URBAN DENSITY AND PUPIL ATTAINMENT

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Abstract

We explore the association between urban density and pupil attainment using three cohorts of pupils in schooling in England. Although – as widely recognised – attainment in dense urban places is low on average, this is not because urban environments disadvantage pupils, but because the most disadvantaged pupils with low average attainments attend the most urbanised schools. To control for this, we exploit changes in urban density faced by pupils during compulsory transition from Primary to Secondary school, and measure educational progress at the end of the Secondary phase, relative to attainments at the end of Primary schooling. Our results suggest that there are small but significant *benefits* from education in schools in more densely urbanised settings: Pupils in schools in relatively dense places – measured in terms of school density and other urban indicators – progress faster than others in their cohort, but the elasticity is low, at around 0.02. We detect this density advantage even amongst pupils moving relatively short distances between Primary and Secondary schools within urban areas, so we cannot attribute it to broad urbanisation effects experienced by pupils making rural-urban school moves. A more likely explanation lies in greater school choice and competition between closely co-located educational providers.

Keywords: Urban Density and Agglomeration; School Choice and Competition; Pupil Achievement.
JEL Classifications: I20, R20, J24

1. Introduction

City schools in the US, UK and elsewhere are widely admonished by politicians, schools inspectors, parents and academics for failing to provide pupils with high standards of education (see discussions in Machin and Vignoles [31], Murnane [34], Neal [37] and Ofsted [40]). With the aim of redressing this situation, governments in many countries have increasingly targeted schools in disadvantaged urban areas; among others, recent policy interventions include the 'Excellence in Cities' program discussed in Machin et al. [30], the 'Aimhigher' initiative described in Emmerson et al. [9], and the STAR experiment debated in Hanushek [18] and Krueger [26].

In some ways, this should come as something as a surprise to economists interested in the benefits of urbanisation and agglomeration: City schools can potentially draw from a diverse pool of high-quality teachers and are geographically placed in settings which should provide incentives through competition with other schools, and facilitate sharing of teaching know-how and technology through cooperation. Of course, given the concentration of poverty in cities, it is also recognised that urban schools are building human capital on a lower base in terms of pupil characteristics, in particular higher rates of hardship and lower initial ability. However, this rarely seems to be taken into account when drawing inferences about the effectiveness of urban schools; the simple observation of a high concentration of low achievers in dense urban places is taken as evidence that urban environments disadvantage pupils.

This paper uses a census of over 1.2 million pupils in England, matched to records on their academic progress, to assess whether pupils in city schools really show low-educational progress relative to schools in lower density suburban, semi-rural and rural areas. We use information on the improvement or decline in the attainment of pupils who shared the same Primary school, but then move from low-density to high-density areas or vice-versa on compulsory transition to Secondary school. We find evidence of small but significant *benefits* from education in schools in more densely urbanised settings: Pupils in schools in relatively dense places – measured in terms of school density and other urban indicators – progress faster than others in their cohort, although the elasticity is low, at around 0.02. We find this association even amongst pupils moving relatively short distances between Primary and Secondary schools within urban areas; so, we argue, our results do not emerge from broad agglomeration and urbanisation effects experienced by pupils making rural-urban school moves. Instead, we interpret our findings as providing evidence on the effects of greater school choice and inter-school competition between closely co-located institutions in more urban settings.

The paper has the following structure. The next section outlines some relevant literature and sets the work in the context of studies on agglomeration and urbanization economies. Section 3 sets out our empirical approach, while section 4 describes the data. Section 5 presents and discusses the results that arise from these approaches, and we make some concluding remarks in section 6.

2. The literature

"Conceptually, a city is just a dense agglomeration of people and firms. All of the benefits of cities ultimately come from reduced transport costs for goods, people and ideas" (Glaeser [15]). This simple intuition, borrowed from the seminal writings of Marshall [33], is nowadays at the core of most research on agglomeration and urbanisation processes. In a nutshell, the fundamental reason why firms and workers concentrate in geographically contained areas, giving rise to cities, is because clustering generates some forms of economies of scale, or increasing returns, due to proximity. As discussed in Glaeser [15] and Rosenthal and Strange [43], these mainly emerge from proximity in three factors: *People*, associated with labour market pooling and accessibility to a wider sets of customers; *Goods*, coupled with input sharing and specialization of services for producers; *Ideas*, linked to the emergence of knowledge and technological spillovers across firms. While proximity of goods and individuals seems a natural requirement for of economies of scale to emerge in urban environments, it could be argued that knowledge spillovers are not constrained by distance, or within the boundaries of urban areas. Yet, Jaffe et al. [27] provides strong evidence on the importance of proximity for know-how diffusion too. So, along all these three dimensions, closeness seems to be the channel through which urban areas generate productivity benefits for both workers and firms.

Technological spillovers are also often invoked as an explanation for the reason why cities not only exist, but prosper and grow too: Knowledge spillovers between neighbouring firms within an industry generate dynamic agglomeration economies, leading to faster pace of innovation, continuous improvements in modes of production, and affecting growth rates of productivity, output and employment. While in the original Marshallian [32] setting dynamic economies emerge because the concentration of an industry in a city gives rise to local monopolies that internalize the benefits of innovation and encourage it, Porter [41] argues that it is the more intense competition among close firms in a specialized location that gives rise to dynamic agglomeration economies. Whatever one's view here, most academics now agree on the relevance of geographical proximity for knowledge flows to take place and *dynamic* agglomeration economies to emerge.

For these reasons, the idea that urban schools fail to provide pupils with a high standard environment for learning comes as something as a surprise to researchers interested in economies of urbanization and agglomeration: City schools have the potential to exploit dense labour markets, therefore attracting high-quality teachers; city schools are located in diversified areas where pupils and teachers can be more efficiently matched through the exercise of school choice; city schools face a large and heterogeneous pool of 'consumers', thus having potential to exploit economies from specialization; pupils in urban schools may also benefit from learning spillovers associated with closer connections to a larger and more diverse group of students. Further, city schools share better common infrastructures, e.g. faster connection for use of information technologies or public transport; finally, city schools are geographically placed in settings which should provide incentives for improvement or adoption of new teaching technologies through competition with other schools, and facilitate sharing of teaching know-how through cooperation. What evidence is available?

A growing body of research on the functioning of the labour market for teachers has been produced over the past years. Using different methodologies and data, Dolton and van der Klaauw [8], Hanushek et al. [19] and [20], Murnane and Olson [34] and [35] all show that individuals mainly respond to (relative) wage incentives in their decision to start teaching or leave this occupation. Chevalier et al. [4] confirm this finding for a longer time horizon (1960s to 1990s), and show that graduates have a lower probability of becoming teachers in urban areas; this might be because teaching is a poor option compared to more remunerative alternatives available in these locations, or because working conditions in urban schools are perceived to be worse than in provincial areas or other occupations. This is consistent with evidence in Hanushek et al. [20], showing that teachers changing schools within urban districts seek out schools with easier to teach pupils, such as private schools.

However, whether this results in lower teacher quality in urban schools is open to debate. Hanushek et al. [21] suggests the opposite is true: Teachers exiting Texas public urban schools are on average less effective at raising pupil attainments than those who stay; moreover, there is no evidence to support the idea that urban schools loose their best teachers to suburban and rural schools. Additionally, Hanushek et al. [19] and Lavy [28] show that teacher performance-related pay has great potential for retaining effective teachers in city schools, improving their motivation and increasing pupils' attainments. Finally, Clotfelter et al. [5] show that a pecuniary bonus granted to qualified teachers in North Carolina greatly reduced their hazard of leaving high-poverty schools; this was especially pronounced for teachers with longer years of experience, associated to better pupil outcomes (see Hanushek et al. [21]). Overall then, city schools seem to be in a favourable position to exploit labour markets to hire and retain high-quality educators.

The benefits of choice and competition among schools should also have greater scope in urban areas. A large number of closely located schools imply that parents have a wider set of schools to choose from within feasible travel-distance; if pupils with many available schools can be more efficiently matched to educational providers that suit their preferences and capabilities, average educational standards should increase. Moreover, in a school market where parents can exercise choice and funding follows pupils (as in the UK setting)[1], schools have to provide 'quality' that parents demand or face falling enrolment, loss of money and ultimately closure. Proximity of urban schools therefore seems to provide incentives for improvement and adoption of new teaching technologies through competition with other educational provides. In fact, the empirical evidence on the benefits of choice and competition is mixed: On the one hand, research by Cullen et al. [6] and [7] shows no performance gains associated with greater parental choice in the Chicago urban setting; on the other hand, Hoxby [23], [24] and [25] finds that competition in US metropolitan areas is beneficial to pupil achievements. As for the English experience, Gibbons et al. [12] show competition among schools which have freedom in managing their admission practises and governance to have a positive effect on pupil achievement in dense urban areas.

While inner-city school competition is commonly credited with inducing teaching-related innovations and high school standards, know-how externalities and spillovers may also emerge because proximity of schools in urban settings facilitates cooperation and sharing of teaching practices and technology among neighbouring institutions. In fact, this is the rationale behind a

[1] And there is no strict zoning, i.e. pupils can attend every non-oversubscribed school of their choice, without restrictions regarding place of residence and school proximity.

recent policy initiative of the UK government – the Beacon school scheme (see the report by GHK [11]). Under this program, schools that deliver outstanding teaching and are well managed are awarded a 'beacon' status (renewable every third year) to represent examples of successful practice; Beacon schools are expected to work in partnership with other neighbouring schools (organizing meetings, cross-institution working, pastoral support as well as increasing teacher participation and retention) to help them achieving similar standards.

Why, then, are city schools so commonly associated with failure? On the one hand, this could just be because cities have a high concentration of children with fewer home resources (Glaeser et al. [16]) who on average do worse at school; these pupils often have additional family background disadvantages, further disrupting their school records. While this suggests that urban schools are building human capital on a lower base in terms of pupil characteristics, it does not necessarily have any bearing on the educational progress of students in city areas or on the effectiveness of urban schools in educating their pupils[2]. On the other hand, there are reasons why pupils might indeed do less well if they attend an inner-city school rather than a suburban or rural one; some of these are analogous to the dispersion forces that appear in standard agglomeration theories. Many 'congestion'-related factors that accompany high urban density are likely to be detrimental to pupil learning: Overcrowding in schools and supporting services (such as libraries); high levels of property crime; violence and other social and emotional problems that cause disruption directly and through peer group influence; high pupil turnover because of demographic mobility. The reports by Ofsted [40] and Lupton [29] present a range of such features that are common to schools in urban areas in England, most of which could be broadly considered as negative peer-group effects.

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[2] The fact that children from poorer family backgrounds have lower school attainment is well known, but the reasons are many, varied and poorly understood; we will not enter this discussion here.

Ultimately, whether the combination of positive and negative factors characterizing city schools is beneficial or detrimental to pupil educational progress is an empirical question. *Levels* of attainment in dense urban areas might be low because the most disadvantaged pupils attend the most urbanised schools; yet, urban areas might provide better learning environments in terms of pupil academic *progress*, relative to lower density suburban, semi-rural and rural areas. While this seems to be rarely taken into account when assessing the performance of pupils in urban schools, it is the empirical problem which we tackle in the next sections. There, we will make use of a census of over 1.2 million pupils in England, matched to records on their academic achievement, to compare academic improvement of pupils who shared the same Primary school, but then move from low-density to high-density areas or vice-versa on compulsory transition to Secondary school.

3. Empirical methods: The value added model of attainment

Our aim is to study the influence of urban density on pupil attainment in schools in England. We will investigate this in the context of compulsory-age Secondary schooling between the ages of 11 and 16. At the beginning of this period, nearly all pupils in the state sector in England switch schools as they move from the Primary to Secondary phase; our identification strategy will exploit changes in school setting that occur on this transition. This offers an advantage over most empirical strategies that exploit voluntary changes initiated by movers; everyone here is a 'mover', so that the problem of endogeneity of the choice and direction of move to pupil achievement is less acute.

The model we have in mind is one in which attainment y_{ij} of individual i in school j depends on unobserved individual characteristics (a_i) that are constant within individuals across schools and with age, observed school characteristics (z_j) and random individual-school specific factors (ε_{ij}); we also allow for the possibility that an individual's trend in attainment with age t is dependent on observable personal characteristics x_i:

$$y_{ij} = \beta u_{ij} + a_i + \gamma x_i t + \lambda z_j + \varepsilon_{ij} \quad (1)$$

The key variable of interest is a measure or vector of measures u_j describing the urbanisation of the environment in which a school is located. The exact form of these proxies will be discussed later (section 4), but its intention is to capture the general aspects of density, agglomeration and urbanisation that may influence pupil attainment; these may act through greater school accessibility and competition, a deeper pool of good teachers in urban labour market, better inter-school networking, more efficient matching of pupils and teachers to schools, broadly defined 'neighbourhood' effects, such as role models and expectations, and much else which might lead pupils to perform better (or worse) in places where there are more schools, more infrastructure and more people. In fact, we make no definite attempt at separating the impact of these indices on pupil educational achievement from other unobservable characteristics of urban schools, as we want to capture general efficiency/quality benefits associated with attending a school in dense urban areas. Our main concern, instead, is taking care of individual unobservable heterogeneity which may simultaneously drive attainment and school of choice, creating a spurious link between measures of urbanization and pupil educational performance. Notice that this model is an analogous (but more general) set up to that typically used to study agglomeration economies in firm or aggregate productivity; in our case the dependent variable is not productivity, but individual pupil attainment.

Consistent estimation of β in (1) is not possible in the cross section because unobserved individual factors (such as family income and various forms of advantage/disadvantage) are highly correlated with choice of residential location, and hence choice of school and the urban density of its surroundings. But, since an individual is observed in two or more schools, at different ages – namely Primary school j and Secondary school k – it is (at least) possible to difference out fixed individual factors using the familiar transformation:

$$\begin{aligned} y_{ik} - y_{ij} &= \beta(u_{ik} - u_{ij}) + \gamma x_i \bar{t} + \lambda(z_k - z_j) + (\varepsilon_{ik} - \varepsilon_{ij}) \\ \Delta y_{i,jk} &= \beta \Delta u_{i,jk} + (\gamma \bar{t}) x_i + \lambda \Delta z_{jk} + \Delta \varepsilon_{i,jk} \end{aligned} \tag{2}$$

This is the common 'value-added' model of pupil attainment; the influence of education in an urban setting leads to a gain (or loss) in expected attainment when a pupil changes school. Here, $\bar{t}$ is the number of periods between our observation of the pupil in school j and k.

In model (2), it is still possible that the changes in unobservable individual-specific factors $\Delta\varepsilon_{i,jk}$ are correlated with the change in urban density. However, we can partly control for this by estimating fixed effects models that allow for Primary or Secondary school influences ($\tilde{s}_j$ or $\tilde{s}_k$, which we denote $\tilde{s}_{j/k}$) on pupil progress that are common across pupils within a school. Identification here is achieved using either the variation in the change of urban density for pupils going to the same Secondary but coming from different Primary schools or the variation in the change of urban density for students attending the same Primary and moving to a different Secondary school; we are therefore conditioning out any school-specific influences on attainment growth that are common to all individuals within a school, including unobservable individual school preferences that are shared with schoolmates (components of $\Delta\varepsilon_{i,jk}$). Additionally, given that few Primary to Secondary school transitions involve long-distance geographical mobility, school fixed effects also control for broader agglomeration effects which are common to both the Primary and Secondary phase. That is, we mainly identify our effects off the variation in density of urban environments in the immediate proximities of the schools attended.

To go one step further, we also estimate models controlling for Primary or Secondary school influences and including residential neighbourhood fixed effects ($\tilde{n}_l$); this can be done using detailed information on individual's home postcodes (corresponding to 10 or so contiguous housing units) and allows us to control for unobservable characteristics (such as income or preferences over local amenities and schools) common to families sorting into the same small residential neighbourhood. So our final specifications are of the form:

$$\Delta y_{i,jkl} = \beta \Delta u_{jk} + (\gamma \bar{\pi}) x_i + \lambda \Delta z_{jk} + \tilde{s}_{j/k} + \tilde{n}_l + \varepsilon_{i,jkl} \quad (3)$$

The underlying assumption for obtaining an unbiased estimate of β after controlling for either Primary or Secondary school influences and home postcode fixed effects, is that the differences in urban density between the Primary and Secondary phase are *not* systematically correlated with a change in unobservable pupil characteristics that drives attainment growth between the two phases, but only reflect changes in school quality/effectiveness associated to more or less dense environments. This assumption would be violated if, for example, urban Secondary schools picked pupils from rural Primaries who had higher expected educational progress than their peers living in the same neighbourhood but from an urban Primary school. Or if those pupils who expect faster attainment growth chose: lower density Primary schools, conditional on choice of Secondary school and residential neighbourhood; *and* higher density Secondary schools, conditional on choice of Primary school and residential neighbourhood. In the analysis that follows, we will spend considerable effort to assess the validity of our assumptions.

Our main empirical results are based on estimates of Equation (3) in more or less restricted forms. The main challenge to estimating these two-way fixed effects models (once the necessary data has been assembled) is the large number of school (around 14,000 Primaries and 2800 Secondaries) and postcode fixed effects (more than 500,000) that need to be estimated or eliminated, especially when we have a large number of pupil observations. Direct estimation of the full model with either Secondary or Primary school dummies as regressors on data de-meaned using a within-groups transformation to eliminate home postcode fixed effects is infeasible on the full data. We therefore follow a step-by-step procedure inspired by a series of papers by Abowd and co-authors (Abowd and Kramarz [1], Abowd Kramarz and Margolis [2] and Abowd, Creecy and Kramarz [3]) for firm and individual effects; this is detailed in Appendix section 10. Implementing this strategy requires very rich data, with information on pupil characteristics, schools attended and their exact location, attainment in at least two periods arising from education in at least two different school settings, and detailed pupil residential address. The next section describes how our data sources allow us to obtain all required information.

4. The data

4.1. Schools, pupils and tests

Compulsory education in England is organised into five stages referred to as Key Stages. In the Primary phase, pupils enter school at age 4-5 (or earlier if the school has nursery provision) in the Foundation Stage and then move on to Key Stage 1, spanning ages 5-6 and 6-7. At age 7-8 pupils move to Key Stage 2, sometimes – but not usually – with a change of school. At the end of Key Stage 2, when pupils are 10-11, children leave the Primary phase and go on to Secondary school where they progress through Key Stage 3 to age 14. At the end of each Key Stage, prior to age-16, pupils are assessed on the basis of standard national tests (SATS). At age 16, at the end of the compulsory schooling, pupils sit GCSEs (academic) and/or NVQ (vocational) tests in a range of subjects, and these provide their basic qualifications.

The UK's Department of Education and Skills (DfES) collects a variety of data on school pupils centrally, because the pupil assessment system is used to publish school performance tables and because information on pupil numbers and characteristics is necessary for administrative purposes – in particular to determine funding. A database exists from 1996 holding information on each pupil's assessment record in the Key Stage SATS throughout their school career. For Key Stages 2 and 3 we have information on pupil test scores in Maths, Science and English. For GCESs/NVQs, although we also know specific subjects taken and grades achieved, we make use of pupil 'Point Score' – an indicator of total achievement devised by the Qualifications and Curriculum Authority (QCA) and used by the DfES in the performance tables. This point score is based on allocating points to different grades, and aggregating across types of qualification using appropriate weights (details are available from the DfES or QCA). To make these comparable to earlier Key Stage test scores and construct measures of educational progress during the Secondary phase, we assign pupils a level which is their percentile ranking in the distribution across pupils.

Since 2002, the DfES has also carried out a Pupil Level Annual Census (PLASC) which records information on pupil's school, gender, age, ethnicity, language skills, any special educational needs or disabilities, entitlement to free school meals and various other pieces of information including postcode of residence (a postcode is typically 10-12 neighbouring addresses)[3].

PLASC is integrated with the pupil's assessment record (described above) in a National Pupil Database (NPD), giving a large and detailed dataset on pupils along with their test histories. Unfortunately, the length of the time series in the data means that it is not, at present, possible to trace individuals through from their first tests (Key Stage 1) to their final tests (GCSE/NVQ). It is however, possible to follow the academic careers of three cohorts of children through from age-11 to age-16, and to join this information to PLASC data at age-16. We use information on these three cohorts – those aged 16 in 2002, 2003 and 2004 – as the core dataset in this study. Various other data sources can be merged in at school level, including institutional characteristics (from the DfES) and information on the geographical location of each school

[3] Prior to 2002 this information was collected only at school level.

(down to postcode level). This allows us to geo-code the pupil data based on school attended, and to perform spatial data operations using a Geographical Information System (GIS).

From this large and complex combined data set we are able to construct a balanced panel providing information on three cohorts of over 400,000 pupils each, observed over three academic years, attending more than 14,000 Primary schools (when aged 11) and around 2800 Secondary schools (when aged 16). We include only those pupils who are in schools that do not admit students on the basis of academic ability schools; additionally, we do not have data on pupils attending private schools. In the work that follows, pupils' attainment is always measured in terms of their percentile ranking within their cohort at each Key Stage, using the distribution within pupils in this balanced panel. We will exploit this to estimate the influence of urban density on a pupil's position in the attainment distribution relative to his/her national peer group; central to this aim is the construction of various measures of the urban density of the school setting, which we describe in the next section.

4.2. Indices of urban density

There are obviously innumerable measures we could use to describe the extent to which a school's geographical setting can be characterised in terms of urban density. We pick three that we think capture key aspects relevant to our goals: The density of schools in the locality, the amount of local developed land and the residential population density. The first can be thought of as an 'educational' urban definition and relates to educational infrastructure, school competition or cooperation, choice and accessibility; the second is an environmental definition, and is intended to pick out schools in large metropolitan areas through the built environment; the third simply identifies schools as urban if they are in places where there are high concentrations of people. All three are, of course, highly mutually correlated, as well as correlated with many other things. We will begin by making few claims about picking precise causal channels through use of these variables; our main objective is simply to use these as indices of urbanisation.

In order to construct the first of these indices, we use a Geographical Information System to calculate the number of schools within predetermined distances of each school using the matrix of inter-school distances. For the second, we exploit a land cover dataset – Landcover Map 2000 – based on Landsat satellite imagery for the late 1990s; this data set records land cover type in 27 categories for 25m square tiles covering the whole of Great Britain[4]. Using this data, we compute for each school the proportion of land within a predetermined radius that is defined as *continuous urban* or *suburban/semi rural* according to the Landcover Map 2000 definitions. For the third index, information on population density is derived from the 2001 Census. Again, we estimate the population density within predefined radii of each school using population counts and land areas of the smallest Census unit (Output Areas). So, formally, these are all kernel estimates of school density, proportion of developed land and population density at the school site, using a uniform kernel. With this data in hand we next proceed to estimate the models described in section 3. The next section describes and discusses our results.

5. Results and discussion

5.1. Descriptive statistics

The descriptive statistics on the main variables we will use in the regression analysis are presented in Table 1. As described in section 4.1, attainment at age 16 is based on percentiles derived from pupil point scores relating to end-of-school qualifications; attainment at age 11 and 14 instead is measured in percentiles derived from Maths, Science and English tests. Since the descriptive statistics of these pupil attainment percentiles are not very interesting (being

[4] The data is provided by the Centre for Ecology and Hydrology, Huntingdon, Cambridgeshire, England

determined by construction) we show only those for attainment at age 16; more interesting is instead the change between ages 11 and 16 (educational progress). As expected, this is close to zero on average and, although there is substantial variation across pupil attainment at the two ages, these are highly correlated: From these figures it can be deduced that the correlation between pupil attainment percentiles at the two ages is 0.69[5].

Our empirical goal is to see to what extent these shifts up and down the achievement distribution are linked to the urbanisation of the school environment; the next four rows of Table 1 summarise the urban indices we set out in section 4.2. We investigated various radii (kernel bandwidths) for estimating these indices – 2km, 5km and 10km – but report results only for the 2km bandwidth. Preliminary experimentation indicated unambiguously that there is no additional information in the 5km and 10km-based estimates that is relevant for the attainment models we estimate below: When the indices are entered in our regressions simultaneously, the coefficient based on the 2km-based measure always dominates in terms of magnitude and statistical significance.

Looking back at the summary statistics we can see that there is a lot of variation in school setting in England: The number of neighbouring schools within 2km varies substantially ranging from 0 to 63, with a mean of 10 and standard deviation of 7.4. The map in Figure 1, which illustrates the number school per square kilometre in and around the Greater London area, suggests that school density is picking out inner city locations in particular; yet, even within London, the number of schools per square kilometre varies widely over short distances. The proportion of neighbouring land that is defined as continuously developed varies from 0 up to almost 90%, though on average, schools are in locations where only 17% of land is urban under

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[5] $Cov(age11, age16) = 0.5x(28.8^2 + 28.8^2 - 22.8^2) = 569.5$

$r = \frac{569.5}{28.8^2} \cong 0.69$

this definition. It should be pointed out that this definition also mainly captures development in inner city settings; land that is a closely integrated combination of buildings and open spaces (e.g. gardens) is classified as suburban and rural developed. Finally, looking again at Table 1, it can be seen that neighbouring population densities vary widely too.

These findings are not wholly unexpected, since we know that England contains a wide mix of urban, suburban and rural schools. Perhaps more surprising is the range of variation in the *change* in school setting that occurs when pupils move from Primary to Secondary school, though its average is close to zero[6]. The change in the number of local schools varies between a decrease of 58 and an increase of 59 (almost the whole range possible), with standard deviation of just over 4.5. Pupils experiencing the biggest shift from high-density to low-density environments see an 84 percentage point fall in the proportion of developed land surrounding their school; a change that is mirrored by pupils moving from low-density to high density locations. This variation is exceptional, while the standard deviation is much more modest – at about 11 percentage points; additionally, these changes seem quite exaggerated considering that pupils typically move to Secondary schools that are fairly close to their Primary schools.

Indeed, this distance is going to be important when it comes to interpreting our results: Are the changes in urban density predominantly the result of long-distance movements of pupils between rural and urban locations, or between inner and outer metropolitan locations; or are they the result of small shifts in urban context that occur within cities, towns and other localities? As we can see in the last two rows of Table 1, the typical distance a pupil moves between Primary and Secondary school is quite low: The median is only 1.67km. However, the distribution is

[6] So apparently, Secondary schools are not located in predominantly more urban areas, though the results on urban development and population density might be slightly misleading since Secondary schools usually have much larger sports grounds, and so are likely appear to be in lower density and less developed locations than Primary schools.

highly skewed with a mean of nearly 6.6 km, the top 10% moving over 7.6km and the most mobile 1% of pupils moving over 160km.

Finally, we note that our chosen urban indices are – as expected – highly mutually correlated with correlation coefficients as high as 0.87. This is obviously going to limit the capacity of our regression analysis to disentangle their relative contributions, though, as it turns out, this is not infeasible given our sample size. We consider this issue at the start of the next section, where we begin the analysis of the impact of urban density on pupil attainment.

5.2. Estimates of the attainment models

We move now to regression estimates of the models described in section 3. With these, we want to test whether pupils educated in denser urban settings perform at least as well, better, or worse, than other pupils, once we fully control for pupil and school disadvantages. As a start, Table 2 presents the results from various specifications incorporating our urban indicators – described in section 4.2. Note that the rows report coefficients from three different regressions, one with school density (Row 1) as the urban indicator, one with *both* types of developed land cover entered together (Rows 3 and 4), and lastly one in which population density enters individually (Row 5).

Column (1) shows the raw Ordinary Least Squares (OLS) association between age-16 attainment percentile and the urban density of the school in which the pupil takes their GCSE/NVQ examinations. In this column there are no controls for pupil or school characteristics. It is immediately clear that attainment is, on average, worse in schools in denser urban areas – regardless of which measure of urban density we use. The coefficient in the first row shows that an additional school within 2km (i.e. 0.0008 schools per hectare or 0.000008 schools per km^2) is associated with a drop in pupil attainment of just under 0.28 percentiles. This means that children in schools in the densest urban areas are around 8.4 percentiles in the attainment distribution below others in their cohort who are in the least dense areas (based on a four standard deviation difference of 30 schools per km^2). Similarly, if we consider land-cover (Rows 3 and 4), we see that schools in areas with more continuous urban or sub-urban development have lower-performing pupils, and the picture is the same for population density. All these other urban measures give a similar picture in terms of magnitude: A four standard deviation increase in urban density is associated with a six to seven percentile attainment gap. Moving to Column (2), we now add controls for basic pupil characteristics – ethnicity, gender, and indicator of entitlement to free school meals (poverty) and an indicator that English is the pupil's first language. This attenuates the coefficients slightly, but the overall picture is unchanged: Pupils in dense areas are doing badly.

As discussed earlier, we conjecture that this association could be the result of sorting into urban areas of more disadvantaged children, with abilities and background characteristics that are less conducive to academic achievement; it is obvious and well known that the poor live, predominantly, in cities. The 'value-added' attainment model in Column (3) shows that this conjecture is, by and large, correct. This specification differences within pupils between Primary (age-11) and Secondary (age-16) schools (and hence differences between ages) and so removes any (unobservable) factors that are fixed for individuals over time or for the same pupil in the two different schools; these include innate abilities and family background, and, for the vast majority of pupils who do not move house between the two schooling phases, neighbourhood influences from residential location too[7]. The results are striking: Pupils experiencing a relative increase in the density of their school location when they change from Primary school to Secondary school *move up* the attainment distribution relative to other pupils in their cohort. The

[7] Based on information in our data, we can calculate that only 10% of pupils change their residential address between the end of Primary school (age 11) and the end of the Secondary phase (age 16).

expected attainment gap for someone experiencing a two standard deviation increase in urban density relative to another experiencing two standard deviation decrease is around 2.5 – 2.8 percentiles. This is a substantial difference, and is comparable to the gap between poor pupils who are entitled free school meals and others, and only slightly less than the gender gap (4 percentiles), which has been the subject of much academic attention. Even so, the gains are not large enough to close the gap in the *level* of attainments of pupils in the most urban schools relative to students in more rural areas at the end of Secondary compulsory education (which we showed to remain as large as 8.5 percentiles). Note finally, that the suburban/rural developed land cover is not significant in the value-added models – it is the influence of central urban location (measured by continuous urban land cover) that is most closely related to attainment.

The remaining columns of Table 2 check the robustness of our results to inclusion of other controls and school fixed effects. In Column (4) we allow for Primary school fixed effects, such that we compare pupils who move from the same Primary school to Secondary schools in differing settings; in other words, the coefficients are estimates of the influence of Secondary school density on the age-11 to age-16 changes in attainment, conditional on Primary-school specific attainment trends. Column (6), replaces Primary fixed effects with Secondary school effects, so now we identify from pupils who share the same Secondary school trend but originated from Primary schools in locations with differing urban density. With school fixed effects, the coefficients in Columns (4) and (5) are slightly lower than in (3), but the message is still the same: Pupils in higher density locations can expect higher attainments than students with comparable characteristics in low density locations.

In terms of magnitude, there is not much to choose between the various urban indicators employed in these value-added specifications (except suburban/rural developed, which is always non-significant), although interestingly the coefficient on our measure of school density is always more statistically significant than the others. In the results in the next section, we will try to disentangle the relative influence of these indices as best we can.

Note finally that most schools in England have been established for a long time and their location is driven predominantly by long-standing housing and population patterns, so it is very unlikely that school density is endogenous to pupil attainment through school location decisions. This is in contrast to the standard empirical models of agglomeration economies in production, where firms and employees choose where to locate, and hence employee and firm density is clearly endogenous to the productivity of those locations. Also, in our specifications, we have effectively ruled out endogeneity arising from sorting of pupils on the basis of fixed-over-time pupil or family characteristics. Yet, we have not ruled out other sources of endogeneity: For instance, certain types of high productivity schools may be historically located in predominantly urban locations for reasons unconnected with urban density (Faith schools perhaps – though in other work, Gibbons and Silva [13], we show that the academic advantages conferred by Faith schools are small); or pupils who progress faster may have a preference for certain schools or types of school that tend to be located in urban areas. In the following sections we try to address some of these issues.

5.3. Estimates of one and two-way fixed effects models

Table 3 presents results of more fully specified models of age-11 to age-16 pupil attainment gains, which include the three urban indices – school density, land cover, and population density – together. Since it does not seem relevant either theoretically or statistically (from Table 2), we drop the suburban land-cover indicator.

Notice that, in addition to the controls described in Table 2, we include the mean age-11 attainment of the age-16 Secondary school pupils (unless the model has Secondary school fixed effects) and a dummy variable indicating if the pupil switched in or out of the standard secular

Community school sector, for example into or out of a Faith school or a school run by other charitable foundations. These controls may be important because there are differences between the spatial distribution of Faith and secular schools and we want to rule out the possibility that the association of attainment with urbanisation is driven by covert selection of higher ability pupils into religious schools (West [45])[8]. Moreover, other work on similar data has shown that mean peer-group attainment at the start of Secondary school has a small but significant impact on pupil progress through Secondary school (Gibbons and Telhaj [14]). Broadly speaking, these additional regressors allow us to control for general effects of peer characteristics and composition within schools on individual attainments.

Looking at Column (1), school density wins out convincingly in the 'fight' between these highly-correlated urban indices: The coefficient on population density is near zero and completely insignificant; the coefficient on urban land cover is sizeable, but also insignificant. Undoubtedly, there are many things that are correlated with school density that we have not taken into account here; we make no claim at this stage that it is actually school density that has a causal impact on attainment. Yet, our findings suggest that aspects of the urban environment associated with high school density – such as accessibility and choice, competition or cooperation – are conducive to higher attainment, a conjecture to which we will return later in section 5.6. Column (2) repeats this analysis with Secondary school fixed effects. This does not make much difference to interpretation of the school density coefficient, though we have stronger evidence of a more general association with urbanisation reflected in land cover; this might suggest that urban density in Primary Schools has a larger effect on earlier age-11 attainments,

[8] Yet, it is important to remark that these schools are public-sector schools (funded by the central government, via the Local Education Authority) and that none of them operates selection openly based on ability. See more institutional details in Gibbons and Silva [13].

than urbanization in Secondary schools has on age-16 achievements. On the other hand, we find a small but weak negative association between educational progress and population density.

Appendix section 10 outlines how we can estimate urban density influences whilst controlling for Primary or Secondary influences *and* residential postcode fixed effects, and discussed methods of implementation. This strategy controls for trends in educational achievements shared by individuals within the same Primary or Secondary schools; these may arise from school institutional features or unobservable school preferences shared by schoolmates and their parents. The strategy also controls for unobservable characteristics common to families sorting into the same residential neighbourhoods, and other local unobserved amenities which may affect pupil value added.

Columns (3) and (4) of Table 3 present the results of this exercise. In Column (3), we compute the postcode fixed effects on an LEA-by-LEA basis and then estimate a final Primary within-groups model on the full sample with the estimated postcode effects entered as a regressor. Even with this very stringent specification, we find a robust link between urban density and pupil attainment. The impact of school density is almost unaffected in both size and significance relative to the earlier results, while proportion of urban land and population density still do not play a significant role. In Column (4) we include postcode fixed effects in the Secondary fixed effects model; this also makes little difference. Overall, it seems that whatever we are picking up in terms of density influences on attainment, this is not related to place of residence (including residential neighbourhood effects and unobserved family background influences), but more genuinely to a change in school location.

Given the results so far, there seems little doubt that a relative increase in urban density on transition between Primary and Secondary school is linked to small but significant improvement in mean pupil attainment. This is true even if we control for Primary school fixed effects, Secondary school fixed effects, postcode fixed effects or combinations of these. The results in remaining tables and the discussion in the sections that follow try to shed some light on possible sources and scope of these gains from urban density.

5.4. Geographical scope: Who benefits?

In this section we try to uncover the sources of the 'density' attainment advantage by considering which groups of pupils gain and which groups lose after the transition between Primary and Secondary school. We do this in Table 4, which shows the impact of urban density on attainment for various sub-groups of the population. All the models are age-11 to age-16 value-added models, with the same controls as in Table 3, Column (1); the results for this specification are repeated in the first column of Table 3 for comparison.

A first question to ask is whether the density effect is driven predominantly by pupils moving from high-density (e.g. urban) locations or by those moving from low-density (e.g. rural) locations. We consider this first by splitting the sample into pupils originating in Primary schools in the bottom (Column (1)) and top (Column (2)) density quartile. Looking at the coefficients in the table we see that the magnitude of the relationship between school density and attainment is similar for both groups, though the point estimate is considerably larger and more significant for pupils starting out in high-density Primary school locations. This is, perhaps surprising: The main gains arise not from pupils moving from low-density areas, but amongst pupils *already* schooled in high-density locations who either: a) Loose out through moving to lower density Secondary school locations; or b) Gain by moving into higher density locations within the top quartile.

Coming at this from a different angle, we next split the sample into two other groups: those who make a school transition that results in a top-quartile change (rise) in school location density, and those whose transition results in a bottom-quartile change (fall) in density. Again, looking at Columns (3) and (4), we see that, although both groups seem to experience relative gains from density increases (or relative losses if density decreases), the effect is strongest amongst those whose Secondary school is in a less dense location than their Primary school.

Apparently, what we are seeing is *not* easily explained by simple agglomeration or urbanisation stories in which rural or semi-rural pupils gain from moving into urban locations for their Secondary schooling. We can see this even more clearly if we consider the distance between the Primary and Secondary schools that pupils attend, as in Columns (5) and (6). The first of these columns reports the results for the sub-group of pupils whose Primary-Secondary distance is in the lowest quartile (<900m) and the second for the upper quartile (>3.6km). Surprisingly, there are positive attainment impacts from school density for both groups, though as we would expect these are much larger and much more statistically significant for the long-distance movers. Even so, many of the moves in this upper quartile are still quite short and it is doubtful that many of the density changes in our data are really the result of major transitions between rural and urban locations; they mainly capture more marginal changes amongst lower and higher density places in urban settings. This is revealed even more explicitly when we look at the distinction between pupils moving schools within London and those moving within the rest of England: Columns (7) and (8) report results for this sample split. We see here that school density is strongly linked to pupil attainment even for pupils moving within the metropolitan London region – moves that are clearly not in any way rural-urban – though the association is there for the out-of-London pupils too. Finally, the same argument carries over to Columns (9) and (10) where we split by pupils making the primary-secondary transition within Local Education Authorities (by far the majority) and those moving to secondary schools in a different LEA. Again, although the magnitude of the link between school density and achievement is bigger for pupils making between LEA-moves, the difference between these groups is not enough to suggest local labour markets as the driving factor.

5.5. Robustness checks: Strategic behaviour, mean reversion, pre-transition trends, greater urban heterogeneity?

One possible and slightly mundane explanation for what we have found is that pupil attainment is measured inappropriately. Our measures at age 11 and at age 16 may not really be directly comparable, because pupil percentile score at age 11 is based on tests in Maths, Science and English only, whilst at age 16 it is based on a wide range of different tests in different subjects (though Maths, Science and English are compulsory subjects). Pupils can sit a number of tests of different varieties (GCSEs and National Vocational Qualifications at different levels), but the mix will depend to some extent on school expertise. Schools tend also to be evaluated on the basis of the proportion of students passing at least 5 GCSE grade C exams or equivalent (GCSEs are graded between G and A*), so there are incentives for schools to act strategically to maximise the number of students reaching this target. This may mean, for instance, that it is in the school interests to encourage pupils to qualify in many exams at a moderate grade, rather than excel in just a few; also, pupils may be encouraged to switch to 'softer' options to maximise their chances of success. Clearly there would be a problem in terms of the interpretation of our results if they are driven by some link between urbanisation and the incentives for schools (or pupils) to act strategically in this way. We go some way to allaying these fears in Columns (1) and (2) of Table 5, which present results for alternative measures of attainment; to keep things simple we just consider school density as the urban index here, where we observe most of the action. In the two columns, we still focus on age-16 attainment, but look at pupil percentile based on mean grade (points) across all their GCSE/NVQ subjects rather than on total points added up across subjects. The results here are almost identical to before, so it does not seem that strategic behaviour in terms of 'numbers' versus 'grades' can explain our findings.

Another issue is that, as we have noted, pupils enrolling in urban schools tend to be those with lowest attainments and from the most disadvantaged backgrounds. Pupils in urban schools may then experience the fastest 'value-added', simply through reversion towards mean attainment at later stages in their education. Since we consider the value-added arising from changes in school density, the issue for us is whether pupils experiencing the biggest changes in density when they move school are those starting from the lowest base in terms of their initial conditions; or more pertinently, whether it is only the children starting from a low-attainment base that appear to benefit from transition to a higher density school. Unfortunately, we cannot observe initial attainment (prior to age-11) for the cohorts on which our estimates are based (the time series in our data is not yet long enough). However, we can calculate the mean age-7 attainments of other age-cohorts in the Primary schools from which these pupils originate, in order to investigate if indeed it is only those pupils from Primary schools enrolling students with poor initial conditions who seem to gain ground in terms of academic achievement. To test this we repeated our age-11 to age-16 value-added regressions with interactions between Primary school mean age-7 attainment and the change in urban density when pupils move between Primary and Secondary school. As it turns out, the pupils from schools in the lowest attainment decile do experience a bigger gain from greater urban density, while pupils in the highest attainment decile gain the least; yet, none of these differences is statistically significant from the main effect of changing urban density that we have already reported.

A third argument against a causal interpretation of our urban density impact is that we cannot properly account for pre-existing trends in pupil performance. Perhaps, what is happening is that pupils on more rapidly rising attainment trajectories are also those who experience the biggest change in urban density, through their choice of Primary and Secondary schooling. In fact, it is difficult to see clear theoretical justification for why this should be the case, and our previous estimates imply that the pupils showing the fastest progress must both: a) Prefer lower density Primary schools, conditional on choice of Secondary school and place of residence; and b) Prefer higher density Secondary schools, conditional on choice of Primary school and residential neighbourhood. There is no obvious way to reconcile these patterns with any consistent preferences that might be related to pupil attainment trends. However, one might conjecture that schools in denser places are somehow picking the pupils most likely to progress, and that they do so to a greater extent for students who attended a Primary school in a more rural environment; we would clearly like to rule this out as a candidate explanation for our findings[9].

As explained above, we do not have information on pupil attainment trends prior to the Primary-Secondary school transition for these cohorts. We can however, provide a weaker test based on the deviation of the age-11 to age-16 attainment gain from a linear trend, using an intermediate measure of attainment at age 14. This is done in Column (3) and (4), where the dependent variable is the difference between age-16 and age-14 percentile, minus the difference between the age-14 and age-11 percentile – i.e. the acceleration in attainment. The coefficient in Column (3), which includes pupil characteristics, Primary fixed effects and an indicator for transition in or out of Community schooling suggest that attainment *does* rise at a faster rate in more densely located schools, so our main results are not solely due to pupil pre-existing linear attainment trends. Controlling for secondary school peer group quality (in line with earlier specifications) attenuates this effect slightly, but it is still evident that sorting of pupils with heterogeneous performance trends cannot be the main story behind our findings.

As one further step, we devise an Instrumental Variable (IV) strategy based on differences in travel costs at different home locations, which change behaviour over school choice in ways that are not directly related to pupils' expected growth in achievement. Our argument is that

[9] In fact, we are partly controlling for this by including a dummy for individuals who switch out of secular Community schools at the end of the Primary phase to opt, for example, for Church Secondary schools or schools run by other charitable foundations; West [45] suggests that these institutions may still operate some forms of 'covert' selection.

individuals having easy access to public transport in metropolitan areas are likely to travel longer distances to Secondary school and experience the biggest changes in urban density on transition from Primary to Secondary school; so, our strategy is to predict the change in urban density experienced by pupils on transition from Primary to Secondary school using proximity between pupil homes and underground or railway stations within a metropolitan area. To implement this approach, we confine our attention to pupils living in London and attending Secondary schools in London when they are aged 16. Although movements in either direction seem possible – i.e., either towards the centre or the periphery of the metropolitan area – we argue that living near a station in London makes it more likely that a pupil travels in towards the centre of town; this is because it is only in this direction that the rail network brings pupils anywhere close to Secondary schools[10]. So, we construct the following instruments: two measures for (straight line) distance between individuals' residential postcode and the closest train and underground stations, within 2km of home; and two dummies indicating whether there are no railway or underground stations within 2km of residential location[11]. Results from using these instruments for the change in school density are reported in Columns (5) and (6) of Table 5. Column (5) includes the set of controls detailed before, while in Column (6) we add Postcode District fixed effects to control for

[10] This is simply a feature of the geographical density of schools and stations, which both increase towards the centre of London. This means that it is much more likely that a Secondary school can be reached by walking from a station in inner London, than by walking from a station in the outskirts. This intuition is borne out by our results.

[11] Critical to this instrumental variable approach is the assumption that residential choice in relation to transport access is not linked to unobserved individual and family characteristics or other local amenities that may affect pupil educational outcomes. In our defence we should emphasize that our value added models already deal with pupil unobservable attributes (including family background and preferences) that are fixed over time.

broad geographical differences[12]. First stage statistics are reported at the bottom of the table; for both the specifications, they show our instruments to be powerful predictors of changes in urban density and not significantly correlated with unobservable characteristics which may affect educational progress. The second-stage IV estimates confirm that pupils tend progress faster if they move to more densely located schools; the coefficient on the change in the number of schools within 2km is larger than before[13], though its statistical significance is greatly reduced. Apparently, pupils facing lower travel costs are more likely to experience bigger changes in their educational achievement. This lends further support to the idea that a relative increase in urban density on transition between Primary and Secondary school is linked to small but significant improvement in pupil attainment.

Finally, we consider briefly whether our regressions – which are based on what happens to pupils on average – mask a heterogeneity in school quality that belies our general point that urban schools are not systematically failing: Perhaps there really are many more 'very bad' schools in dense places, but these are more than compensated by many 'very good' schools in similar situations. This argument implies that the variance in school quality is higher amongst schools in dense urban settings, a point which we can easily test by regressing the square of our regression residuals (from the specification in Column (1) of Table 3) against the urban indicators and other regressors (i.e. an *à la* White's test for heteroscedasticty). The results of this exercise suggest that there is no statistically significant link between urban density and the variance in attainment; the F-test on our three urban indicators yields an $F(3,2816)$ statistic of

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[12] Full UK postcodes are typically of the form AB# #CD, where # is numeric. Deleting the last three characters generates a Postcode District code. There are more than 400 Postcode Districts in the extended London region.

[13] Although it is comparable to the estimates for the number of schools only (Column 5, Table 2) and for the London area only (Column 8, Table 4).

0.18, with a p-value of 0.9085. In other words, higher urban density seems to be associated with a rightwards-shift throughout the distribution of school quality[14].

5.6. Looking for an explanation: School choice and competition, resources or policy?

In the discussion so far, we have shown that pupils progress faster between ages 11 and 16 when they move school from low to high density locations, and that they progress more slowly when the change is in the other direction. We have also emphasised that school density seems to be the driving factor behind this. In what follows, we try to unpick what aspects of school density matter and why, and to consider the role of local educational policies.

The results in section 5.4 seemed to rule out explanations based on better functioning urban teacher labour markets, deeper pools of competent teachers in urban settings, and other broad urbanisation, or agglomeration-based explanations. The distances between Primary and Secondary schools are simply not large enough for these explanations to make much sense; moreover we can detect a density impact on attainment amongst pupils moving short distances within Local Education Authorities and within metropolitan areas[15]. We have also ruled out strategic course choice selection and selection of pupils with stronger attainment trends into schools in denser settings.

What other explanations are on offer? Although we argued that the inter-school distances over which we detect an effect are not large enough for these schools to be operating in distinct

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[14] A better test might be to use quantile regressions, but this proved infeasible given our model specifications and sample size.

[15] Additionally, we have tried to include in our specifications the change (between Primary and Secondary education) in the number of qualified teachers and the change in number of pupils, within 2km from the school. Unfortunately both indices are highly collinear with the change in number of schools and the results from this exercise were uninformative.

teacher labour markets, they can be operating in zones facing very different markets in terms of pupils and competing or cooperating schools. Indeed, because catchment areas for schools are geographically based and quite localised, two schools just a few kilometres apart in an urban environment may face a very different set of potential pupils and different set of schools with which they are effectively competing. Similarly, two such schools may be linked to entirely different networks of other schools with which they cooperate and share knowledge; such networking and cooperation in professional development is a heavily promoted aspect of current Government educational policy (e.g. NCSL [38] and the 'Beacon' initiative described above). So perhaps the underlying story is one in which school density – and the competition or networking opportunities that it engenders – is the driver behind the density-attainment link.

There is only so far we can go with testing this hypothesis with the data at hand, but we provide some additional evidence that is supportive of this interpretation. In the first column of Table 6, we split up the school density index into two components: The number of Primary schools within 2km and the number of Secondary schools. All specifications in the table are for pupil gains in attainment between ages 11 and 16, and include Primary school fixed effects and the usual controls.

What is apparent here is that *all* the impact of the change in density on the change in attainment between ages 11 and 16 arises through the number of neighbouring Secondary schools, not the number of local Primary schools. This is exactly what we would expect if it is choice, competition or cooperation among co-located schools that matters. This is because, when we include Primary school fixed effects, it is only variation in the density of schools near the Secondary school of destination that identifies the coefficient on school density. If school markets matter, then only the density of Secondary schools should be relevant at the Secondary phase; Primary schools do not provide competition, and are unlikely to be closely networked with Secondary schools. This result is robust to the inclusion of postcode and Primary school fixed effects in the two-way fashion detailed before (not reported in Table 6).

Pupils in denser locations may also perform better because schools in these locations are better resourced and are part of Government initiatives to encourage collaboration and boost performance. Indeed, a recent raft of Government policies has been targeted specifically at 'failing' inner city schools in disadvantaged areas in an effort to raise attainments and improve other school-related outcomes. Others have found evidence of benefits arising from these policies (Machin et al. [30]). Perhaps then, what we observe may be the benefit to pupils attending schools in locations subject to these policy initiatives.

In Columns (2) and (3) of Table 6, we address this question by adding some controls for basic school resources to our attainment models. These are average expenditure per pupil within the Local Education Authority that funds schools, the number of qualified teachers in the school, plus indicators of whether or not the Secondary school comes under the umbrella of various city-related educational policy programmes; these initiatives are: 'Excellence in Cities' (EiC), which puts additional money into areas facing disadvantages, and was rolled out over three phases in 1999, 2000 and 2001 followed by a 'Clusters' scheme focussed on group of schools from 2001 onwards; and 'Education Action Zones', which are groups of schools in disadvantaged areas which receive extra funding, face tougher targets and receive other assistance. Additionally, we control for the number of pupils enrolled at the school, mainly because school funding in England is linked to pupil numbers. Looking back at Table 6, the signs of the coefficients on the resources variables in the attainment models are as expected and the impact of additional teachers is statistically significant, but the EiC and Education Action Zone dummies are insignificant and unsystematically signed (not reported)[16]. The specifications in Columns (2) and (3) are otherwise comparable to those in the first column. Moving right across these three, it can be seen that the impact of Secondary school density is unchanged after controlling for resource differences. Clearly, differences in resources matter, but are not responsible the difference in pupil attainment between dense and less dense school locations.

Next, in Columns (4) to (6) of Table 6, we speculate further about possible mechanisms that could give rise to the link between the number of local Secondary schools and pupil performance. In Columns (4) and (5) we run the regression separately for Community Secondary schools and non-Community Secondary schools. As detailed in Gibbons et al. [12], the institutional arrangements of non-Community schools (e.g. structure of Governing bodies, control over admission practices, teacher management and governance) may make these institutions more responsive to the incentive of competition from closely co-located schools. In line with this intuition, we find that our results are mainly driven by the effect of changes in school density for pupils enrolled in non-Community Secondary schools, where the coefficient on the number of Secondaries is above 0.4 and significant at the 5% level; this compares with a smaller and marginally insignificant effect of school density for pupils in Community institutions.

Finally, we investigate whether co-operation among near-by schools and networks of local professionals lie behind our correlations; to do so, we include in our specification variables counting the number of 'Beacon' schools (separately for Primaries and Secondaries) within 2km

[16] The negative sign on some of the policy dummies presumably indicates that the decision to include a school under the programme is endogenous to average pupil performance, rather than that the policy had adverse impacts.

of the school[17]. As discussed above, under the Beacon scheme, institutions that deliver outstanding teaching and managing practices are awarded a 'beacon' status to represent examples of successful practices and help neighbouring schools achieving similar standards, through the creation of partnerships and organization of joint initiatives. We also include a term counting the number of Independent (private) schools within a 2km range from the school; this should shed some light on whether the competitive threat posed by a large number of local private institutions raises educational standards in the public sector (as claimed, among others, by Epple and Romano [10] and Hoxby [22]).

Results from this exercise confirm that the number of Secondary schools has a positive and significant effect on pupil educational progress. We also find some link between local Beacon schools and pupil achievement, although the effect is mainly driven by the number of Primary Beacons; this seems more likely to be due to unobserved aspects of neighbourhoods and Secondary intake quality rather than any direct causal impact from networking with Beacon primaries. Finally, the number of Independent schools never enters our specifications significantly; at least in this context, private school competition does not raise state-school average performance. The link between the change in urban density and pupil educational progress during Secondary school thus seems primarily related the competition forces that are in place among closely co-located state Secondary schools, or cooperation of a different sort from that set up through the Beacon scheme.

[17] When the number of Beacons is added to the specification, we also include a dummy to control for the Beacon status of the school itself.

6. Conclusions

Although pupil attainment in dense urban places is low on average, this is not because urban environments disadvantage pupils but because disadvantaged pupils with low average attainments attend the most urbanised schools. Our results show that comparable pupils progress *better* in schools located in denser urban settings, where by urban density here we mean higher density of schools, more continuous urban land cover and higher population density. Interestingly, amongst these three factors, school density generally dominates as an explanatory factor.

Our results additionally show that progress during Secondary school is linked explicitly to the density of local Secondary schools and conditionally unrelated to Primary school density. Whilst certainly not conclusive, this is indicative of localised educational effects related to inter-school competition. We have also shown that the density impact on attainment can be measured amongst pupils moving between schools that are in quite close proximity within Local Education Authorities and within urban areas. For this reason, it seems very unlikely that these 'density' economies can be attributed to teacher labour markets or other sources of urbanisation and agglomeration advantages usually cited in the context of firm productivity.

From our estimates, we can derive the elasticity of pupil attainment with respect to school density: This is low – less than 0.02 – but it still implies that pupils educated in the most dense environments could gain around 2-3 percentiles in the national pupil attainment distribution relative to others in their cohort educated in the least dense settings. This is quite substantial, in relation to the total contribution of schools to pupil attainment, considering that pupils in the top 1-in-10 schools in terms of attainment are, on average, only 20 percentiles above pupils in the bottom 1-in-10 schools. Even so, the gains are not large enough to close the attainment gap between pupils educated in urban schools and students in more rural areas at the end of the Secondary compulsory phase. This is due to city schools enrolling children with major background disadvantages, rather than low school effectiveness; sensible policy interventions should be targeted at tackling inner city high levels of deprivation and poverty.

Interestingly, but perhaps just coincidentally, the elasticity of pupil achievement to school density is at the lower end of the range of estimates on the effects of urban size and density on firm productivity, in the 0.03 to 0.08 range[18].

[18] See Rosenthal and Strange [44] for an international survey, and Rice and Venables [42] and Graham [17] for British evidence.

7. References

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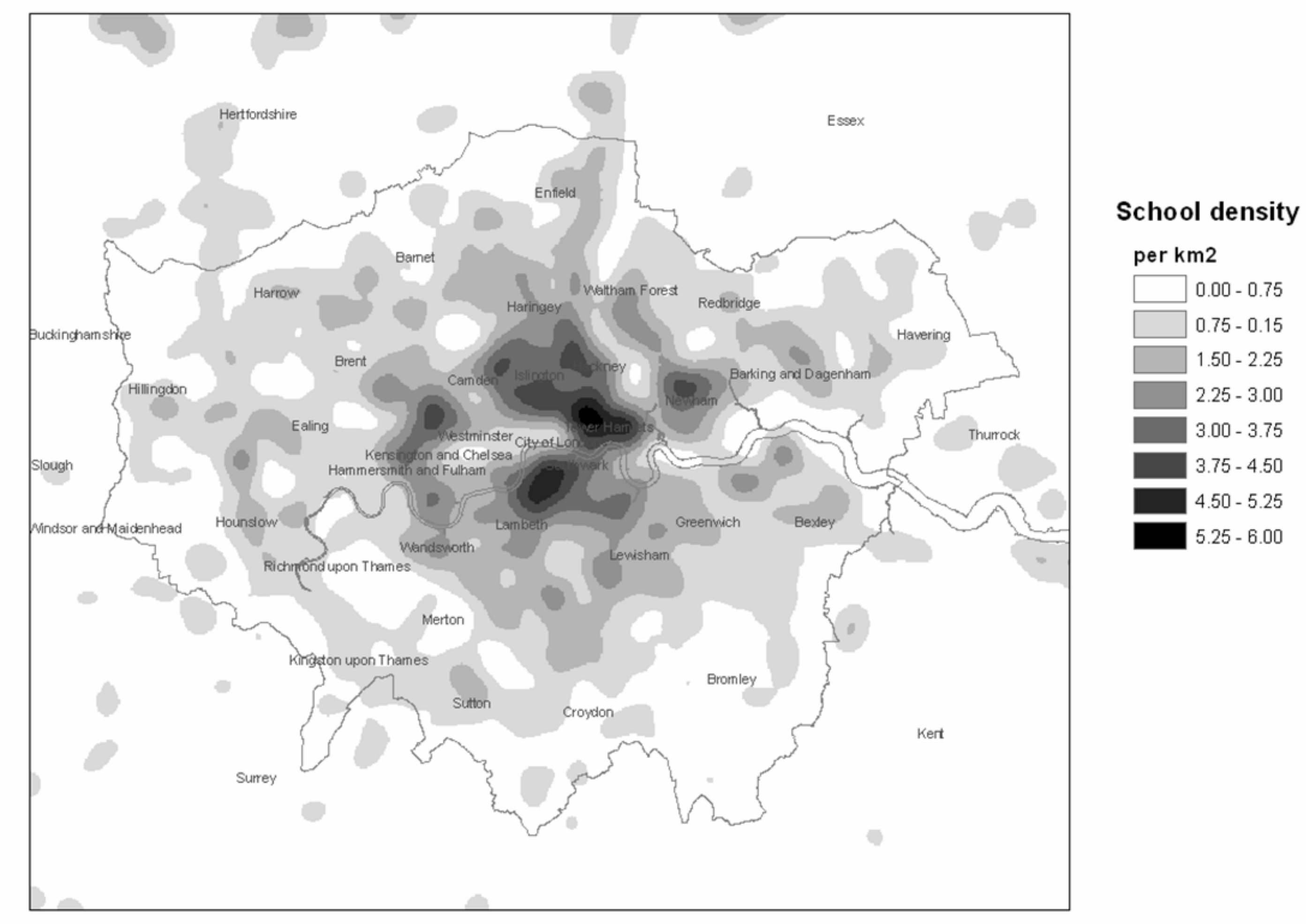
8. Figures

Figure 1: Density of schools, illustrated for the London area



Notes: Figure shows Kernel density estimates for total school density in the Greater London region and environs. In our estimates we use information for the whole of England.

9. Tables

Table 1: Descriptive statistics for age-16 sample

Variable	Mean	Std.Dev.
Percentile attainment at age 16	49.939	28.842
Change in percentile age 11-16	-0.029	22.852
Number of schools within 2km	10.089	7.445
Proportion continuous urban within 2km	0.172	0.180
Proportion suburban/rural developed within 2km	0.300	0.139
Population density within 2km (per hectare)	26.554	19.328
Change in number of schools within 2km	0.014	4.590
Change in proportion continuous urban within 2km	-0.014	0.108
Change in proportion suburban/rural developed within 2km	0.013	0.109
Change in population density within 2km	-0.711	11.977
Number of Primary schools within 2km	7.836	6.136
Number of Secondary schools within 2km	2.343	1.593
Change in number of Primary schools within 2km	-0.322	3.850
Change in number of Secondary schools within 2km	0.352	1.316
Distance between Primary and Secondary school (km)	Mean = 6.594	s.d. = 28.984
	Median = 1.676	i.q.r. = 2.750

Note: Sample size 1,202,970 based on pupils with non-missing data from age 11 to age 16 in non-selective Secondary schools, excluding special needs schools. Population density is based on output areas of the 2001 Census and is in persons per hectare. Change in pupil percentile is non-zero because percentiles are calculated on sample of 1,202,566 pupils, with some missing data; pupil attainment percentile is based on total GCSE/NVQ points at age 16 and test scores in Maths, Science and English tests at age 11. Number of primary schools: approximately 14500. Number if secondary schools: approximately 2800. Number of LEAs: 147.

Table 2: Urbanisation and pupil attainment percentile age-16; various urban indicators

	Separate regressions for each urban indicator groups				
	(1)	(2)	(3)	(4)	(5)
	Level	Level	Age-11 to 16 Diff.	Age-11 to 16 Diff.	Age-11 to 16 Diff.
School density:					
Number of schools within 2km	-0.279 (0.029)	-0.210 (0.029)	0.139 (0.017)	0.120 (0.019)	0.131 (0.017)
Proportion developed within 2km:					
Continuous urban	-9.069 (1.158)	-7.044 (1.176)	6.322 (0.785)	4.404 (0.961)	5.979 (0.625)
Suburban/rural developed	-10.857 (1.466)	-9.668 (1.336)	0.494 (0.728)	-0.499 (0.814)	-0.731 (0.624)
Population:					
Population density within 2km	-0.093 (0.012)	-0.071 (0.011)	0.050 (0.007)	0.039 (0.008)	0.042 (0.005)
Pupil characteristics	No	Yes	Yes	Yes	Yes
Primary school effects	No	No	No	Yes	No
Secondary school effects	No	No	No	No	Yes

Note: Table reports regression coefficients from pupil level regressions. Standard errors in parentheses (clustered on Secondary school in Columns 1 to 4; clustered on Local Education Authority in Column 5). Underline significant at 1% or better. Dependent variable is pupil's percentile attainment at age-16, or percentile gain from age 11 to age 16. Pupil controls are ethnicity (8 categories), entitlement for free school meals, English as additional language, male. Models include year dummies. Level of urbanisation is proportion of 2km radius around school that is classified as continuous urban in 2000 (Landcover map 2000). Population density is persons per hectare based on population and land areas of 2001 Census Output Areas for which centroid is within 2km of school. Sample size approximately 1.2million. Number of primary schools: approximately 14500. Number if secondary schools: approximately 2800. Number of LEAs: 147.

Table 3: Urbanisation and percentile attainment gains; alternative one and two-way fixed-effects strategies

	(1)	(2)	(3)	(4)
	Primary fixed effects only	Secondary fixed effects only	Residential postcode and Primary	Residential postcode and Secondary
Number of schools within 2km	*0.087* (0.037)	0.100 (0.028)	0.083 (0.032)	0.098 (0.025)
Proportion urban within 2km	1.103 (1.440)	4.530 (0.795)	0.846 (1.289)	3.056 (0.809)
Population density within 2km	0.004 (0.015)	-0.015 (0.010)	0.008 (0.013)	-0.016 (0.009)

Note: Table reports regression coefficients from pupil level regressions. Standard errors in parentheses (clustered on Secondary schools in Columns 1 and 3; clustered on LEAs in Columns 2 and 4). Underline significant at 1% or better. Italics significant at 5% or better. Dependent variable is pupil's percentile attainment gain from age 11 to age 16. Controls are pupil ethnicity (8 categories), pupil entitlement to free meals, English as additional language, male dummy, year dummies, Community school dummy, Secondary school average age-11 attainment (Columns 1 and 3 only). Proportion continuous urban is proportion of 2km radius around school that is classified as continuous urban in 2000 (Landcover map 2000). Population density is persons per hectare based on population and land areas of 2001 Census Output Areas for which centroid is within 2km of school. Sample size approximately 1.2million (about 900,000 in Columns 3 and 4, where a minimum of two observations per postcode is needed). Number of primary schools: approximately 14500 in one way fixed effects models and 13200 in two way fixed effects models. Number if secondary schools: approximately 2800. Number of LEAs: 147.

Table 4: Urbanisation and percentile attainment gains; geographical scope

	-	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Whole sample	Primary school low-density	Primary school high-density	Low to high density move	High to low density move	Short distance move	Long distance move	Move not within London	Move within London	Move within LEA	Move outside LEA
Number of schools within 2km	*0.087* (0.037)	0.075 (0.029)	0.099 (0.029)	0.059 (0.036)	0.127 (0.028)	0.062 (0.035)	0.088 (0.023)	0.073 (0.019)	0.092 (0.036)	0.073 (0.019)	0.110 (0.029)
Proportion urban within 2km	1.103 (1.440)	-1.183 (1.300)	1.076 (0.936)	-0.158 (1.088)	*1.658* (0.800)	0.288 (1.529)	0.732 (0.885)	*1.672* (0.723)	-2.945 (1.982)	*1.472* (0.712)	-0.294 (1.193)
Population density (per hectare)	0.004 (0.015)	-0.011 (0.010)	0.018 (0.011)	-0.011 (0.010)	0.008 (0.009)	0.004 (0.011)	0.003 (0.009)	-0.004 (0.007)	0.045 (0.016)	0.003 (0.007)	0.005 (0.011)
Sample	1201894	327949	274365	258946	323025	314728	302363	1049819	135130	1082839	119055

Note: Table reports regression coefficients from pupil level regressions. Standard errors in parentheses (clustered on Secondary school). Underline significant at 1% or better (Italics significant at 5%). Dependent variable is pupil's percentile attainment gain from age 11 to age 16. Controls are pupil ethnicity (8 categories), entitlement to free school meals, English as additional language, male dummy, Community school dummy, Secondary school average age-11 attainment, year dummies, Primary (age-11) school fixed effects. Proportion continuous urban is proportion of 2km radius around school that is classified as continuous urban in 2000 (Landcover map 2000). Population density is persons per hectare based on population and land areas of 2001 Census Output Areas for which centroid is within 2km of school. Low and high density refers to bottom (≤5) and top (≥13) quartile of schools within 2km. Low to high density is top quartile change (and vice versa). Long and short distance refers to bottom (<0.9km) and top (>3.6km) quartile of distance between Primary and Secondary school attended.

Table 5: Urbanisation and pupil attainment; robustness of results

	Percentile based on mean age-16 points		*Acceleration in attainment, ages 11-14-16*		*Instrumental variable estimates*	
	(1)	(2)	(3)	(4)	(5)	(6)
	Levels	Age-11 to 16 Diff	Double-diff	Double-diff	Age-11 to 16 Diff	Age-11 to 16 Diff
Number of schools within 2km	-0.352 (0.029)	0 .082 (0.017)	0.098 (0.023)	0.067 (0.024)	0.205‡ (0.108) [0.122]	0.181 (0.113) [0.123]
First Stage Statistics						
F-Statistics	-	-	-	-	210.40 (0.0000)	198.41 (0.0000)
Hansen Statistics (p-value)	-	-	-	-	3.515 (0.319)	2.740 (0.4335)
Pupil characteristics	No	Yes	Yes	Yes	Yes	Yes
Primary school effects	No	Yes	Yes	Yes	Yes	Yes
Secondary school average peer achievement	No	Yes	No	Yes	Yes	Yes
Postcode Area effects	No	No	No	No	No	Yes

Note: Table reports regression coefficients from pupil level regressions. Standard errors in parentheses (clustered on Secondary school, expect Columns 5 and 6). Underline significant at 1% or better (‡ significant at 6%). Dependent variable is pupil's percentile gains from age 11. Controls are pupil ethnicity (8 categories), entitlement to free school meals, English as additional language, male dummy, Community school dummy, Secondary school average age-11 attainment, year dummies. Sample size approximately 1.2million (Columns 1 to 4). Instrumental variable in Columns 5 and 6 for London metropolitan area only; sample size about 140,000 observations. Instruments are: residential postcode distance from closest tube station and to closest rail station within 2km, plus dummies for no rail station and no train station within 2km of residential postcode. Column 6 additionally controls for postcode area fixed effects. First stage statistics from models with standard errors clustered at the postcode level (p-values in round brackets); second stage standard errors clustered at postcode level in round brackets and at the Secondary school level in square brackets.

Table 6: Urbanisation and percentile attainment gains; resources, policy interventions and school competition

	(1)	(2)	(3)	(4)	(5)	(6)
	All schools	All schools	All schools	Community only	Non-community	All schools
Number of state Secondary schools within 2km	0.363 (0.101)	0.363 (0.101)	0.374 (0.102)	0.250 (0.131)	0.439 (0.168)	0.332 (0.109)
Number of state Primary schools within 2km	0.016 (0.044)	0.005 (0.044)	0.005 (0.045)	-0.003 (0.052)	-0.005 (0.069)	-0.026 (0.046)
Number of qualified teachers (FTE)	-	0.065 (0.017)	0.066 (0.017)	0.066 (0.019)	0.044 (0.029)	0.064 (0.017)
Number of pupils x100 (FTE)	-	-0.321 (0.104)	-0.324 (0.104)	-0.302 (0.110)	-0.155 (0.186)	-0.321 (0.103)
Expenditure per pupil in Local Education Authority (£00s)	-	*0.080* (0.034)	*0.093* (0.041)	*0.095* (0.039)	0.036 (0.059)	0.074 (0.034)
Number of Beacon Secondary schools	-	-	-	-	-	0.039 (0.306)
Number of Beacon Primary schools	-	-	-	-	-	0.419 (0.160)
Number of Independent Secondary schools	-	-	-	-	-	-0.106 (0.083)
Number of Independent Primary schools	-	-	-	-	-	0.037 (0.120)
Urban land cover and population density	Yes	Yes	Yes	Yes	Yes	Yes
Urban school policies	No	No	Yes	No	No	No
Primary school fixed effects	Yes	Yes	Yes	Yes	Yes	Yes

Note: Table reports regression coefficients from pupil level regressions. Standard errors in parentheses (clustered on Secondary school). Underline significant at 1% or better (Italics significant at 5%). Dependent variable is pupil's percentile attainment gain from age 11 to age 16. Controls are pupil ethnicity (8 categories), entitlement to free school meals, English as additional language, male dummy, Community school dummy, Secondary school average age-11 attainment, year dummies, Primary (age-11) school fixed effects. FTE means full time equivalent. Column 6 also controls for whether current Secondary is a Beacon. Regressions in Columns 4 and 5 are run separately for pupils in Community Secondary schools and pupils in Secondary schools other than Community (Voluntary Controlled, Voluntary Aided and Foundation). Sample size approximately 1.2million (approximately 801,000 in Column (4) and 400,300 in Column (5)).

10. Appendix: Estimation of two-way fixed effects

The main challenge to estimating the two-way fixed effects models described by equation (3) in section 3 is the large number of school and postcode fixed effects that need to be estimated or eliminated, especially when we have a large number of pupil observations.

In the data for England (described above) we have over 14000 Primary schools, over 2800 Secondary schools, around 500000 postcodes, and data on over 1.2 million pupils. The simplest approach to estimating the full model would be to include either the 2800+ Secondary school or the 14000+ Primary school dummies as regressors, and de-mean the data using a within-groups transformation to eliminate home postcode fixed effects. Since this is infeasible on the full dataset of pupils, we follow a procedure inspired by a series of papers by Abowd and co-authors (Abowd and Kramarz [1], Abowd Kramarz and Margolis [2], and Abowd, Creecy and Kramarz [3]) for firm and individual effects. Our approach involves, as a first stage, using this estimator on sub-groups (A) of the full data set in order to estimate the postcode fixed effects for each sub-group. When this is complete, we use the full sample to re-estimate the model, using the either within-Primary or within-Secondary school transformation on a model that includes the postcode fixed effects estimated from the first stage as a regressor.

More formally, consider the case of Primary and residential postcode fixed effects; we estimate:

$$\Delta y_{i,jk} - \Delta \bar{y}^{l}_{i,jk} = \beta(\Delta u_{jk} - \Delta \bar{u}^{l}_{i,jk}) + (d'_{sk} - \bar{d}'^{l}_{sk})\delta + \upsilon_{i,jk}, i \in A \qquad (4)$$
$$\hat{n}_l = \Delta \bar{y}^{l}_{i,jk} - \hat{\beta}\Delta \bar{u}^{l}_{jk} + \bar{d}'^{l}_{sk}\,\hat{\delta}$$

for all subgroups A (defined below); then, on the full data set:

$$\Delta y_{i,jk} - \Delta \bar{y}^{j}_{i,jk} = \beta(\Delta u_{jk} - \Delta \bar{u}^{j}_{i,jk}) + \theta(\hat{n}_l - \bar{\hat{n}}^{j}_l) + \omega_{i,jk} \qquad (5)$$

Ideally, each subgroup A would be defined such that that it includes all pupils living in a specific set of postcodes R, who all attend Primary schools within a set P, to which no other pupils (other than those in R) are admitted. All the relevant postcode and Primary fixed effects could then be estimated consistently for each of these ‘autarchic’ systems using only data from pupils in each subgroup A.

In practice, school admissions systems are not so cleanly defined, but the process of identifying suitable groups is aided by the fact that admission in England is organised geographically by Local Education Authorities (LEAs). In most cases, pupils attending a school within a given LEA come from neighbourhoods within that LEA, or from a closely neighbouring LEA. So we form sub-groups A on an LEA-by-LEA basis and proceed using the following steps:

(a) For a given LEA L, draw all pupils who live in the set of postcodes R in that LEA, plus all pupils in a set Primary schools P which intersects the set R through pupil Primary school choice, i.e. pupils in a set of postcodes Q outside the LEA L, going to the same set of Primary schools P as pupils in R.

(b) Estimate (4) on this sub-sample of pupils (sub-group A), using dummy variables for the Primary schools P, allowing for postcode fixed effects for the postcode set R plus the set Q of postcodes that intersect with P through pupil Primary school choice, but are outside the LEA.

(c) Retrieve estimates for the postcode fixed effects for the set R, i.e. $\hat{n}_l$ in (4).

(d) Repeated for each LEA until all postcode fixed effects have been estimated.

(e) Estimate (5) using the full England sample and the estimated postcode effects from step (c).

Note that this is an approximate method, because at step (b) we have not used data on all pupils in the set of postcodes Q that are outside the LEA in order to compute the fixed effects Q. However, these postcode fixed effects will be estimated consistently if pupils in the set $Q \cap P$ are a random sample of all pupils living in postcode Q. Moreover, we do not use the estimates of effects Q in the last stage (e), but re-estimate them when we reach the LEA in which they are located during step (d). So, the only concern is that not estimating Q correctly (i.e. on the full set of pupils living in those postcodes) may bias our estimates of the Primary school effects P, which in turn could affect our estimates of postcode effects R. We checked the sensitivity of the results to these sorts of problems by re-defining our group A in various ways, for example by excluding Q completely and using only the sample of pupils in R. A similar method can be used to control for residential postcode and Secondary school fixed effects.