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Travel to School and Housing Markets: a Case Study of Sheffield, England

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Key words: active transport to school, excess commuting, housing markets, school choice, school travel, urban form

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Abstract

How children travel to school is at the centre of a complex set of interrelated issues with significant policy implications. This paper reviews the relation of patterns of travel to school to concerns about public health, school choice, urban form, and residential housing markets. The spatial relations between pupils' homes and the schools that they attend provides the basis of an analytical framework that links local neighbourhood characteristics, school performance, and house prices to the distance and mode of travel to school and the level of 'excess commuting' in the urban system. A unique analysis of several integrated micro-data sets from Sheffield, UK, suggests that, while there are high levels of excess commuting, there remains a complex interrelationship between housing and neighbourhood characteristics, school performance, and commuting patterns. There are differences between the pictures for primary schools and secondary schools. Policies aimed at promoting transport efficiency and those promoting school choice are likely to remain in tension.

Key words: school travel, housing markets, excess commuting, urban form, school choice, active transport to school.

Introduction

The journeys that children make to school have come to symbolise and exemplify some of the fundamental tensions that exist in urban societies. The 'journey to learn' today exists at the intersection of a range of contemporary public policy debates, including those related to public health; urban transportation; choice within education markets and other public services; and the structure and behaviour of residential property markets. While trips to school have achieved status as something of a *cause célèbre* among those concerned with the role that increasing levels of car dependence plays in explaining and reproducing public health epidemics, especially childhood obesity (see *inter alia* Schlossberg et al, 2006; Davison et al, 2008; Panter et al, 2010), this concern with public health, though justified, belies the complexity of the wider geographical and policy issues at play. How children travel to school is also at the heart of broader concerns about the decentralising tendencies of urban structure and land use in contemporary capitalist societies (Halcrow Group et al, 2009; Weitz, 2003; Cervero, 1996), associated trends in ‘suburbanised’, auto-dependent urban forms (Larsen et al, 2009; McMillan, 2006; Schlossberg et al, 2006), and the limits of choice in the delivery of key public services within fragmented social and geographic space (West, 2006; Reay and Lucey, 2003; Ball, 1993).

The purpose of this paper to explore some of these interconnected issues through the lens of children’s’ travel to school. The methods include a unique GIS analysis of micro-data on school commuting and the neighbourhood geography of an English city. The paper is motivated by a concern that the spatial and economic inefficiencies suggested by school commuting patterns ought to be an important factor within debates about choice within local education markets (Wilson et al, 2007). Donegan et al (2007) and Newman and Kenworthy (2000), for example, point to the sustainability implications of transport choices and infrastructure that result from the many thousands of daily decisions made as part of the journey to school. The uneven geography of urban housing markets bear some resemblance to educational inequalities, such that house prices may serve to lock-in and exacerbate patterns of socio-spatial segregation (Cheshire and Sheppard, 2004; Gibbons and Machin, 2003; Leech and Campos, 2001).

It is possible to theorise the interconnections between these processes in two mutually reinforcing ways. First, the factors implicated in the education choice equation exemplify a fundamental dialectic between the liberalisation of access to public services and the reduction of social inequalities. Both the access and inequalities dimensions of this dialectic comprise an ambiguous relation. On the one hand, increasing access to educational opportunities irrespective of home location may be important in breaking down social barriers and promoting patterns of social mobility. Yet, on the other hand, this might come with increased carbon emissions and congestion, both being potential results of the increased levels of 'excess commuting' (Horner, 2002; Ma and Banister, 2007) implied by greater school choice. The impacts of these economic and environmental costs may be unequal across space. Variations in households' average capacities to absorb transport costs are likely to have strong socioeconomic and ethnic dimensions, for example, and these variations in may themselves impose profound limits on the social levelling that school choice might otherwise bring about. Such limits may be additional to, and reinforcing of, the class and ethnic stratification within education markets that themselves can also result from choice programmes (Ball, 1993).

Second, the prime locus for the implicit 'trading' of educational choices against the spatial access (see Reay and Lucey, 2003) to those choices is assumed to be the residential housing market. Alongside other factors, the housing market works as a structural determinant of the reproduction of social inequalities. If key aspects of residential housing markets, both in morphological (urban form) and outcome (price) terms, seem to have an impact on school commuting patterns then this may offer important insights into how further liberalisation of choice in education markets might affect socio-economic and environmental sustainability within cities. The key question addressed here is: does the structure of residential housing markets explain school commuting patterns? If it is found that they do, this raises important further questions about the role of residential property markets in working against some of the putative benefits of educational choice in reducing social inequalities.

We explore the above questions empirically, through an initial analysis of school commuting and the residential housing market in Sheffield (England), a typical self-contained urban education market. Some initial results are presented, and the paper goes on to discuss their implications for a range of related policy issues while scoping out an agenda for further research in this area.

Urban structure, choice and equality within education markets

The access-space trade off

The housing market is assumed to be the basic arena in which access to education and other services are traded off against a host of other housing and neighbourhood characteristics. The spatial fixity of housing means that house price arbitrage occurs through the mechanism of residential mobility. House prices (and rents) therefore capitalise not only features of houses but the bundle of myriad attributes of the (wider) neighbourhood, including urban form, as well as the aggregate accessibility to schools, jobs and services implied by that location's urban structure (Orford, 2000; Rosen, 1974; Olsen, 1969). Choices that households make involve complex behaviours, and their search activity is conditioned by (though not determined absolutely by) the set of locational alternatives generated by their own resources and the spatial structure of the city. The interrelations between urban morphology, house prices and school performance can be hypothesised because, over time, the aggregate choices that households make – either directly in terms of school choice, or indirectly in terms of residential location – will become structurally embedded as observable submarket differentials between different neighbourhoods and housing types (Watkins, 2001).

Urban structure and form

There is a rich literature, especially from the US, on the impact of urban structure and urban design characteristics on transport choices. The intellectual antecedents of this literature can be traced back to the classic economic models of land use, such as the access-space trade off models of Alonso (1964) and Mills (1969). In these models, which examine the relation between consumption of space and ease of accessibility, the basic determinant of commuting behaviour in general terms is distance, itself a function of urban structure. Although developed with workplace commuting in mind, increases in the length of journeys to school (linked in part to rises in car borne workplace commuting) suggests that analyses of urban structure could be logically extended to include school commuting as well.

While such models are theoretically compelling, their practical value is somewhat limited given the imposition of myriad other potential factors (Giuliano and Small, 1993). These might include complex socio-behavioural determinants of travel, income, discrimination and other constraints on location choice, and variations in urban form (as opposed to structure). Hence, despite relatively distinct eras in the historic development of cities, the evidence on the impact of urban form on travel behaviour is ambiguous, although some clear factors include residential density and the specific configuration of transport infrastructure. Studies (for example Giuliano and Narayan, 2003; Cervero and Murakami, 2010) have shown that the density of urban areas can have an impact on the number and distance of trips made as well as influencing choice of mode. Chatman (2008) opines, however, that increases in density brought about planning policy are unlikely to influence travel behaviour on their own without complementary policies serving to dis-incentivise certain behaviours (for example parking restrictions).

The role of education

The relations between school education, residential property markets, urban structures, and socio-spatial inequalities have been increasingly recognised (Leech and Campo, 2001; Gibbons and Machin, 2003; Fack and Grenet, 2010). There has been an increasing evidence, for example, of the extent to which educational quality within local 'education markets' is capitalised into house prices (Cheshire and Sheppard, 2004; Fack and Grenet, 2010). Access to good schools is also recognised as a key policy goal in breaking down entrenched social problems and income inequalities.

The response of residential property markets to school quality can serve to deepen residential divisions. A 'sorting process' is created (Gibbons and Machin, 2003), shutting out mainly those from disadvantaged backgrounds through both geography and the cost of accessing neighbourhoods with better schools. The whole process is cyclic and reinforcing, as demand to live near good schools both inflates prices and concentrates 'catchment areas' used to govern pupil admissions. Working counter to these trends are school choice policies that serve to erode the spatial links between local neighbourhoods and schools and permit the emergence of more fluid networks of relations between where pupils live and where they go to school, although schools engaged in 'cream skimming' may enforce spatial controls more rigidly (West, 2006)

There has also been a rise in concern about the impact of suburbanised urban structures and associated urban form characteristics on the abilities of school children to access local schools, especially using healthy and environmentally sustainable forms of 'active transport' (McMillan, 2006; Panter et al, 2010; Schlossberg et al, 2010; Stewart, 2011). A set of basic policy contradictions arises. On the one hand, attempts to minimise school commuting (for example to lessen its environmental impact or promote active modes of travel) cut across the desire to stimulate more fluid markets of choice.

Choice in education markets

Burgess and Briggs (2010) describe education markets in England as being highly complex, using local administrative procedures to 'match' pupils to schools (explicitly and implicitly) on the basis of various combinations of pupil ability, pupil and family characteristics (including measures of poverty and income), locational characteristics, kinship ties and geography. The precise policies and procedures vary from place to place (and school to school), and the extent to which parents are able to make explicit choices also varies.

Despite concerns about stratification within local education systems, there is considerable fluidity in the nature of the spatial relations between pupil and school. In England, only around half of secondary school pupils attending a state school actually attend their nearest school (Burgess et al, 2006). Allen (2007) shows that when more students attend their nearest school, levels of social and ability segregation are lower. Despite the widespread use of spatial determinants in the allocations processes, such as 'catchment areas' and locational preferences, there are considerable overlaps in the effective zones of influence of schools (Harris and Johnston, 2008). A further recent complication in England arises from moves to encourage the establishment of 'free schools' outside of local authority control (Allen, 2010). These schools operate with pedagogic and financial freedoms, with separate admissions procedures, and are intended to stimulate more competition in education provision.

The impact of schools on house prices

There have been comparatively few UK studies analysing the capitalisation of schools into house priceslink, unlike in the US where the empirical literature is far richer. Leech and Campos (2001) use a small sample of house sales within the 'catchment areas' of two schools in Coventry to demonstrate, after controlling for other determinants of price, that membership of the school catchment zone increases house prices by between 16 and 20%. Gibbons and Machin (2003) recognise that there is a weaker link between home and school location in the UK than in other contexts (such as the US) and that this complicates attempts to value 'good' schools. They also argue that it is primary (generally ages 4-11), rather than secondary (11-16), schools that have the greatest local impact on housing markets owing to their smaller size and service area. Orford (2000), on the other hand, finds that the spatial effect of primary schools on house prices decays much more rapidly than secondary schools.

Cheshire and Sheppard (2004) use a hedonic specification to quantify the value of schools on house prices. Whilst they find that the quality (measured by examination results) of both primary and secondary schools is capitalised into house prices, they also point to the role of the distribution of quality in the local supply of schools in determining the strength of this effect. They found secondary schools were found to be valued more highly than primary schools, contrary to the findings of Gibbons and Machin (2003). With the high long-term costs involved in buying houses, parents are more likely to look towards the future to maximise their investment.

Active commuting to school

The final strand of literature worth considering is that related to 'active transportation'. This interest has been galvanised around statistics that show that the proportion of schoolchildren walking to school has fallen dramatically in recent years, to around 47 per cent in 2010 for primary schools (Department for Transport, 2011). Current trends would suggest that for the first time, walking to school may become overtaken by car use, which was recorded at 43 per cent and continues to rise. This is, however, not as dramatic for secondary schools (36 per cent walk and 24 per cent go by car), owing to the bigger role of buses. Trips to schools have also been steadily getting longer, increasing by 13 per cent over the decade since 2000. Allen (2007) estimates that in aggregate secondary school pupils in England travel over five million kilometres further per day than they need to as a result of not attending the nearest school, representing an excess commute of around 60 per cent. This trend has been replicated globally among rich nations including Europe (Fyhri et al., 201; Gize et al., 2010) and North America (Buliung et al., 2009; McDonald, 2007).

There has been increasing interest in the potential role that walking and cycling can play in improving the health of schoolchildren. There is strong evidence regarding physical activity levels and individual health (Bouchard et al., 2012; Hardman and

Stensel, 2009). This has become more important with the recent growth in obesity levels in England (Stamatakis et al.,2010). Active transportation to school acts to establish, supplement or provide an alternative to physical activity. This is supported by Faulkner et al.'s (2009) systematic review which found that school children who commute using active modes of transport have higher levels of physical activity. Nevertheless Metcalf et al. (2004) found that for five year olds, there was no difference in total physical levels between those who were driven to school and those who used active forms of transport. There is also potential for increased exposure to air pollution as children switch mode of transport.

Very few studies explicitly link commuting behaviour to broader socio-spatial and urban structural contexts. Martinez-Gomez et al (2011), for example, look at adolescents' lifestyle traits to determine correlates with the choice to walk or bike to school and find little in the way of significant explanatory effects. That their study ignores measures of household income and characteristics of the neighbourhood or local housing market, however, is potentially significant in explaining these weak effects.

A US study by Schlossberg et al (2006) found that, taken together, distance and urban form factors accounted for around 41 per cent if the variation in whether children walk from school (they also found that the trip *from* school was more frequently made using active transport; cf Larsen et al, 2009). They found that the density of street junctions and of cul-de-sacs (as measure and inverse respectively of the walkability of the environment) were significant predictors of children walking to school (although not necessarily of cycling).

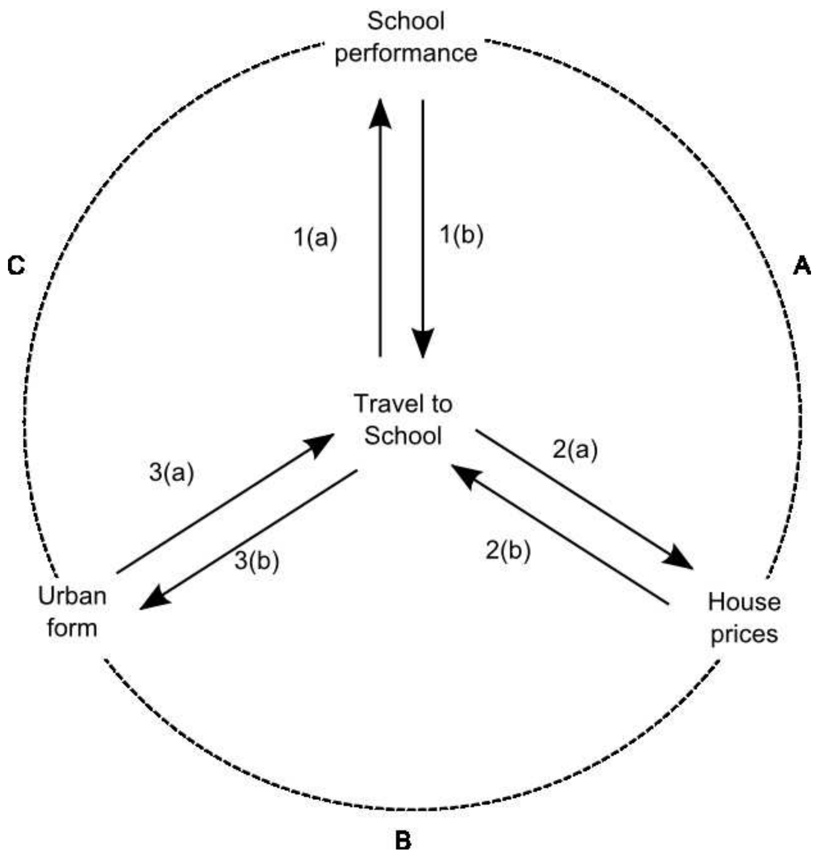
Whilst the urban form is an important driver, it is insufficient to consider it outside of socio-economic factors, including discourses arising from 'complex social and cultural values' (Jones et al, 2012). Social norms and parental perceptions are as strong influences on behaviour as physical urban form characteristics (McMillan, 2005; 2006; Davison et al, 2008). Areas with greater junction density can limit the 'walkability' of an area through fear of traffic and safety issues (Barker, 2003). Distance is important in moderating these influences, for example safety concerns become more prevalent when the distance travelled is longer (Panter et al., 2010a).

Socio-economic factors are not just important in affecting social views on transport. Many studies have shown that children of low socio-economic status are more likely to walk due their parents unable to afford a car (Davison et al., 2008; McDonald, 2007; Steinbach et al., 2012). This, however, was contrasted by Panter et al.'s (2010b) findings, where an opposite pattern was found once distance was controlled for (this was linked to issues surrounding the perception of environmental safety). Owen et al. (2012) also notes ethnic variations in mode of transport to school, with White children more likely to use active forms, Black children to use public transport and Asian children to be driven. Steinbach et al. (2012) finds similar, but weaker associations for ethnicity.

Conceptual framework and hypotheses

In summary, there are important connections between perceptions of school performance (as underpinning schooling choices), house prices and urban form. Each of these factors is related to the journey to school. It is therefore possible to conceptualise these three interconnected relations, as depicted in Figure 1. These are: the relation between school quality and travel to school [1(a) and 1(b)]; the relation between house prices and travel to school [2(a) and 2(b)]; and the relation between urban form and travel to school [3(a) and 3(b)]. There are also relations between school quality and house prices [A]; house prices and urban form [B]; and urban form and school quality [C].

Figure 1. Conceptual framework.



This conceptual framework gives rise to an array of interrelated hypotheses in which travel to school (i.e., the optimality and mode of travel choices) are either predictive of, or predicted by, the other factors. So, for example, relation 1(b) might arise where poor local school performance encourages 'excess commuting' (i.e. non-optimal aggregate travel) associated with travel to better, but more distant, schools. Such longer commutes are less likely to be undertaken using 'active' modes of travel. On the other hand, relation 1(a) might explain why resource-poor families, who are unable to exercise choice due to high transport costs, are restricted to more poorly performing schools. At the least, we can hypothesise a correlative relation between school performance and aspects of travel to school.

The housing market is also conceptually linked to travel to school. Good access to schools, with a variety of modal choices, might be reflected in house prices [relation 2(a)], while the desire to live in high price neighbourhoods, or those strong in market terms, may necessitate certain forms of travel to school [relation 2(b)]. So there may also be a hypothetical correlation between house prices and travel to school.

Finally, we can hypothesise of a correlation between urban form and travel to school. Specifically, relation 3(a) might suggest that car-dependent urban forms, which discourage walking and cycling, might encourage longer commutes and discourage active forms of travel to school. Relation 3(b) might result when the choice of neighbourhoods made by resource-poor households is constrained because of travel to school considerations.

These three general hypotheses are accompanied by a set of exogenous relations (A, B, C), which may indirectly condition the relations between school performance, house prices, urban form and travel to school. The capitalisation of measures of school quality into house prices would be represented by A; and the tendency for house prices to reflect urban form characteristics would be represented by B. There is no immediately relevant direct hypothesis linking school quality and urban form (C).

Methods

Sheffield is a relatively self-contained education market, with minimal levels of cross border commuting to school. Although self-contained, it is a large city with a population (according to the 2011 census) of approximately 552 700 persons. In 2009 the local education authority, Sheffield City Council, controlled 38 secondary schools and 133 primary schools, although there has been some reorganisation and consolidation since.

Data

The core dataset comprised an extract from a data file collected by Sheffield City Council for the purposes of making a return to the School Census (formerly Pupil Level Annual School Census, PLASC) maintained by the Department for Education (DfE). This anonymised extract covered all primary and secondary school pupils in 2009 and was supplied by officers working on a local 'Safe Routes to Schools' (SRTS) initiative. The data contained map coordinates of the approximate home locations for each pupil and information on what year they were in, their usual mode of travel to school, and the school that they attended. The data set contained information on 41 642 primary school pupils and 31 188 secondary school pupils.

Using the network analyst extension of ArcGIS, an origin-destination cost matrix was produced for each pupil to calculate the network distance between each pupil and all possible schools. The network distance of the closest relevant school was recorded, as was the network distance of the actual school attended. This permitted the calculation of excess commuting. The network analysis was based on the Integrated Transport Network (ITN) layer of Ordnance Survey's Mastermap database as supplied by Edina Digimap. A limitation of this method was that it assumes that pedestrians can walk only on roadside pavements (except grade-separated dual carriageways and motorways). A future development of the model will incorporate pedestrian footpaths but this data was not available as part of the ITN at the time of analysis.

Data on schools and school performance (taken as a proxy for school 'quality') were extracted from the publicly available Edubase2 database maintained by the DfE. The specific measure used for primary schools was the percentage of eligible pupils achieving level 4 English and Mathematics at national curriculum Key Stage 2 in the 2008-09 school year. For secondary schools, the chosen measure was the percentage of pupils achieving five or more GCSEs[1] at grades A-C, including English and Mathematics in the 2008-09 school year. These were chosen as they represent the expected standard that pupils should achieve at the end of primary and secondary education.

Two measures of neighbourhood characteristics were gathered. Average mix-adjusted house prices were obtained for Middle level Super Output Areas (MSOAs) from the Joseph Rowntree Foundation's Housing and Neighbourhoods Monitor (Wong et al, 2009). Each home postcode in the pupil dataset was assigned a range of

[1] General Certificate of Secondary Education, a secondary school qualification that has been awarded to pupils aged 14-16 in the UK (except Scotland) since 1988. Pupils typically take between eight and ten GCSE subjects.

absolute and relative price measures on the basis of the MSOA it was a member of. Vickers and Rees' (2006) socio-demographic typology of English neighbourhoods was employed to attach a 'neighbourhood type' label to each home location in the database. This enabled cross-sectional analysis using a broad socio-economic descriptor of areas and provided a proxy for broad housing sub-markets.

A range of urban form characteristics were created using the Mastermap database. Average building density over a 500m radius was calculated by extracting building polygons from the Mastermap topology layer and calculating the density of their centroids using ArcGIS's Spatial Analyst extension (Figure 2). The same process was applied to geocoded data on residential postal delivery points obtained from the ONS Postcode Directory (ONSPD) to obtain a measure of residential density (Figure 3).

Two further urban form characteristics were modelled using network data obtained from Mastermap's ITN layer. Junction density was calculated using a development of Schlossberg et al's (2006) method as follows: a north-facing hectare-cell lattice (grid) was constructed with extents equal to the Sheffield city boundary; the number of junctions with three or more paths (ignoring directionality) was counted for each cell; this was then smoothed using a simple radius of 500m to represent the generalised junction density across an area approximate to the walkable hinterland of each point. The resulting density surface is at Figure 4. The same process was used with 'junctions' with only one related edge to calculate the density of cul-de-sacs (Figure 5).

Although more correctly describing ‘permeability’, these latter two measures were taken as simple proxies for the inherent ‘walkability’ of the local neighbourhood. Although other factors are important in measuring walkability (see Manaugh & El-Geneidy, 2011 for a recent review), we considered that, in general, a more walkable neighbourhood will have a high density of junctions (and hence a higher density of possible routes). More walkable neighbourhoods have fewer cul-de-sacs which can lead to unnecessary deviations and additional journey lengths. As expected the city centre is the most ‘walkable’ area of Sheffield, but it is not the most populated. The areas with the highest residential density are found in the older inner suburbs to the west of the city centre and some satellite townships. Other ‘walkability’ factors, such as perceptions of crime and safety, are clearly difficult to measure at this scale. Although point-level crime data are now available, McDonald et al (2010) found a weak relationship between crime and school travel and, while they cite fear of bullying as an important factor, such incidents are rarely reported in crime statistics.

Testing for correlation between the raster layers representing the measures of urban form shows little interrelation between them (Table 1). There is a moderately strong positive correlation between building and residential density, which would seem appropriate. However the combinations of the other forms show that each is capturing a different pattern.

Table 1. Correlation matrix (Pearson's *r*): urban form measures

	Residential density	Junction density	Cul-de-sac density	Building density
Residential density	1.000	0.107**	0.183**	0.564**
Junction density	0.107**	1.000	0.282**	0.344**
Cul-de-sac density	0.183**	0.282**	1.000	0.367**
Building density	0.564**	0.344**	0.367**	1.000

Note: correlations exclude empty cells (i.e. 0 = No Data).
** Correlations are significant at the 0.01 level (2-tailed).

Figure 2. Average building density within 500m.

Figure 3. Average residential density within 500m.

Figure 4. Junction density surface.

Figure 5. Cul-de-sac density surface.

Limitations

Some important limitations remain as a result of the data and methods employed. No account was taken of cross border flows, i.e., pupils originating outside the city but attending school within the city, or vice versa. That said, Sheffield is a relatively self-contained education ‘market’ and the vast majority of pupils in our study travelled from within the city boundary. No account was taken of the nature of schools and, in particular, the faith orientation (if any) of specific schools. The data related only to state supported schools under the control of the local education authority and, in particular, did not include private schools (although Sheffield has comparatively few of these) or the newer quasi-independent ‘academies.’ For analytical simplicity the whole school roll was used, which included pupils at a range of levels and whose admissions were made over a number a years. Attribute data on schools and neighbourhoods, by contrast, were taken from a single point in time. A more complex analytical scheme would have separated students into year groups and used differential school and neighbourhood attributes based on (imputed) year of admission to the school.

Although mode of travel is often reported by schools in aggregate terms, the Sheffield data set permits analysis at the individual level. That said, ‘usual’ travel mode was self-defined by the respondent and does not account for environmental or structural variations in children’s’ normal travel patterns. Most importantly, it assumes that travel to and from school are undertaken by the same mode. Wong et al. (2011) find important differences in morning and afternoon commutes, on the other hand. Despite these limitations, the data set is remarkably complete and permits disaggregate analysis to a high level of spatial resolution, making it ideal for this study.

Results

Proximity

Some 18 909 primary school pupils (45 per cent) attended the school that was their nearest in network distance terms. More than half of all primary school pupils, therefore, actually attended a school which was not their nearest. The average network distance travelled by primary school pupils was 1.39 km, while the average network distance to the nearest school was 0.73 km. Some 12 832 secondary school pupils (41 per cent) attended their nearest school in network distance terms. A slightly higher proportion of secondary pupils than primary pupils, therefore, attended a school that was not their nearest. The average network distance travelled by secondary school pupils was 3.02 km compared to an average network distance to the nearest secondary school of 1.49 km. On average, both primary and secondary pupils travel around twice as far as they would in an 'optimal' system, suggesting that the option of choice is clearly being exerted by pupils on a significant scale.

Excess commuting

It is instructive to consider the phenomenon of 'excess commuting' in more depth. Simply put, excess commuting occurs where aggregate travel is greater than the minimum that might be implied by a particular arrangement of homes and workplaces (or schools) (Horner, 2002; Ma and Banister, 2007). Across the sample there was an estimated aggregate level of daily excess commuting associated with travel to primary schools of approximately 27 500 km in each direction (90.5 per cent of the minimal possible commute). Unsurprisingly, the lowest levels of excess commuting were associated with cycling (77 per cent) and walking (48 per cent) while the highest levels were associated with motorised forms of transport, including taxis (462 per cent), school buses (307 per cent), public buses (240 per cent), and light rail (200 per cent). Commutes by private car entailed excess commuting of around 126 per cent.

Levels of excess commuting also varied according to the neighbourhood types from which children started their commute. Children living in 'city living'[2] neighbourhoods on average had the largest excess aggregate commute (135 per cent of the optimal aggregate commute) followed by those living in 'multicultural' (116 per cent) and 'constrained by circumstances' (109 per cent) neighbourhoods. It is possible that these patterns are explained by the paucity of schools, or of perceived problems with school quality, in central urban areas, which may encourage families to send their children to more distant schools where resources allow.

The lowest levels of excess commuting were associated with 'countryside' (54 per cent) and 'prospering suburbs' (64 per cent) neighbourhoods. In the case of countryside communities this may be partly explained by the longer distances required to cover to reach any school (the average network distance to the nearest primary school for 'countryside' residents was, at two kilometres, more than twice that associated with other neighbourhood types). Being located further from services is likely to have translated into less choice. However the relationship for 'prospering suburbs' was not the same. Rather, children in these areas were more likely to travel

[2] The descriptors used here are based on census output areas and are taken from Vickers and Rees (2006). The proportion of pupils in Sheffield with each descriptor was: 'Blue Collar Communities' (28.7%); 'Prospering Suburbs' (19.6%); 'Multicultural' (16.9%); 'Typical Traits' (16.6%); 'Constrained by Circumstances' (14.6%); 'City Living' (2.5%); 'Countryside' (1.1%).

to their nearest school. These areas represent better off areas (Vickers and Rees, 2006) and hence school quality may be playing an important role in the housing market through neighbourhood selection. Actual network distances travelled to primary schools were only marginally associated with school quality (r = .099, p = .000). There was, however, no significant correlation between school quality and levels of excess commuting (r = .009, p = .102).

Although the distances travelled were generally greater, similar overall patterns were found among secondary school pupils. There was an estimated aggregate excess commute of around 43,700 km each school day in each direction. This represented a proportional average level of excess commuting of 102 per cent. The largest proportional levels of excess occurred among those that used taxis (229 per cent), school buses (218 per cent) and public buses (148 per cent). Car trips made by secondary school pupils led to 96 per cent excess commuting, surprisingly less than for cyclists (123 per cent). In terms of neighbourhood type, it was 'multicultural' (132 per cent) and 'blue collar' (112 per cent) communities that were associated with the highest levels of excess commuting. These poorer communities (Vickers and Rees, 2006) tend to be more distant from 'good' schools and may be where choice is leading to longer commutes for children.

Mode

Fewer than half (46.1 per cent) of secondary school pupils walked to school. Only 0.2 per cent said that they cycled (the topography of Sheffield is not as conducive to cycling as in other cities). As might be expected, those travelling to their nearest school were far more likely to walk than those travelling to a more distant school.

Again as expected, given the shorter distances involved, more primary school pupils (62.4 per cent) walked to school (either accompanied or unaccompanied). Those travelling to their nearest school were much more likely to walk. But nearly two fifths of primary school children travelling to the nearest school were taken by car. Whilst this may be seen as something policy could easily tackle, it is likely that most of these journeys were part of a 'trip-chain' with parents dropping their children off before going on to work. There were only slight differences by gender within secondary schools, however this was never significantly different.

Relationship to house prices

Previous studies (Leech & Campos 2001; Cheshire & Sheppard 2004) have demonstrated a link between school quality and house prices on the basis of proximity. Table 2 shows that there is a moderate but significant ($p = .01$) positive relationship between school performance and both actual and nearest school. The relationship is stronger for the actual schools that children attend than it is for the nearest school. Given that children from more affluent neighbourhood types are more likely to attend their nearest school this is indicative of both a house price premium and a close travel relationship associated with 'better' schools. This effect appears to be even stronger for secondary schools.

Table 2. Correlations (Pearson's *r*) between primary school achievement and average neighbourhood house price

	Actual school	Nearest school
Primary school pupils	.537**	.486**
Secondary school pupils	.577**	.412**

** significant at the p = 0.01 level (2-tailed).

Table 3 provides a hedonic model of house prices based on the actual school of attendance and other factors. For secondary school pupils, a one point increase in the percentage of resident pupils obtaining five A to C passes including English and Maths increases house prices by approx £2 330. When the coefficients are standardised to allow for comparisons, this has the largest value (β = .561, p = .000). Other statistically significant (p = .05) predictors of price include the network distance travelled to school and whether pupils travelled to school using an active mode or by public transport. The higher the average house price of a neighbourhood, the more likely that a child going to his or her nearest school will be to walk or cycle to school if it is not far. All of the urban form variables are highly significant predictors of the average house price of an area. The relationships mainly show that higher house prices are found in areas, such as suburban localities, where there are more cul-de-sacs, lower residential densities and sparser road networks.

Similar results were found when the analysis was carried out for primary school children (table 4). Once again, school 'quality' was the strongest predictor of average house prices. Interestingly, the standardised beta coefficient was slightly less than for the equivalent variable in the secondary school model, suggesting that secondary schools play a more important role in defining house prices (although the models should not be directly compared). In contrast to the secondary school model, the use of public transport was found to be negatively related to price, which may relate to the distance pattern. It must be further noted that the variables entered only account for around 45 per cent of the variability in price in the secondary school model and 28 per cent in the primary school model, suggesting that there are a range of other unobserved predictors.

Table 3. Hedonic model of house prices (where children attend a secondary school)

Variable	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	*β*	*t*-stat	Sig.
Constant	90430.458	1539.856		58.727	.000
School performance	2330.845	19.807	.561	117.678	.000
Network distance to school	-4.224	.145	-.156	-29.060	.000
Residential density	-2522.775	54.920	-.341	-45.935	.000
Building density	1375.506	44.808	.217	30.697	.000
Junction density	-43947.173	1313.726	-.242	-33.452	.000
Cul-de-sac density	64022.057	2028.940	.201	31.554	.000
Excess commuting %	.022	.028	.004	.784	.433
Active mode of travel	6001.347	923.742	.045	6.497	.000
Public transport mode	625.318	965.187	.005	.648	.517

Note: R^2 = .449

Table 4. Hedonic model of house prices (where children attend a primary school)

Model	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	*β*	*t*-stat	Sig.
(Constant)	64080.469	1660.033		38.602	.000
Network distance to school	-.631	.199	-.015	-3.165	.002
Residential density	-1740.117	48.808	-.252	-35.652	.000
Excess commuting %	-.055	.042	-.006	-1.323	.186
School performance	149452.892	1722.151	.422	86.783	.000
Junction density	-26966.513	1124.766	-.170	-23.975	.000
Cul-de-sac density	45042.170	1718.797	.161	26.206	.000
Active mode of travel	1690.350	609.218	.014	2.775	.006
Public transport mode	-9768.093	1377.038	-.033	-7.094	.000

Note: R^2 = .285

Distance Travelled

Analysing the actual distance travelled for each primary school pupil also produced some insightful findings, although the study variables only accounted for around 17 per cent of variability (R^2 = .166). Furthermore, the literature suggests that while absolute distance is paramount in predicting mode there are complex interactions (such as with socioeconomic factors) that were not included in our model specification. That said, three of the urban morphology measures were significant ($p < .05$): junction density was positively related (B = 80.433, SE = 30.101) to distance travelled, as was residential density (B = 3.072, SE = 1.319), while building density (B = -18.915, SE = 1.063) were negatively related. This suggests that the walkability of an area affects the distance travelled to school: primary school pupils living in higher density residential neighbourhoods appeared to travel further to school. Pupils walking or cycling travelled around 1 km less to school on average (B = -921.984; SE = 15.425).

The same model was also applied for secondary school pupils (R^2 = .326). There were similarities to the primary pupil model. In particular, average house price was a significant (p = .001) inverse predictor of network distance (B = -.007, SE = .000). The performance of the school attended was also significant (p = .01; B = 44.494; SE = .958). The effect of 'walkability' on distance was not evident for secondary pupils, although pupils living in areas with a high density of cul-de-sacs had significantly longer commutes to school (α = .001, B = 655.523, SE = 84.451).

Modelling 'Active' Commuting

Finally, the analysis sought to model the characteristics of those children using active transport (i.e. walking or cycling) to get to school. For primary school children, some obvious patterns emerged (Table 5). Where children had to travel further, they were less likely to use active transport. If there was a good school nearby then children were more likely to use active transport, although in general *attending* a good school reduced the probability of using active transport. Earlier findings suggest that very long commutes associated with school choice among pupils living in more deprived neighbourhoods may mask the shorter commutes of pupils living near good schools. Indeed, higher house prices were associated with children being more likely to use active transport to get to school. The notion of walkability was once again borne out in the model, with junction density found to increase the likelihood of children using an active mode. Higher residential densities also increased the odds of using an active mode, while higher cul-de-sac density had the opposite effect. The inclusion of the neighbourhood classification indentified three types of areas of importance. Those living in areas classified as 'constrained by circumstances' were more likely to use active transport. These areas are more impoverished (Vickers and Rees, 2006) and hence costs may restrict their ability to use other forms of transport. The two other areas types which were significant were those which are more affluent ('countryside' and 'suburbs') and each had negative relationships (though with the countryside areas, this is likely to be more related to distance).

The model for secondary school children shows some similarities to the relationships in the primary school children model. However, house price was not a significant predictor and, while more walkable neighbourhoods did not exert as much of an influence on active travel choices as in the primary school model, secondary school pupils living in the 'prospering suburbs' were significantly more likely to walk or cycle to school.

Table 5. Logistic regression predicting active transport mode of primary and secondary school pupils

Variable	Primary school model		Secondary school model	
	Coefficient	SE	Coefficient	SE
Network distance to attended school	.337	.023***	.178	.045***
Network distance to nearest school	.768	.024***	.649	.028***
Average house price	1.111	.018***	1.035	.027
Residential density	1.063	.022**	1.071	.028*
Performance of nearest school	1.157	.019***	1.252	.020***
Performance of attended school	.708	.018***	.905	.025***
Junction density	1.105	.022***	.666	.030***
Cul-de-sac density	.928	.020***	.950	.026*
Building density	1.005	.002*	1.364	.027***
Excess commuting	1.000	.000	.243	.773
Neighbourhood type: reference = Blue collar communities				
City Living	.876	.105	1.150	.097
Countryside	.644	.155**	.385	.224***
Prospering suburbs	.800	.045***	1.205	.056***
Constrained by circumstances	1.117	.040**	1.194	.052***
Typical traits	.941	.043	1.077	.050
Multicultural	.910	.045*	.854	.064*
Constant	1.511	.061***	.551	.037***
Nagelkerke pseudo-R^2	.238		.406	

*(Significance Levels: *<0.05, **<0.01, ***<0.001)*

Discussion

The results presented in this paper provide some tentative evidence of the hypothetical links between housing markets, school performance, urban form and travel to school. While the data and methods have some limitations and simplifications, the findings are generally supportive of contributions in the separate literatures outlined at the paper's outset, and can be summarised with reference to the conceptual framework outlined earlier. House prices appear to be negatively related to distance of travel to school (relation 2a), supporting past research findings about 'sorting' (Gibbons and Machin 2003) and 'cream skimming' (West 2006). Consistent with this, children from high price neighbourhoods are more likely to go to their nearest school (relation 2b). Furthermore school performance appears to be a stronger predictor of house prices, for both primary and secondary pupils, as does urban form. House prices were also shown to be positively related to 'active' commuting (for both sets of pupils), probably due to house prices being higher where there is less distance to actual school.

There was some support of past findings on active transport and urban form, such as Cervero and Murakami's (2010) work on built environment predictors of car use. The 'walkability' of an area appeared to be important in predicting active transport for primary school children, although it was insignificant for secondary children. Cul-de-sac density was also negatively related to active transport (3a). The relationships for secondary school children existed, but appeared more complex. The possibility that school travel imperatives might restrict movers to certain neighbourhood types (relation 3b) could not be tested, though it should be noted that with rising fuel and public transport costs this type of constraint is likely to become more important in the future. In general, urban form variables were significantly related to house prices.

Finally, school performance seemed to be somewhat important. The role of school travel imperatives in constraining school choice (relation 1a) was beyond the scope of the analysis, but, as for relation 3b, will be an important consideration for policymakers. The impact of school performance on active commuting to school (relation 1b) was only found for primary school pupils. Where there was a good nearby school, pupils were more likely to walk.

Together, these findings suggest the coexistence of significant, but complex, interrelationships between urban form (itself related to urban structure), school quality and housing markets. These relationships can be analysed through travel to school as the prime geographic and dynamic connection between the home and school locations. The interconnectedness of the relations highlighted in this paper suggest that educational goals aimed at improving school choice, and planning goals aimed at improving urban structural and transport efficiency, are doomed to remain in tension. The consequences are non-trivial in terms of the socio-spatial inequalities bound up in urban housing markets, and also in terms of the levels of excess commuting that school travel patterns produce.

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