

# **Valuing School Quality Via School Choice Reform**

**Stephen Machin**

**Kjell Salvanes**

**CENTRE FOR THE  
ECONOMICS OF  
EDUCATION**

**March 2010**

Published by  
Centre for the Economics of Education  
London School of Economics  
Houghton Street  
London WC2A 2AE

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## **Executive Summary**

A lot of existing research documents a sizable and significant correlation between house prices and school quality. This has led some commentators to express concerns about 'school selection by mortgage' and to policy concerns about whether the presence of such correlations implies a need for school admissions reform. However, an ongoing issue in this literature concerns the means by which the impact of school quality on housing valuations is identified. This is pertinent since the main empirical challenge is to ensure that results capture only the portion of housing expenditures affected by variations in school quality, and not due to other (observed and unobserved) housing characteristics or local amenities.

In this paper we adopt a different approach to much of the literature so as to identify the impact of school quality on house prices. We implement a research design based on a school admissions reform. The reform increased pupil choice to high schools by allowing mobility across catchment area boundaries that was not permitted before. We use this variation to empirically identify the relationship between house prices and school performance.

We study a change in school choice that took place in Oslo county in Norway in 1997, where the school authorities opened up the possibility for every pupil to apply to any high school. Prior to this, rigid catchment areas were present and children had to attend schools in the area in which they resided. Thus to identify school quality capitalization we are able to exploit both a time-series variation (through the school choice experiment) as well as cross-sectional variation using neighbourhood discontinuities generated by the catchment area approach that has been more commonly used in the recent literature.

Our estimates show that parents do indeed substantially value better performing schools. They also show that school choice matters. When proximity to high school is the criterion for admission, parents are prepared to pay significant amounts of money to live in the catchment area of schools they prefer. However, once the reform occurred and the residence based zoning criterion for admission was removed, the house price-school performance relation was significantly weakened. Indeed, in most of the specifications that we report the house price premium linked to school quality falls by at least 50 percent once school choice was introduced.

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## **Acknowledgments**

The authors would like to thank Sandy Black, Steve Gibbons, Caroline Hoxby, Sandra McNally, Olmo Silva and numerous seminar and conference participants for some very helpful comments. Thanks also to Roger Bivand for his great help in producing the Figures.

Stephen Machin is Director of the Centre for the Economics of Education (CEE), Director of Research at the Centre for Economic Performance, London School of Economics and a Professor at the Department of Economics, University College London. Kjell Salvanes is Professor and Chairman of the Department of Economics, Norwegian School of Business Administration, Research Fellow at Statistics Norway and an International Research Associate at the Centre for the Economics of Education.

## 1. Introduction

The way in which housing markets are affected by differences in local school quality is an important economic and social phenomenon and a highly topical and politically charged issue. All over the world, parents are concerned that they get the best education for their children. Empirical evidence shows that parents are willing to pay significant amounts of money to buy houses located in the catchment areas of better performing schools.<sup>1</sup>

Many papers in this literature show there to be sizable and significant capitalizations linked to school quality. However, an ongoing issue in this literature concerns the means by which the impact of school quality on housing valuations is identified. This is pertinent since the main empirical challenge is to ensure that results capture only the portion of housing expenditures affected by variations in school quality, and not due to other (observed and unobserved) housing characteristics or local amenities.

Early work in this area tried to net out these correlated effects by conditioning on a range of observables. More recent work has tried to deal more effectively with the unobserved aspects. One strand considers house price differences across school catchment area boundaries to remove unobserved heterogeneity that could contaminate any house price-school quality relation seen in the data.<sup>2</sup> Other researchers have adopted a quasi-experimental approach based on the redrawing of catchment area boundaries.<sup>3</sup>

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<sup>1</sup> See the literature reviews of Black and Machin (2010) or Gibbons and Machin (2008).

<sup>2</sup> There are by now quite a few boundary discontinuity papers. See, *inter alia*, the early papers by Bogart and Cromwell (1997) and Black (1999) and the more recent work combining the boundary approach with other empirical methods by Gibbons and Machin (2003), Gibbons, Machin and Silva (2009) or Bayer, Ferreira and McMillan (2007).

<sup>3</sup> In the context of a loss of neighbourhood schools and re-districting in Cleveland, Bogart and Cromwell (2000) adopt a quasi-experimental approach based upon the redrawing of catchment area boundaries. Ries and Somerville (2004) also treat a redrawing of school catchment zones in Vancouver in January 2001 as an experiment that they claim exogenously induces changes in school quality that in turn can affect housing valuations.

Despite these advances in methodology, there remain concerns and worries about identification. For example, some critics argue that administrative boundaries are endogenous to housing prices, possibly because of differential growth over time or because they have differing institutional features (e.g. in the US where local property taxes may differ on either side of the boundary). Similarly quasi-experimental variations based on redrawing boundaries are also likely to be endogenous to school quality and/or house prices (i.e. there are correlated reasons as to why the boundaries were redrawn).

In this paper we therefore adopt a different approach to causally identify the relationship between house prices and school quality. We also use a quasi-experiment, but one that is very different to those used to date. We implement a research design based on a school admissions reform. The reform increased pupil choice to high schools by allowing mobility across catchment area boundaries that was not permitted before. We use this variation (sometimes coupled with a boundary discontinuity approach) to identify the relationship between house prices and school performance.

To be more specific, we study the change in school choice that took place in Oslo county in 1997, where the school authorities opened up the possibility for every pupil to apply to any high school. Prior to this, rigid catchment areas were present and children had to attend schools in the area in which they resided. Thus to identify school quality capitalization we are able to exploit both a time-series variation (through the school choice experiment) as well as cross-sectional variation using neighbourhood discontinuities generated by the catchment area approach that has been more commonly used in the recent literature.

Our estimates show that parents substantially value better performing schools. They also show that school choice matters. When proximity to high school is the criterion for admission, parents are prepared to pay significant amounts of money to live in the catchment area of schools they prefer. However, once the reform occurred and the residence based



zoning criterion for admission was removed, the house price-school performance relation was significantly weakened. Indeed, in most of the specifications that we report the house price premium linked to school quality falls by at least 50 percent once school choice was introduced.

The rest of the paper is structured as follows. In Section 2 we discuss the key features of the school choice reform. Section 3 describes the data and offers an initial descriptive analysis. Section 4 presents the results, while Section 5 concludes.

## **2. The School Choice Reform**

### **School admissions in Norway**

At elementary school level in Norway (for pupils aged 6-13 in grades 1-7) all pupils are allocated to schools based on fixed school catchment areas within municipalities. With the exception of some religious schools and schools using specialized pedagogic principles, parents are not able to choose the school to which their children are sent (except by moving neighbourhood). There is a direct link between elementary school attendance and attendance at middle or lower secondary schools (ages 13-16/grades 8-10), in that elementary schools feed directly into these lower secondary schools. In many cases, primary and lower secondary schools are also integrated.

Admissions procedures are different for upper secondary schools (attended by pupils aged 16-19 in grades VG1-VG3), where they are administered at county level. In some

counties parents can freely choose schools, but in others children are allocated to school based on well-defined catchment areas, or high school zones.

### **The Oslo school choice reform**

The system for allocating pupils at elementary school in Oslo - by far the largest county of Norway with half a million inhabitants<sup>4</sup> - consists of a system of catchment areas for 98 schools. These 98 elementary schools then link directly into 47 middle schools. Before the 1997/1998 school year, there was a direct link between a group of elementary/middle schools and a group of secondary schools such that pupils graduating after the last year of middle school could choose only within six well-defined high school zones. There was no possibility of applying outside the zones.<sup>5</sup> Altogether there are 17 high schools in Oslo qualifying for an academic track (see Figure 1), and thus within each zone there was on average around three high schools and eight middle schools.<sup>6</sup>

A change in high school admissions policy took place in the 1997/98 school year (see Oslo kommune, 2005; Wærnes and Lindvig, 2000; Nordli-Hansen, 2006). In February 1997 the municipality of Oslo (which also acts with the authority of a county for secondary schools) decided to offer free choice at high school level. All fifteen year olds were eligible to apply to any secondary school within Oslo from the school year starting in August 1997. There had been a lot of discussion of this issue both in the press and in the political arena

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<sup>4</sup> Out of the total Norwegian population of four and a half million.

<sup>5</sup> This rule of zones at the high school level was only used for high schools giving credits for entering college. This comprises about 85 percent of the pupil population. All vocational high schools had open enrolment prior to the reform. There are also two general high schools that, at least to a certain degree, had open enrolment prior to the reform. We exclude these from the empirical analysis.

<sup>6</sup> The share of private schools at this level and at this time in Oslo comprised about 1 percent of the students (Nordli-Hansen, 2005).

from the fall of 1996, ensuring that parents and students were well informed when the reform was enacted in the school year of 1997/1998.

Whilst at the time of the reform there was no public information on school performance, there were very clear perceptions in the Oslo population (as in other parts of the country) that pupil performance differences existed across schools.<sup>7</sup> In addition, it was clear what was considered as best performing schools were not equally distributed across the city.<sup>8</sup> Therefore, it was argued (mostly by right-center politicians in Oslo) that a free choice system would improve allocation of talent in Oslo, as well as improving accountability. Left oriented politicians, on the other hand, argued that free choice would lead to elite schools and deprive schools located in the poorest areas of the county.<sup>9</sup>

From the school year 1997/98 onwards all students were able to apply to go to high school anywhere within Oslo. Students ranked six schools according to their preferences and the central school authorities in Oslo matched students to school based on their average grades in 10<sup>th</sup> grade (the last year of lower secondary school). More specifically, if some schools were over-subscribed, based on average grades students were allocated to their second ranked school (and so on) until a match was found. The grades were based on study of ten subjects from both exam results and assessment during the year. Students were able to obtain grades from 1 to 6 in every subject (below in our empirical work we consider three of these subjects: Mathematics, Norwegian and English). One total grade then would be between 0 and 60, with the average being around 35. Only the central school authority was involved in the matching and not the schools themselves, so this was a one-sided matching process. Since the grades could vary between 1 and 60, there does not appear to have been an issue of uniquely matching students to schools. Indeed, it is clear that people had a strong knowledge of which

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<sup>7</sup> That the perception of how schools were ranked is also supported by the sociological literature (Nordli-Hansen, 2005), and by articles in the main newspapers around the time for applying to high schools.

<sup>8</sup> Public information about school performance across high schools in Norway – league tables - became available from 2001 (see Raaum, Hægeland, Kirkebøen and Salvanes, 2004 for a description).

<sup>9</sup> In 2005 the system of free choice was again changed to a combination of free choice and zoning.

schools were considered the best, and certain schools had many more applications than they had capacity to offer.

### **3. Data and Initial Descriptive Analysis**

#### **Data**

Data on school zones were provided to us by the school authorities in Oslo and the exact geo-codes were provided by the geo-map section of the Oslo municipalities. This office also provided geo-codes for elementary and secondary schools in Oslo. We have matched these to house price data from 1995 to 2002, comprising two and a half years of data on house prices before the reform and five and a half years after the reform.

The geography of high school zones and schools in Oslo are laid out in the map in Figure 1. It shows the six different high school zones (Center, East, North West, South, South East and West). The Figure also shows catchment area boundaries for elementary and secondary schools. From the Figure it is evident that most high schools are located in Central Oslo and in the Western and North-Western Zones.

We use annual data on grade point averages from each secondary school in Mathematics, Norwegian and English. These have also been provided by the education authorities in Oslo. As already noted, the marks are scaled from 1 to 6, with 6 being the highest mark. We use the high school pupil average over pupils, and then average over the pre- and post-reform years. This should give a more ‘permanent’ measure of high school performance, and is confirmed by the rankings of schools being very similar over the years

we study. The reason we average across schools within zones is that there was choice across schools within zones.

The house price data covers transactions on all (used) houses and apartments sold in Norway<sup>10</sup>, although we restrict the data set to Oslo for our purpose. The data is collected by Statistics Norway (Lillegard, 1994) and the sales statistics are compiled from two sources: the Register of Landed Property, Addresses and Buildings (GAB); and a follow up survey conducted by Statistics Norway to obtain additional information on the houses. These variables are: the age of the house, the size of the house in square metres, the number of rooms, number of bathrooms, and year of renovation. It also contains information on 6 categories of house type, from apartments in large high rises to villas. The month of the transaction is given in the data. The response rate for the survey is between 80 and 90 percent. This means that we have access to information on 80-90 percent of the census of all sold apartments and houses in Oslo.

From 1995 onwards it is possible to match in the identity of the owner and to link this to register data.<sup>11</sup> This was done by Statistics Norway using the personal identifier of the buyer. This gives us a number of advantages. First, we can place all houses into their relevant school zones. Second, we can link owners to a very extensive set of demographic information. Third, we have annual geo-code for all inhabitants in Oslo so that we can identify the demographic composition of school zones by year.

Table A1 in the Appendix presents descriptive statistics for the pre- and post reform time periods. We have also defined a boundary sample covering all properties within 500 meters of the catchment area boundaries. We use this sample since it is now an established procedure in the literature to implement research designs treating catchment area boundaries

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<sup>10</sup> The data set does not include apartments owned by housing cooperatives since these properties are not traded freely in the market.

<sup>11</sup> These register data are collected from other administrative sources and maintained by Statistics Norway. A description of these data sets is given in Møen, Salvanes and Sørensen (2004).

as discontinuities to identify the impact of school quality on house prices (see, *inter alia*, Black, 1999; Gibbons and Machin, 2003; Kane, Staiger and Reigg, 2005; Fack and Grenet, 2007), an approach we consider in more detail below.

## **Descriptive statistics**

Figure 2 shows the spatial distribution of high school grades across the city areas of Oslo. Darker (lighter) shading corresponds to higher (lower) grades. It is clear that schools in zones in the West; North-West and Centre do better.<sup>12</sup> This corresponds closely to the perceived ranking of parents in Oslo, as reported in the sociological literature (Nordli-Hansen, 2005).

In Figure 3 we do the same exercise for house prices (measured in real NOK per square metres). The Figure splits the house price distribution in 6 parts and again shows higher (lower) mean prices in city areas in darker (lighter) shading. It is evident that the high house price areas are also the West and North-West zones plus the Center zone, which are the areas where the highest performing schools are located.

In Table 1 we present some descriptive statistics on house prices before and after the school admissions reform and the simple correlation between log(house prices) and school performance for various samples. The top Panel of the Table shows house prices rose significantly between the two time periods, and that school grades went up a little (but not by a statistically significant amount). It also shows a significant correlation between house prices and school performance in both the pre- and post-reform periods but, interestingly, the correlation falls after the reform occurred. The lower Panel of the Table considers the boundary sample defined as all properties within 500 meters of the catchment area

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<sup>12</sup> We have excluded the two schools in the Centre zone which had open access all the time.

boundaries.<sup>13</sup> It is interesting that very much the same pattern of change of house prices and grades, and their correlations, is seen for this sub-sample.

One vital issue about the school reform is whether the opening up to school choice did in fact alter high school attendance patterns. Table 2 shows the reform had a strong impact on where students went to high school pre and post reform. In the pre-reform period the vast majority of students (between 85-95 percent) attended a high school within their zone of residence.<sup>14</sup> After the reform, much more boundary crossing is seen as only between 36 and 57 percent of the students went to a high school in the zone where the student was living.

## 4. Methods and Results

### Methods

At a particular point in time, say period  $t$ , a standard hedonic formulation<sup>15</sup> relating log (house prices) to school quality can be expressed as:

$$p_{ist} = \beta s_{st} + \gamma z_{ist} + g(s, s(e), t) + u_{ist} \quad (1)$$

where  $p_{ist}$  is the log property price for house  $i$  in a neighbourhood or school catchment zone  $s$  at time  $t$ ,  $z_{ist}$  includes property, neighbourhood and demographic characteristics<sup>16</sup>,  $s_{st}$  measures school quality and the  $g(s, s(e), t)$  function contains various different fixed effects, for school

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<sup>13</sup> We find similar results (in the descriptives and empirical work below) for cut-offs of 1000m and 250m.

<sup>14</sup> There are likely to be several reasons why the pre-reform attendance rates are less than 100 percent, including some students moving in the middle of a school year, private schooling and school attendance outside Oslo county.

<sup>15</sup> See Rosen (1974) for the classic exposition of the hedonic pricing approach and the review by Sheppard (1999).

<sup>16</sup> We present estimates that do and do not control for these characteristics as we remain uncertain about the plausibility of an exogeneity assumption about them owing to possible sorting by residents that is directly linked to the particular characteristics in question.

s, elementary school<sup>17</sup> e (which is directly linked to school s as shown in Figure 1 and as discussed in Section 2 above) and time t. Finally,  $u_{ist}$  is a random error term.

This kind of function has been used in the existing literature to try to estimate  $\beta$ , the sensitivity of house prices to (measured) school performance. One worry is that there are unobserved variables which this approach cannot control for. Therefore, some studies make use of the fact that there is a discontinuity at catchment area boundaries by comparing houses on either side of school area boundaries, and thus effectively controlling for unobserved characteristics of the houses or omitted neighbourhood characteristics such as local public goods. This is a much more convincing approach, but one worry that remains is that unobserved factors (like house maintenance) may grow differently on either side of the borders. Moreover, even if houses were similar on either side of the border when zone borders were originally established, houses may change character over time as they are bought and sold. For example, it may be the case that if one is willing to pay a premium to live in a school area with good school, it may also mean that one is willing to invest more and maintain and improve the house.

The reform potentially changes the house price-school quality relation in a time series context and we can use reform induced variations in school quality to get around the problems linked to differential unobservables across boundaries. To do so we use two, related but different, modelling strategies. First, we estimate equation (1) separately for the pre-reform and post-reform time periods. Adding a k superscript ( $k = \text{pre, post}$ ) to (1) gives the equation

$$p_{ist}^k = \beta^k s_{st} + \gamma^k z_{ist} + g^k(s, s(e), t) + u_{ist} \quad (2)$$

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<sup>17</sup> In Oslo there is a connection between elementary school attended and secondary school attendance, again working through fixed catchment zones although the link may not be too strong since even in the pre-reform period there was choice of high schools based on primary school marks within each zone. Hence, since there is a potential link between good primary schools/neighbourhoods and good high schools even after the reform. This is one reason why we also include elementary school fixed effects in some of our empirical specifications.



Thus we can study what happens to the school quality premium before and after reform by testing the null hypothesis  $\beta^{\text{pre}} = \beta^{\text{post}}$ .<sup>18</sup> We implement this before-after comparison for the full sample of housing transactions. We are also able to use the discontinuity approach of controlling for additional common unobservables in the boundary sub-sample. One feature of this is to generalise the  $g(\cdot)$  function to include boundary fixed effects, thus re-specifying as  $g(s, s(p), t, b)$ , with  $b$  denoting a boundary.<sup>19</sup>

$$p_{\text{ist}}^k = \beta^k s_{\text{st}} + \gamma^k z_{\text{ist}} + g^k(s, s(e), t, b) + u_{\text{ist}} \quad (3)$$

Our second approach recognises that the school choice reform induced policy variation at the level of the admission zone, by permitting children to cross what were previously non-crossable catchment area boundaries. The catchment area zones each contained several high schools (around three on average). The idea behind this approach is that the pre-reform capitalization is likely to be embedded in catchment area fixed effects,  $\alpha_c$ . We therefore first estimate these catchment area fixed effects separately pre- and post-reform, then relate them to school grades in a second stage at catchment area level,  $c$ .

This two stage procedure can be represented as:

$$\begin{aligned} p_{\text{ist}}^k &= \gamma^k z_{\text{ist}} + \alpha_c^k + g^k(s(e), t, b) + u_{\text{ist}} \\ \hat{\alpha}_{ck}^k &= \theta^k s_{ck} + \varepsilon_{ck} \end{aligned} \quad (4)$$

Notice in (4) that the school quality measure appears only in the second stage, which we estimate pre- and post-reform. Structuring in this way gives us two ways to uncover whether the school quality premiums change before and after reform. We can relate the (pre- and post-) catchment area fixed effects to grades before and after reform, or just to pre-reform school grades. In our analysis we do both, and discuss their interpretation below.

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<sup>18</sup> One way to think about this is that we are using a supply shock – the school reform – to identify the parameters in the hedonic price function for houses.

<sup>19</sup> Use of boundaries amounts to assuming that unobserved factors affecting house prices change smoothly across space, and are not correlated with school quality differences across boundaries. Of course, there may be differences in sorting and unobserved house differences along borders. Our (effective) use of the school choice reform as an instrument, by estimating before and after reform, should enable us to avoid such potential problems.

### Pre- and post-reform differenced model

A baseline set of results, for all house price transactions in the period 1995-2002, is given in Table 3 for the full and boundary samples, respectively in Panels A and B. For each of these, the Table presents four specifications, each of which differs in the way that it controls for spatial house price differences. In (1) we include a full set of house characteristics (see the notes to the Table for a full list) and year dummies. In (2) we additionally include a set of area demographics (also listed in Table notes). In (3) we add a set of school fixed effects, whilst (4) includes a full set of elementary school fixed effects.

In both panels there is a strong and significant pre-reform house price premium for better school performance (signified by the coefficient  $\beta^{\text{pre}}$  in the Table). In the upper panel A for the full sample, a one standard deviation increase in the average exam grade (.21 of a grade) is, dependent on specification, associated with somewhere between 7.6 (=  $\{.21 \times .362\} \times 100$ ) and 11.5 (=  $\{.21 \times .547\} \times 100$ ) percent higher log house prices. In the lower panel for the boundary sample comparable percentage log house price premia in the pre-reform period are between 7.0 and 10.4 percentage points. Thus in the pre-school choice period with fixed catchment zones Oslo parents valued school quality very highly indeed.

After the opening up to school choice, parents still strongly valued better school performance, but the relationship with house prices significantly fell. This is shown by the halving (or more) of the post-reform coefficient  $\beta^{\text{post}}$  shown in the Table. Indeed the estimated coefficient falls very strongly and significantly (from -.18 to -.28 in the full sample in Panel A and by a very similar -.18 to -.29 in the boundary sub-sample in Panel B). All in

all, this is very strongly suggestive of a significant impact of the opening up to school choice on school quality related house price premia.<sup>20</sup>

One pertinent observation is that the house price premium does not fall to zero when the catchment areas were removed. Presumably this is because transport costs still remain, combined with the fact that persistent neighbourhood differences induced by the former catchment areas remain. On the question of transport costs this generates a willingness to pay to be closer to schools simply to reduce travel costs. Of course, school locations do not change pre- and post-reform so our differencing across the pre- and post-reform periods should not be affected by this.

### **Catchment area fixed effects model**

Tables 4a and 4b show results from the two stage approach. This, of course, is similar to the fully differenced models in Table 3, but changes the focus to see how house price variations at the catchment area level vary with school quality change pre- and post-reform. Tables 4a and 4b differ in which school quality measure is used. In Table 4a the catchment area fixed effects retrieved from the first stage are regressed on pre-reform grades, whilst in Table 4b the same period grades are utilised. The story that emerges is the same.<sup>21</sup> Both Tables show a strong fall in the magnitude of the empirical connection between house prices and school quality after the opening up to school choice. In all specifications, this falls by 50 percent or more after the reform.

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<sup>20</sup> Inclusion of catchment area trends in all reported models made little difference and the key results remained intact.

<sup>21</sup> This is reassuring in that one may worry that estimates from the model including post-reform fixed effects could induce a bias as the first stage model does not capture pre-reform variation in school quality. This is not a problem in the models including pre-reform period fixed effects as school quality is assigned by the catchment area.

## **Extensions**

In Table 5 we present some extensions and robustness checks. The very rich data we have means that, unlike almost all studies in the literature, we know whether households have children living in them. In (1) we thus consider results from the differenced model for households with high school age children. For sample size reasons we can do this only for the full sample, but the estimates are strikingly reassuring, with the school quality premium falling by around 50 percent from .552 to .276.

In (2) and (3) we present (again for the full sample only) what we refer to as a short run or 'instantaneous' sample (one year before reform, 1995-96, compared to one year after, 1997-98) and a long run sample (one year before reform, 1995-96, compared to five years later, 2001-02). Again reassuringly we find significant falls in the school quality premium for both, but with there being stronger, more sizable effects in the long run as compared to the short run 'instantaneous' impact.

## **Residential mobility before and after the reform**

It is evident that another feature of the opening up to school choice would not only be a reduced need for parents to pay for better school quality, but also a reduced need to move into the catchment areas of better performing schools. We therefore consider how residential mobility relates to measured pre-reform school quality before and after reform in Table 6. At a particular point in time, there is no strong theoretical reason to expect a clear linkage

between residential turnover and school quality<sup>22</sup>, but our focus is on whether there is a change post-reform owing to less of a need to move for school quality.

The Table actually shows a strong association between the probability of residential moves and school quality in the pre-reform period (where the estimated coefficient  $\lambda^{\text{pre}}$  ranges from .10 to .12, always being strongly significant in statistical terms, dependent on specification). In the post reform period this falls, by somewhere between 20 and 25 percent, showing there to be less need for parents to move house to 'buy' school quality after the school choice reform. We view this as strongly corroborating our earlier results on significant falls in willingness to pay after the opening up to school choice.

## 5. Concluding Remarks

In this paper we study the connections between local house prices and school quality in a different, but complementary, way to existing work in the area. Our main advance on existing work arises as we look at what happens to willingness to pay for school quality before and after a school admissions reform. This reform took place in the 1997/98 school year in Oslo, when the mode of high school admission changed from a fixed catchment area based system to one based on school choice with open enrollment.

Our estimates based on the reform show evidence that parents substantially value better performing schools. They also show that school choice matters. When proximity to high school through residence in a fixed catchment area is the criterion for admission, parents are prepared to pay significant amounts of money to live in the catchment area of schools they

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<sup>22</sup> For example, residential turnover may be higher in good school quality areas because parents wish to move there, but equally it could be higher in bad school areas if they are occupied by singles who are just passing through and have no interest in school quality.

prefer. The pre-reform magnitudes are in line with other work in the area (perhaps towards the upper end), with a one standard deviation increase in test scores implying a 7-10 percent higher level of house prices. However, once the reform occurred and the proximity criterion for admission was removed, the house price-school performance relation was significantly weakened, falling by a large magnitude with the house price premium for school quality dropping by 50 percent or more compared to the pre-reform time period.

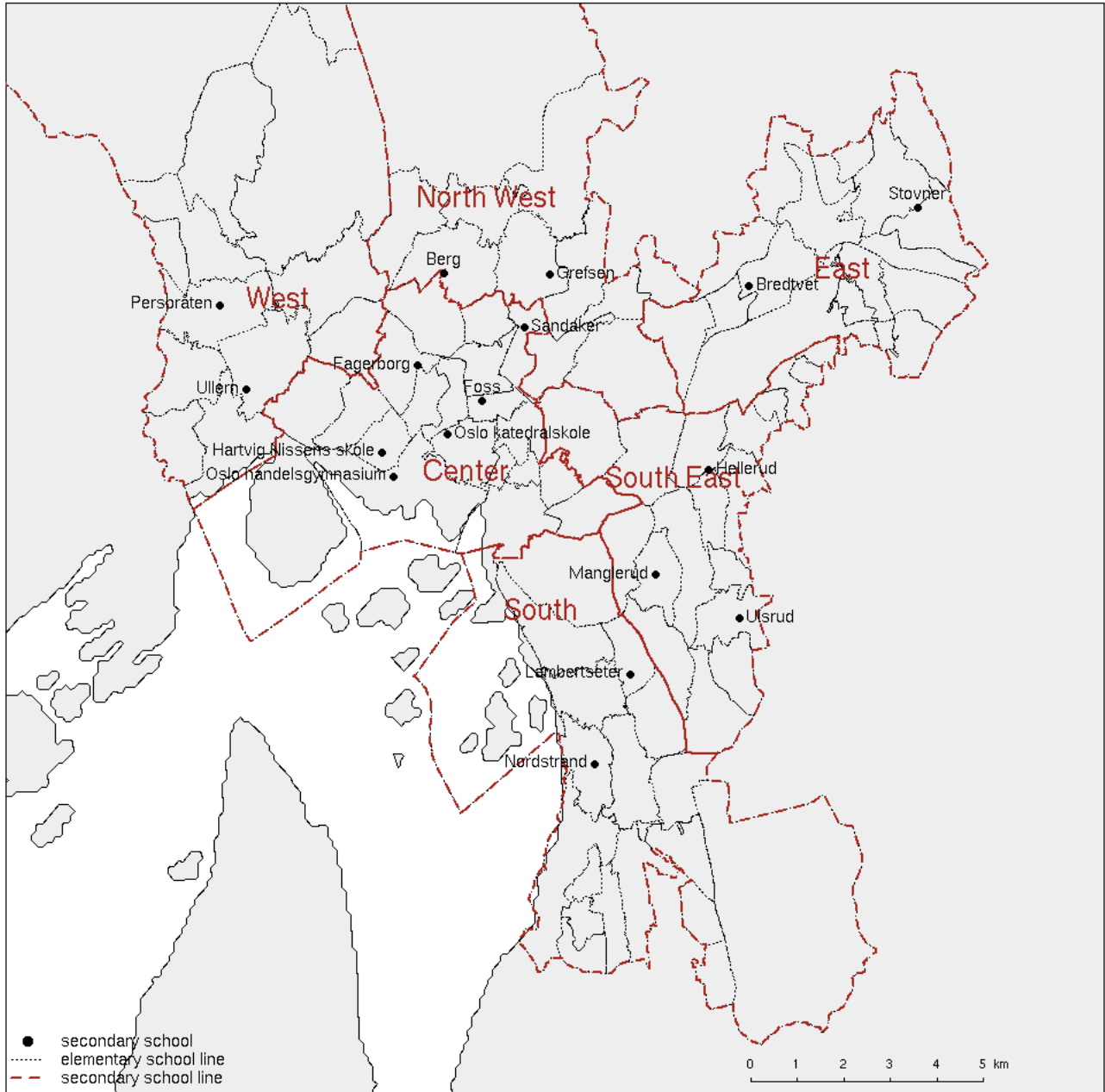
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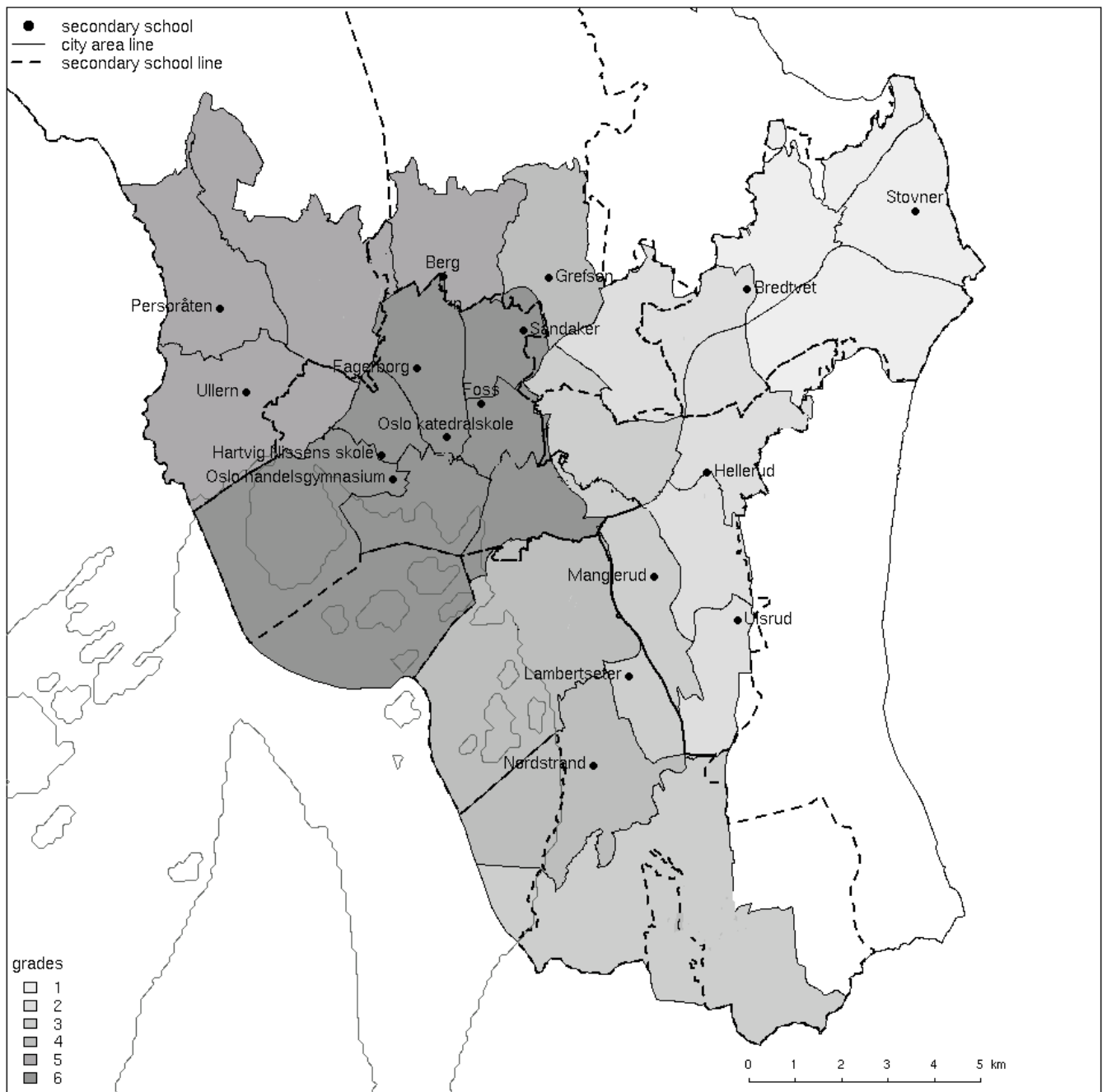
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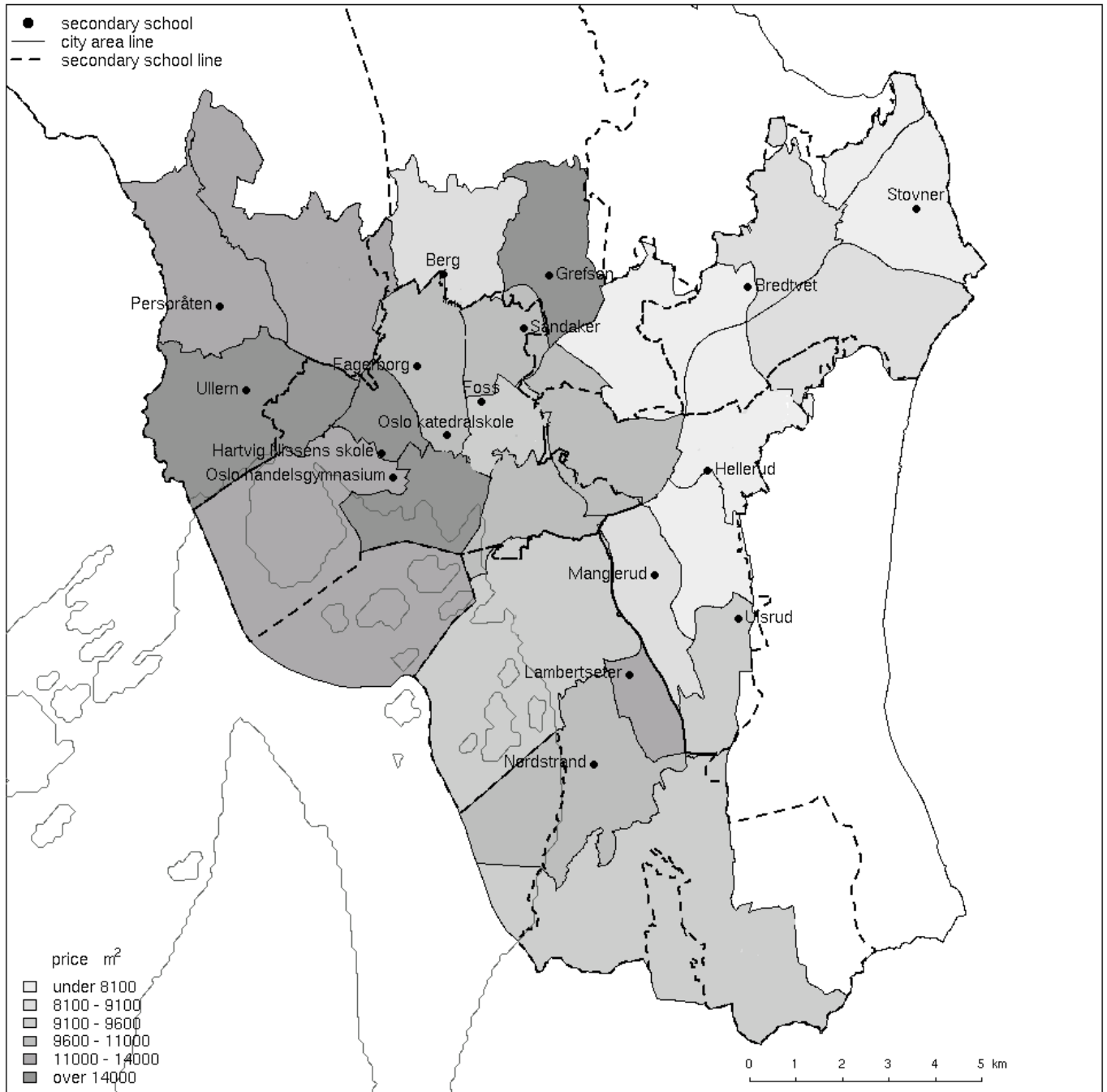
**Figure 1 High School Locations and Zones and Elementary and Secondary Catchment Boundaries in Oslo, Pre-Reform**



**Figure 2 School Grades Pre-Reform**



**Figure 3 House Prices Pre-Reform**



**Table 1 Descriptive Statistics, Before and After School Choice Reform**

|  | Pre-Reform                   | Post-Reform     |                            |
|--|------------------------------|-----------------|----------------------------|
|  | Mean<br>(Standard Deviation) |                 | Change<br>(Standard Error) |
| <b>A. Full Sample</b>                  |                              |                 |                            |
| Log (Price Per Square Metre))          | 13.92<br>(0.61)              | 14.21<br>(0.65) | 0.29<br>(0.02)             |
| Grades                                 | 3.53<br>(0.21)               | 3.88<br>(0.30)  | 0.35<br>(0.21)             |
| Raw Correlation: Log(Price) and Grades | 0.18                         | 0.12            | -0.06                      |
| <b>B. Boundary Sample</b>              |                              |                 |                            |
| Log (Price Per Square Metre))          | 13.72<br>(0.50)              | 14.01<br>(0.64) | 0.29<br>(0.02)             |
| Grades                                 | 3.51<br>(0.22)               | 3.81<br>(0.32)  | 0.30<br>(0.18)             |
| Raw Correlation: Log(Price) and Grades | 0.17                         | 0.10            | -0.07                      |

Notes: Prices in real terms (using 2000 CPI). The boundary sample is all properties 500 metres or less from catchment area boundaries.

**Table 2 Proportion of Pupils Attending High School in Their Zone of Residence, Before and After School Choice Reform**

| Pre-Reform    |                   |             |             |                   |              |
|---------------|-------------------|-------------|-------------|-------------------|--------------|
| Center<br>.95 | North-West<br>.90 | East<br>.85 | West<br>.92 | South-East<br>.94 | South<br>.89 |
| Post-Reform   |                   |             |             |                   |              |
| Center<br>.57 | North-West<br>.44 | East<br>.40 | West<br>.37 | South-East<br>.46 | South<br>.36 |

Note: These figures are proportions of pupils attending high school (first year) within their zone of residence. Note that two schools that did not restrict access by catchment areas are excluded.

**Table 3 Pre- and Post-Reform Differenced Model**

| <b>A. Full Sample</b>         | Specification:   |              |              |              |
|-------------------------------|--|--------------|--------------|--------------|
|                               | $p_{ist}^k = \beta^k s_{st} + \gamma^k z_{ist} + g^k(s, s(e), t) + u_{ist}$    |              |              |              |
|                               | (1)  | (2)          | (3)          | (4)          |
| $\beta^{pre}$                 | .547 (.015)  | .472 (.016)  | .390 (.017)  | .362 (.018)  |
| $\beta^{post}$                | .272 (.006)  | .222 (.006)  | .198 (.007)  | .182 (.007)  |
| $\beta^{post} - \beta^{pre}$  | -.276 (.005)   | -.250 (.006) | -.192 (.006) | -.180 (.006) |
| House characteristics         | Yes  | Yes          | Yes          | Yes          |
| Area demographics             | No   | Yes          | Yes          | Yes          |
| Year effects                  | Yes  | Yes          | Yes          | Yes          |
| School effects                | No   | No           | Yes          | Yes          |
| Elementary school effects     | No   | No           | No           | Yes          |
| Sample size                   | 16330  | 16330        | 16330        | 16330        |
| <b>B. Boundary Sub-Sample</b> | Specification:   |              |              |              |
|                               | $p_{ist}^k = \beta^k s_{st} + \gamma^k z_{ist} + g^k(s, s(e), t, b) + u_{ist}$ |              |              |              |
|                               | (1)  | (2)          | (3)          | (4)          |
| $\beta^{pre}$                 | .473 (.022)  | .369 (.023)  | .342 (.024)  | .320 (.024)  |
| $\beta^{post}$                | .183 (.007)  | .167 (.007)  | .150 (.007)  | .137 (.007)  |
| $\beta^{post} - \beta^{pre}$  | -.290 (.009)   | -.203 (.009) | -.193 (.009) | -.183 (.009) |
| House characteristics         | Yes  | Yes          | Yes          | Yes          |
| Area demographics             | No   | Yes          | Yes          | Yes          |
| Year effects                  | Yes  | Yes          | Yes          | Yes          |
| School effects                | No   | No           | Yes          | Yes          |
| Elementary school effects     | No   | No           | No           | Yes          |
| Boundary fixed effects        | Yes  | Yes          | Yes          | Yes          |
| Sample size                   | 3142   | 3142         | 3142         | 3142         |

Notes: The dependent variable is ln(sales price). School grades are an average of Norwegian and Math and English. Robust standard errors allowing for clustering at the high school catchment area level in parentheses. Sample is limited to all sales 1995-2002. House characteristics are: number of rooms, number of bathrooms, wc, square metres, whether renovated, year built, type of house in defined as apartments in small houses, single houses and apartments in high rises. Area demographics are: proportions with higher university degree, some college, and less than high school, proportion first and second generation immigrants for non-OECD countries, mean family earnings. The boundary sample restricts to houses 500 metres or less from the catchment area boundaries. Clustering of standard errors at high school catchment area.

**Table 4a Catchment Area Fixed Effects Model – Pre-Reform Grades**

| <b>A. Full Sample</b>          | Specification:   |              |              |              |
|--------------------------------|--|--------------|--------------|--------------|
|                                | $p_{ist}^k = \gamma^k z_{ist} + \alpha_c^k + g^k(s(e), t) + u_{ist}$ $\hat{\alpha}_{ck}^k = \theta^k s_{c,pre} + \varepsilon_c$    |              |              |              |
|                                | (1)  | (2)          | (3)          | (4)          |
| $\theta^{pre}$                 | .428 (.009)  | .407 (.010)  | .391 (.010)  | .371 (.010)  |
| $\theta^{post}$                | .221 (.006)  | .211 (.006)  | .192 (.008)  | .176 (.010)  |
| $\theta^{post} - \theta^{pre}$ | -.207 (.011)   | -.196 (.011) | -.199 (.011) | -.195 (.011) |
| House characteristics          | Yes  | Yes          | Yes          | Yes          |
| Area demographics              | No   | Yes          | Yes          | Yes          |
| Year effects                   | Yes  | Yes          | Yes          | Yes          |
| School effects                 | No   | No           | Yes          | Yes          |
| Elementary school effects      | No   | No           | No           | Yes          |
| Sample size                    | 16330  | 16330        | 16330        | 16330        |
| <b>B. Boundary Sub-Sample</b>  | Specification:   |              |              |              |
|                                | $p_{ist}^k = \gamma^k z_{ist} + \alpha_c^k + g^k(s(e), t, b) + u_{ist}$ $\hat{\alpha}_{ck}^k = \theta^k s_{c,pre} + \varepsilon_c$ |              |              |              |
|                                | (1)  | (2)          | (3)          | (4)          |
| $\theta^{pre}$                 | .429 (.016)  | .334 (.016)  | .318 (.016)  | .302 (.016)  |
| $\theta^{post}$                | .237 (.008)  | .189 (.007)  | .160 (.007)  | .145 (.007)  |
| $\theta^{post} - \theta^{pre}$ | -.292 (.007)   | -.225 (.008) | -.158 (.008) | -.157 (.008) |
| House characteristics          | Yes  | Yes          | Yes          | Yes          |
| Area demographics              | No   | Yes          | Yes          | Yes          |
| Year effects                   | Yes  | Yes          | Yes          | Yes          |
| School effects                 | No   | No           | Yes          | Yes          |
| Elementary school effects      | No   | No           | No           | Yes          |
| Boundary fixed effects         | Yes  | Yes          | Yes          | Yes          |
| Sample size                    | 3142   | 3142         | 3142         | 3142         |

Notes: As for Table 3

**Table 4b Catchment Area Fixed Effects Model – Pre and Post-Reform Grades**

| <b>A. Full Sample</b>          | Specification:  |              |              |              |
|--------------------------------|---|--------------|--------------|--------------|
|                                | $p_{ist}^k = \gamma^k z_{ist} + \alpha_c^k + g^k(s(e), t) + u_{ist}$ $\hat{\alpha}_{ck}^k = \theta^k s_{ck} + \varepsilon_c$    |              |              |              |
|                                | (1)   | (2)          | (3)          | (4)          |
| $\theta^{pre}$                 | .428 (.009)   | .407 (.010)  | .391 (.010)  | .371 (.054)  |
| $\theta^{post}$                | .203 (.007)   | .191 (.006)  | .192 (.008)  | .176 (.010)  |
| $\theta^{post} - \theta^{pre}$ | -.225 (.011)  | -.216 (.011) | -.209 (.011) | -.195 (.011) |
| House characteristics          | Yes   | Yes          | Yes          | Yes          |
| Area demographics              | No  | Yes          | Yes          | Yes          |
| Year effects                   | Yes   | Yes          | Yes          | Yes          |
| School effects                 | No  | No           | Yes          | Yes          |
| Elementary school effects      | No  | No           | No           | Yes          |
| Sample size                    | 16330   | 16330        | 16330        | 16330        |
| <b>B. Boundary Sub-Sample</b>  | Specification:  |              |              |              |
|                                | $p_{ist}^k = \gamma^k z_{ist} + \alpha_c^k + g^k(s(e), t, b) + u_{ist}$ $\hat{\alpha}_{ck}^k = \theta^k s_{ck} + \varepsilon_c$ |              |              |              |
|                                | (1)   | (2)          | (3)          | (4)          |
| $\theta^{pre}$                 | .429 (.016)   | .334 (.016)  | .318 (.016)  | .302 (.016)  |
| $\theta^{post}$                | .198 (.006)   | .174 (.007)  | .150 (.007)  | .142 (.007)  |
| $\theta^{post} - \theta^{pre}$ | -.231 (.007)  | -.260 (.008) | -.168 (.008) | -.159 (.008) |
| House characteristics          | Yes   | Yes          | Yes          | Yes          |
| Area demographics              | No  | Yes          | Yes          | Yes          |
| Year effects                   | Yes   | Yes          | Yes          | Yes          |
| School effects                 | No  | No           | Yes          | Yes          |
| Elementary school effects      | No  | No           | No           | Yes          |
| Boundary fixed effects         | Yes   | Yes          | Yes          | Yes          |
| Sample size                    | 3142  | 3142         | 3142         | 3142         |

Notes: As for Table 3.

**Table 5 Extensions to Pre- and Post-Reform Differenced Model**

| Full Sample                  | Specification:  |              |              |
|------------------------------|---|--------------|--------------|
|                              | $p_{ist}^k = \beta^k s_{st} + \gamma^k z_{ist} + g^k(s, s(e), t) + u_{ist}$ |              |              |
|                              | (1)   | (2)          | (3)          |
|                              | Households<br>With Children   | Short Run    | Long Run     |
| $\beta^{pre}$                | .552 (.205)   | .224 (.012)  | .578 (.028)  |
| $\beta^{post}$               | .276 (.089)   | .137 (.008)  | .294 (.014)  |
| $\beta^{post} - \beta^{pre}$ | -.276 (.089)  | -.073 (.010) | -.284 (.013) |
| House characteristics        | Yes   | Yes          | Yes          |
| Area demographics            | Yes   | Yes          | Yes          |
| Year effects                 | Yes   | Yes          | Yes          |
| School effects               | Yes   | Yes          | Yes          |
| Sample size                  | 1913  | 790          | 820          |

Notes: As for Table 3.



**Table 6 Residential Mobility, Catchment Area Fixed Effects Model – Pre-Reform Grades**

| Full Sample                                    | Specification:   |              |              |              |
|--|--|--------------|--------------|--------------|
|  | $\text{Pr}[\text{move}]_{\text{ist}}^k = \phi^k Z_{\text{ist}} + \alpha_c^k + g^k(s(e), t) + v_{\text{ist}}$ $\hat{\alpha}_{\text{ck}}^k = \lambda^k s_{\text{c,pre}} + v_c$ |              |              |              |
|  | (1)  | (2)          | (3)          | (4)          |
| $\lambda^{\text{pre}}$                         | .123 (.015)  | .120 (.016)  | .108 (.017)  | .102 (.018)  |
| $\lambda^{\text{post}}$                        | .090 (.031)  | .090 (.034)  | .088 (.036)  | .081 (.037)  |
| $\lambda^{\text{post}} - \lambda^{\text{pre}}$ | -.033 (.010)   | -.030 (.008) | -.021 (.009) | -.020 (.009) |
| House characteristics                          | Yes  | Yes          | Yes          | Yes          |
| Area demographics                              | No   | Yes          | Yes          | Yes          |
| Year effects                                   | Yes  | Yes          | Yes          | Yes          |
| School effects                                 | No   | No           | Yes          | Yes          |
| Elementary school effects                      | No   | No           | No           | Yes          |
| Sample size                                    | 16330  | 16330        | 16330        | 16330        |

Notes: The dependent variable in the first stage is the probability of residential mobility. Notes other than the dependent variable definition as for Table 3.

## Appendix

**Table A1 Descriptive Statistics (Means)**

|                                     | Full Sample |             | Boundary Sub-Sample |             |
|-------------------------------------|-------------|-------------|---------------------|-------------|
|                                     | Pre-Reform  | Post-Reform | Pre-Reform          | Post-Reform |
| <b>Property Data</b>                |             |             |                     |             |
| Price Per Square Metre (NOK)        | 11575       | 18101       | 11524               | 17245       |
| Number of rooms                     | 3.89        | 3.58        | 3.27                | 3.13        |
| Number of bathrooms                 | 1.37        | 1.29        | 1.17                | 1.20        |
| Number of WCs                       | 1.60        | 1.45        | 1.27                | 1.31        |
| Square metres                       | 114.3       | 104.1       | 84.54               | 87.43       |
| Year built                          | 1956        | 1954        | 1961                | 1956        |
| Proportion renovated                | .37         | .44         | .26                 | .44         |
| Proportion apartments in high rises | .62         | .68         | .81                 | .78         |
| Proportion apartments               | .15         | .11         | .08                 | .09         |
| Proportion villas                   | .22         | .20         | .10                 | .12         |
| <b>Residents Data</b>               |             |             |                     |             |
| Proportion completed college        | .18         | .21         | .18                 | .20         |
| Proportion some college             | .26         | .27         | .26                 | .26         |
| Proportion less than high school    | .35         | .34         | .35                 | .08         |
| Proportion immigrants               | .078        | .087        | .077                | .091        |
| Earnings (NOK)                      | 182124      | 218039      | 183290              | 211966      |
| <b>School Data</b>                  |             |             |                     |             |
| Grades                              | 3.53        | 3.88        | 3.51                | 3.81        |

Notes: All prices in real values (2000 CPI).