metric to match treated and controls, we use Mahalanobis distance. In the context of matching, this is a scalar measure of the square of the distance between the vector of covariates for a pupil at CH relative to the one for a pupil in the control group, multiplied by the inverse of the covariance matrix of the difference between the vectors.

Table 1.8 shows ATT estimates separately by matching method across different horizontal panels. The top panel shows estimates obtained using kernel matching, estimates in the central panel were obtained using radius matching and those in the bottom panel using a Mahalonobis distance. Overall the table shows that the sign, size and precision of point estimates is in line with our main results in table 1.4. As for the size of point estimates, those of the probability of obtaining 1+ GCSE with A or with A-A* are slightly greater than our main results.[14]

Finally, we implement the methodology proposed by Ichino, Mealli, and Nannicini (2008), to assess the sensitivity of our main results to a failure of the CIA. We consider the case of a binary unobservable confounder that has both an effect on the untreated outcome and on the selection into treatment; by imposing the parameters of its distribution we can predict a value of the confounder for each individual in our sample. The simulated confounder can then be added to the set of matching variables to obtain an estimate of the ATT. This procedure is repeated 1000 times and the final estimated ATT is the average of the ATTs over the distribution of the simulated confounder. Similarly, the simulated values of the unobservable confounder can be used to obtain an estimate of its effect on the relative probability of a positive outcome for the non-treated (outcome effect) and on the relative probability of treatment (selection effect). These relative probabilities are obtained as average odds ratios after estimating a logit model for the

[14] The number of matched controls is not shown in the table 1.8 as the matching methods used to obtain the estimates shown in it are not one-to-one, i.e. each treated is not matched to a single control but rather to several ones.

probability of a positive outcome of the untreated and one for the probability of treatment. We now provide a more detailed description of this methodology.

We let U be an unobserved term, assumed binary in Ichino, Mealli, and Nannicini (2008) for simplicity, with its distribution be fully determined by four parameters $p_{ij} = Pr(U = 1 \mid D = i, A = j, X)$ measuring the probability that the unobserved term is equal to 1 given that the treatment D, i.e. school choice in our setting, is equal to i and the outcome A, i.e. achievement, is equal to j, with $i, j = \{0, 1\}$.

$$\Gamma = \frac{\frac{Pr(A=1 \mid D=0, U=1, X)}{Pr(A=0 \mid D=0, U=1, X)}}{\frac{Pr(A=1 \mid D=0, U=0, X)}{Pr(A=0 \mid D=0, U=0, X)}} \tag{1.2}$$

By assuming $p_{01} > p_{00}$, i.e. that the unobserved confounder has a positive effect on the untreated outcome, and accounting for the relationship between U and X, Ichino, Mealli, and Nannicini (2008) define the outcome effect Γ as the effect of U on the probability of a positive outcome A and compute it as the odds ratio of U after estimating the logit model of $Pr(A = 1 \mid D = 0, U, X)$, as shown in equation (1.2). In addition, the selection effect Δ is defined as the effect of U on the probability of treatment, i.e. $D = 1$, and is computed as the odds ratio of U after estimating the logit model of $Pr(D = 1 \mid U, X)$, as shown in equation (1.3).

$$\Delta = \frac{\frac{Pr(D=1 \mid U=1, X)}{Pr(D=0 \mid U=1, X)}}{\frac{Pr(D=1 \mid U=0, X)}{Pr(D=0 \mid U=0, X)}} \tag{1.3}$$

Based on values of p_{ij}, with $i, j = \{0, 1\}$ obtained by using the empirical distribution of a relevant covariate, a value of U is imputed for each pupil in the dataset. The variable U is then treated as any observed covariate in X to first estimate the pscore and then the ATT using nearest neighbour matching. Varying the values of the sensitivity parameters p_{ij} and repeating the pscore and ATT estimation in a simulation with 1000 repetitions, the average of the ATT over the distribution of U is obtained.[15]

[15] A more detailed description of the econometric details behind the sensitivity analysis is found in section 4 in Ichino, Mealli, and Nannicini (2008).

In our setting achievement in Key Stage 2 tests at age 11 and SES are observable characteristics used by CH to select its pupils while suitability for boarding is unobservable to the econometrician, due to the impossibility of matching CH admission data with NPD administrative data on all pupils. Hence, we assess the sensitivity of our main results to unobserved binary covariates whose distribution is similar to the one of observed measures of pupils' ability, as at least part of a pupil's ability is typically unobserved and may be correlated with the pupil's resilience to adapt to boarding.

As ability proxies, we use dummies equal to 1 if a pupil achieved in the Key Stage 1 Maths test a level greater than the expected one, i.e. 2, as it is typically a more precise measure of ability than using the English test, and if the level is greater than the expected one, i.e. 4, in all Key Stage 2 tests. In addition, we use the distance between primary school and CH or the closest grammar or independent secondary school as an observable measure of the opportunity cost of attending CH.[16] This may be a relevant factor for secondary school choice as we hypothesise that the further away a pupil lives from CH the higher the psychological effort required to adapt to boarding.

Panel A in table 1.9 shows estimates of the effect of CH obtained on our three measures of achievement at GCSE by using pupils in grammar schools as controls. Estimates on each row are obtained by using a confounder U distributed according to a different covariate. Along a row, the first four columns on the left-hand side show values of the probabilities p_{ij} characterising the distribution of U by using the empirical distribution of a covariate, then the outcome and selection effect are shown and, finally, ATT estimates.

For each outcome variable, table 1.9 shows firstly estimates obtained using a neutral confounder, i.e. with all p_{ij} set equal to approximately 0.5. On the two following rows the unobserved confounder is distributed similarly to observed measures of ability, proxied by dummies measuring achievement at Key Stage 1 and at Key Stage 2. In the three final rows the confounder is distributed following the empirical distribution of a dummy equal to 1 if the distance in miles between primary school and CH is greater than the median value, as well as two additional dummies equal to 1 if the distance to the closest grammar secondary or to the closest independent secondary is greater than the median.

[16] Distances are computed by using publicly available data on schools' postcodes and on longitude and latitude coordinates associated to postcodes, measured using the World Geodetic System 1984 (Ordnance Survey website). They are then converted into Ordnance Survey Maps northing and easting coordinates thanks to a Helmert transformation (Watson, 2006) to eventually obtain distances in miles.

Estimates in table 1.9 show overall that both their magnitude and precision are in line with our main results. When we look instead at the outcome effect, i.e. the effect of U on the probability of higher achievement, and at the selection effect, i.e. the effect of U on the probability of attending CH, the table shows that the value of both effects is very close to one in the case of neutral confounder, which is expected as by setting all p_{ij} to 0.5 the confounder is close to being a random error. When we look at proxies for unobserved ability, both the outcome and selection effect are greater than 1, with the outcome effect being greater. This suggests a positive selection into CH and a positive effect on achievement for CH pupils with high unobserved ability.

Finally, when we look at proxies for the opportunity cost of attending CH, table 1.9 shows that both the outcome and selection effect are smaller than 1, which suggests that a high unobserved opportunity cost leads to a lower probability of high achievement and of attending CH respectively. In addition, the outcome effect is closer to one than the selection effect, suggesting that the opportunity cost affects selection more. These results hold qualitatively for all the three outcomes we consider and for both our control groups, shown in Panel A and B respectively.

1.7 Discussion

In this paper we tested the hypothesis that attending Christ Hospital (CH), a boarding school admitting a high share of high ability pupils with low socio-economic status (SES), improves achievement in the compulsory school final exams (GCSEs), by using administrative data on pupils in England. Our propensity score matching estimates are substantial: the probability of achieving A or A* in five or more GCSEs is 17.4 percentage points higher with respect to 59% for matched pupils in grammar schools, i.e. a 29% increase, with similar results when the control group are independent school pupils. As an additional hypothesis, we tested for heterogeneous effects and find that the CH effect is higher for low SES pupils and for girls.

Since CH differs from independent day schools in that it is boarding and tends to be more selective based on ability, when pupils in independent day schools are the control group we estimate the joint effect of boarding and of ability selection. However, since independent schools display a higher variability in pupils' ability, ranging from very high for pupils admitted with a bursary to a lower level for fee-paying pupils, the quality of the matching is preserved as high ability pupils at independent schools can be repeatedly matched to similar pupils at CH. Boarding, therefore, is the most plausible mechanism underlying our estimated effect.

When, instead, pupils in grammar schools are the controls, our estimates capture the overall effect of substituting family with school inputs and of having access to better school inputs since CH is boarding and has more resources. Although we cannot separately quantify the boarding effect and the resources effect without additional assumptions, the fact that we obtain similar results with the independent day schools control group, where resources are much closer to those of CH, suggests that boarding is an important part of the explanation for the difference between CH's and the grammar schools' exams performances.

Our paper contributes to two related and recent studies exploiting lottery-based admission into oversubscribed boarding schools in the US (Curto and Fryer Jr, 2014) and in France (Behaghel, de Chaisemartin, and Gurgand, 2017). First, in our setting we can test hypotheses on pupils with high ability coming from low SES, thanks to an overall sample size of approximately 8,000 observations while the lottery studies cannot as they have fewer observations, approximately 400 in total. Secondly, by estimating a treatment on the treated (ATT), we offer complementary evidence to the quasi-experimental one obtained using a local average treatment effect (LATE). On the one hand, ATT has a somewhat "stronger" identification assumption based on selection on observables while, on the other, it relies on a bigger control group than quasi-experimental studies. One limitation that our study and the two related ones on boarding schools have in common is low external validity as they all use as treated group either a single boarding school or a small number of them, which makes them unrepresentative of the universe of boarding schools in a country.

Our paper also contributes to empirical studies estimating an educational production function to assess the effect of those school-based policies set up to counteract the negative influence of low SES on pupils' achievement (see for a survey Todd and Wolpin, 2003). We isolate the boarding, i.e. school, effect in a simple setting in which parental responses are low for all boarders while it cannot be done in the production function, where family inputs may either decrease if school and family inputs are substitutes or increase if they are complements.

Our additional results, that the impact of CH is substantially higher for girls over boys, are novel as they show that the documented gender achievement gap in favour of girls in England also holds for high ability children in selective schools. However this result is based on a low number of observations for pupils in selective schools and additional work based on a greater number of pupils would be required to fully test for gender differences.

Our econometric strategy based on propensity score matching relies on the unconfoundedness assumption that unobservable characteristics, such as ability or motivation, are unlikely to be different for CH pupils relative to their match in selective day schools if the set of observables used is rich enough to capture the most relevant factors driving selection into a selective secondary school. We showed in our sensitivity analysis that our results are robust to a number of assumptions on the correlation between unobservable and observable characteristics, such as ability. A complementary approach would consist in making a different set of assumptions on the role played by unobservables to quantify the value of the ratio between the extent of selection on unobservables and of selection on observables such that our results would be completely driven by selection, using the methodology in Altonji, Elder, and Taber (2005a).

Our analysis paves the way for a number of extensions, some of which we plan to develop in the future. We have not yet looked at the probability of continuing with post-compulsory education, namely sixth form, achievement in A-levels, admission into prestigious universities, degree choice and achievement and, finally, labour market outcomes. In addition, we have so far focused on a single selective and boarding school. Considering state boarding schools, a number of which are Academies, may help us obtaining as treatment group one that is more representative of secondary school pupils than the highly selected one at CH. Finally a particularly relevant extension for policymakers would be to perform a cost-benefit analysis of subsidising boarding education for high ability with low SES.

Table 1.1: Compulsory education in England

Phase	Age	School year	Key Stage	Assessment	Expected achievement level
Primary School	5-7	1-2	1	Teachers (state schools)	2
	7-11	3-6	2	External (state schools)	4
Secondary School	11-14	7-9	3	Teachers (state schools)	5 or 6
	15-16	10-11	4	External (GCSE) (all schools)	5 GCSEs at A*-C

Table 1.2: Resources in different types of schools

	CH	Grammar schools	Independent schools	State schools
Pupil/teacher ratio	8.800	16.444	7.911	14.652
Pupil/Full-time qualified teachers ratio	9.901	18.867	6.803	13.889
Pupil/Part-time qualified teachers ratio	50	62.5	8.403	38.461
Pupil/Total N of qualified teachers ratio	82.644	14.49	3.75	10.101

Notes: authors' own calculations using school-level data provided by the Department for Education.

TABLE 1.3: Descriptive statistics for treated, matched controls and all controls

	Grammar schools					Independent schools			
	Treated	Matched	pval	All controls	pval	Matched	pval	All controls	pval
Female	0.448	0.463	0.659	0.477	0.237	0.470	0.521	0.372	0.002
Born in 4th quarter	0.179	0.202	0.428	0.224	0.032	0.189	0.725	0.247	0.001
White	0.599	0.665	0.056	0.794	0.000	0.681	0.016	0.765	0.000
Asian	0.014	0.014	0.965	0.072	0.000	0.005	0.225	0.037	0.011
African	0.140	0.074	0.003	0.008	0.000	0.084	0.013	0.015	0.000
Caribbean	0.012	0.005	0.351	0.002	0.000	0.011	0.910	0.017	0.364
KS2 Faith	0.510	0.501	0.798	0.394	0.000	0.468	0.227	0.382	0.000
KS1 in Eng at lev>=3	0.704	0.711	0.824	0.583	0.000	0.649	0.095	0.423	0.000
KS1 in Maths at lev>=3	0.711	0.700	0.742	0.651	0.012	0.684	0.405	0.480	0.000
KS1 in Eng & Maths at lev>=3	0.599	0.594	0.885	0.492	0.000	0.554	0.199	0.353	0.000
KS2 Eng score	75.704	74.798	0.150	73.133	0.000	74.597	0.103	66.167	0.000
KS2 Maths score	88.352	87.488	0.146	87.036	0.003	87.081	0.060	76.837	0.000
KS2 Sci score	70.510	69.962	0.158	68.990	0.000	69.951	0.167	64.570	0.000
K2 English at lev. >4	0.851	0.828	0.389	0.752	0.000	0.803	0.072	0.543	0.000
K2 Maths at lev. >4	0.895	0.880	0.504	0.861	0.046	0.857	0.100	0.601	0.000
K2 Science at lev. >4	0.925	0.929	0.840	0.874	0.002	0.914	0.537	0.701	0.000
IDACI	0.229	0.187	0.002	0.149	0.000	0.206	0.091	0.134	0.000
IDACI 25-75 pctl	0.396	0.463	0.057	0.599	0.000	0.405	0.793	0.425	0.248
IDACI 75 pctl	0.310	0.232	0.013	0.105	0.000	0.257	0.097	0.116	0.000
FSM	0.161	0.117	0.078	0.035	0.000	0.151	0.713	0.047	0.000
EAL	0.189	0.128	0.020	0.109	0.000	0.124	0.013	0.105	0.000
SEN	0.014	0.022	0.404	0.027	0.108	0.030	0.124	0.124	0.000
N	429	367		7,075		370		8,690	

Table 1.4: Effect of attending CH on results in school-leaving exams

	Grammar schools			Independent schools		
	ATT	Matched	All	ATT	Matched	All
1+ GCSE with A	0.044**	0.888	0.868	0.100***	0.832	0.754
s.e.	0.020			0.024		
1+ GCSE with A*	0.170***	0.653	0.570	0.084**	0.739	0.527
s.e.	0.031			0.031		
5+ GCSE with A-A*	0.174***	0.593	0.513	0.126***	0.641	0.422
s.e.	0.033			0.034		
N		494	7,075		369	8,118

Notes: ATT estimates obtained using nearest neighbour pscore matching. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Table 1.5: Effect of attending CH for pupils in the pscore thick support

	Grammar schools			Independent schools		
	ATT	Matched	All	ATT	Matched	All
		Pscore thick support 0-0.2				
1+ GCSE with A	0.065***	0.868	0.868	0.072***	0.856	0.754
s.e.	0.021			0.026		
1+ GCSE with A*	0.192***	0.623	0.570	0.084***	0.730	0.527
s.e.	0.032			0.034		
5+ GCSE with A-A*	0.179***	0.576	0.513	0.126***	0.631	0.422
s.e.	0.034			0.037		
N		450	7,075		306	8,118
		Pscore thick support 0-0.1				
1+ GCSE with A	0.079***	0.844	0.868	0.081***	0.856	0.754
s.e.	0.026			0.030		
1+ GCSE with A*	0.231***	0.576	0.570	0.077***	0.703	0.527
s.e.	0.038			0.043		
5+ GCSE with A-A*	0.218***	0.523	0.513	0.126***	0.581	0.422
s.e.	0.040			0.046		
N		338	7,075		214	8,118

Notes: ATT estimates obtained using nearest neighbour pscore matching. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Table 1.6: Effect of attending CH for pupils' subgroups by gender and SES

	Grammar schools			Independent schools		
	ATT	Matched	All	ATT	Matched	All
			Males			
1+ GCSE with A	0.081***	0.856	0.848	0.127***	0.810	0.722
s.e.	0.028			0.034		
1+ GCSE with A*	0.177***	0.587	0.527	0.072***	0.692	0.495
s.e.	0.044			0.044		
5+ GCSE with A-A*	0.127***	0.560	0.471	0.093***	0.595	0.390
s.e.	0.046			0.047		
N		292	3,701		208	5,460
			Females			
1+ GCSE with A	-0.016***	0.944	0.890	0.151***	0.776	0.746
s.e.	0.026			0.038		
1+ GCSE with A*	0.174***	0.722	0.618	0.214***	0.682	0.518
s.e.	0.041			0.044		
5+ GCSE with A-A*	0.190***	0.675	0.558	0.271***	0.594	0.423
s.e.	0.044			0.047		
N		227	3,374		169	3,230
			IDACI in bottom quartile			
1+ GCSE with A	0.112***	0.830	0.885	0.125***	0.839	0.790
s.e.	0.044			0.056		
1+ GCSE with A*	0.204***	0.563	0.623	0.125	0.661	0.556
s.e.	0.066			0.087		
5+ GCSE with A-A*	0.204***	0.515	0.544	0.107	0.589	0.444
s.e.	0.068			0.094		
N		112	1,758		52	2,184
			IDACI between bottom and top quartile			
1+ GCSE with A	0.075***	0.860	0.869	0.106***	0.829	0.721
s.e.	0.032			0.039		
1+ GCSE with A*	0.262***	0.585	0.552	0.171***	0.676	0.492
s.e.	0.046			0.050		
5+ GCSE with A-A*	0.270***	0.525	0.500	0.241***	0.553	0.385
s.e.	0.049			0.053		
N		193	4,240		153	3,689

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Table 1.6 – continued from previous page

	Grammar schools			Independent schools		
	ATT	Matched	All	ATT	Matched	All
			IDACI in top quartile			
1+ GCSE with A	0.050	0.881	0.833	0.154***	0.771	0.616
s.e.	0.036			0.043		
1+ GCSE with A*	0.149***	0.691	0.514	0.154***	0.692	0.418
s.e.	0.049			0.051		
5+ GCSE with A-A*	0.212***	0.581	0.456	0.214***	0.582	0.316
s.e.	0.052			0.054		
N		174	1,720		157	2,125
			IDACI below median			
1+ GCSE with A	0.002	0.930	0.881	0.117***	0.818	0.782
s.e.	0.028			0.042		
1+ GCSE with A*	0.124***	0.652	0.607	0.080	0.693	0.550
s.e.	0.049			0.056		
5+ GCSE with A-A*	0.152***	0.575	0.544	0.102***	0.620	0.451
s.e.	0.052			0.059		
N		227	3,562		126	4,393
			IDACI above median			
1+ GCSE with A	0.055***	0.877	0.854	0.089***	0.842	0.679
s.e.	0.026			0.031		
1+ GCSE with A*	0.172***	0.679	0.534	0.113***	0.733	0.456
s.e.	0.041			0.039		
5+ GCSE with A-A*	0.190***	0.601	0.481	0.147***	0.640	0.352
s.e.	0.044			0.043		
N		274	3,513		227	4,297
			FSM			
1+ GCSE with A	0.174***	0.754	0.777	0.130***	0.797	0.335
s.e.	0.080			0.073		
1+ GCSE with A*	0.275***	0.551	0.458	0.203***	0.623	0.196
s.e.	0.103			0.096		
5+ GCSE with A-A*	0.290***	0.449	0.343	0.159	0.580	0.149
s.e.	0.105			0.100		
N		44	251		43	409
			No FSM			

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Table 1.6 – continued from previous page

	Grammar schools			Independent schools		
	ATT	Matched	All	ATT	Matched	All
1+ GCSE with A	0.050***	0.884	0.871	0.089***	0.844	0.751
s.e.	0.021			0.025		
1+ GCSE with A*	0.174***	0.648	0.575	0.097***	0.725	0.519
s.e.	0.032			0.033		
5+ GCSE with A-A*	0.183***	0.589	0.519	0.167***	0.606	0.415
s.e.	0.034			0.036		
N		437	6,824		328	8,281

Notes: ATT estimates obtained using nearest neighbour pscore matching. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Table 1.7: Matching estimates of CH effect using pscore from multinomial logit

	Grammar schools			Independent schools		
	ATT	Mean for controls		ATT	Mean for controls	
		Matched	All		Matched	All
		P-score from multinomial logit				
1+ GCSE with A	0.023	0.907	0.868	0.096***	0.837	0.754
s.e.	0.032			0.024		
1+ GCSE with A*	0.202***	0.622	0.570	0.147***	0.676	0.527
s.e.	0.049			0.032		
5+ GCSE with A-A*	0.183***	0.574	0.513	0.184***	0.583	0.422
s.e.	0.051			0.034		
N		175	7,075		370	8,118

Notes: ATT estimates obtained using nearest neighbour pscore matching.***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Table 1.8: Matching estimates of CH effect using different matching methods

	Grammar schools			Independent schools		
	ATT	Matched	All	ATT	Matched	All
			Kernel			
1+ GCSE with A	0.047***	0.885	0.868	0.129***	0.803	0.754
s.e.	0.013			0.015		
1+ GCSE with A*	0.204***	0.619	0.570	0.165***	0.658	0.527
s.e.	0.020			0.022		
5+ GCSE with A-A*	0.203***	0.564	0.513	0.202***	0.564	0.422
s.e.	0.022			0.023		
N			7,075			8,118
			Radius with size 0.1			
1+ GCSE with A	0.056***	0.876	0.868	0.146***	0.787	0.754
s.e.	0.013			0.015		
1+ GCSE with A*	0.230***	0.593	0.570	0.206***	0.617	0.527
s.e.	0.019			0.021		
5+ GCSE with A-A*	0.231***	0.536	0.513	0.244***	0.522	0.422
s.e.	0.021			0.023		
N			7,075			8,118
			Mahalanobis			
1+ GCSE with A	0.049***	0.883	0.868	0.058***	0.874	0.754
s.e.	0.020			0.022		
1+ GCSE with A*	0.210***	0.613	0.570	0.131***	0.692	0.527
s.e.	0.029			0.028		
5+ GCSE with A-A*	0.203***	0.564	0.513	0.182***	0.585	0.422
s.e.	0.028			0.030		
N			7,075			8,118

Notes: ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Table 1.9: Sensitivity analysis of CH effect using calibrated confounders

	p_{11}	p_{10}	p_{01}	p_{00}	Outcome effect Γ	Selection effect Δ	ATT	s.e.
				Panel A: grammar schools				
				1+ GCSEs with A				
Neutral conf.	0.507	0.448	0.499	0.521	0.915	1.012	0.044***	0.020
KS1 Mat >2	0.993	0.966	0.996	0.993	1.804	0.687	0.049***	0.023
All KS2 >4	0.752	0.655	0.676	0.391	3.261	1.640	0.035	0.025
Miles pri.-CH > median	0.100	0.138	0.505	0.597	0.692	0.108	0.031	0.026
Miles pri.-gram. > median	0.530	0.517	0.496	0.498	0.999	1.145	0.048***	0.026
Miles pri.-indep. > median	0.270	0.345	0.494	0.520	0.903	0.393	0.043***	0.026
				*1+ GCSEs with A**				
Neutral conf.	0.467	0.500	0.506	0.496	1.042	0.893	0.170***	0.031
KS1 Mat >2	0.994	0.974	0.996	0.994	1.617	0.661	0.185***	0.036
All KS2 >4	0.796	0.513	0.777	0.453	4.190	1.563	0.164***	0.039
Miles pri.-CH > median	0.099	0.118	0.472	0.577	0.659	0.111	0.156***	0.041
Miles pri.-gram. > median	0.521	0.566	0.487	0.508	0.919	1.149	0.190***	0.038
Miles pri.-indep. > median	0.261	0.342	0.473	0.529	0.801	0.392	0.179***	0.040
				*5+ GCSEs with A-A**				
Neutral conf.	0.523	0.560	0.497	0.497	1.002	1.156	0.174***	0.033
KS1 Mat >2	0.994	0.980	0.997	0.993	2.432	0.637	0.185***	0.037
All KS2 >4	0.815	0.520	0.804	0.463	4.751	1.540	0.157***	0.040
Miles pri.-CH > median	0.109	0.080	0.475	0.562	0.704	0.110	0.155***	0.043
Miles pri.-gram. > median	0.517	0.570	0.483	0.510	0.901	1.157	0.189***	0.040
Miles pri.-indep. > median	0.255	0.340	0.469	0.527	0.795	0.392	0.173***	0.042
				Panel B: independent schools				
				1+ GCSEs with A				
Neutral conf.	0.490	0.586	0.505	0.510	0.983	0.966	0.103***	0.024
KS1 Mat >2	0.993	0.966	0.976	0.828	8.721	7.321	0.094***	0.030
All KS2 >4	0.752	0.655	0.511	0.169	5.023	3.633	0.059***	0.029
Miles pri.-CH > median	0.417	0.345	0.490	0.542	0.818	0.707	0.110***	0.032
Miles pri.-gram. > median	0.388	0.379	0.511	0.491	1.085	0.616	0.112***	0.031
Miles pri.-indep. > median	0.463	0.414	0.497	0.515	0.935	0.857	0.114***	0.031
				*1+ GCSEs with A**				
Neutral conf.	0.513	0.592	0.503	0.499	1.017	1.115	0.107***	0.031
KS1 Mat >2	0.994	0.974	0.987	0.885	9.194	6.704	0.122***	0.038
All KS2 >4	0.796	0.513	0.656	0.178	8.846	2.867	0.054	0.038
Miles pri.-CH > median	0.431	0.329	0.463	0.546	0.723	0.741	0.126***	0.039
Miles pri.-gram. > median	0.374	0.447	0.494	0.517	0.912	0.629	0.128***	0.039
Miles pri.-indep. > median	0.462	0.447	0.471	0.534	0.781	0.892	0.129***	0.039
				*5+ GCSEs with A-A**				
Neutral conf.	0.483	0.420	0.495	0.492	1.015	0.898	0.163***	0.034
KS1 Mat >2	0.994	0.980	0.991	0.899	12.351	6.379	0.160***	0.041
All KS2 >4	0.815	0.520	0.733	0.207	10.469	2.740	0.085***	0.042
Miles pri.-CH > median	0.438	0.330	0.480	0.521	0.849	0.715	0.160***	0.042
Miles pri.-gram. > median	0.377	0.420	0.507	0.504	1.013	0.618	0.166***	0.042
Miles pri.-indep. > median	0.459	0.460	0.472	0.522	0.820	0.887	0.168***	0.041

Notes: ATT estimates obtained using nearest neighbour pscore matching and simulations described in Ichino, Mealli, and Nannicini (2008) based on 1000 replications. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

FIGURE 1.1: Number of CH pupils by LA and location of grammar (g) and independent schools (i)

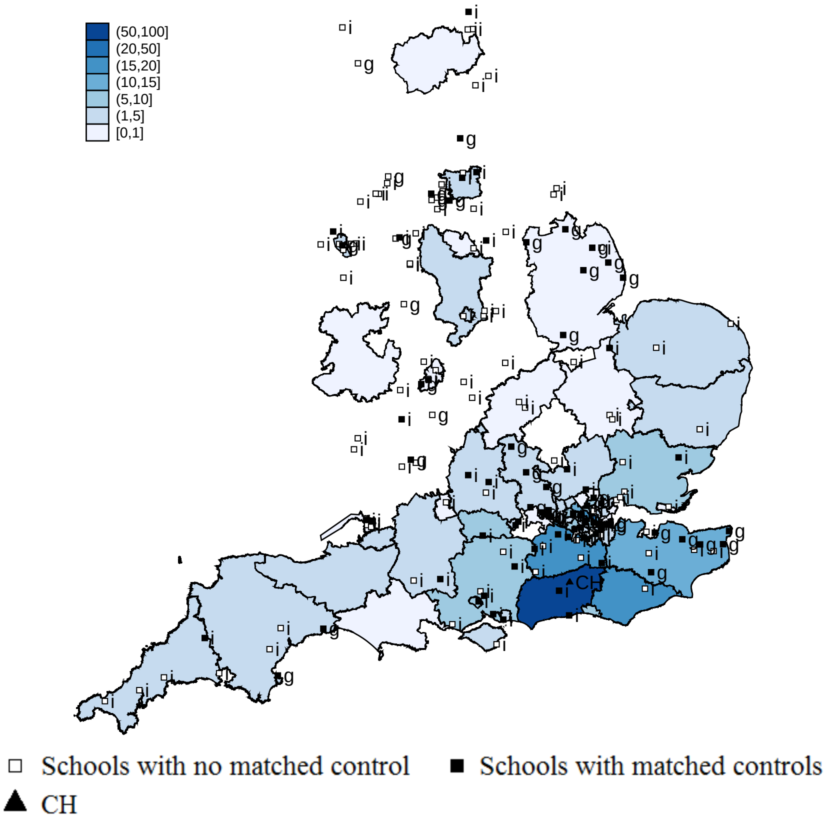


FIGURE 1.2: Achievement at Key Stage 2 (KS2) and FSM by secondary school

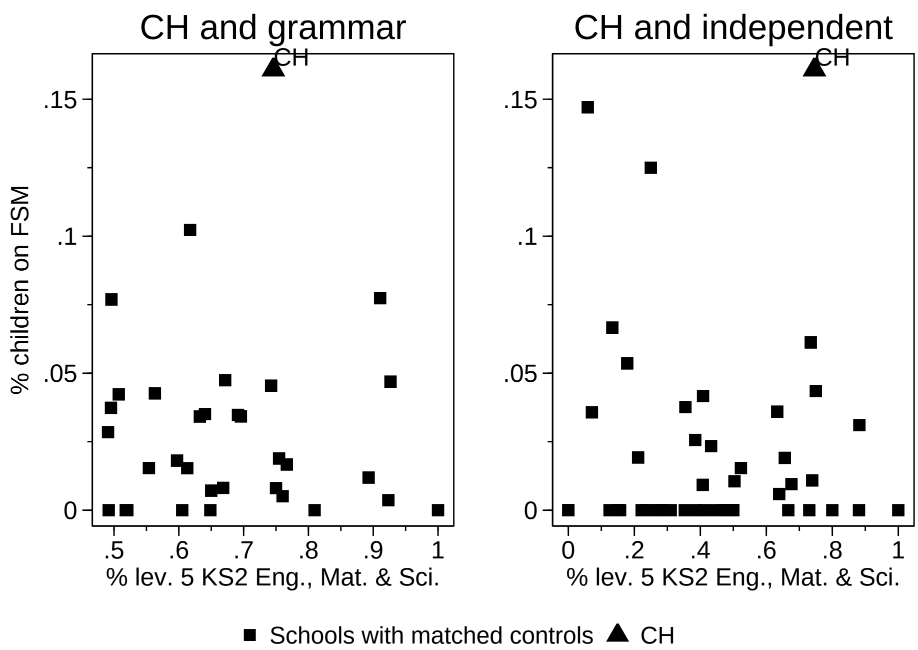
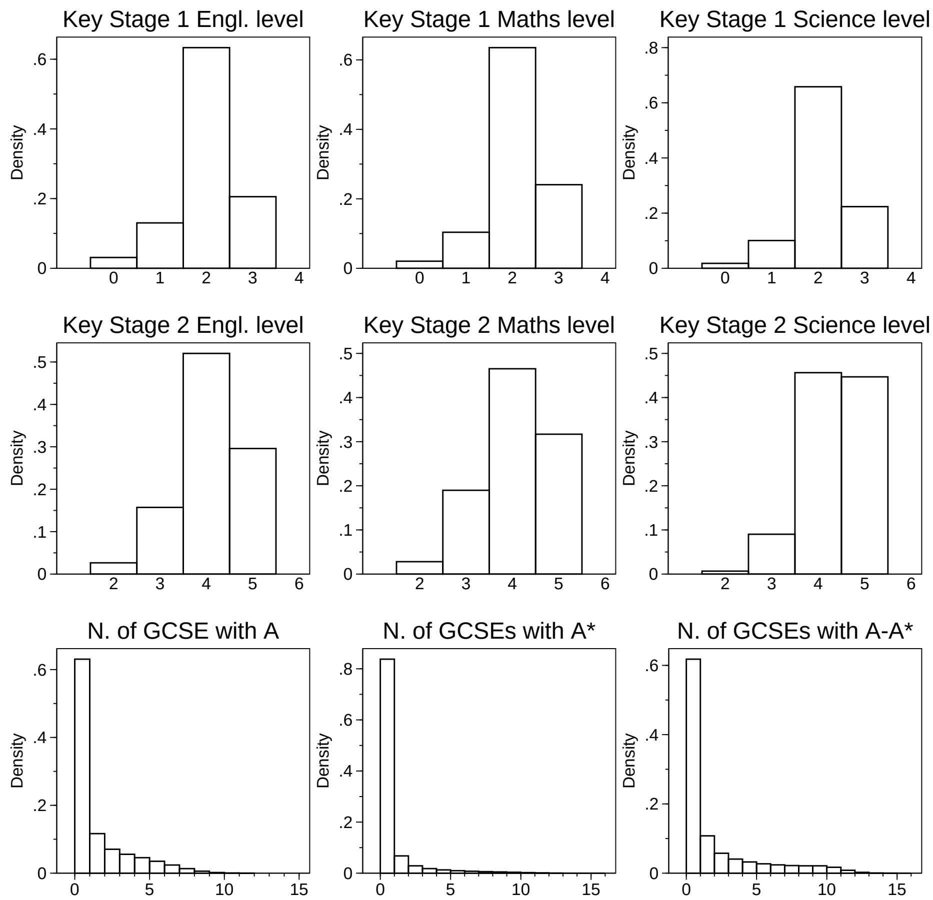
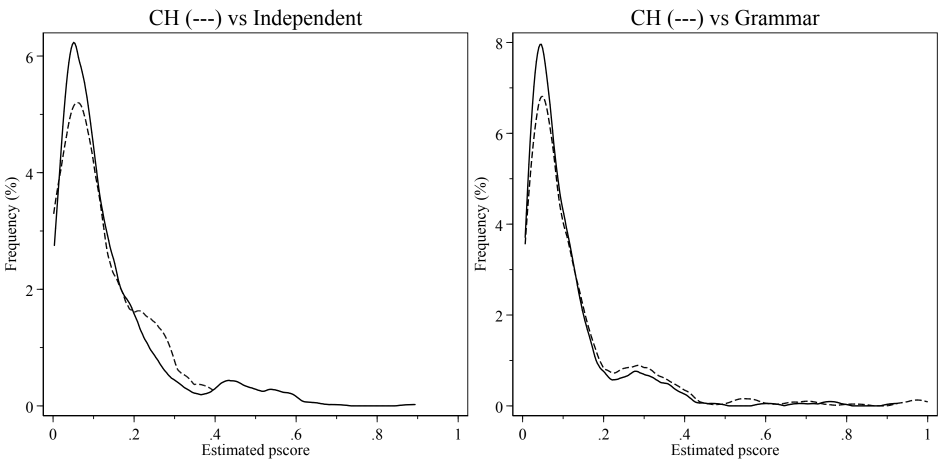


Figure 1.3: Histograms of achievement at Key Stage 1 and 2 and at GCSE



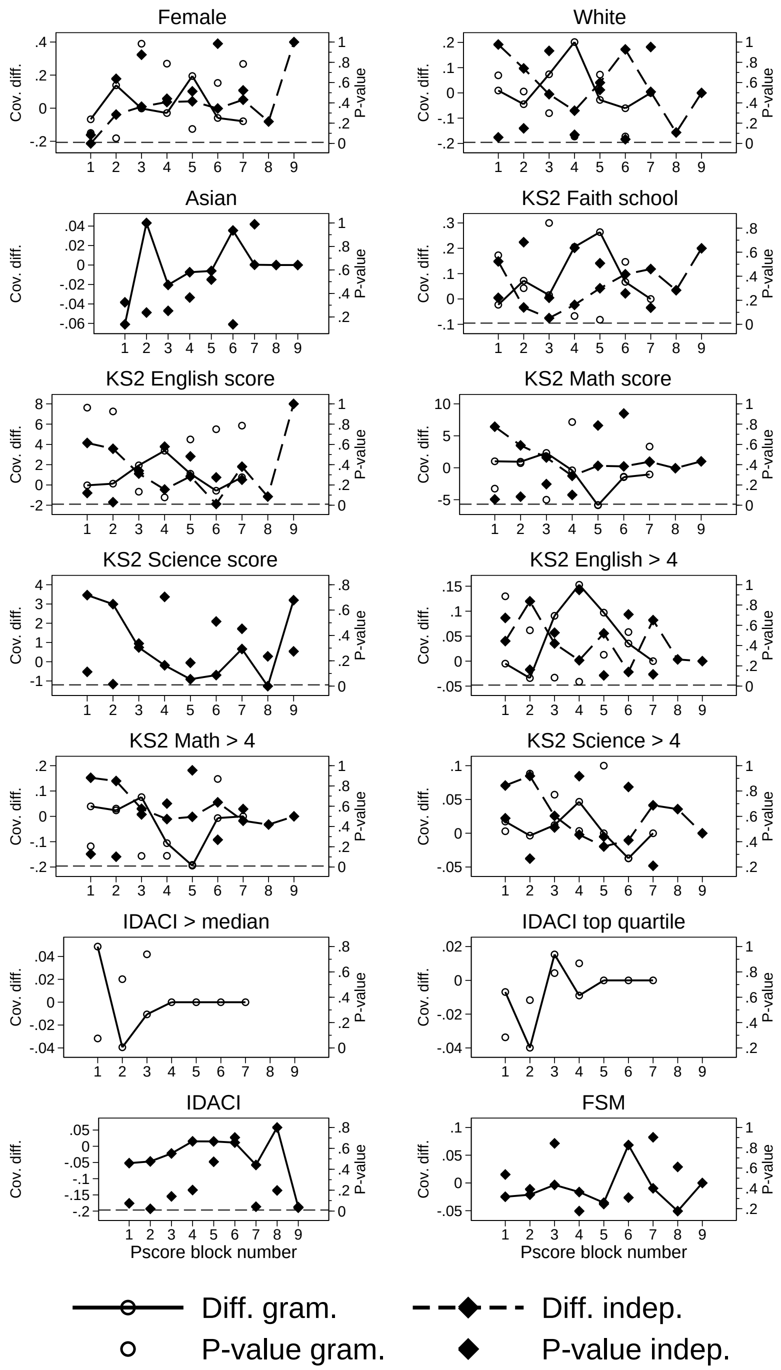
Notes: authors' own calculations using NPD data for academic years 2006/07 to 2010/2011

Figure 1.4: Kernel density estimate of the propensity score



Notes: kernel density estimate for CH pupils and matched controls in independent and grammar schools

FIGURE 1.5: Covariates differences for CH relative to grammar and independent by pscore block



Notes: The vertical axis on the left-hand side measures the difference between pupils at CH and controls inrelative frequencies and means. After estimating the pscore, the blocks were defined along the pscore support to ensure that predetermined characteristics are balanced. Pscore estimation using pupils in grammar schools as controls required splitting the data sample into 7 different blocks according to pupils' estimated pscore while 9 blocks were used when the control group were pupils in independent schools.

Chapter 2

The effect of gender segregation on achievement and subject choice. Evidence from single sex schools in England

2.1 Introduction

In recent years there has been extensive research in economics about the effect of gender composition of peers on individual behaviour and outcomes. Experimental studies have looked into how competitive behaviour is affected by the gender composition of peers (Balafoutas and Sutter, 2012; Booth and Nolen, 2012; Gneezy, Niederle, and Rustichini, 2003): evidence from experiments in labs shows that women and men respond differently to competition and the gender composition of the competitive environment affects their response. In particular women perform better in single-sex competitive environments and shy away from competition in mixed sex groups. Boys instead are always over-competitive. Huguet and Regner (2007) show that 10-12 year-old girls underperform in a mixed-sex environment (but not in all-female groups) in a test they were led to believe (erroneously) measured mathematical ability: this result supports the idea presented by Niederle and Vesterlund (2010) that the attitude towards competition observed in the lab can be extended to the attitude towards mathematics and science in school to explain the gender gap in these subjects.

In economics of education several studies have looked at the link between the gender composition of peers and individual outcomes. Results in co-educational environments seem to suggest that male students perform better when surrounded by a higher proportion of female peers (Ciccone and Garcia-Fontes, 2014; Hill, 2017; Hoxby, 2000; Lavy and Schlosser, 2011) whereas female students make less gender stereotyped choices and do better in more male-dominated subjects when they have a higher proportion of female peers (Bostwick and Weinberg, 2017; Schneeweis and Zweimüller, 2012; Schøne, von Simson, and Strøm, 2017).[1] Three mechanisms emerge from this literature as likely to be at work behind gender peer effects in education. First, a higher proportion of female students in the classroom leads to less disruptive behaviour and a better learning environment (Lavy and Schlosser, 2011; Hill, 2017). Second, female students can improve the performance of the classroom through ability peer effects if they outperform their male peers (Hoxby, 2000). Third, girls in classrooms with a higher proportion of same-gender peers may feel less pressure from gender stereotypes and stereotype threats, that is the fear of being judged by the negative stereotypes associated to one's gender: they may engage more with those subjects that are generally considered for boys and where behaving competitively is desirable (Huguet and Regner, 2007; Schøne, von Simson, and Strøm, 2017).[2] This third mechanism is particularly interesting from a policy perspective because it implicitly suggests a way to boost the number of girls studying more male dominated subjects in high school and post-secondary education such as science, technology, engineering, and mathematics (STEM) in an economy where there is an endemic need for technical skills[3].

A closely related literature looks at the effects of single-sex educational environment on school performance and attainment. This literature includes relatively few papers partly because of the challenge of finding experimental data. There are three exceptions. Lee, Turner, Woo, and Kim (2014) exploit the random assignment of Korean middle school students to single-sex schools and find that male students score 0.15% of

[1]There are a few studies which find no gender peer effect (Oosterbeek and Van Ewijk, 2014) or an adverse gender peer effect (Zölitz and Feld, 2017). However these are studies based on experimental data collected in very limited contexts and the external validity of their results should be treated carefully.

[2]Gender stereotypes and stereotype threats may also explain the findings of the experimental literature mentioned earlier.

[3]The UK Commission for Employment and Skills has estimated that the STEM professional categories have 43% ratio of skill shortages to vacancies by using the Employer Skills Survey 2013 . The report can be found at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/444052/stem_review_evidence_report_final.pdf (accessed: March 15, 2018).

a standard deviation above their counterparts in co-ed classes whereas there is no effect for female students. Eisenkopf, Hessami, Fischbacher, and Ursprung (2015) observe female pupils that are randomly assigned to either single sex or co-ed classes within a secondary school in Switzerland. They show that students in all-girl classes perform better in maths but not in German and that they have a more positive self-assessment of mathematics skills. Jackson (2012b) finds that only girls with a strong preference for single sex schools perform better when assigned to one of them, but for all the other students of both genders single sex schooling has no effect on academic performance. Most studies on single sex schools are however based on observational data. Billger (2009) focuses on the private sector, which most of the single sex schools in the US belong to and finds that single sex schools do not have any effect on attainment but they may support gender equity by generating the least gender-specific college major choices. Sullivan (2009) uses a longitudinal cohort study for the UK (the 1958 National Child Development Study) to evaluate whether single-sex schools affect the academic self-assessment of their pupils and finds that the perception of their abilities is less gendered: girls have higher self-concepts in maths and science and boys in English when compared to their co-ed counterparts. Favara (2012) uses English administrative data to investigate the role of gender stereotypes in educational choices during secondary school. She creates a masculinity index that measures how each student's curriculum differs from that of the average male student and models it as a function of average achievement in mostly male subjects and average achievement in mostly female subjects. The results point out that girls are affected by gender stereotypes more than boys, that is they are less likely to make an anti-conformist choice on the basis of their academic abilities. The effect of gender stereotypes is however mitigated in years 12 and 13 (sixth form) for girls who attend a single sex-school; conversely the single sex environment seems to reinforce gender stereotypes for boys in subject choice.

In this paper I focus on single sex schools in England to evaluate how the environment, in the form of gender peer effects, affects achievement and subject choice at the end of compulsory secondary education in England. In particular I test the following two hypotheses:

H1 Whether a single sex environment affects achievement for one gender or for both and whether this effect is heterogeneous across different subgroups of the population of students. Gender segregated schools are part of the state secondary system in the UK and understanding whether they have a positive effect on achievement for all pupils or certain groups of them is policy relevant: if that was the case then allocating more pupils to these schools would have an effect for the economy as a whole by raising attainment in compulsory schooling. It could also help inform parents which secondary school to choose for their children.

H2 Whether, as widely suggested in the economic and experimental literature, girls in gender segregated schools are more likely to study scientific subjects. If a gender segregated environment mitigates the effect of gender stereotypes, as found by Favara (2012), it could increase the proportion of girls taking scientific subjects, that is those subjects that are the most competitive, financially rewarding and generally male-dominated. Girls who do more science in high school are more likely to take more challenging courses in higher education such as medicine (De Philippis, 2016) and land more remunerative jobs (London Economics, 2015), thus reducing the gender wage gap. Moreover Dilnot (2017) shows that sitting scientific subjects at A-level increases the probability of being admitted to better universities across all subjects, however pupils with low SES are consistently less likely to choose these subjects at A-level (Dilnot, 2016). Therefore quantifying the effect of a single sex educational environment on the probability of studying hard-science subjects at A-level is important because it could show a way to use the educational environment to affect girls' choices and later outcomes. Whether this effect differs by SES of pupils is therefore another important question.

I explore a possible channel through which gender segregation affects achievement and subject choice. Typically girls and boys with similar achievement have very different assessment of their abilities in mathematics and science. This is possibly as a result of being exposed to gender stereotypes that are embedded in society and that affect young people through several channels (teachers, peers, parents). Having only female peers in school could change a girl's perception of own abilities directly (because of the gender of peers) and indirectly (because of teachers' preconceptions about girls' abilities). Perceived ability plays also an important role in the decision to invest in later education (Chevalier, Gibbons, Thorpe, Snell, and Hoskins, 2009) and can therefore affect subject choice in post-compulsory education. Therefore I will test the following mechanism:

M1 Whether girls in single sex schools prefer maths and science more and whether they are more confident about their abilities in these two subjects conditional on their previous test scores. More confident girls may expect lower costs and higher benefits from the study of these subjects and therefore be more likely to select them for A level qualifications.

To explore the effect of same sex peers on achievement and subject choice I use NPD and PLASC data. I follow two cohorts of pupils, specifically the ones that sat Key Stage 4 in 2009 and 2010. The administrative dataset includes information about test scores, the neighbourhood[4] where pupils live and a rich set of individual characteristics that I supplement with records on school resources and effectiveness. First I estimate the effect of single-sex schools on achievement in English, Maths and Science in the GCSE exams (year 11). I then estimate the effect on the probability of studying at least one hard-science subject at A level (year 13).[5] I finally use the Longitudinal Study of Young People in England (LSYPE) matched to the NPD/PLASC to explore students' attitudes and subjects self-assessment.

In order to compare similar schools I only include in the analysis state non-selective schools. To identify the effect of single-sex schools on achievement in year 11 I estimate a specification of the education production function that includes lagged achievement and a rich set of individual and school characteristics and neighbourhood fixed effects. To identify the effect of single sex schools on the probability of studying scientific subjects at A level I estimate a linear probability model that includes past achievement in science and maths and a rich set of individual and school characteristics and neighbourhood fixed effects. I then test the robustness of the findings from the regression analysis by implementing a robustness check based on a reasonable assumption about the selection on observables and unobservables. Finally to explore whether pupils in single sex schools have different attitudes towards the subjects they study and their abilities in those subjects I use a ordered probit where I include past achievement and a rich set of students' and parents' characteristics.

[4] I define as neighbourhoods the Lower Layer Output Areas (LSOAs) that are geographical units used by the Office of National Statistics. The population of LSOAs varies between 400 and 1200 households. In England there are 32,220 LSOAs.

[5] Hard-science subjects are Maths, Further Maths, Chemistry, Physics.

I find that attending a school with same-gender peers has no effect on achievement for girls and a small effect for boys; there is also evidence of a small but significant and robust effect on educational choices at A level: all girls, and in particular girls from low SES who attend single sex schools are respectively 1.9% and 2.6% more likely to choose at least one scientific subject compared to the baselines for the two groups that are 13.1% and 7.3%. It is important to point out that girls from low SES are amongst the least likely subgroups of pupils to choose science or maths at age 16 in state schools: a positive effect of all-female peers on these girls' decision to take up hard science subjects, even if small, is an interesting result from a policy perspective. The analysis of students attitudes indicates that girls and boys in single sex schools have less gender stereotyped tastes about academic subjects. Girls are also more confident about their abilities in maths and science whereas boys seem more positive about their skills in English. These findings suggest that the environment in the classroom can affect attitudes and behaviour and be used by the policy maker to influence educational choices.

This paper contributes to the literature on the effect of single sex schools on achievement and choice in several ways. First, unlike previous studies, I focus on non-selective state schools, thus reducing the possibility of the results being driven by the selectivity of the school and the ability of the peers. Second, using a very large and rich administrative dataset allows me to control for several pupil and school characteristics. For past test scores I estimate a value added model for achievement. This type of empirical model reduces the risk of omitted variable bias. Similarly I can estimate the probability of taking a science subject in the sixth form by controlling for as many observables as possible as well as past achievement in the same subjects. Third, information about the fairly small neighbourhoods pupils live in allows me to control for neighbourhood fixed effects therefore taking into account a potential source of unobserved heterogeneity in students' background that is correlated with housing choice. Finally I use survey data for England to test one possible mechanism behind the observed effects of gender segregation, that is whether girls in single sex schools have less gender stereotyped academic tastes and are more confident about their mathematical and scientific skills and therefore more driven to those subjects.

The rest of the paper is structured as follow: section 2.2 outlines the theoretical framework that incorporates gender stereotypes and gender peer effects in an economic setting; section 2.3 describes the institutional setting, section 2.4 details data and relevant descriptive statistics; section 2.5 explains the empirical strategy and the robustness check; section 2.7 presents the results; I then conclude in section 2.8.

2.2 Conceptual framework

The idea that the gender composition of peers can affect achievement and choice in secondary school could be translated into an economic model where the level of effort exerted by an individual depends on non-pecuniary and pecuniary, returns. As in Favara (2012) and Humlum, Kleinjans, and Nielsen (2012) I rely on the theoretical framework set out by Akerlof and Kranton (2000, 2002). I then modify it to introduce gender composition of peers as a determining factor of non-pecuniary rewards.
The original framework can be adapted to the education context where effort is defined as time invested in education *and* choice of subjects to study, since different subjects will require different amount of commitment and exertion. In particular a student's i utility is defined as:

$$U_i = U_i(w \cdot k(e_i), e_i, I_i) \tag{2.1}$$

where $k(e_i)$ is human capital as a function of effort and w are the pecuniary returns to it. The new element in this utility function is I_i, that is identity, or student self-image, defined as:

$$I_i = I_i(e_i, c_i, \epsilon_i, \mathbf{N}, \pi) \tag{2.2}$$

cs are categories defined in the society and $\mathbf{N}$ is a set of norms prescribing the behaviour and the ideal characteristics associated to each category c. Each individual is assigned to a certain category c (for instance girl or boy) and his or her self-image is represented by the distance between individual characteristics ϵ_i and behaviour e_i, and those prescribed by $\mathbf{N}$. The bigger the distance the bigger the disutility associated to it. The self-image may also depend on π, the proportion of peers belonging to the same category as individual i: a higher π could mitigate or exacerbate the perception of distance from N that defines one's self-image given a certain level of effort. Therefore this model predicts that individuals with equal ability but assigned to distinct categories may undertake different levels of effort according to how this affects their identity and their utility.

Gender stereotypes in education are an example of norms that prescribe the different levels of effort boys and girls with same abilities are expected to exert in mathematics or science. Even though the returns from STEM subjects are higher, higher ability girls may decide to put less effort in studying them because of the disutility they would receive through their self-image. The gender peer effects on effort is an empirical question that can be addressed with regression analysis.

2.3 Institutional setting

As described in chapter 1, the state school system in England entails 11 years of compulsory education divided into two phases, primary and secondary, and 4 Key Stages, as table 1.1 shows. Primary school starts with Key Stage 1 (age 5 to 7) and it is followed by Key Stage 2 (age 7-11), whereas secondary school starts with Key Stage 3 (age 11 to 14) followed by Key Stage 4 (age 15-16). All of these Key Stages end with a national standardised assessment, either carried out by teachers or externally marked. Pupils are tested in English, Mathematics and Science. At the end of Key Stage 4 pupils are also tested in additional subjects that they choose between those offered by the school they attend. Schools typically have to offer computing, physical education, citizenship and at least one subject from each of these areas: arts design and technology, humanities and modern foreign languages. After the 11 years of compulsory schooling pupils may continue for further two years: this phase is called Key Stage 5 or Sixth Form. Only 60% of secondary schools offer this phase of education. For this phase pupils can choose the subjects they want to study, usually between 3 and 4 A-level or equivalent qualifications. The complete list of A-level subjects offered by English schools is presented in table 2.1. Each sixth form school offers a set out of these subjects. Pupils apply to their preferred local secondary schools and admission to these schools is based on rules set by the local council: priority is usually given to children who live close to the school or whose siblings are already at the school. Exceptions are faith and selective (grammar) schools, which set their own admission criteria. Gender segregated schools are part of the secondary state school system. Unlike other western countries where these schools are private and fee-funded, single sex schools in England are mostly state-funded and therefore not aimed at a restricted group of the population. They were the norm until the 1960s when they started to turn into co-educational schools. Today in England around 10% of pupils in the secondary non-selective[6] education system are enrolled in single sex schools and there is a higher demand of places in these schools for girls than for boys.[7] These schools are located in small number of LAs, as shown by figure 2.1, and most of them are concentrated in South-East England.

2.4 Data and descriptive statistics

I first describe the sample and the variables used in the empirical analysis in subsection 2.4.1; then I present the main descriptive statistics for co-ed and single-sex schools in subsection 2.4.2; finally in subsection 2.4.3 I present the patterns of subject uptake by gender at A level in all schools in England and in the sample used in this study.

2.4.1 Data

The empirical analysis is mainly based on the NPD and the PLASC data. I complement these data with school level information on the effectiveness scores from the most recent Ofsted inspections and school resources from the LEASIS data and the School Workforce Census.

Around one third of single sex schools in England are selective grammar schools. To address the concern that selective schools may differ from non-selective schools in important ways I focus the analysis on non-selective schools only, therefore eliminating a relevant dimension that could confound the relationship between single sex schools and outcomes. Dropping all selective schools removes a source of bias, however single-sex schools and co-ed schools present observable differences. Single sex schools have a different intake of pupils and, as a consequence, have different resources.[8] Controlling for as many observable differences as possible in the analysis will therefore help further reducing the bias but I cannot exclude other important unobservable differences at pupil and school level. The final dataset contains information on two cohorts of students who sat their Key Stage 2 in years 2005 and 2006 and accordingly sat GCSEs at the end of Key Stage 4 in years 2010 and 2011 and A-level exams in 2012 and 2013. The final dataset includes also a rich set of characteristics of the secondary schools attended by these pupils.

[6] 120 out of 162 state selective schools in England are gender segregated.

[7] 57% of pupils in non-selective single sex schools are girls.

[8] Jackson (2012b) points out that schools have by definition different pupils, in terms of ability, behaviour, parental investment and as a consequence they respond with different levels of observable and unobservable resources

The analysis is carried out at pupil-level. I consider two outcomes of interest: standardised scores achieved at the end of the compulsory school period in the three main subjects, that is English, Mathematics and Science; a binary variable equal one if the individual completed at least one A-level qualification in hard science subjects, zero otherwise. I define as hard science subjects the following: Chemistry, Physics, Mathematics and Further Mathematics. These subjects constitutes almost half of the list of facilitating subjects to obtain an offer in one of the Russell Group Universities.[9]

In the regression analysis I control for pupil and school-level characteristics. The pupil-level variables I use are previous standardised achievement for each subject and socio-demographic characteristics such as the IDACI index, ethnicity, whether the individual is EAL, eligible for FSM, SEN and whether the individual was born in the June-August trimester. The school-level characteristics I use are: the quality of school intake, measured in terms of standardised Key Stage 2 average points score of all pupils in the school; the size of the school; the proportions of FSM and ethnic minority pupils in the cohort; the average IDACI of the school; the pupil teacher ratio; the proportion of qualified teachers; the proportion of male teachers and the most recent OFSTED score for the overall effectiveness of the school. To explore secondary students attitudes and subjects self assessment I use data from the first wave of the LSYPE linked to administrative records. The LSYPE is a survey of about 15,770 young people in England who were aged 13 and 14 in 2003/2004. These pupils have been followed and interviewed on an annual basis. The survey provides detailed information on a pupil personal characteristics, attitudes, experiences and behaviours, as well as on family background, household composition and parents characteristics and aspirations. In particular I focus on the six variables that come from the responses to the questions “How much do you like or dislike these subjects: Maths, English, Science” and “How good or bad are you at these subjects: Maths, English, Science”. Respondents are at the end of their year 9 and therefore have already attended three years of their secondary school. I also include in this analysis of attitudes past achievement in the subject the question refers to and several individual characteristics such as ethnicity, EAL and FSM status. I also control for parental education, work status and income.

[9] The other subjects are biology, english literature, geography, history, modern and classical languages.

2.4.2 Descriptive statistics

Tables 2.2 and 2.3 report the main descriptive statistics broken up by school type and gender. A pattern that emerges from these tables is that while pre-secondary school achievement of pupils in single sex schools is marginally higher than that of their counterparts in co-educational schools, their achievement at the end of compulsory secondary school is higher (as also figures 2.2 and 2.3 show): girls and boys in single sex schools have test scores that are respectively 0.172 and 0.194 (0.2 and 0.154) standard deviations higher in english (in mathematics) than those of girls and boys in co-ed schools. Pupils in single sex schools are also more likely to continue to A-levels after year 11: girls are 7.5% and boys are 6.5% more likely than their counterparts in co-ed schools. Pupils in single-sex schools are more likely to be FSM and EAL, to come from more deprived neighbourhoods and to belong to ethnic minorities. Finally table 2.4 reports some descriptive statistics of observable features of secondary schools in England. Interestingly all-girl schools have a higher proportion of pupils per teacher and all-boys schools have a smaller proportion of pupils per teacher than co-ed schools. Similarly all-girl schools have a lower proportion of qualified teachers when compared to all-boys schools and co-ed schools. Even though the resources in all-girl schools seem less than the ones available to other schools, single-sex schools for girls have on average a better overall effectiveness score as defined by OFSTED during their inspections[10]. Another very important difference concerns the gender of teachers in single sex schools: all-girls schools have a very high percentage of female teachers whereas all boys schools have a high percentage of male teachers. One possible explanation for the difference in attainment between pupils in single-sex schools and co-ed schools is that single-sex schools are on average better in terms of their resources and management: for this reason I include in the empirical analysis as many confounding factors at school level as possible to identify the effect of same-gender peers.

2.4.3 Subject choice and gender

Table 2.1 reports the percentages of girls and boys taking up A-levels by subject in England in the academic year 2014/15 (source: Gill and Williamson, 2016). The underlying data include all state (selective and non-selective) and independent schools. It is clear that there is a gender pattern in the choice of subjects: girls choose significantly more

[10]OFSTED overall effectiveness ratings are 1 to 4. 1: Outstanding, 2; Good, 3; Requires improvement; 4, Inadequate

psychology, english, sociology and religious studies; boys select predominantly mathematics, physics, chemistry and economics. This divergence in the choice of subjects is very interesting because it does not reflect the achievement pattern of the two genders: girls outperform boys in english but perform as well as them in science and only marginally worse in maths in Key Stage 4 exams (as reported in table 2.2). Therefore if all pupils maximise their utility by choosing effort to increase future earnings they should choose STEM subjects in more similar proportions. Boys and girls may have different expectations of the pecuniary returns to STEM subjects and this could explain the gender pattern in subject choice. However figure 2.4, based on the wave four of the LSYPE, shows that boys and girls studying for their A-levels have similar expectations about the returns to STEM subjects. They also seem to agree on the amount of effort these academic subjects entail. 65% of both girls and boys agree that STEM subjects are more difficult, 36% of girls and 46% of boys agree that STEM jobs require working for longer hours, 72% of girls and 77% of boys think that there is more demand for STEM skills and finally 46% of girls and 49% of boys agree that these skills are paid higher wages in the labour market. This lack of difference in expectations supports the hypothesis that gender stereotypes may be at work behind different patterns in subject choice. Tables 2.5 and 2.6 report the row means of the uptake of maths and hard sciences at A-level for, respectively, all students and all students eligible for FSM in my sample. The percentage of pupils taking up these subjects is much lower in this sample where I have excluded grammar and independent schools, however the gender difference in the pattern of subject choice persists. All girls in single sex schools are 6.5 percentage points more likely than their counterpart in co-ed schools to choose at list one hard science subject. Girls eligible for FSM are instead 6.8% more likely, that is almost twice more likely than their counterpart in co-ed schools.

2.5 Empirical strategy

This section describes how I aim to reasonably identify the effect of single sex schools on achievement and subject choice. Empirical studies that aim to identify the causal effect of a school type on attainment by using observational data have to address the mechanisms of selection into the school that may bias the results. In England students and their families can choose the secondary school they want to attend in the area where they live. Pupils who choose single sex schools over coeducational schools could have different unobservable characteristics that also affect their cognitive outcomes, hence confounding the causal effect of the school they attend. There are several empirical strategies that have been adopted to identify the causal effect of school type on educational outcomes with observational data. One method relies on geographical proximity as exogenous source of variation in school choice, for instance by using distance to the school or density of schools as instruments for choice (Favara, 2012; Neal, 1997). However households are likely to sort into residential areas according to their income and preferences and schools are likely to be an important factor in this choice. For this reason geographical variables are unlikely to be good instruments for school choice. Some studies address the endogeneity of school choice by using individual fixed effects (Andrabi, Das, Khwaja, and Zajonc, 2011; Imberman, 2011a). This empirical strategy relies on the assumption that for students who switch between schools, thus allowing the identification of the school type parameter, the unobservable factors determining the education outcomes in one year are uncorrelated with the school attended that year, conditional on the student observable characteristics and fixed effects. This assumption is strong in economics of education as it rules out all the cases where mobility between schools is an adjustment to events or students traits that also affect achievement. Another method is the one implemented by Gibbons and Silva (2011) who use a value added model with lagged achievement and neighbourhood fixed effects to compare pupils who are close residential neighbours and have identical observable ability but differ by the type of school they attend. In this specification of the education production function, lagged achievement is not only a baseline measure of ability but it is taken to be a sufficient statistic for past inputs and investments. In support of this empirical strategy recent studies have showed that value added models with lagged achievement yield very similar estimates to the ones obtained in experimental settings such as lotteries (Angrist, Pathak, and Walters, 2013; Deming, Hastings, Kane, and Staiger, 2014; Kane and Staiger, 2008). Additionally, in the presence of residential sorting, neighbourhood fixed effects are a partial control for the unobservable characteristics of the pupils and their families that determine endogenous school choice.

My identification strategy follows this last approach.[11] I specify pupils achievement

[11] I cannot explore a pupil fixed effect estimator as in Imberman (2011a) or a GMM estimator as in Andrabi, Das, Khwaja, and Zajonc (2011) because in order to do so I would need two or more comparable data points for achievement collected in secondary school. KS3 tests are not externally marked and therefore their scores are not comparable to Key Stage 4 ones. Moreover only 8% of the pupils in the administrative dataset switch school between the beginning and the end of the secondary education cycle and such a small sample is unlikely to produce a relevant estimate for the parameter of

in each subject as a reduced form of an education production function with lagged achievement: here previous achievement is considered a sufficient statistic for unobserved past family and school inputs as well as the unobserved endowment of cognitive ability. I also control for current pupil characteristics as proxies for current family inputs and as many current school resources as possible in order to *isolate* the effect of same-gender peers from other features of single sex schools. I estimate the following model:

$$A_{ijt} = \alpha T_{jt} + \beta A_{ijt-1} + \boldsymbol{Z'_{ij}}\boldsymbol{\delta} + \boldsymbol{X'_{it}}\boldsymbol{\phi} + \eta_i + v_{it} + \epsilon_{ijt} \tag{2.3}$$

where A_{ijt} is achievement for student i in school j in year t, A_{ijt-1} is past achievement, $\boldsymbol{X'_{it}}$ and $\boldsymbol{Z'_{ij}}$ are individual and school time-variant characteristics, η_i are the unobservable pupil and family characteristics; v_{it} is ability that speeds learning in each period and ϵ_{ijt} is an idiosyncratic error. The parameter of interest is α, the average effect of single-sex versus co-ed schools. I then extend this specification to include neighbourhood fixed effects. The empirical problem in this setting is that school choice is endogenous to η_i and the identifying assumption is that the composite error $\eta_i + v_{it} + \epsilon_{ijt}$ is uncorrelated with the choice of attending a single sex school once I take into account past achievement, current pupil and school observable characteristics, neighbourhood fixed effects. More formally:

$$E(\eta_i + v_{it} + \epsilon_{ijt} | T_{jt}, A_{ijt-1}, \boldsymbol{Z_{ij}}, \boldsymbol{X_{it}}, neighbourhood) = 0 \tag{2.4}$$

This assumption requires that there are no unobserved characteristics that determine achievement *growth* and that are systematically related to the decision to attend a single-sex versus co-ed secondary school, conditional on observable student and school characteristics. If this assumption fails the parameter is not identified. Another problem for the identification of α could come from the presence of a lagged dependent variable as shown by Andrabi, Das, Khwaja, and Zajonc (2011) among others. However value added models have been shown to behave well and produce estimates of the parameters with relatively small degree of bias (Andrabi, Das, Khwaja, and Zajonc, 2011; Guarino, Reckase, and Wooldridge, 2015) as long as many contemporaneous family and school inputs are included. In the estimation, besides pupil characteristics as proxies for family

interest α. Finally a pupils fixed effect estimator in this context would require the strong assumption that unobserved characteristics affecting the test scores *growth* are uncorrelated with patterns of mobility between schools.

investments and school resources, I include neighbourhood fixed effects: Gibbons and Silva (2011) find that including home postal code fixed effects as controls in their value-added model accounts for a substantial amount of the estimated differences in quality between faith-based and secular public schools in England. The idea is to control for a potential source of unobserved heterogeneity in students' background that is correlated with housing choice. Unlike Gibbons and Silva (2011) I do not observe home postal code, instead I observe another fairly small geographic unit, the lower super output area (LSOA), designed by the Office of National Statistics to improve the reporting of small area statistics.

I specify the probability of taking at least one hard science subject at A-level as the following linear probability model:

$$S_{ijt} = \alpha T_{jt} + \beta A_{ijt-1} + \boldsymbol{Z'_{ij}\delta} + \boldsymbol{X'_{it}\phi} + \eta_i + \epsilon_{ijt} \tag{2.5}$$

where S_{ijt} is an indicator equal 1 if the pupil has chosen a hard science subject and zero otherwise, A_{it-1} is now the average achievement in science and maths at the end of year 11. Here the identifying assumption is that the unobservable factors that determine the choice of the subjects for the A-level are uncorrelated with the choice of attending a single-sex school. As for the value added model of achievement I include as many pupil and school characteristics as are available and neighbourhood fixed effects.

2.6 Robustness check

Including all the available pupil characteristics and neighbourhood fixed effects does not completely eliminate the threat that comes from omitted variable bias and self selection. To address this problem I use a novel bounding technique introduced by Oster (2015) as a robustness check of my results. Oster's work builds on the intuition of Altonji, Elder, and Taber (2005b) according to which the selection on observable characteristics is informative on the selection on unobservable characteristics. More formally:

$$\frac{Cov(T,U)}{Var(U)} = \delta \frac{Cov(T,O)}{Var(O)} \tag{2.6}$$

where O in this case is the set of all the observable inputs and pupils' characteristics and U is the set of unobservables inputs and cognitive and non-cognitive abilities such as v_{it}. In other words the magnitude and the sign of $\frac{Cov(T,O)}{Var(O)}$ provides information on the relationship between T and U through the parameter δ. Oster, as Altonji, Elder, and Taber (2005b), argues that it is reasonable to expect the degree of selection on observables not to exceed the degree of selection on unobservables, therefore $\delta \leq |1|$. Starting from this main assumption Oster (2015) shows that:

$$\alpha^* = \widetilde{\alpha} - \delta \frac{(\alpha^0 - \widetilde{\alpha})(R_{MAX} - \widetilde{R})}{\widetilde{R} - R^0} \tag{2.7}$$

where α^* is a consistent estimator for α, $\widetilde{\alpha}$ is the estimate obtained by regressing the outcome variable on the treatment and all the observable characteristics and $\widetilde{R}$ the R^2 of this regression, α^0 is the estimate obtained by regressing the outcome variable only on the treatment variable and R^0 is the R^2 of this regression. R_{MAX} is the R^2 of a regression where a researcher would be able to control for all the observable and unobservable variables affecting the outcome of interest. R_{MAX} is different from 1 mainly because of the presence of measurement errors and this is particularly relevant in a context where the outcomes of interest are test scores. Since δ and R_{MAX} are not known Oster proposes some feasible values for them in order to develop a set of bounds for α^*. In particular she proposes $R_{MAX} = min\{1.3\widetilde{R}, 1\}$ and that α^* be calculated for all the values $-1 \leq \delta \leq 1$.[12] If the set of values for α^* excludes zero the results of the regression are robust to omitted variable bias and $\alpha^* \neq 0$.

2.7 Results

In subsection 2.7.1 I describe the results of the main analysis and of the robustness check. In subsection 2.7.2 I then present the results from the analysis of survey data.

2.7.1 Main analysis and bounds

Tables 2.7, 2.8 and 2.9 present the main estimates of the effect of attending a single sex school on achievement in english, maths and science for different specifications of the value added model. Columns 1 to 3 present the estimates from linear regressions with

[12] In order to set this value for R_{MAX} Oster (2015) draws a sample of papers with results from RCTs published in top economic journal and empirically calculates the R_{MAX} that would allow these results to survive 90% of the times.

additional sets of controls, column 4 shows the preferred specification with neighbourhood fixed effects. As expected the bias of the coefficient is upward and the estimate gets smaller as I correct for selection with an increasing number of control variables and different specifications. These results show a small and positive effect of single sex schools on achievement. Girls achieve respectively 0.036, 0.010 and 0.047 of a standard deviation more in maths, english and science compared to their counterparts in co-ed schools. The effect for boys is smaller in maths and science and greater in english: they achieve respectively 0.020, 0.045 and 0.015 in maths, english and science. Table 2.10 present the results of the analysis by subgroups, in particular FSM pupils, low achievers and high achievers.[13] The estimates presented in this table are from the preferred specification of the value added model with neighbourhood fixed effects. FSM eligible girls in single sex schools do better only in science compared to FSM eligible girls in co-ed schools; girls who are low achievers in single sex schools achieve more in maths and science than the low achiever girls in co-ed schools; high achiever girls instead do better in all subjects. For all subgroups of boys there is a positive effect in english of attending a single-sex school; low achiever boys perform better in science and high achievers marginally better in maths than their counterparts in co-ed schools. Table 2.11 present the main estimates for the probability of undertaking at least one hard science qualification at A-level. Here as well the bias of the coefficient is upwards for girls and the estimate gets smaller as I correct for selection. This table only includes results for one subgroup, the one of FSM eligible pupils. It is less meaningful now to look at low achievers and high achievers because the pupils who continue academic studies after the GCSE are likely to be the high achievers in their cohort. The results are statistically different from zero only for girls and show a positive effect of attending single sex schools on the probability of choosing at least one hard science subject at A-level: for the all sample the effect is of 1.9 percentage points compared to an average of 13.1% for girls in co-ed schools, whereas for FSM eligible girls the effect is slightly higher, 2.6 percentage points, compared to a baseline of 7.3% for FSM eligible girls in co-ed schools. Tables 2.12 and 2.13 present bounds for the estimates of the value added model and the linear probability model based on Oster's methodology to check the robustness of the results. Bounds are calculated for $-1 \leq \delta \leq 1$ and $R_{MAX} = 1.3\widetilde{R}$. Table 2.12 reports the bounds for the effect of single sex schools on achievement. For girls the effect in

[13] I define as high (low) achievers pupils in the top (first) quartile of the distribution of achievement at Key Stage 2.

same-gender peers is never robust to selection on unobservables and the bounds always include zero. Effects for boys are robust to the omitted variable bias for low achievers in english and science and high achievers in english and maths. Table 2.13 reports the bounds for the effect of single sex schools on the probability of choosing at least one hard science subject at A-level. The estimated bounds for girls are wide but exclude zero: for the whole population of girls and for FSM eligible girls the bounds are respectively [0.001, 0.029] and [0.009, 0.034]. Under the assumption that the selection on observable characteristics is informative on the selection on unobservable ones, the effect of single sex schools is therefore robust to the problem of omitted variable bias.

2.7.2 Mechanisms

The above results evidenced a small but significant effect of an all female peer group on girls' decision to study maths and science after compulsory education. This effect is greater for girls from disadvantaged backgrounds. The theoretical framework this analysis relies on predicts that the proportion of same gender peers affects one's self-image and therefore the non-pecuniary returns from actions that do not reflect the incumbent norm. Girls in an all female class may be less affected by gender stereotypes and experience a smaller disutility from not conforming to them by choosing to study hard science subjects. If this is the case girls in single sex schools should enjoy more the study of these subjects and be more confident about their abilities in them. Tables 2.14 and 2.15 report estimation results for ordered probit models of subject enjoyment and self-assessment by gender. Girls in a secondary single sex school like more maths and science and are more confident about their abilities in these subjects conditional on their achievement in Key Stage 2 whereas the effect on the self-assessment in english is not statistically significant. Boys in single sex schools are less confident about their ability in maths but perceive their ability in English as higher. I cannot exclude that this association between single sex schools and enjoyment/self assessment is affected by self-selection into secondary schools however this result is very interesting and in line with the results obtained by Sullivan (2009) with the 1958 National Child Development Study.

2.8 Discussion

Increasing the number of girls that choose to study STEM subjects is a priority in education policies for most countries. Several studies on gender peer effects have found that girls are more competitive and engage more in maths and science when they are in classrooms with a higher proportion of same-gender peers. I use administrative data on state schools in England to test whether girls in single sex schools achieve more in maths and science and are more likely to choose these academic subjects for their post-compulsory education. I estimate a value added model with lagged achievement and a linear probability model for subject choice while controlling for as many individual and school characteristics as possible to identify the effect of same-gender peers. The estimates show a small and positive impact on achievement of girls in all subjects. When I test the heterogeneity of the effect for girls I found that girls with previous low achievement presented a significant effect in maths and science and girls from low SES achieved more in science. Boys studying with same-gender peers consistently perform better in english than boys in co-ed schools. The results of the analysis for girls did not withstand a robustness check based on the assumption that the selection on observable factors is informative about the selection on unobservable ones. This means that I cannot rule out the presence of an omitted variable bias. The estimates from a linear probability model show that attending a single sex school has a small but robust effect on the probability of girls taking up hard science subjects at age 16. This effect appears to be greater for girls with low SES.

The findings seem to suggest that girls are not affected by the gender composition of their peers in the level of effort they exert to study compulsory maths and science for their GCSEs. They are however more likely to choose maths and science when they are given the possibility to do it, that is after year 11, particularly if they come from disadvantaged backgrounds. These findings appear to be robust to omitted variable bias. Using survey data linked to administrative records I explore the possibility that girls in single sex schools are more confident about their abilities in subjects that are typically seen as more fitting for boys, such as maths and science, and enjoy studying them more. I find that this is the case and at the same time boys are more confident about their ability in english.

Studying with same gender peers may lessen the effect of gender stereotypes on own self-image, particularly for girls from a more disadvantaged backgrounds. This affects the self assessment of their abilities and gives them an incentive to undertake subjects that are more suitable for boys according to dominant gender stereotypes in education. The effect of same-gender peers on the probability of undertaking hard science subjects is particularly important for girls from low SES who are more likely to take hard science subjects compared to their counterparts in co-ed schools, however the size of the effect is quite small. In order to increase the proportion of girls choosing these subjects a single sex education environment is unlikely to be enough: the set-up of new single sex classes should be combined with other policies, such as the introduction of more advanced science subjects in earlier stages of education (De Philippis, 2016). In March 2018 the Department for Education announced the "New Advanced Maths Premium" where schools and colleges with sixth form will be given £600[14] for each pupil taking 1 year As in maths with the aim to support institutions to increase the number of girls and those from disadvantaged backgrounds taking advanced maths qualifications. This initiative is very important and it will be interesting to see whether the effect will be greater in single-sex schools. The findings of this study have strong external validity because they are based on administrative data for all pupils in England attending non-selective secondary schools over two cohorts. The large number of observations has also allowed the estimation of the heterogeneous effects of same-gender peers for several subgroups. This empirical investigation has however some limitations that should be considered in the interpretation of the results. This study is based on observational data and the rich set of controls used cannot guarantee that all mechanisms of selection into the school are accounted for. The robustness check used to test the main findings is based on the assumption that the selection on observable factors is informative on the selection on unobservable ones; however it is possible some omitted controls that determine the selection into the school do not share covariance properties with the observed ones. In this case the robustness check would not hold. Nonetheless this analysis is important because it is a first step to show that same-gender peers have a positive but very limited effect on the probability of girls studying science and maths in post-compulsory education in England; moreover it provides some evidence on the influence of gender stereotypes on girls' choices.

[14]This premium would amount to £1,200 for each additional pupil who takes the two-year A-level in maths or further maths

Table 2.1: Uptake of A-level subjects by gender in all secondary schools in England (for the academic year 2014/2015)

Subject group	All	% of Boys	% of Girls
Mathematics	27.9	38.0	19.8
Physics	11.4	20.1	4.4
Chemistry	16.4	18.7	14.5
Mathematics (Further)	4.9	8.0	2.5
Biology	19.4	17.1	21.3
Psychology	19.4	10.3	26.7
History	18.1	18.9	17.5
English Literature	16.8	9.8	22.5
Geography	12.1	13.4	11.1
Sociology	10.7	5.5	14.8
Economics	9.3	14.1	5.5
Business Studies:Single	8.7	11.7	6.4
English Language	8.2	5.8	10.1
Religious Studies	7.8	5.4	9.7
Media/Film/TV Studies	7.1	6.5	7.5
General Studies	6.8	6.9	6.7
English Language Literature	4.9	3.1	6.4
Art Design (Fine Art)	4.8	2.3	6.8
Government Politics	4.8	6.0	3.9
Art Design (Photography)	4.5	2.4	6.2
Drama Theatre Studies	4.4	3.1	5.4
Physical Education/Sports Studies	4.0	5.7	2.7
Law	3.5	2.9	4.1
French	3.3	2.3	4.1
DT Product Design	3.2	5.1	1.7
Spanish	2.8	2.0	3.3
Information Communications Technology	2.4	3.5	1.5
Art Design	2.4	1.1	3.4
Film Studies	2.3	2.6	2.2
Computer Studies/Computing	1.8	3.6	0.3
Music	1.7	1.9	1.5
Art Design (Graphics)	1.6	1.6	1.6
Classical Civilisation	1.4	1.2	1.6

Continued on next page

Table 2.1 – continued from previous page

Subject group	All	% of Boys	% of Girls
German	1.3	1.2	1.4
Art Design (Textiles)	1.2	0.1	2.2
Chinese	1.0	1.0	1.0

Notes: the source of this table is the Statistics Report Series No. 109 by the Cambridge Assessment (June 2016). This table includes all schools in England: grammar schools, state non-selective schools and independent schools. The report can be found at: http://www.cambridgeassessment.org.uk/Images/323211-uptake-of-gce-a-level-subjects-2015.pdf (accessed: March 11, 2018).

TABLE 2.2: Descriptive statistics of academic outcomes by school type - All pupils enrolled in non-selective schools

	Girls				Boys			
	Comprehensive	Single Sex	Δ	(p-value)	Comprehensive	Single Sex	Δ	(p-value)
KS1 Maths grade	-0.003	-0.028	0.025	0.000	0.058	0.090	-0.033	0.000
KS1 Eng grade	0.182	0.161	0.021	0.000	-0.134	-0.097	-0.037	0.000
KS2 Eng grade	0.161	0.210	-0.049	0.000	-0.139	-0.048	-0.091	0.000
KS2 Maths grade	-0.047	-0.021	-0.025	0.000	0.068	0.126	-0.058	0.000
KS3 Eng grade	0.196	0.327	-0.131	0.000	-0.171	-0.001	-0.169	0.000
KS3 Maths grade	-0.056	0.014	-0.070	0.000	0.089	0.147	-0.057	0.000
KS4 Eng grade	0.115	0.253	-0.138	0.000	-0.205	-0.038	-0.168	0.000
KS4 Maths grade	-0.046	0.130	-0.176	0.000	0.002	0.134	-0.132	0.000
KS4 Science	-0.033	0.097	-0.130	0.000	-0.047	0.060	-0.108	0.000
Taking KS5	0.643	0.725	-0.081	0.000	0.560	0.635	-0.075	0.000
N	415,804	45,199			433,842	29,476		

Table 2.3: Descriptive statistics of selected covariates by school type - All pupils enrolled in non-selective schools

	Girls				Boys			
	Comprehensive	Single Sex	Δ	(p-value)	Comprehensive	Single Sex	Δ	(p-value)
FSM	0.154	0.213	-0.059	0.000	0.149	0.166	-0.017	0.000
EAL	0.076	0.276	-0.200	0.000	0.088	0.188	-0.100	0.000
IDACI	0.205	0.276	-0.071	0.000	0.205	0.242	-0.037	0.000
Born in 3rd quarter	0.257	0.257	-0.000	0.994	0.256	0.257	-0.001	0.808
White	0.848	0.576	0.272	0.000	0.833	0.679	0.154	0.000
African	0.012	0.067	-0.055	0.000	0.014	0.053	-0.040	0.000
Caribbean	0.011	0.042	-0.031	0.000	0.012	0.029	-0.017	0.000
Bangladeshi	0.008	0.035	-0.027	0.000	0.009	0.020	-0.010	0.000
Pakistani	0.022	0.077	-0.055	0.000	0.027	0.040	-0.014	0.000
Indian	0.019	0.037	-0.018	0.000	0.021	0.029	-0.007	0.000
SEN with Statement	0.008	0.008	0.000	0.714	0.024	0.023	0.001	0.376
SEN with Action	0.099	0.107	-0.007	0.000	0.151	0.148	0.003	0.208
SEN with Action+	0.032	0.030	0.001	0.113	0.070	0.064	0.006	0.000
N	415,804	45,199			433,842	29,476		

Table 2.4: School characteristics by school type

	Comprehensive schools	All-girls schools	All-boys schools
Pupil/teacher ratio	14.404	16.360	12.758
Percentage of male teachers	39.382	23.927	54.57
Full-time qualified teachers per-pupil	0.079	0.054	0.096
Part-time qualified teacher per-pupil	0.019	0.015	0.015
Total number of qualified teachers per-pupil	0.098	0.070	0.112
Overall effectiveness	2.205	1.786	2.221
N	3,200	154	154

Notes: author's calculations using LEASIS data, School Workforce Census data and Ofsted inspection data.

Table 2.5: Uptake of A-level maths and science by school type in all secondary state schools in England (academic years 2010/11 and 2011/12)

	Girls				Boys			
	Comprehensive	Single Sex	Δ	(p-value)	Comprehensive	Single Sex	Δ	(p-value)
Chemistry	0.070	0.116	-0.046	0.000	0.099	0.105	-0.006	0.009
Physics	0.018	0.038	-0.020	0.000	0.105	0.101	0.005	0.049
Maths	0.101	0.150	-0.049	0.000	0.189	0.213	-0.025	0.000
Further Maths	0.010	0.011	-0.002	0.007	0.031	0.031	-0.000	0.962
1+ Science A level	0.131	0.196	-0.065	0.000	0.222	0.243	-0.021	0.000
N	271,445	33,032			249,850	19,115		

Notes: this table includes all pupils in state non-selective schools who sat their A-levels in the academic years 2010/11 and 2011/12 and is based on NPD data.

Table 2.6: Uptake of A-level maths and science by school type in all secondary state schools in England (academic years 2010/11 and 2011/12, only FSM eligible pupils)

	Girls				Boys			
	Comprehensive	Single Sex	Δ	(p-value)	Comprehensive	Single Sex	Δ	(p-value)
Chemistry	0.048	0.099	-0.051	0.000	0.070	0.095	-0.025	0.000
Physics	0.007	0.019	-0.011	0.000	0.050	0.064	-0.014	0.006
Maths	0.056	0.098	-0.043	0.000	0.115	0.174	-0.059	0.000
Further Maths	0.004	0.005	-0.001	0.339	0.015	0.027	-0.012	0.000
1 + Science A level	0.073	0.141	-0.068	0.000	0.123	0.180	-0.057	0.000
N	29,733	5,951			27,493	2,528		

Notes: this table includes all FSM eligible pupils in state non-selective schools who sat their A-levels in the academic years 2010/11 and 2011/12 and is based on NPD data.

Table 2.7: OLS and Fixed Effects estimates of single sex school effects on achievement in GCSE Math

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Girls				Boys			
	OLS	OLS	OLS	FE	OLS	OLS	OLS	FE
Single-sex school	0.157***	0.121***	0.069***	0.036***	0.091***	0.070***	0.019***	0.020***
	(0.003)	(0.003)	(0.004)	(0.005)	(0.004)	(0.003)	(0.004)	(0.005)
Previous achievement	✓	✓	✓	✓	✓	✓	✓	✓
Pupil characteristics	X	✓	✓	✓	X	✓	✓	✓
School characteristics	X	X	✓	✓	X	X	✓	✓
Observations	460,683	460,683	460,683	460,683	462,084	462,084	462,084	462,084
R-squared	0.584	0.619	0.629	0.671	0.579	0.611	0.621	0.664

Notes: previous achievement is defined as standardised Key Stage 2 total test score in maths; individual characteristics include FSM eligible, EAL and SEN status, the IDACI for the postcode where the pupil leaves, trimester of birth, indicators for ethnic groups; school characteristics include proportion of FSM eligible, EAL and SEN pupils, average IDACI of the school, quality of the intake measured as average Key Stage 2 total score for the school, size of the school, indicators for the Ofsted rating of the school, pupil-teacher ratio, proportion of qualified teachers and proportion of male teachers. All regressions include an indicator for the cohort 2009/10 and standard errors are clustered at school-year level. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Table 2.8: OLS and Fixed Effects estimates of single sex school effects on achievement in GCSE English

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Girls				Boys			
	OLS	OLS	OLS	FE	OLS	OLS	OLS	FE
Single-sex school	0.106***	0.091***	0.012***	0.010*	0.113***	0.104***	0.058***	0.045***
	(0.003)	(0.003)	(0.004)	(0.006)	(0.004)	(0.004)	(0.005)	(0.006)
Previous achievement	✓	✓	✓	✓	✓	✓	✓	✓
Pupil characteristics	X	✓	✓	✓	X	✓	✓	✓
School characteristics	X	X	✓	✓	X	X	✓	✓
Observations	460,683	460,683	460,683	460,683	462,084	462,084	462,084	462,084
R-squared	0.450	0.487	0.499	0.552	0.436	0.471	0.483	0.537

Notes: previous achievement is defined as standardised Key Stage 2 total test score in english; individual characteristics include FSM eligible, EAL and SEN status, the IDACI for the postcode where the pupil leaves, trimester of birth, indicators for ethnic groups; school characteristics include proportion of FSM eligible, EAL and SEN pupils, average IDACI of the school, quality of the intake measured as average Key Stage 2 total score for the school, size of the school, indicators for the Ofsted rating of the school, pupil-teacher ratio, proportion of qualified teachers and proportion of male teachers. All regressions include an indicator for the cohort 2009/10 and standard errors are clustered at school-year level. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Table 2.9: OLS and Fixed Effects estimates of single sex school effects on achievement in GCSE Science

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Girls				Boys			
	OLS	OLS	OLS	FE	OLS	OLS	OLS	FE
Single-sex school	0.130***	0.105***	0.042***	0.047***	0.090***	0.075***	0.006	0.015**
	(0.003)	(0.003)	(0.004)	(0.006)	(0.004)	(0.004)	(0.005)	(0.007)
Previous achievement	✓	✓	✓	✓	✓	✓	✓	✓
Pupil characteristics	X	✓	✓	✓	X	✓	✓	✓
School characteristics	X	X	✓	✓	X	X	✓	✓
Observations	421,590	421,590	421,590	421,590	424,975	424,975	424,975	424,975
R-squared	0.429	0.476	0.492	0.561	0.411	0.463	0.478	0.545

Notes: previous achievement is defined as standardised Key Stage 2 total test score in science; individual characteristics include FSM eligible, EAL and SEN status, the IDACI for the postcode where the pupil leaves, trimester of birth, indicators for ethnic groups; school characteristics include proportion of FSM eligible, EAL and SEN pupils, average IDACI of the school, quality of the intake measured as average Key Stage 2 total score for the school, size of the school, indicators for the Ofsted rating of the school, pupil-teacher ratio, proportion of qualified teachers and proportion of male teachers. All regressions include an indicator for the cohort 2009/10 and standard errors are clustered at school-year level. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Table 2.10: Effects of single sex schools on achievement in English, Math and Science - Value Added Model with neighbourhood effects

	(1)	(2)	(3)	(4)	(5)	(6)
	Girls			Boys		
	KS4 Maths	KS4 Eng	KS4 Sci	KS4 Maths	KS4 Eng	KS4 Sci
			All			
Single-sex school	0.036***	0.010*	0.047***	0.020***	0.045***	0.015**
	(0.006)	(0.006)	(0.007)	(0.006)	(0.007)	(0.007)
Observations	460,683	460,683	421,590	462,084	462,084	424,975
R-squared	0.596	0.444	0.445	0.591	0.433	0.434
			FSM			
Single-sex school	0.015	-0.002	0.062***	0.008	0.052***	0.023
	(0.015)	(0.016)	(0.019)	(0.018)	(0.020)	(0.021)
Observations	73,719	73,719	62,603	69,226	69,226	59,192
R-squared	0.541	0.387	0.388	0.530	0.360	0.368
			Low achievers			
Single-sex school	0.055***	-0.014	0.060***	0.019	0.044***	0.073***
	(0.014)	(0.014)	(0.017)	(0.015)	(0.016)	(0.019)
Observations	113,596	113,596	94,589	118,375	118,375	99,357
R-squared	0.280	0.197	0.159	0.265	0.169	0.135
			High achievers			
Single-sex school	0.033***	0.033***	0.051***	0.021*	0.063***	-0.013
	(0.010)	(0.011)	(0.012)	(0.011)	(0.013)	(0.013)
Observations	118,071	118,071	116,007	113,635	113,635	112,021
R-squared	0.248	0.142	0.152	0.239	0.173	0.154

Notes: all regressions include previous achievement, indicators for FSM eligible, EAL and SEN status, the IDACI for the postcode where the pupil leaves, trimester of birth, indicators for ethnic groups; proportion of FSM eligible, EAL and SEN pupils in the school, average IDACI of the school, quality of the intake measured as average Key Stage 2 total score for the school, size of the school, indicators for the Ofsted rating of the school, pupil-teacher ratio, proportion of qualified teachers and proportion of male teachers an indicator for the cohort 2009/10 and standard errors are clustered at school-year level. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Table 2.11: OLS and Fixed Effects estimates of Effect of single sex schools on the probability of taking 1 or more STEM subjects at Key Stage 5

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Girls				Boys			
	OLS	OLS	OLS	FE	OLS	OLS	OLS	FE
All sample								
Single sex school	0.032***	0.005***	0.010***	0.019***	-0.002	-0.014***	-0.017***	-0.005
	(0.002)	(0.002)	(0.002)	(0.004)	(0.003)	(0.003)	(0.003)	(0.004)
Previous achievement	✓	✓	✓	✓	✓	✓	✓	✓
Pupil characteristics	X	✓	✓	✓	X	✓	✓	✓
School characteristics	X	X	✓	✓	X	X	✓	✓
Observations	292,429	292,429	292,429	292,429	252,439	252,439	252,439	252,439
R-squared	0.260	0.277	0.277	0.361	0.363	0.373	0.373	0.458
FSM								
Single sex school	0.035***	0.004	0.001	0.026**	0.029***	0.010	0.013	0.005
	(0.004)	(0.005)	(0.006)	(0.012)	(0.007)	(0.008)	(0.009)	(0.018)
Previous achievement	✓	✓	✓	✓	✓	✓	✓	✓
Pupil characteristics	X	✓	✓	✓	X	✓	✓	✓
School characteristics	X	X	✓	✓	X	X	✓	✓
Observations	31,652	31,652	31,652	31,652	24,914	24,914	24,914	24,914
R-squared	0.205	0.230	0.231	0.562	0.280	0.297	0.298	0.656

Notes: previous achievement is defined as the standardised sum of Key Stage 4 test score in maths and science; individual characteristics include FSM eligible, EAL and SEN status, the IDACI for the postcode where the pupil leaves, trimester of birth, indicators for ethnic groups; school characteristics include proportion of FSM eligible, EAL and SEN pupils, average IDACI of the school, quality of the intake measured as average Key Stage 2 total score for the school, size of the school, indicators for the Ofsted rating of the school, pupil-teacher ratio, proportion of qualified teachers and proportion of male teachers. All regressions include an indicator for the cohort 2009/10 and standard errors are clustered at school-year level. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

TABLE 2.12: Oster Bounds for the effect of single-sex schools on achievement, $-1 < \delta < 1$

	Girls			Boys		
	KS4 Math	KS4 English	KS4 Science	KS4 Math	KS4 English	KS4 Science
All sample	[-0.082,0.122]	[-0.109,0.092]	[-0.068,0.225]	[-0.048,0.078]	[-0.023,0.104]	[-0.051,0.071]
FSM	[-0.143,0.128]	[-0.162,0.103]	[-0.099,0.151]	[-0.052,0.067]	[-0.042,0.014]	[-0.031,0.078]
Low ach.	[-0.026,0.122]	[-0.114,0.054]	[-0.032,0.118]	[-0.003,0.050]	[0.017,0.081]	[0.054,0.098]
High ach.	[-0.020,0.070]	[-0.012,0.070]	[-0.001,0.091]	[0.002,0.035]	[0.039,0.082]	[-0.042,0.014]

Notes: the bounds are obtained with the Stata command *psacalc* and are based on $R_{MAX} = 1.3\widetilde{R}$..

TABLE 2.13: Oster Bounds for the effect of single-sex schools on the probability of taking at least one science subject at A-level, $-1 < \delta < 1$

	Girls	Boys
	1+Sci A-level	1+Sci A-level
All sample	[0.001,0.029]	[-0.017,0.009]
FSM	[0.009,0.033]	[-0.015,0.023]

Notes: the bounds are obtained with the Stata command *psacalc* and are based on $R_{MAX} = 1.3\widetilde{R}$.

TABLE 2.14: Survey responses on subject enjoyiment, year 9, LSYPE

	(1)	(2)	(3)	(4)	(5)	(6)
		Girls			Boys	
	Maths	Eng	Sci	Maths	Eng	Sci
Single-sex school	-0.168***	0.014	-0.210***	0.060	-0.190***	0.050
	(0.038)	(0.039)	(0.039)	(0.048)	(0.049)	(0.049)
Observations	6,451	6,440	6,454	6,578	6,480	6,578
Marginal Effects:						
Pr[Like=1 | T=1]-Pr[Like=1 | T=0]	0.052 (.011)	-0.005 (0.014)	0.068 (0.013)	-0.021 (0.017)	0.061 (0.015)	-0.022 (0.019)
Pr[Like=2 | T=1]-Pr[Like=2 | T=0]	0.009 (.002)	0.001 (0.004)	0.001 (0.001)	.003 (0.002)	-0.002 (0.001)	0.006 (0.005)
Pr[Like=3 | T=1]-Pr[Like=3 | T=0]	-0.025 (.005)	0.002 (0.006)	-0.035 (0.006)	0.009 (0.007)	-0.034 (0.008)	0.009 (0.007)
Pr[Like=4 | T=1]-Pr[Like=4 | T=0]	-0.035 (.008)	0.001 (0.003)	-0.034 (0.006)	0.008 (0.007)	-0.024 (0.006)	0.006 (0.005)

Notes: Columns 1 and 4 refer to the question 'How much do you like or dislike these subjects: Maths'; columns 2 and 5 refer to the question 'How much do you like or dislike these subjects: English'; columns 3 and 6 to the question 'How much do you like or dislike these subjects: Science'. These questions where asked in the first year of the LSYPE when the participants were in Year 9. The answers have the following coding: 1=Like it a lot, 2=Like it a little, 3=Don't like it very much, 4=Don't like it at all. $T = 1$ if the pupil is enrolled in a non-selctive single-sex school and $T = 0$ otherwise. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Table 2.15: Survey responses on subject self assessment, year 9, LSYPE

	(1)	(2)	(3)	(4)	(5)	(6)
	Girls			Boys		
	Maths	Eng	Sci	Maths	Eng	Sci
Single-sex school	-0.123***	0.024	-0.192***	0.215***	-0.186***	0.074
	(0.041)	(0.040)	(0.039)	(0.052)	(0.051)	(0.050)
Observations	6,444	6,438	6,445	6,572	6,475	6,568
Marginal Effects:						
Pr[Good=1 | T=1]-Pr[Good=1 | T=0]	0.038 (0.010)	-0.007 (0.012)	0.048 (0.011)	-0.035 (0.016)	0.047(0.013)	-0.033 (0.017)
Pr[Good=2 | T=1]-Pr[Good=2 | T=0]	-0.001 (0.001)	0.003 (0.005)	0.002 (0.001)	0.015 (0.007)	-0.001 (0.001)	.013 (0.006)
Pr[Good=3 | T=1]-Pr[Good=3 | T=0]	-0.028 (0.007)	0.004 (0.006)	-0.039 (0.009)	0.017 (0.007)	-0.041 (0.011)	0.017 (0.008)
Pr[Good=4 | T=1]-Pr[Good=4 | T=0]	-0.008 (0.002)	0.001(0.001)	-0.011 (0.002)	0.002 (0.001)	-0.005 (0.001)	0.003 (0.001)

Notes: Columns 1 and 4 refer to the question ‘How good or bad are you at these subjects: Maths’; columns 2 and 5 refer to the question ‘How good or bad are you at these subjects: English’; columns 3 and 6 to the question ‘How good or bad are you at these subjects: Science’. These questions where asked in the first year of the LSYPE when the participants were in Year 9. The answers have the following coding: 1=Very good, 2=Fairly good, 3=Not very good, 4=No good at all. $T = 1$ if the pupil is enrolled in a non-selctive single-sex school and $T = 0$ otherwise. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

FIGURE 2.1: Proportion of pupils in non-selective single-sex schools by Local Authotities

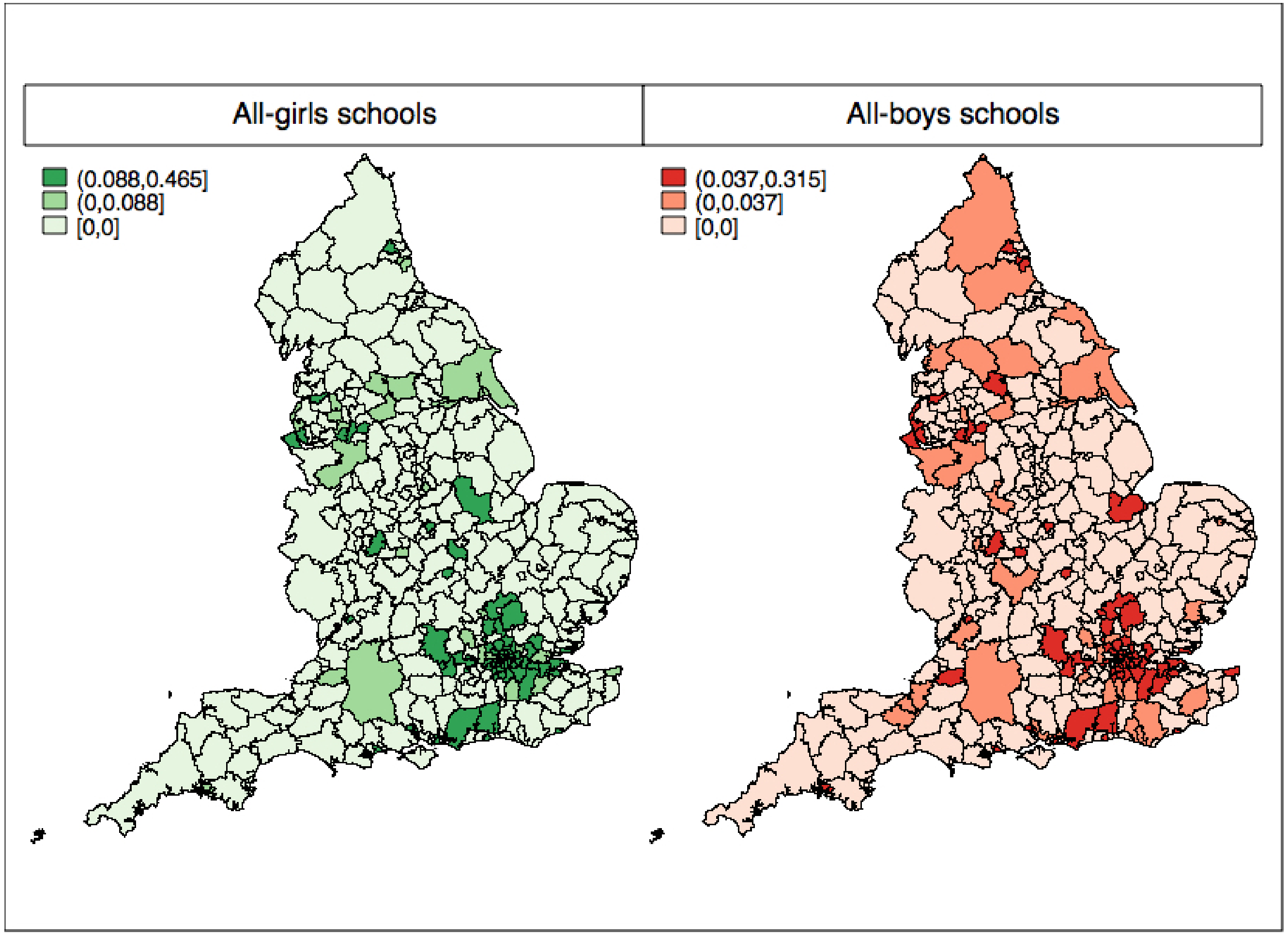
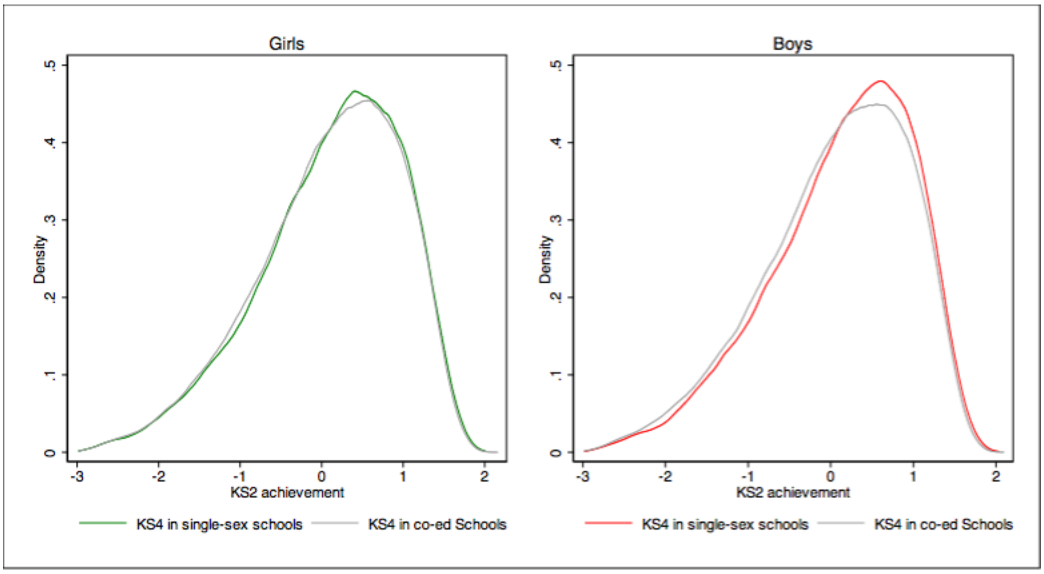
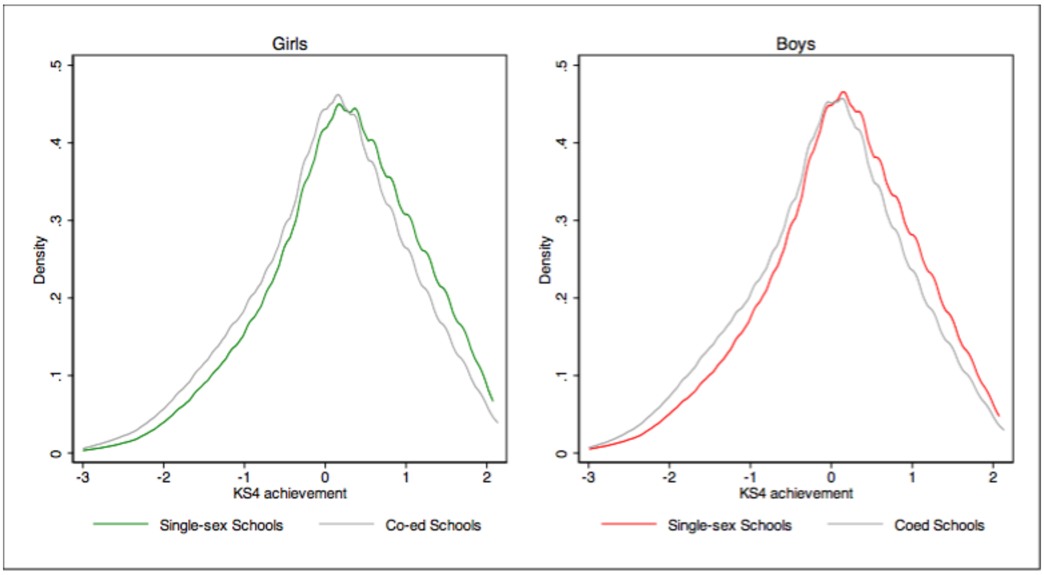


Figure 2.2: Key Stage 2 mean standardised achievement by type of secondary school attended



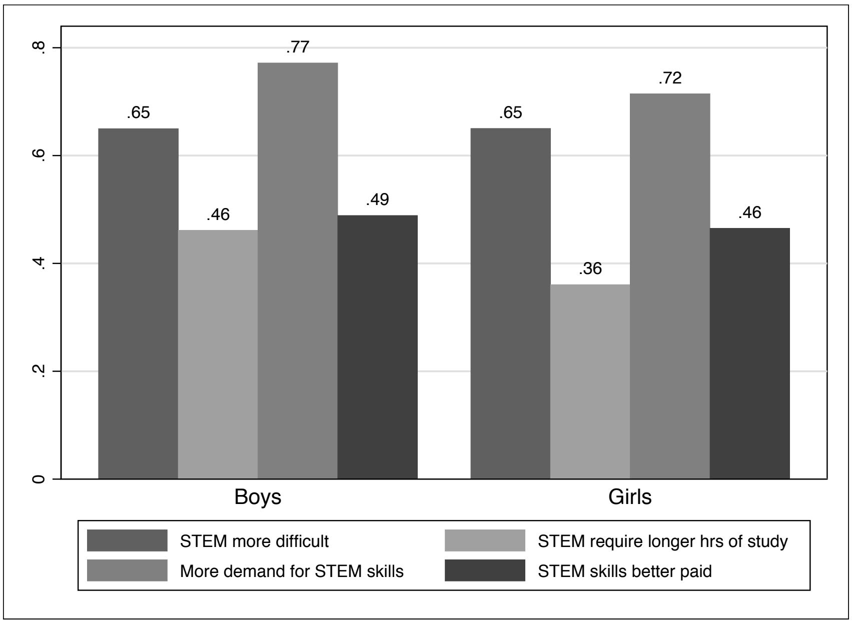
Notes: author's calculation using NPD data for 2008/09 and 2009/10.

Figure 2.3: Key Stage 4 mean standardised achievement by type of secondary school attended



Notes: author's calculation using NPD data for 2008/09 and 2009/10.

Figure 2.4: Attitudes of young people about STEM, wave 4 LSYPE



This bar chart represents the proportion of young people in the LSYPE that agree with the following statements: "Subjects like science or maths are more difficult than others"; "Studying science or maths at university means working longer hours"; "People with science or maths degrees are in demand by employers"; "People with science or maths degrees get better paid jobs". The individuals included are all young people in Year 12 (wave 4 of the LSYPE) studying for their A-levels in state non-selective schools: 2,068 boys and 2,551 girls.

Chapter 3

School choice, competition and pupil achievement: the effect of an unexpected school reform in England

3.1 Introduction

In 1988 the Education Reform Act in the United Kingdom introduced elements of a market-based approach to the education sector. Parents were allowed to choose where they sent their children to school and head-teachers became responsible for the management of school funds which were now a direct function of the number of pupils and their characteristics. Schools were allowed to opt out of being under the direct financial control of local authorities. Finally, the Act established that all pupils would sit national tests in year 2, 6, 9 and 11, and the school-level results of all tests would be published in league tables, thus giving parents a criterion on which to base their choice. As noted by Le Grand (1991) this new system is essentially comparable to an education voucher funded by the central government and given to independent schools that have to compete for funds allocated through the choice of parents. This setting is what Legrand calls "quasi-market": it is a market because the monopolistic provider, the state, has been replaced by several independent ones that compete with each other; however it differs from a market because these providers are not privately owned and consumer purchasing power is not expressed in money but by a voucher funded by the state for the purchase of a specific service.

In the last twenty years a new literature in economics has developed to investigate the full potential of school choice and whether it could be the ”tide that lifts all boats” (Hoxby, 2003): the underlying empirical question is whether schools that compete with each other to attract new pupils eventually increase standards to meet parental demand, or whether instead competition is actually detrimental for some schools and pupils. The creation of charter schools in the US and voucher policies in several countries around the world have allowed researchers to add an increasing number of empirical analyses to the literature on school choice and competition and a new perspective on the theoretical approach to the quasi-market in education. In 2003 the Labour government introduced in the UK a new education policy, the academy programme, to raise standards and support schools with low performance in disadvantaged neighbourhoods (mainly urban and inner-city). This policy, the most radical and encompassing of recent years as described by Eyles and Machin (2015b), defined a new type of school outside the control of local authorities and under the management of a private team of independent co-sponsors. The main novelty of academies was their independence from Local Authorities (LAs) that gave them the freedom to decide their expenditures and the pay of their staff; academies were also given some autonomy in the definition of their curriculum. Similarly to other countries this unexpected reform introduced a shock in the secondary education quasi-market providing parents and students with a new option. The extent of this shock was probably exacerbated by the fierce debate that surrounded this new type of school which was supported by many in government but encountered the opposition from some parents and teachers and most unions.[1] The interest raised by academies was immediately clear: generally oversubscribed, they received an average of three applications per available place (Long, 2015).

200 academies had been created by the end of the Labour government, in May 2010. The newly elected Coalition government made this type of school the main feature of its education long-term plan and with the Academies act in 2010 revolutionised once again the school landscape. In the current academic year 2017/18 in England there are 4,440 primary academy schools and 2,220 secondary schools and several more waiting for approval.[2]

[1] An article in *The Guardian* (May 26, 2010) reports that several attempts to create new academies encountered the protest of local residents, parents and teachers in London and Manchester.

[2] This number includes middle deemed schools, all-through and 16 plus.

School choice has been a bi-partisan feature of most education policies in the UK and competition is now a feature of the education sector in England. The Coalition government explicitly promoted the idea that competition would help improving standard and performance of schools.[3] However the National Union of Teachers (NUT) in 2013 gave evidence to the House of Common of the importance of school partnerships, pointing out that the main challenge to school cooperation was the competition in the sector encouraged by the Coalition government (HC 269 Education Committee, 2013). The importance of school competition in the public debate is not reflected by a systematic study of its effects in economics and education, with very few exceptions. This paper contributes to the general literature on school choice and competition by looking at an unexpected shock that changed the supply of schools in some local education markets; I also contribute to the literature on academy schools by looking at the indirect effect of these schools on pupils enrolled in traditional schools (rather than their own).

An education reform that unexpectedly affects the set of choices available to parents is a natural experiment that gives researchers the opportunity to evaluate the effect of competition on pupils outcomes. To the best of my knowledge I am the first to test using an individual level dataset whether pupils in traditional schools were affected by the entry of nearby academies. Credible estimates of the causal effect of academies on the academic performance of neighbouring traditional schools are obtained by using a rich pupil-level administrative dataset for England covering a period of seven years. I use a difference in difference strategy that identifies the competitive effect of academies entry into the education market from three main sources of variation: the timing of the entry, the number of entries and the penetration in non-academy schools' catchment areas. The main treatment considered in the empirical analysis is a binary measure of *exposure* to academies that equals one when an academy opens within three miles from a traditional school, zero otherwise. Two more treatments are also considered: the number of academy entries within three miles from a traditional school and the percentage of pupils attending academies in non-academies catchment areas. These two additional treatments are measures of the *intensity* of competition. Endogenous movement of students (between schools) after the entry of an academy can introduce a bias in the

[3] In a speech in 2012 Michael Gove, the Secretary of State for Education from 2010 to 2014, claimed the the government needed "to create more new schools to generate innovation, raise expectations, give parents choice and drive up standards through competition". The speech can be read here: https://www.gov.uk/government/speeches/how-are-the-children-achievement-for-all-in-the-21st-century (accessed: March 15, 2018).

estimates: I therefore carry out an intent-to-treat (ITT) analysis where I fix pupils in the school where they were initially enrolled. In addition the large dataset used in the study allows me to retrieve also the heterogeneous estimates of the effect of academy competition on achievement in subgroups of pupils and schools. I then examine the relationship between academy entry and per-pupil expenditures (PPE) of the nearby schools to recover a possible mechanism schools under the pressure of competition may have used in the short term to raise their standard. I plan to explore other mechanisms in my future research. The empirical strategy used in this investigation is similar to the one used by several studies that have tried to identify the spillover or competitive effects of charter schools in the US.

I find that pupils in schools within three miles radius from a new academy experience a small but statistically significant increase in their achievement at the end of compulsory education. The average effect ranges from 1.5% to 2.5% of a standard deviation (sd). These very small positive effects are in line with most of the empirical literature that has studied the effects of charter school penetration in the US and they have to be interpreted as the effect of more competitive pressure as opposed to less competitive pressure rather than no competitive pressure at all. The most relevant result is however the positive effect of competition on poorer pupils, low achievers and pupils in community schools, that is those pupils that most detractors of academies feared would be negatively affected by these new type of schools. These short term effects can be the result of increased per pupil expenditures, changes in school practice and management, better or more motivated teachers. When I explore the expenditure channel I find no evidence of an increase in PPE in schools nearby academies.

The rest of the paper is structured as follow: section 3.2 describes school characteristics and choice in England and the academy reform; section 3.3 reviews the literature; section 3.4 details data and relevant descriptive statistics; section 3.5 explains the empirical strategy employed for the analysis; section 3.6 presents the results; I then conclude in section 3.7.

3.2 Institutional setting

In subsection 3.2.1 I describe the different types of schools in England; I then detail the academy reform in subsection 3.2.2; finally in subsection 3.2.3 I describe the characteristic of the education system in England that can trigger competition between schools.

3.2.1 School types in England

Most pupils in England attend state schools that are funded directly by central government, or indirectly though the Local Authority (LA). Schools differ mainly in the way they are governed and partly by admission criteria. There are six types of schools with different degrees of autonomy and types of governance: community schools, voluntary controlled schools, foundation schools, voluntary aided (VA) schools, city technology colleges (CTCs) and academy schools. Their main features are summarised in table 3.1 taken from Eyles and Machin (2015b). Schools are managed by their headteacher and the senior management team who are accountable to the Governing Body (GB). The GB is composed of elected representatives from parents, teachers, the local community and the Local Authority; in faith schools it also includes representatives of the church and the charitable foundation that own buildings and land. Its main role is to monitor the academic performance of the school, oversee the school budget, determine the necessary expenditures of the school and approve any staff appointments or dismissal. The six types of schools listed above mostly differ in the degree of control the LA has over the GB: between the non-academies the two extremes of this control are Community schools, run predominantly by the LA, and VA schools managed by their GB. VA schools also have a certain degree of discretion in the definition of their admission criteria. More autonomous schools may have greater scope to counteract the challenge represented by competition with new popular schools however they may have less incentive to do so if they are already oversubscribed. On the other hand community schools may have less scope to adapt to competition but they may be more driven to compete because of the need to maintain their enrolment. Ultimately understanding what type of school responded to the competition introduced by academies is an empirical matter.

3.2.2 The academy reform

The first academies opened in 2002 to replace failing schools in disadvantaged inner-urban areas. Through the academy reform the Labour government committed to open 400 academies, with a target of 200 by 2010. Table 3.2 shows how academies gradually established over eight years. The great majority of academies were converted from pre-existing schools; only 16 were brand new. Academies were essentially independent institutions under the guidance of a sponsor willing to invest in them and support the needed organisational change. Most of the funds for these schools came directly from the state rather than through local authorities. Academies were all specialist schools in one or more areas. Their admission criteria had to follow the School Admission Code like all other state funded schools: this meant that they were non-selective schools, however 10% of all admission intake could be allocated to pupils with a particular aptitude for the specialism taught. There were several features that set academies apart from other state funded schools: academies could establish their own pay and conditions for their staff; they had more flexibility in their curriculum provisions than other schools; they had more flexibility over the size and composition of the governing body; they could choose length of school day and number of sessions taught. Initially destined to substitute schools with low academic results, from 2006 conversions were allowed more widely with the *the Education and Inspections Act 2006*. Independent schools could also be considered for academy status where they demonstrated they could increase the supply of good-quality school places serving diverse communities (Long, 2015).

In May 2010 the new Conservative Lib-Dem coalition government approved the *Academies Act 2010* that unexpectedly allowed all primary and secondary schools to obtain the status of academies. To minimise the risks of this radical change the government prioritised applications for conversion from better performing schools, in particular those rated "oustanding" or "good" by the school inspectorate Ofsted. In January 2018, 22% of all primary schools and 66% of all secondary schools were academies.

3.2.3 Choice and competition in English schools

Two main characteristics of the English school system should create conditions for a competitive market in education: open enrolment and the school funding system.

Open enrolment. The Education Reform Act of 1988 gave parents more freedom of choice allowing them to apply for a place in their favourite local school. Best schools are usually oversubscribed and LAs set criteria to regulate the admission in these cases: priority is usually given to children who live close to the school or whose siblings are already at the school, to pupils with special education needs and children in care of the LA. Exceptions are faith and specialist schools which can set their own admission criteria: faith schools prioritise pupils with a particular religious background; specialist schools instead can select up to 10% of their intake based on their attitude for the speciality taught. Parents who want to know more about their local primary and secondary schools before applying for a place can gather information from two main sources: the performance tables and the Ofsted inspection reports. The league tables published by the government allow parents to compare the performance of local schools by reporting the percentage of their pupils that met the required standard in the previous academic year.[4] The school inspectorate OFSTED carries out (short notice) regular inspections in all schools. A detailed report with the results of each inspection is published on its website. In addition to the report Ofsted rates schools for their overall effectiveness on a 4-point grade scale: 1 (Outstanding), 2 (Good), 3 (Satisfactory) and 4 (Inadequate). Hussain (2016) finds evidence of strong effect of a change in the inspection rating on parents' choice of school.

Funding. As explained by Sibieta (2015) the school funding system in England entails a two stage process. In the first stage the central government allocates funds to LAs on the basis of the number of pupils living within the authority and their educational needs. In the second stage local authorities allocate the per-pupil funding to schools using a formula that takes into account socio-economic conditions of pupils and their education needs: schools with more disadvantaged pupils receive more funds. During the early 2000s more deprived schools would also receive direct grants from central government. With the change of government in 2010 these direct grants were eliminated and LAs now receive a fixed additional sum for each disadvantaged pupil.

Given these characteristics of the English education system it is reasonable to imagine a context where schools compete for pupils and funds by raising standards.

3.3 Literature Review

Subsection 3.3.1 presents the previous literature on school competition; subsection 3.3.2 describes the literature on the mechanisms through which competition affects the academic performance of pupils; finally subsection 3.3.3 summarises the main studies on academies.

3.3.1 Prior literature on competition

An extensive number of empirical studies have looked at the effect of school choice and competition. One of the most studied policy shocks in this context is the introduction of voucher programs in several countries around the world. Voucher programs increase

[4] The required standard in primary school is level 4 or above in English, Maths and Science at the end of KS2; in secondary school it is the achievement of five or more A*-C grades at GCSE at the end of KS4.

the competition between private and public schools by giving parents a subsidy to enrol their children in private schools. Several analyses rely on changes in the private school supply over time to identify the effect of school competition (Böhlmark and Lindahl, 2015; Hoxby, 2003; Hsieh and Urquiola, 2006; Figlio and Rouse, 2006) whereas Figlio and Hart (2014) identify the effect of the competitive threat introduced by a voucher program in Florida by looking at the effect of the pre-policy private school supply on the performance of public schools. All these papers find small but positive effects of increased school competition on pupil academic outcomes in public schools.

A related literature, based on US data, looks at the impact of charter schools on traditional state school outcomes in different states and districts. This literature includes several quasi-experimental studies that with slightly different econometric strategies aim to identify the effect of competition by taking into account the endogeneity of charter school location. The evidence from these studies is quite mixed: Bettinger (2005) and Imberman (2011b) find small negative effects; Booker, Gilpatric, Gronberg, and Jansen (2008), Cremata and Raymond (2014), Cordes (2017), Hoxby (2003), Jinnai (2014) and Winters (2012) find small positive effects; Bifulco and Ladd (2006) finds no effects.

In the UK a small literature on school competition, choice and performance has developed over the last twenty years. Bradley, Crouchley, Millington, and Taylor (2000) find that a quasi-market in secondary education actually exists and Bradley and Taylor (2010) extend this analysis to evaluate whether competition introduced by the open enrollment reform had an effect on school outcomes in the period 1992-2006: they find that around a fifth of the overall improvement in exam performance at the end of compulsory school can be attributed to competition in the local education market. Further work looks at how the effect of competition between secondary schools increased their efficiency (Bradley, Johnes, and Millington, 2001) and the effect of the market on the trade-off between equity and efficiency at school level (Bradley and Taylor, 2002). Clark (2009) investigates the impact of a reform that allowed secondary schools to opt out of the control of local authorities: he finds a strong positive effect on the academic performance of pupils that obtained more autonomy but no effects of competition for the schools nearby. Finally Gibbons, Machin, and Silva (2008) look at the primary school market in England and identify the distinct effect of school choice and school competition[5] on pupil academic outcomes: they find a small positive causal link between

[5]In this paper I consider school choice and competition as equivalent concepts from the point of view of the school: schools in a local education market with more/better choice will also face more

competition and achievement for those schools that have more autonomy in governance and admission practices.

3.3.2 How competition affects pupil performance

Figlio and Hart (2014) point out that there are at least three ways the introduction of academies can affect the achievement of traditional state-school pupils. First there is the direct effect of competition: if academies are seen as better schools within their local education market they could drive pupils, and therefore funds, away from other traditional state schools. The traditional schools may respond to competition with academy schools by raising standards through a change in effort, practices and investments (Hoxby, 2003; Manski, 1992) thus keeping their student population (at least) constant.
Secondly academies may attract high ability pupils or those with more involved parents, therefore negatively changing the composition of peer groups in the remaining schools. An increase in the proportion of low ability peers could consequently affect the achievement of pupils in traditional schools (Lavy, Silva, and Weinhardt, 2012).
Thirdly, the financial resources of traditional schools could be affected if academies attract pupils away from them. There are two possible scenarios: the school population of traditional schools decreases only by few students increasing the per-pupil resources that cannot be marginally reduced such as teachers; the school population of traditional schools decreases considerably affecting the total funds available that the school can spend in the academic year. If pupil outcomes are sensitive to changes in school resources then a positive effect on achievement would be observed in the first case, whereas a negative effect would be observed in the second case. However even when financial resources decrease marginally, there is the possibility that school competition could drive away good teachers from schools with more disadvantaged pupils: Jackson (2012a) finds an association between the decline in teacher quality in difficult-to-staff schools and a charter entry nearby.

3.3.3 Literature on academies

Since the introduction of the academy program in 2002 very few studies in economics have examined the impact of this new type of school. Machin and Vernoit (2011) were

competition. Gibbons, Machin, and Silva (2008) instead distinguish between the two concepts and define the school choice index at pupil level as the number of schools accessible to a pupil whereas the school competition index is defined at school level as the average number of schools accessible to the pupils in the school.

the first to study the effect of academies on their own pupils and on neighbouring schools, finding positive effects for all. However this study was carried out with school-level data that did not allow the authors to take into account endogenous pupil movement after the entry of an academy and test the heterogeneity of the effects. Eyles and Machin (2015b) estimate the causal impact of academy school conversion on pupil intake and pupil performance. Their identification strategy relies on a difference-in-difference estimation where the carefully selected control group includes all the schools that converted to academy after the period studied. They find that academy conversions generated a significant improvement in pupil intake and performance. There is heterogeneity in the performance result, with the greatest improvements happening in schools that experienced the largest increase in autonomy with the conversion. Looking at the possible mechanisms behind this effects Eyles and Machin (2015b) find that a strong feature of academy conversion is a change in headteachers, management structure and curriculum. Eyles, Machin, and McNally (2017) study the impact of an unexpected change in academy reform, when the new government in 2010 allowed the best primary schools to fast-track convert to become academies: schools that converted were already doing well and their pupils were less likely to be non-white British, eligible for Free School Meals and English Additional Language. In their analysis they find no effect on the academic performance of pupils in primary schools that converted to academy; this result is in line with other studies that show positive effects of school autonomy mostly for disadvantaged students. Bertoni, Gibbons, and Silva (2017) quantify the impact of the academy conversion on the probability of families listing a secondary school as the top preference amongst a set of choices. They focus on the second batch of academies that converted after the change of government in 2010 and find that on average parents responded positively to academy conversion and the probability of these schools being ranked first increases by 8% to 14%. However they observe heterogeneity in their results: FSM eligible families are indifferent or less likely to choose these schools whereas white high-income British families are the ones that drive the results being 30% more likely to choose a school after the conversion. These results are very important because they highlight sorting into academy-converted schools and segregation of pupils along income and ethnic lines.

3.4 Data and measures

In subsection 3.4.1 I detail the data and the sample used in the empirical analysis; in subsection 3.4.2 I describe the measures of exposure to competition and intensity of competition.

3.4.1 Data and sample

The main data used in my analysis come from the PLASC and the NPD. Some school level variables, such as the total school population, are obtained from the School Performance Tables published by the Department for Education (DfE). Precise dates for the openings of new academies, both conversions and new schools, their postcodes and postcodes for all state schools in England are recovered from the Edubase, a register of all schools in England. Data on schools PPE come from the Section 251 Budget Data, provided by LAs and published by the Department for Education. The pupil-level outcome considered in the analysis is the sum of GCSE scores in English and Maths standardised by cohort. Individual characteristics that are included in the empirical analysis as controls are: previous achievement (measured as the standardised sum of English and Maths scores in KS2), FSM eligibility, EAL and SEN status, gender and ethnicity. School level characteristics included in the analysis are: percentage of FSM eligible, EAL and SEN pupils, percentage of ethnic minorities and intake quality measured as average KS2 achievement for each cohort.

I use individual level data for seven cohorts of year 11 pupils in England. In my analysis I focus on the academies that opened in the six academic years 2005/06 to 2010/11. The first academies opened in 2002/03, however for the first three years their establishment was very limited and their number only took off in the fourth year as shown by table 3.2. I therefore drop from the sample all the pupils in the 15 LAs where academies opened before the year 2005/06 and I use the year 2004/05 as a pre-policy period when there are no academies open. I limit my analysis to LAs with academies because some administrative barriers made it difficult for pupils to apply for schools in LAs where they were not residing.[6] Finally I exclude from the sample all pupils in schools that converted to academies during this seven-year period. Figure 3.1 shows the geographical distribution of academies before 2006 (on left panel) and after 2006 up

[6]These barriers have been lifted in the last two years and now an online system allows parents and pupils to choose schools across the boundary of their LAs.

until 2010 (on right panel). My final sample includes all individuals with non-missing information on Key Stage 2 and GCSE test scores in English and Maths enrolled in schools that did not close in the period considered located in LAs with academies: the result is a total of 1,786,657 unique pupils attending 1,667 schools.

3.4.2 School market and academy exposure

The first step in the analysis is to understand whether a school market exists, where traditional state schools experience a competitive pressure from academies, and how geographically dispersed the market is. A necessary condition for a market to exist is that academies have the potential to attract pupils from neighbouring schools after their establishment. As a sign for this potential I check whether the total enrolment in state schools is affected by the establishment of a nearby academy. I therefore estimate the following equation:

$$S_{j,t} = \alpha + \beta academy^{d}_{j,t-1} + \eta_j + \tau_t + \epsilon_{j,t} \tag{3.1}$$

Where S_{jt} is total enrolment of school j in year t and *academy* is an indicator equal to one if an academy opened within a distance d from school s in the previous year.[7] The model includes also school effects (η_j) and year effects (τ_t). Table 3.3 shows the estimated coefficients for different mutually exclusive ds. It is clear that there is a negative relationship between the enrolment of state schools and the establishment of an academy within 3 to 4 miles. It is not surprising that non-community schools are affected by academies that are further away since they tend to have a more selective intake willing to travel further for better schools. With this information I define the school market area using a three mile radius around each traditional state school. These distance allows me to obtain balanced numbers of schools that are potentially affected by competition and schools that are not, as shown in table 3.4. It is also more suited for densely populated areas such as the LA within Greater London and reflect the distance that most secondary school pupils travel to go to school in England as shown by figure 3.2. Finally I restrict this radius to only schools in LAs with academies.

[7] Distances are computed by using publicly available data on schools' postcodes and on longitude and latitude coordinates associated to postcodes, measured using the World Geodetic System 1984 (Ordnance Survey website). They are then converted into Ordnance Survey Maps northing and easting coordinates thanks to a Helmert transformation (Watson, 2006) to eventually obtain distances in miles.

After defining the school market I define the measures of academy exposure and intensity of competition. The main measure I will use is whether there is any academy located in each school market: this measure of exposure is a binary variable that takes the value of one if a pupil attends a school located within three miles from an academy, zero otherwise. I also consider two measures of intensity of competition: the number of academies within the school market; the percentage of pupils in a school's catchment area that attended the schools that converted to academies within 3 miles.[8] The distribution of these three measures is shown in figures 3.3, 3.4 and 3.5.

3.5 Empirical strategy

There are three main challenges to the identification of the effect of academies on nearby schools. The first concern is the endogenous movement of students in and out of schools located near an academy. For example parents who are more involved in the education of their children may move them to a school near an academy hoping for positive spillovers for them. Alternatively if they think the academy can be detrimental for nearby schools they may move their children away from the area. In both cases the students in schools potentially affected by academies would be selected and would bias the estimates of the competition effect. To address this issue I use an ITT analysis where I fix the pupils in the secondary school where they were first observed in the pupil census. Pupils who move school to attend an academy are excluded from the sample with all other pupils.

The second issue for the identification of the competition effect is the non-random location of academies. Academies were originally established to replace failing schools in disadvantaged neighbourhoods (mainly urban and inner-city). It is therefore likely that pupils in nearby schools are poorer and lower performing than the pupils in the rest of the LA. The main descriptive statistics for academies, schools within 3 miles from an academy and other schools are reported in table 3.5 for two years 2006 and 2011. In 2006 academies had a higher share of pupils who were eligible for FSM and that belonged to ethnic minorities. The quality of the intake, measured as standardised average achievement in KS2, is also lower compared to the other schools. Similarly, schools located within 3 miles from an academy have more FSM eligible and ethnic

[8] Historical data on schools catchment areas are not available. Therefore I define as catchment area of a school the set of neighbourhoods where its pupils live. I then calculate the percentage of pupils residing in this catchment area that attend academies located within 3 miles from the school. This measure of exposure is zero until an academy opens in the school's market area.

minority pupils and lower quality intake. These characteristics of pupils by school type and location do not change much over time as academies increase rapidly in number and their presence is geographically more disperse. As a result a cross-sectional comparison of schools near an academy with schools located further away would produce downward biased estimates of the effect of academy spillovers. In order to take into account the non-random location of academies I use longitudinal data and school fixed effects. My estimation is based on a difference-in-difference strategy where the identification of the impact of competition in the education market is obtained by exploiting the variation in the timing and the location of academy establishments. The baseline model I estimate is the following:

$$A_{ijt} = \alpha + \beta academy_{jt} + \gamma A_{ij,t-1} + \boldsymbol{Z'_{ij}}\boldsymbol{\delta} + \boldsymbol{X'_{it}}\boldsymbol{\phi} + \eta_j + \tau_t + \epsilon_{ijt} \tag{3.2}$$

where A_{ijt} is achievement for student i in school j in year t, A_{ijt-1} is past achievement, $\boldsymbol{X'_{it}}$ and $\boldsymbol{Z'_{ij}}$ are sets of individual and school time-variant characteristics, η_j are school effects and τ_t are years effects, finally ϵ_{ijt} is a stochastic error. This is a value added specification of the education production function where lagged achievement controls for past inputs and individual ability. The variable *academy* captures the *exposure* to academies and is an indicator that equals one for every year an academy is located within 3 miles from the school attended by individual i, zero otherwise. School effects capture characteristics that are constant over time, including those that are correlated with the academy location; year effects control for factors that affect all schools in England in each year. The parameter of interest β, the impact of competition, is identified by the variation in the timing of academy establishment in a school's market area if, conditional on all controls, school effects and year effects, the timing of the entry is random.

The third obstacle to identifying the competitive effect of academies is the possibility that their location is not just correlated with time-invariant characteristics of the nearby schools but also with their pre-existing trend in performance and the trend of their pupils. Academies were opened to replace failing schools in disadvantaged areas, therefore it is possible that other schools nearby were also on a declining path: this could result in a spurious positive correlation induced by mean reversion. I empirically explore this possibility and find no statistically significant trends in the years before the opening of an academy (table 3.6). I however augment the baseline model with school specific indicators for the 3, 4 and 5 years before the entry of a nearby academy similarly to

Cordes (2017) leaving the 1 and 2 year prior academy entry as a comparison period. The model is as follows:

$$A_{ijt} = \alpha + \beta academy_{jt} + \gamma A_{ijt-1} + \boldsymbol{Z'_{ij}\delta} + \boldsymbol{X'_{it}\phi} + \\ + \sum_{p=3}^{5} \eta_j yr_{-p} + \eta_j + \tau_t + \epsilon_{ijt} \tag{3.3}$$

I also estimate two additional versions of model 3.3 with different measures of *intensity* of competition. In the first I let the effect of competitive pressure to vary with the number of academies within 3 miles and I estimate a model with three mutually exclusive indicators: 1 academy, 2 academies, 3 or more academies. In the second I capture the intensity of competition by using a continuous measure of market penetration, that is the proportion of pupils in a school's catchment area that are enrolled in academies nearby.

The βs from the estimation of these three models are the effect of exposure to academy and intensity of competition. These effects may be heterogeneous between different types of schools or pupils as shown by the literature. I will check for heterogeneity in the results by estimating the main models for different subgroups of schools and pupils. In all regressions the standard errors are clustered at school-year level: if in one year a school is affected by the competition of a nearby academy, the standard errors of all its pupils are likely to be correlated.

Schools in the counterfactual group are likely to be different, both in terms of observable and unobservable characteristics, from those schools ever located within 3 miles from an academy. By including several time-varying school and pupil characteristics I balance the sample between schools close to an academy and schools located further away. I also implement a robustness check where I exclude from the sample of schools those that do not have common support by calculating a propensity score matching based on pre-academy characteristics as in Machin, McNally, and Meghir (2010). The details of this methodology are explained in figure 3.6.

Schools that face competition from academies and want to maintain their pupil enrolment constant may respond directly by raising their standards and improving the academic performance of their pupils as a consequence. One way this may happen is through more investments and resources as discussed in section 3.3. Finally I explore this possibility by using a difference in difference strategy that exploits the variation in the timing of the academy entry. I therefore estimate the following model at school level:

$$PPE_{jt} = \alpha + \beta academy_{jt} + \gamma PPE_{jt-1} + \boldsymbol{Z'_{ij}\delta} + \sum_{p=3}^{5} \eta_j yr_{-p} + \eta_j + \tau_t + \epsilon_{jt} \qquad (3.4)$$

where PPE_{jt} are per-pupil expenditures in school s in year t, Z'_{is} are school time varying characteristics and $\eta_j yr_{-p}$ are school specific indicators for pre-academy years; finally *academy* is a binary indicator as defined in equation 3.2.

3.6 Results

Table 3.7 reports the estimates for the effect of exposure to academy. The raw difference in achievement reported in column 1 shows that academies are located in areas with lower performing schools. Adding increasingly more controls (columns 2 to 4) reduces this difference until it becomes positive and statistically significant. A similar pattern of results can be observed for the two measures of intensity of competition. The estimates obtained after including all the available controls reveal that pupils attending schools in areas with more than one academy achieve more and this positive effect increases monotonically with the number of academies (column 4 in table 3.8); in addition pupils in schools facing a higher penetration of their catchment areas perform better (column 4 in table 3.9). All these estimates provide evidence of the beneficial effects of school competition. The positive effects on achievement are small (1.5% to 1.8% of a standard deviation) but their size is highly consistent with the benefits found in other studies on competition.

Tables 3.10 to 3.14 report the results of the heterogeneity analysis. The first interesting finding is that pupils in community schools near academies perform better than pupils in other community schools (table 3.10). Unlike other similar studies I find that pupils in VA schools, the most autonomous type of schools after academies, do not benefit from the competitive pressure caused by the establishment of nearby academies (table 3.11). There is some evidence of benefits for poorer pupils and low achievers[9] (tables 3.12 and 3.13): this is a very important result because it shows that competition does not damage these pupils as feared by some detractors of a market-based approach to education. Table 3.14 reports the estimated coefficients for high achievers[10] revealing that

[9]Low achievers are defined as pupils in the bottom tercile of the distribution of total achievement in KS2.

[10]High achievers are defined as pupils in the top tercile of the distribution of total achievement in KS2.

competition with academies does not improve the academic performance of high ability pupils who remain in non-academy schools. The robustness check in table 3.15 confirms the main finding of a small, positive and statistically significant effect on achievement for pupils in schools located near new academies. Finally table 3.16 presents the estimates from regressions with a lead and 5 lags of the main binary indicator equal one if an academy locates within 3 miles, zero otherwise. The results reported are based on the all sample (column 1) and on all subgroups used in the heterogeneity analysis (columns 2 to 6). The coefficient for the lead is very close to zero or negative and statistically insignificant for most regressions. The coefficients for the lags are positive and increase slightly over time up until 4 years after the establishment of an academy nearby. Only the coefficients for pupils in VA schools and high achievers are mostly close to zero or negative and statistically insignificant. Table 3.17 reports the results for the school-level regression of PPE on the binary measure of exposure to academies: the entry of an academy doesn't have any effect on short term changes in school expenditures.

3.7 Discussion

A quasi-market in education has the potential to benefit all if schools respond to competition by raising their standards in order to attract more pupils. Soon after academies were introduced in England in 2003 they became popular and oversubscribed while neighbouring schools experienced a decrease in enrolment. The introduction of academies was a shock to the education landscape which can be used as a natural experiment to test whether an increase in competitive pressure on some schools has an effect on the achievement of their pupils. Administrative pupil level data for England covering a period of seven years are used to estimate the causal effect of academies on neighbouring traditional schools. I implement a difference-in-difference strategy that identifies the competitive effect of the entry of academies into the education market from two sources of variation: the timing of the entry and the number of entries. I find a positive and statistically significant effect of competition on the achievement of pupils enrolled in schools near academies. The estimated effects on achievement are small but in line with the findings in most of the literature. Pupils in community schools, pupils eligible for FSM and low-ability pupils are the ones that benefit more from proximity to academies. There are no effects for pupils in more autonomous schools and for high achievers in all schools. These results seem to suggest that community schools, the majority in the sample, had a stronger incentive to react to the competitive pressure exerted by academies; they did so by helping more disadvantaged pupils and those at the bottom of the distribution of achievement to improve their academic performance. One explanation for this is that community schools have a stronger incentive to retain pupils and in particular those from more disadvantaged backgrounds who are allocated higher funding from the central government. Schools that want to boost pupil achievement can do so with a change in effort, practice and investments. I test whether schools increased expenditures after the entry of an academy nearby and find no effect. This finding however is not surprising. A school's finances depend entirely on cash flows from the LA and their expenditure decisions have to be approved by the GB. These institutional constraints limit the scope that the school has to make sudden changes in expenditure patterns.

Other mechanisms may explain the small positive effects of competition on affected schools, for example: an increase in productivity due to better use of existing resources, changes in practices, the hiring of better quality teachers. While at present I cannot be certain of the mechanisms driving my findings, I plan to explore this empirical issue in future research.

This empirical analysis has strong external validity because of the detailed administrative data used, however there are some limitations to consider when interpreting the results. The first limitation concerns the outcome used, that is total achievement in english and maths. While these two subjects are compulsory, pupils in year 11 can also take several academic and vocational subjects as GCSEs. A more complete measure of achievement would therefore include all or most of the subjects taken, however at the time of this analysis I did not have access to the relevant data to build such a measure. Another limitation concerns the control group chosen, that is all schools located further than 3 miles from academies. Schools in this group were possibly also exposed as well to competition and therefore my results reflect the comparison between a group treated with high competition and a control group affected by low competition rather than a no-competition control group. Nevertheless the empirical analysis in this study indicates that the competitive pressure introduced by academies can generate positive effects for neighbouring schools and more generally that a quasi-market in education can benefit more disadvantaged pupils and low achievers.

Table 3.1: School types and their characteristics

School type	Non-LA admission authority	Maintained by non LA body	Not obliged to follow National Curriculum
Community school	✗	✗	✗
Voluntary-controlled	✗	✗	✗
Foundation	✓	✗	✗
Voluntary-aided	✓	✗	✗
City Technology College	✓	✓	✓
Academy	✓	✓	✓

Source: Eyles and Machin (2015b)

Table 3.2: Academies opened under the Labour government (September 2002-May 2010)

Academic year	Academies	Conversions	New schools
2002/2003	3	2	1
2003/2004	9	7	2
2004/2005	5	5	0
2005/2006	10	8	2
2006/2007	19	16	3
2007/2008	37	34	3
2008/2009	47	44	3
2009/2010	70	68	2
Total	200	184	16

Notes: the number of academies in England in the years 2003-2011 are based on the author's calculations using EDUBASE.

Table 3.3: Relationship between academy establishment and school enrollment (2005-2011).

	(1) All schools	(2) Community	(3) Non-community
0-2 miles	-14.469**	-24.042**	-11.908*
	(5.993)	(11.136)	(6.820)
2-3 miles	-17.963***	-33.051***	-8.504
	(5.529)	(9.864)	(6.187)
3-4 miles	-11.624**	-11.880	-11.807*
	(5.714)	(9.816)	(6.683)
4-5 miles	0.902	-4.126	3.415
	(5.602)	(9.666)	(6.785)
Observations	10,950	4,598	6,352
R-squared	0.039	0.095	0.014
Number of schools	1,656	702	954

Notes: Dependent variable is total school enrollment. Enrollment data were obtained from the performance tables that are published annually by the DfE and available from https://www.compare-school-performance.service.gov.uk/download-data. Regressions also contain year and school fixed effects. Robust standard errors clustered by school are in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Table 3.4: Type of secondary schools in England and in the sample

		LAs with academies	
	England	Within 3 miles	Other schools
Community school	1,719	366	512
Voluntary-controlled	132	12	88
Foundation	656	178	230
Voluntary-aided	534	206	35
City Technology College	3	2	0

Notes: the number of secondary schools in England and their type is obtained from own calculations using PLASC for the period 2005-2011.

Table 3.5: Descriptive statistics for the academic years 2005/06 and 2010/11

	2005/06				2010/11			
	Academies	3 miles	LA with 1+Ac.	England	Academies	3 miles	LA with 1+Ac.	England
Girl	0.492	0.530	0.499	0.504	0.483	0.509	0.498	0.499
FSM	0.330	0.234	0.103	0.138	0.250	0.200	0.103	0.147
EAL	0.130	0.141	0.045	0.077	0.155	0.194	0.058	0.107
Born in 3rd quarter	0.262	0.268	0.265	0.263	0.256	0.255	0.255	0.255
White	0.704	0.718	0.885	0.835	0.736	0.682	0.877	0.809
African	0.045	0.041	0.004	0.011	0.040	0.044	0.007	0.021
Caribbean	0.047	0.026	0.005	0.012	0.033	0.033	0.005	0.015
Bangladeshi	0.011	0.008	0.004	0.009	0.015	0.016	0.005	0.012
Pakistani	0.031	0.054	0.013	0.022	0.038	0.059	0.017	0.028
Indian	0.028	0.019	0.019	0.023	0.020	0.037	0.020	0.023
SEN with Statement	0.015	0.012	0.011	0.012	0.011	0.011	0.011	0.011
SEN with Action	0.144	0.096	0.076	0.078	0.174	0.137	0.124	0.131
SEN with Action+	0.048	0.033	0.028	0.029	0.069	0.051	0.050	0.051
Intake	-0.241	-0.108	0.068	0.031	-0.268	-0.030	0.076	0.023
N	2,439	13,252	132,383	499,226	32,739	117,683	131,515	501,376

Table 3.6: Trends in traditional state schools performance prior to academy entry, academic years 2005/06 to 2010/11, students in year 11

	(1) GCSE Maths	(2) GCSE Eng
2 years pre	0.000	-0.003
	(0.006)	(0.007)
3 years pre	-0.004	-0.020*
	(0.009)	(0.010)
4 years pre	-0.001	-0.019
	(0.012)	(0.014)
5 years pre	-0.005	-0.013
	(0.016)	(0.019)
Observations	1,039,287	1,034,217
R-squared	0.556	0.465
Number of schools	914	914

Notes: The outcome is standardised test scores and the sample includes those students in traditional state schools ever located near an academy. All models include previous achievement, FSM eligibility, EAL and FSM status, ethnicity, gender, school time varying characteristics and schools and year effects. Standard errors are clustered at school-year level. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Table 3.7: Main results: effects of any academies within 3 miles on achievement, academic years 2005/06 to 2010/11, students in year 11

	(1) GCSE Eng+Maths	(2) GCSE Eng+Maths	(3) GCSE Eng+Maths	(4) GCSE Eng+Maths
1+ Academy within 3 m	-0.067***	-0.015***	0.030***	0.015***
	(0.010)	(0.005)	(0.003)	(0.005)
Lagged test scores	X	✓	✓	✓
Student char.	X	✓	✓	✓
School char.	X	✓	✓	✓
School effects	X	X	✓	✓
Year effects	X	X	X	✓
Pre-ac. trends	X	X	X	✓
Observations	1,786,657	1,786,657	1,786,656	1,786,655
R-squared	0.001	0.638	0.676	0.678

Notes: Standard errors are clustered at school-year level. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Table 3.8: Main results: effects of number of academies within 3 miles on achievement, academic years 2005/06 to 2010/11, students in year 11

	(1) GCSE Eng+Maths	(2) GCSE Eng+Maths	(3) GCSE Eng+Maths	(4) GCSE Eng+Maths
1 Academy within 3 miles	-0.074***	-0.025***	0.023***	0.011**
	(0.012)	(0.006)	(0.004)	(0.005)
2 Academies within 3 miles	-0.083***	-0.012	0.039***	0.019**
	(0.020)	(0.009)	(0.006)	(0.008)
3+ Academies within 3 miles	-0.025	0.027***	0.043***	0.025**
	(0.018)	(0.009)	(0.007)	(0.010)
Lagged test scores	X	✓	✓	✓
Student char.	X	✓	✓	✓
School char.	X	✓	✓	✓
School effects	X	X	✓	✓
Year effects	X	X	X	✓
Pre-ac. trends	X	X	X	✓
Observations	1,786,657	1,786,657	1,786,656	1,786,655
R-squared	0.001	0.638	0.668	0.678

Notes: Standard errors are clustered at school-year level. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Table 3.9: Main results: effects of academies within 3 miles on achievement, academic years 2005/06 to 2010/11, students in year 11

	(1) GCSE Eng+Maths	(2) GCSE Eng+Maths	(3) GCSE Eng+Maths	(4) GCSE Eng+Maths
CA penetration	-0.570***	-0.179***	0.152***	0.076***
	(0.054)	(0.028)	(0.021)	(0.025)
Lagged test scores	X	✓	✓	✓
Student char.	X	✓	✓	✓
School char.	X	✓	✓	✓
School effects	X	X	✓	✓
Year effects	X	X	X	✓
Pre-ac. trends	X	X	X	✓
Observations	1,786,657	1,786,657	1,786,656	1,786,655
R-squared	0.001	0.638	0.668	0.678

Notes: Standard errors are clustered at school-year level. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Table 3.10: Heterogeneity analysis: effects of academies within 3 miles on achievement, only Community schools, academic years 2005/06 to 2010/11, students in year 11

	(1) GCSE Eng+Maths	(2) GCSE Eng+Maths	(3) GCSE Eng+Maths
1+ Academy within 3 m	0.018***		
	(0.007)		
CA penetration		0.113***	
		(0.042)	
1 Academy within 3 m			0.015**
			(0.007)
2 Academies within 3 m			0.024**
			(0.012)
3+ Academies within 3 m			0.029
			(0.018)
Observations	953,162	953,162	953,162
R-squared	0.660	0.660	0.660

Notes: all models control for previous achievement, FSM eligibility, EAL and FSM status, ethnicity, gender, percentage of FSM eligible, SEN and EAL pupils in the school, percentage of ethnic minorities, and average KS2 score for the cohort, schools and year effects and schools specific pre-academy years indicators. Standard errors are clustered at school-year level. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

TABLE 3.11: Heterogeneity analysis: effects of academies within 3 miles on achievement, only Voluntary Aided schools, academic years 2005/06 to 2010/11, students in year 11

	(1) GCSE Eng+Maths	(2) GCSE Eng+Maths	(3) GCSE Eng+Maths
1+ Academy within 3 m	0.013		
	(0.010)		
CA penetration		0.086*	
		(0.046)	
1 Academy within 3 m			0.011
			(0.010)
2 Academies within 3 m			0.014
			(0.016)
3+ Academies within 3 m			0.019
			(0.016)
Observations	321,772	321,772	321,772
R-squared	0.681	0.682	0.682

Notes: all models control for previous achievement, FSM eligibility, EAL and FSM status, ethnicity, gender, percentage of FSM eligible, SEN and EAL pupils in the school, percentage of ethnic minorities, and average KS2 score for the cohort, schools and year effects and schools specific pre-academy years indicators. Standard errors are clustered at school-year level. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

TABLE 3.12: Heterogeneity analysis: effects of academies within 3 miles on achievement, only FSM pupils, academic years 2005/06 to 2010/11, students in year 11

	(1) GCSE Eng+Maths	(2) GCSE Eng+Maths	(3) GCSE Eng+Maths
1+ Academy within 3 m	0.015**		
	(0.007)		
CA penetration		0.067*	
		(0.038)	
1 Academy within 3 m			0.014*
			(0.008)
2 Academies within 3 m			0.017
			(0.011)
3+ Academies within 3 m			0.022
			(0.014)
Observations	269,771	269,771	269,771
R-squared	0.591	0.591	0.591

Notes: all models control for previous achievement, FSM eligibility, EAL and FSM status, ethnicity, gender, percentage of FSM eligible, SEN and EAL pupils in the school, percentage of ethnic minorities, and average KS2 score for the cohort, schools and year effects and schools specific pre-academy years indicators. Standard errors are clustered at school-year level. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Table 3.13: Heterogeneity analysis: effects of academies within 3 miles on achievement, only low achievers, academic years 2005/06 to 2010/11, students in year 11

	(1) GCSE Eng+Maths	(2) GCSE Eng+Maths	(3) GCSE Eng+Maths
1+ Academy within 3 m	0.014**		
	(0.006)		
CA penetration		0.069**	
		(0.032)	
1 Academy within 3 m			0.013*
			(0.007)
2 Academies within 3 m			0.017
			(0.011)
3+ Academies within 3 m			0.021*
			(0.013)
Observations	595,670	595,670	595,670
R-squared	0.381	0.381	0.381

Notes: all models control for previous achievement, FSM eligibility, EAL and FSM status, ethnicity, gender, percentage of FSM eligible, SEN and EAL pupils in the school, percentage of ethnic minorities, and average KS2 score for the cohort, schools and year effects and schools specific pre-academy years indicators. Standard errors are clustered at school-year level. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Table 3.14: Heterogeneity analysis: effects of academies within 3 miles on achievement, only high achievers, academic years 2005/06 to 2010/11, students in year 11

	(1) GCSE Eng+Maths	(2) GCSE Eng+Maths	(3) GCSE Eng+Maths
1+ Academy within 3 m	0.003		
	(0.006)		
CA penetration		0.016	
		(0.030)	
1 Academy within 3 m			-0.001
			(0.006)
2 Academies within 3 m			0.013
			(0.009)
3+ Academies within 3 m			0.018
			(0.011)
Observations	595,319	595,319	595,319
R-squared	0.409	0.409	0.409

Notes: all models control for previous achievement, FSM eligibility, EAL and FSM status, ethnicity, gender, percentage of FSM eligible, SEN and EAL pupils in the school, percentage of ethnic minorities, and average KS2 score for the cohort, schools and year effects and schools specific pre-academy years indicators. Standard errors are clustered at school-year level. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Table 3.15: Robustness check: effects of academies within 3 miles on achievement, schools with common support, academic years 2005/06 to 2010/11, students in year 11

VARIABLES	(1) GCSE Eng+Maths	(2) GCSE Eng+Maths	(3) GCSE Eng+Maths
1+ Academy within 3 m	0.014***		
	(0.004)		
CA penetration		0.065***	
		(0.025)	
1 Academy within 3 m			0.010**
			(0.004)
2 Academies within 3 m			0.019***
			(0.006)
3+ Academies within 3 m			0.021***
			(0.008)
Observations	1,730,998	1,730,998	1,730,998
R-squared	0.679	0.679	0.679

Notes: all models control for previous achievement, FSM eligibility, EAL and FSM status, ethnicity, gender, percentage of FSM eligible, SEN and EAL pupils in the school, percentage of ethnic minorities, and average KS2 score for the cohort, schools and year effects and schools specific pre-academy years indicators. Standard errors are clustered at school-year level. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Table 3.16: Robustness check: effects of academies within 3 miles on achievement, with a lead and lags, academic years 2005/06 to 2010/11, students in year 11

	(1) All	(2) Comm	(3) VA	(4) FSM	(5) Low	(6) High
t-1	-0.001	0.004	-0.005	0.010	0.010	-0.009
	(0.005)	(0.007)	(0.010)	(0.008)	(0.007)	(0.006)
t	0.011**	0.021***	-0.000	0.019**	0.017**	-0.007
	(0.005)	(0.007)	(0.011)	(0.008)	(0.007)	(0.006)
t+1	0.014**	0.014*	0.014	0.020**	0.015**	-0.003
	(0.006)	(0.008)	(0.011)	(0.009)	(0.008)	(0.007)
t+2	0.017**	0.026***	0.019	0.033***	0.027***	0.000
	(0.007)	(0.009)	(0.014)	(0.010)	(0.009)	(0.008)
t+3	0.027***	0.032***	0.027*	0.037***	0.035***	0.008
	(0.008)	(0.012)	(0.016)	(0.012)	(0.011)	(0.009)
t+4	0.032***	0.052***	0.028	0.031*	0.034**	0.022*
	(0.010)	(0.016)	(0.019)	(0.016)	(0.014)	(0.011)
t+5	0.022	0.050*	0.003	0.030	0.026	-0.010
	(0.016)	(0.029)	(0.026)	(0.022)	(0.020)	(0.020)
Observations	1,786,655	953,162	321,772	269,771	595,670	595,319
R-squared	0.678	0.661	0.682	0.592	0.382	0.409

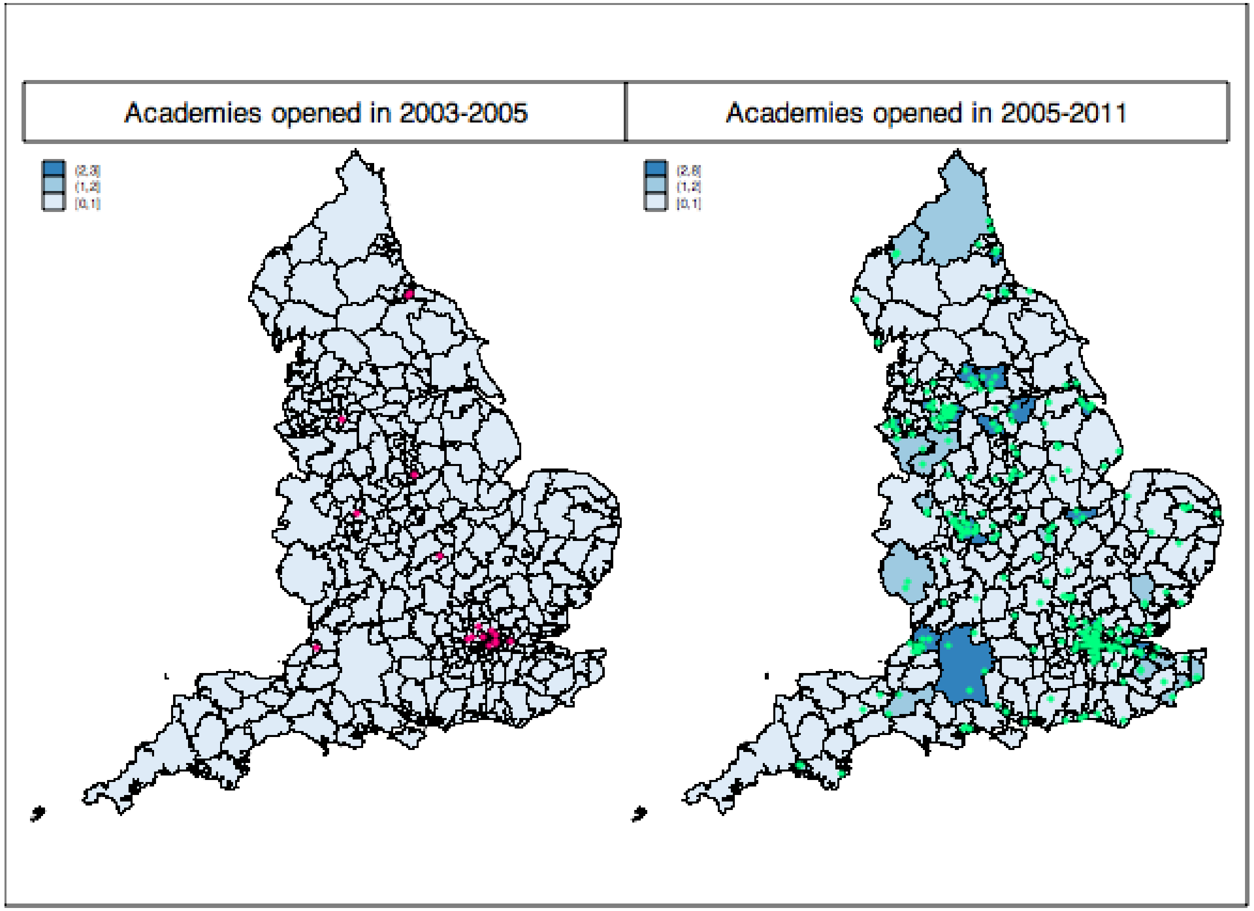
Notes: all models control for previous achievement, FSM eligibility, EAL and FSM status, ethnicity, gender, percentage of FSM eligible, SEN and EAL pupils in the school, percentage of ethnic minorities, and average KS2 score for the cohort, schools and year effects and schools specific pre-academy years indicators. Standard errors are clustered at school-year level. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Table 3.17: Effects of exposure to academies within 3 miles on per-pupil expenditures.

	(1) All schools	(2) Community sc.	(3) Voluntary aided sc.
1+ Academy within 3 m	-0.010	-0.001	0.001
	(0.024)	(0.034)	(0.046)
Observations	9,322	4,794	1,907
R-squared	0.587	0.656	0.615

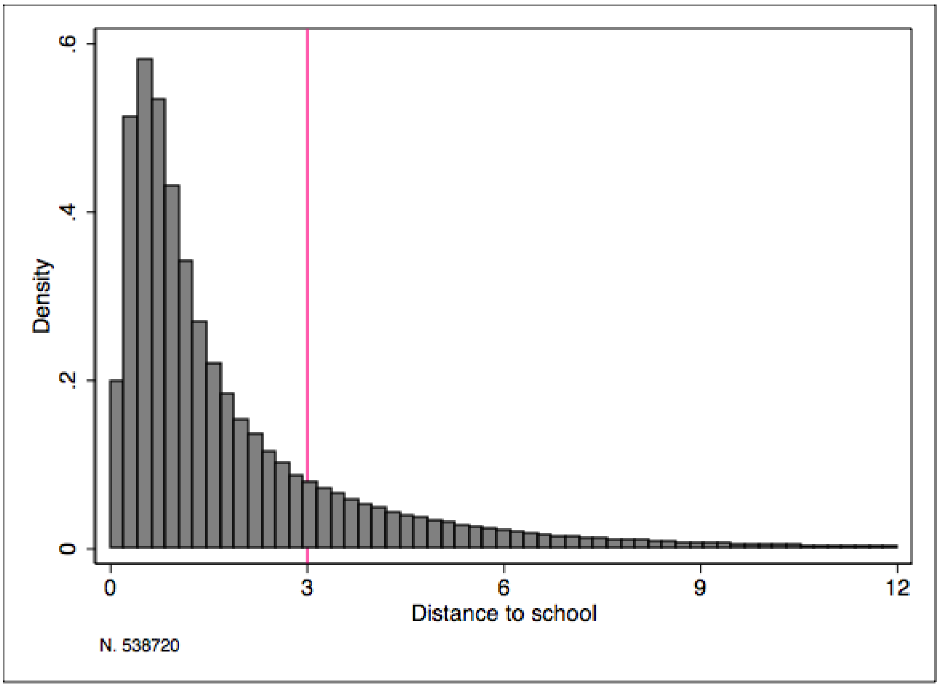
Notes: the regressions include school fixed effects, year fixed effects and school time-varying characteristics (percentage of FSM eligible, SEN and EAL pupils in the school, percentage of ethnic minorities). PPE are in thousands of pounds. Standard errors are clustered at school level. *** p<0.01, ** p<0.05, * p<0.10

FIGURE 3.1: Academies opened in England during the period 2003-2011



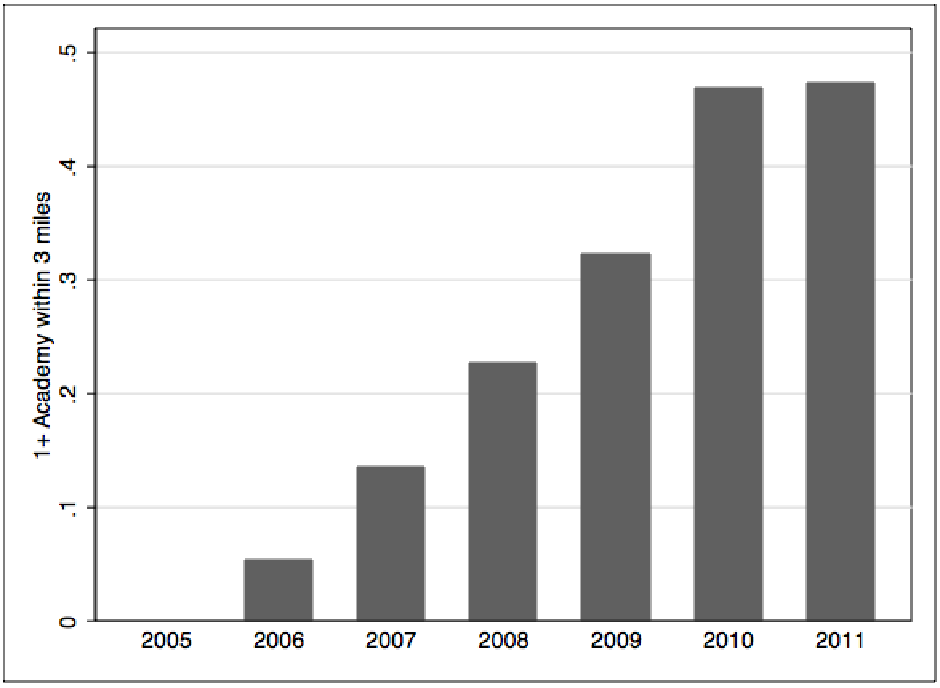
Academies that opened in the period 2003-2005 are showed on the left, academies that opened between 2006 and 2010 instead are showed on the right. All information about academy schools were obtained from *EDUBASE* that is a register of all Educational Establishments in England and Wales and is maintained by the Department for Education.

FIGURE 3.2: Distance to school for pupils in year 11 in 2010



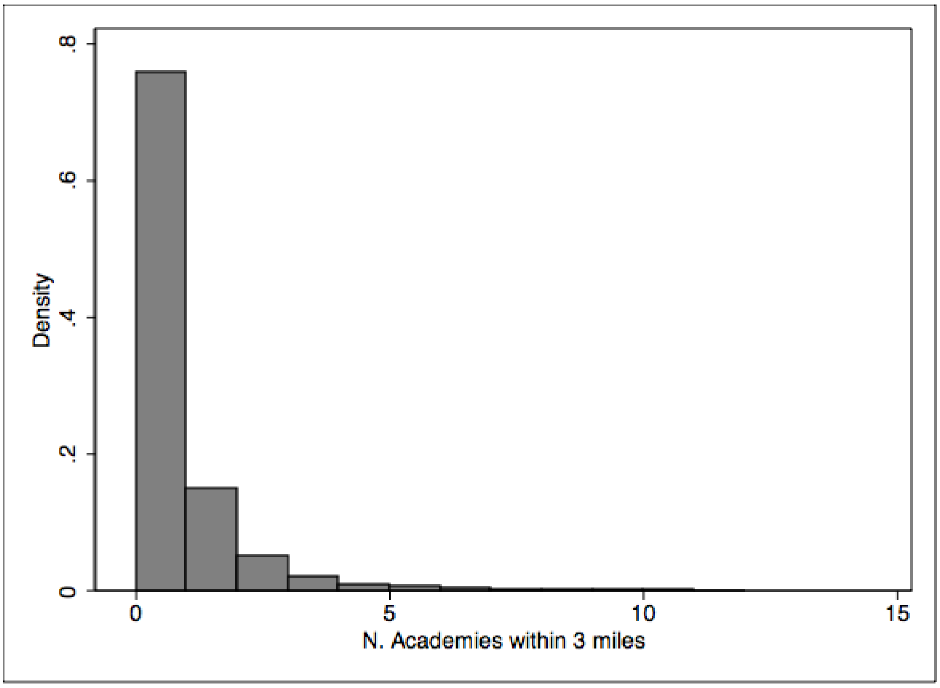
Notes: author's own calculations using the School Census 2010.

FIGURE 3.3: Percentage of pupils in year 11 enrolled in schools within 3 miles from an academy, academic years 2005-2011



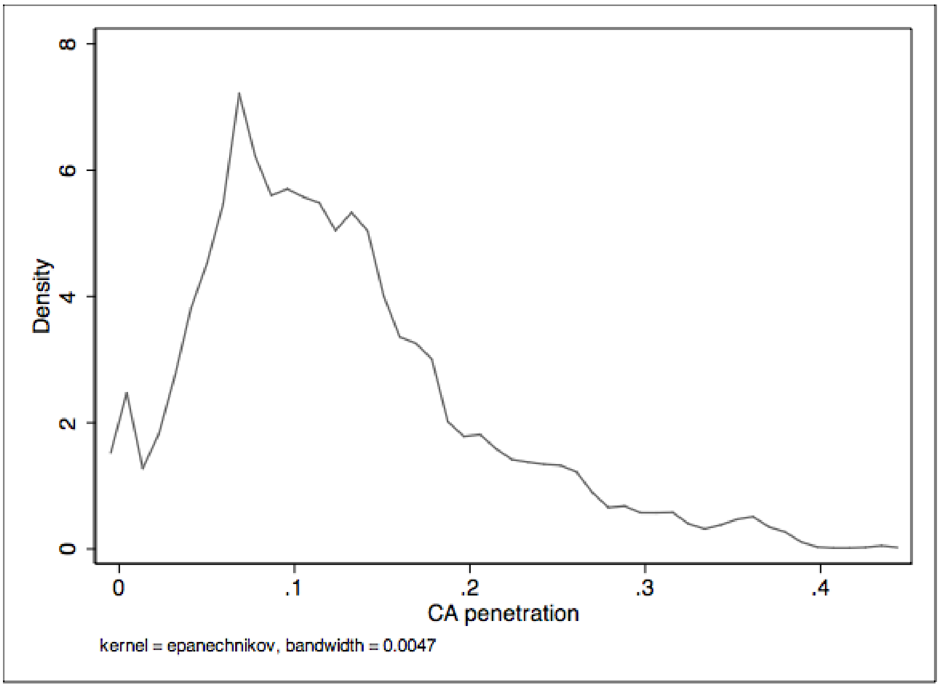
Notes: author's own calculations using the School Census 2010.

FIGURE 3.4: Number of academies within 3 miles from schools attended by pupils in year 11, academic years 2005-2011



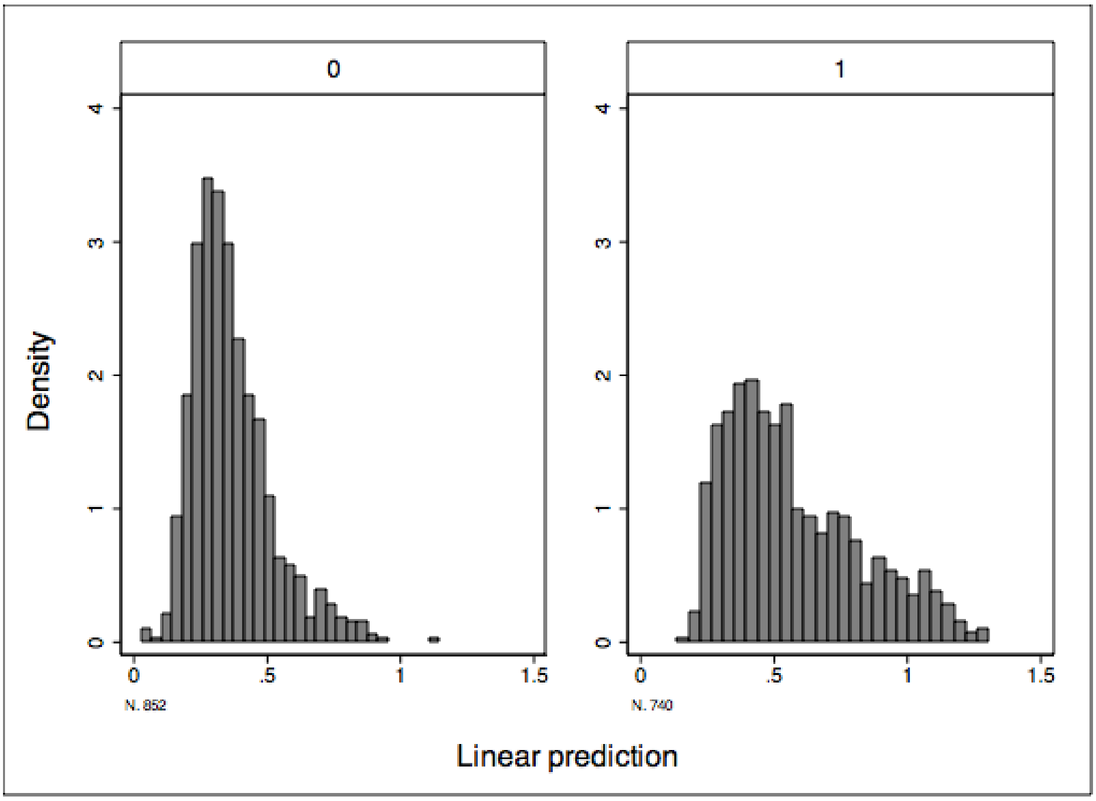
Notes: author's own calculations using the School Census 2010.

FIGURE 3.5: Kernel density estimate of the distribution of catchment area exposure for pupils in schools within 3 miles from academies



Notes: author's own calculations using the School Census 2010.

FIGURE 3.6: Linear prediction for schools near academies and other schools in local authorities with academies



Notes: the linear index of the propensity score is obtained from a regression of whether the school is near an academy or not on the school characteristics in the pre-academy conversion (or location) period. The school level characteristics used in the linear regressions are: the percentage of FSM eligible pupils, the percentage of white pupils, the average KS2 score of the intake and the percentage of SEN pupils. The propensity score is presented for schools near an academy on the left and schools with no academies nearby on the right. The schools selected for the regression analysis are those with a predicted linear index of the propensity score between .14 and .95. This trimming excludes 16 schools within 3 miles from an academy and 7 schools from the control group.

Conclusion

Secondary schools have an important role in preparing their pupils for adult life and the labour market. However many young people, particularly those from disadvantaged backgrounds, do not attain as much as they could. It is then important to understand whether the features of the current education landscape can be used to help pupils at risk of failing to improve their cognitive outcomes.

In this thesis I consider the effect of three aspects of the English secondary school system on pupil attainment. In the first chapter my coauthors and I study the effect of boarding education on bright pupils with low socio-economic status. We test the hypothesis that attending Christ's Hospital, a boarding school admitting a high share of high ability pupils with low socio-economic status, improves achievement in the compulsory school final exams (GCSEs). Our propensity score matching estimates show that the probability of achieving A or A* in five or more GCSEs is 17.4 percentage points higher with respect to 59% for matched pupils in grammar schools, with similar results when the control group are independent school pupils. As an additional hypothesis, we tested for heterogeneous effects and find that the Christ's Hospital effect is higher for pupils from the most deprived backgrounds and for girls.

In the second chapter I evaluate the effect of single-sex schools on achievement and subject choice. I find that same-gender peers have no effect on the achievement of girls and boosts slightly the achievement of boys; all girls, and particularly those with low socio-economic status, are more likely to study maths or science in their post-compulsory education (respectively by 1.9% and 2.6% more likely) whereas the effect for boys is not significantly different from zero. Using a survey of students in England I find that girls and boys in single sex schools have less gender-stereotyped tastes and self-assessment of their abilities. These results support the hypothesis that girls in same-gender classes are less exposed to gender stereotypes, therefore more confident in their abilities in science and maths and more motivated to study these subjects.

In the third paper I investigate whether a quasi-market in education is beneficial for all by studying the effect of an unexpected education policy that broadened the choice of schools available to pupils and their parents and increased competition in the education sector. I find that the achievement of pupils in schools exposed to the competition of academies raises by 1.5% to 1.8%, a modest effect but highly consistent with the benefits found in other studies on competition. Perhaps the most important finding is that this result is driven by the academic performance of pupils in schools with less resources, poorer pupils and low achievers thus showing that competition is not necessarily detrimental for weaker students.

To sum up, with this work I have shown that existing features of the education system in England can be used to improve the attainment of disadvantaged pupils.

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