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How Much do Public Schools Really Cost? Estimating the Relationship between House Prices and School Quality*

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This paper investigates the relationship between housing prices and the quality of public schools in the Australian Capital Territory. To disentangle the effects of schools and other neighbourhood characteristics on the value of residential properties, we compare sale prices of homes on either side of high school attendance boundaries. We find that a 5 percentage point increase in test scores (approximately 1 SD) is associated with a 3.5 per cent increase in house prices. Our result is in line with private school tuition costs, and accords with prior research from the UK and the USA. Estimating the effect of school quality on house prices provides a possible measure of the extent to which parents value better educational outcomes.

I Introduction

Parents deciding where to educate their child are frequently characterised as choosing between an expensive private school and a free public school. Yet if admission into the best public schools is limited, the quality of public schools may in fact be capitalised into the prices of houses in the neighbourhood. Just as house prices are higher when they are close to good parks, transport nodes and shops, might house prices also be affected by the quality of nearby schools?

To test this theory, we estimate the relationship between school quality and house prices in the Australian Capital Territory (ACT). Three features of the schooling system in the ACT make it a useful counterpoint to the USA, on which most of the prior studies in this area have focused. First, parents in the ACT have limited access to test score information with which to judge school performance, by contrast to the high-information regimes prevailing in the USA. Second, the school boundaries that we study are ‘soft’, meaning that being on the wrong side of the boundary does not prevent a child from attending a specific school, but merely sends him or her to the bottom of the enrolment list.

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And third, the presence of a large non-government school sector means that there are more alternatives for parents who find themselves on the wrong side of the boundary. In theory, all of these factors should act to weaken the elasticity of house prices with respect to school quality.

This paper provides the first empirical estimates of the relationship between school test scores and housing prices in Australia. Our approach exploits the sharp discontinuity of school boundaries. By comparing houses that are very close to one another but on opposite sides of a school attendance area boundary, we are able to hold constant neighbourhood characteristics, and obtain precise estimates of the effect of school quality on house prices. This estimation strategy helps overcome the complicating fact that better schools tend to be located in better neighbourhoods.

Estimating the willingness to pay for public schools has important implications for education policy-makers. Understanding what parents are prepared to pay (through taking out a larger mortgage) in order to send their children to a better public school provides an insight into the price elasticity of demand for high quality education. From an equity standpoint, the cost of higher quality public education provides a measure of the constraints that low-income families may face if they wish to send their child to a better performing school. From an efficiency perspective, the model presented in this paper implies that measuring changes in school quality through changes in house prices could provide a benchmark for policy-makers to judge how much parents value a given educational reform.

To preview our results, we find that ACT parents do place a premium on public schools with higher test scores. Specifically, we find that a 5 percentage point increase in high school test scores (approximately 1 SD) is associated with a 3.5 per cent increase in house prices: or \$13 000 at the median 2005 ACT house sale price. These results are robust to a number of sensitivity checks and corrections for potential omitted variable biases.

The remainder of this paper is organised as follows. Section II reviews the literature on the relationship between school quality and housing prices. Section III provides background on the school system in the ACT. Section IV describes the data. Section V briefly outlines the chosen methodology. Section VI discusses the regression results. Section VII presents robustness checks. Section VIII concludes and elaborates on the key policy implications of our findings.

II Previous Literature

In traditional hedonic pricing models, the sale price of a property is described as a function of the internal characteristics of the house as well as its location (Kain & Quigley, 1975; Mingche & Brown, 1980; Jud & Watts, 1981; Abelson, 1997). In such models, the price that is associated with each characteristic represents the marginal purchasers' valuation of that feature, with the parameter of interest being the proxy that is being used to operationalise school performance (Rosen, 1974).

The first type of approach to estimating the effect of school quality on house prices is to use all houses in an area, and include a rich set of neighbourhood controls. Examples of this type of approach include Weimer and Wolkoff (2001) and Cheshire and Sheppard (2002). A related approach is that of Downes and Zabel (2002), who estimate the relationship between changes in school quality and changes in house prices. The risk with such an approach is that the estimates may be biased in the presence of unmeasured neighbourhood quality effects.

A second empirical strategy is to exploit school boundary discontinuities. Black (1999) and Gibbons and Machin (2003) estimate a hedonic pricing function using data only from houses which are close to school attendance zone boundaries, thereby removing variation in neighbourhoods, taxes and school spending.[1] Gibbons and Machin (2006) show results using this approach, as well as a related strategy which involves assigning each property to '3-school clusters', and exploiting differences within clusters.[2]

A third set of studies use variation induced by natural experiments. Kane *et al.* (2005) exploit variation in school boundaries caused by a court-imposed desegregation order in Mecklenburg County, North Carolina. Reback (2005) uses an inter-district school choice program in Minnesota to estimate the capitalisation effects associated with the

[1] In the USA, local schools are typically funded from local property taxes. Estimates which do not control for differences in school district taxes therefore capture the combined effect of differenced in school quality and taxes. For an example of the latter, see Bogart and Cromwell (1997).

[2] The UK estimates discussed here (Cheshire & Sheppard, 2002; Gibbons & Machin, 2003, 2006; Rosenthal, 2003) are consistent with stated-preference studies. For example, one study recently found that parents from across the UK would spend £15 000 extra, on average, on a new home to get their child into a better government school (BBC, 2006).

diminished importance of school district boundaries.[3] Rosenthal (2003) instruments for school quality with random government inspections, which should only affect property prices by raising school quality.

The fourth type of approach is that of Bayer *et al.* (2007), who directly model the household sorting process, using an 'optimal price instrument', which is based on the prices of houses more than 5 miles away. The intuition for this is that the prices of houses beyond this distance should not enter directly into the utility of homebuyers, but should nonetheless influence the equilibrium in the housing market, thereby affecting prices.

How large are the existing estimates of the effect of school quality on house prices? In Table 1, we summarise the results from 10 prior studies (four from the UK and six from the USA). For reasons of comparability, we translate all studies to a common metric: the percentage effect on house prices of a 1-SD increase in school quality. Full details on how each estimate was derived are available from the authors upon request. This simplification does not take account of the non-linearities identified by some studies (e.g. Cheshire & Sheppard, 2002; Bayer *et al.*, 2007), but does have the advantage of making the studies directly comparable. Where a study identifies a particular estimate as being preferred, we show that estimate; otherwise we show the range of estimates from the paper. Overall, the UK estimates are smaller for secondary schools (0.05 and 2 per cent), but primary school estimates are in the range of 2–10 per cent, centred around 4 per cent. The US estimates range from 1 to 14 per cent, centred around 5 per cent.

III Background

The ACT, home to the Australian national capital, Canberra, is an ideal location to study the capitalisation of school quality. Schools are funded at the Territory level, and are broadly subject to the same curricula, class size and administrative standards. This means all observations are subject to similar policy standards at any point in time. Moreover, enrolments in public schools are assigned on the basis of prospective students' residential addresses, with school attendance boundaries tending to be stable over time (Department of Education and Training, 2005). Of all Australian States and Territories, the ACT also has the most socio-economically homogenous population, meaning that the estimates of the relationship between school quality and houses prices are less likely to pick up confounding unobserved neighbourhood characteristics (Australian Bureau of Statistics, 2001a).

The ACT government education system is normally split up into five phases: preschool, primary school (grades K-6), high school (grades 7–10) and college (grades 11–12), followed by studies at university. Most private high schools include years 11 and 12. Since the term 'college' is more commonly used in the economics of education to denote part of a university, we refer to schools catering for years 11–12 as 'high schools' throughout this paper, specifically referring to grade 7–10 high schools where necessary.

The ACT is a relatively high-income community, whose population is very well educated by national standards.[4] Assuming that more educated parents with higher incomes are more likely to value better educational outcomes for their children, this suggests that there is likely to be a high premium placed on better school quality. This is arguably reflected by three qualitative aspects of the ACT's education system. First, ACT students have a reputation for being some of the nation's highest achievers, recently outperforming other jurisdictions in most literacy and numeracy tests.[5] Second, the ACT has the highest retention rate in Australia with 89 per cent of the students who were enrolled in year 7 in 1999 being enrolled full-time in year 12 in 2004 (ABS, 2005). Third, compared with residents of other states, ACT parents are more inclined to send their children to private schools. In 2005, the share of students attending non-government schools was 33 per cent nationally, and 41 per cent in the ACT, higher than any other state or territory.

On one hand these factors might suggest that the marginal ACT parent is more 'willing to pay' for what they judge to be superior educational outcomes; yet on the other, the high proportion of students being educated outside of the public education system

[3] This severing is predicted in the general equilibrium models of authors such as Nechyba (2003), and Epple and Romano (1998).

[4] As of May 2004, 30 per cent of people in the ACT aged 15–64 had a level of educational attainment equal to at least a bachelor's degree, significantly higher that the national average of 19 per cent. The ACT median weekly income for people aged over 15 was in the range \$500–\$599, well above the national average of \$300–\$399 (Australian Bureau of Statistics, 2005).

[5] Results issued in 2005 for year 3, 5 and 7 students revealed ACT pupils topped the nation in four of nine categories. They scored highest when year 5 reading results were compared, and equal highest for year 3 numeracy and year 7 reading (Bellamy, 2006).

TABLE 1
Studies Estimating the Effect of School Quality on House Prices Measured as the Effect of a 1-SD Increase on House Prices

Study	Effect (per cent)	Sample	School quality measure
Australia			
Davidoff and Leigh 2008 (this study)	3.5	Secondary schools in the Australian Capital Territory	Median year 12 test score
UK			
Cheshire and Sheppard (2002)	2.1	Primary schools in Reading, UK	Share of pupils passing the Key Stage 2 standard assessment tests administered at age 11 (average of mathematics, English and science tests)
Cheshire and Sheppard (2002)	0.05	Secondary schools in Reading, UK	Proportion of 15 years olds who pass five or more General Certificate of Secondary Education subjects at grade C or better
Gibbons and Machin (2003)	3–10	Primary schools in the UK	Proportion of pupils reaching the target level of attainment in the Key Stage 2 standard assessment tests administered at age 11 (average of mathematics, reading and English tests)
Gibbons and Machin (2006)	4	Primary schools in Greater London	Proportion of pupils reaching the target level of attainment in the Key Stage 2 standard assessment tests administered at age 11 (average of mathematics, reading and English tests)
Rosenthal (2003)	2	Secondary schools in the UK	Proportion of 15 years olds who pass five or more General Certificate of Secondary Education subjects at grade C or better
USA			
Bayer *et al*. (2007)	2.4	San Francisco Bay Area, CA	Average student test scores in mathematics, literature and writing for grades 4, 8 and 10
Black (1999)	2.5	Elementary schools in Boston, MA	3-year average of mathematics and reading scores in the fourth grade Massachusetts Educational Assessment Program tests
Downes and Zabel (2002)	14	Middle schools in Chicago, IL	Average district/school eighth grade reading component of the Illinois Goals Assessment Program tests
Kane *et al*. (2005)	10	Elementary schools in North Carolina	7-year average of school fixed effects, based on mathematics and reading performance in grades 3–5
Reback (2005)	3.8–7.7	Elementary, middle and secondary schools in Minnesota	Index based on 7 district-level tests, covering grades 3–10
Weimer and Wolkoff (2001)	1.0–8.3	Elementary schools in Monroe, County, NY	Fourth grade English Language Arts exam

indicates that, for a large number of parents, the school their child attends is not necessarily determined by their home address, implying that there might be a limit on the capitalised price of school quality.

The amount of information about school quality which is publicly available to parents in the ACT is typically far less than in other jurisdictions, especially when compared with the UK and the USA, where league tables are typically available online. The ACT Government's long-standing policy to prohibit the release of publication of school test score averages in reading and mathematics from grades K-10 was recently upheld by a *Review of Government School Reporting*. The report argued that the provision of school test scores may 'provide an inaccurate and misleading picture of school quality; lead to the construction of partial or full league tables of school results; and undermine effective school improvement' (GSEC, 2004, 17). The only comparative reporting which the review did sanction was the ongoing publication of overall median year 12 test score outcomes by school, currently published by the ACT Board of Senior Secondary Studies, and reproduced in mid-December in the ACT's daily newspaper, the *Canberra Times*.

In light of recent findings that the greater the amount of information about school quality available to the public, the greater is the likely capitalisation effect (Figlio & Lucas, 2004), the ACT's restricted information regime is a further factor which might limit the capitalisation of test score results into house prices.

IV Data

The housing price data for this study come from allhomes.com.au, a rich interactive database of properties sold in the ACT and surrounding areas over the last 15 years. The sample consists of nominal sale prices of individual family residences sold between 1 January 2003 and 1 September 2005. For reasons of data comparability, apartments and other subdivisions are excluded from the sample. As the database only records properties listed for sale on the open market, token sales (e.g. intra-family sales) which may not reflect true market valuations have also been systematically excluded from the sample.

The houses in the sample were drawn from streets that are within 600 m of a school attendance boundary. (We also test the robustness of our results to using only houses that are located closer to the boundary.) In recognition of the fact that neighbourhoods may differ as one moves along the boundary, our sampling method sought to balance clusters of houses on either side. For every cluster of houses that were selected on one side of a boundary at a given point, an equal number of houses were selected on the opposite side of the boundary, at the same point along the boundary.

As indicated above, public school students in the ACT complete years 11 and 12 in separate high schools. Given that the chosen measure of school quality for this study is year 12 test scores, the attendance boundaries which separate high school attendance zones thus function as the lines of demarcation around which the housing data was gathered. Figure 1 presents an example of an attendance boundary in the sample which separates two high schools. The solid line represents a high school attendance boundary and the light grey shading denotes the surrounding streets from which the property sales were drawn.

All school zones boundaries for the ACT are shown in Figure 2. Attendance boundaries are represented by the solid lines and high schools by dots. (Two dots in one attendance district reflect different campuses of the same school: Canberra High.) The six boundaries that are included in this analysis are denoted by either stars or triangles (the difference is explained below). Figure 2 also reveals three additional pieces of information that shape the data sample. First, it is clear that some boundaries are divided by natural markers, such as large lakes or parklands. Owing to concerns about neighbourhood differences on opposite sides of such an attendance boundary, boundaries which are formed in this way are excluded from the sample.

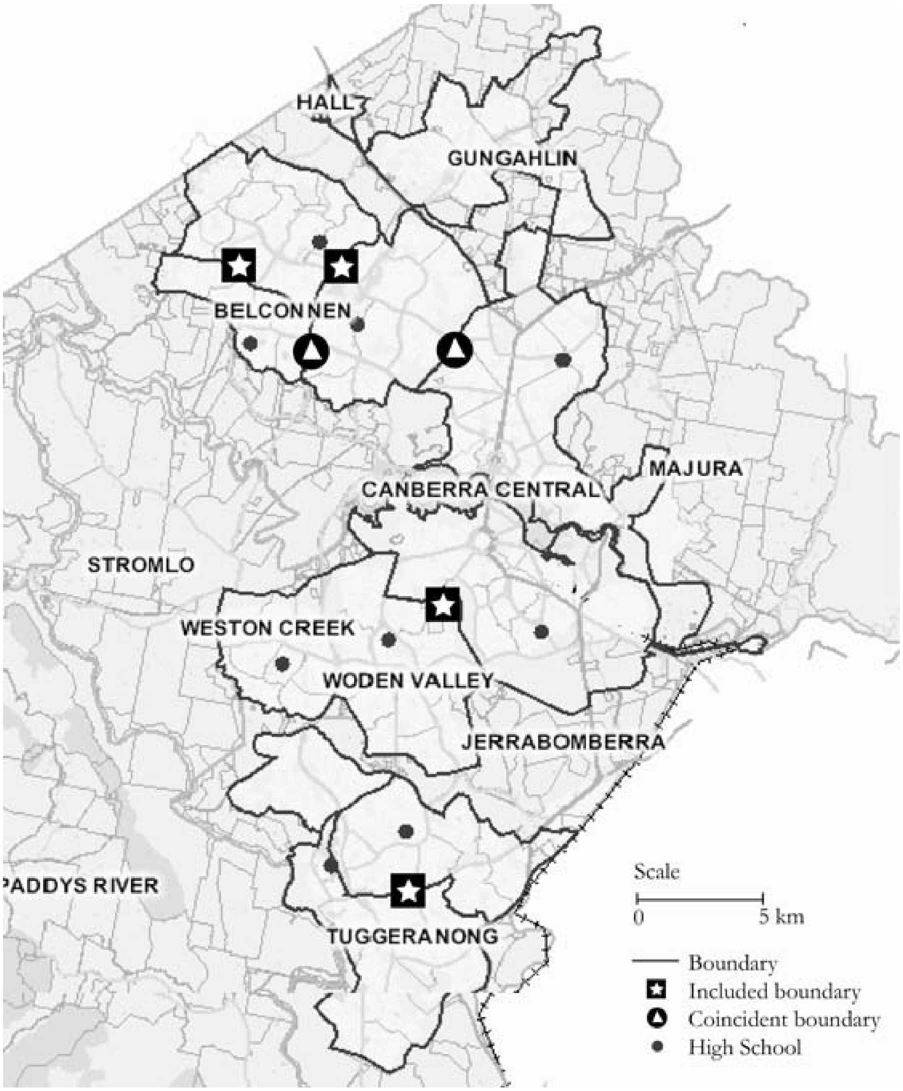
Second, not all boundaries are contiguous, meaning that there is not a designated school zone on either side of the boundary. This is especially true of boundaries on the outer perimeter of Figure 2, which are at the urban fringe. Non-contiguous boundaries are also excluded from the sample.

Third, in addition to separating the enrolment zones for grade 11–12 high schools, two boundaries in the sample (marked with triangles) also divide enrolment zones for grade 7–10 high schools. (Owing to the smaller size and far greater number of primary schools in the ACT, each high school attendance zone also typically incorporates multiple primary schools.) Since test score information is not available at the grade 7–10 level, we do not believe this is likely to substantially bias our estimates. However, it is worth noting the likely direction of the any bias. If the quality of grade 7–10 schools is positively correlated with the quality of grade 11–12 high schools, this will cause an upwards bias in our estimates, while if they are negatively correlated, this will lead to attenuation bias.[6]

[6] In fact, given the absence of any information it is possible that parents use the test score information from high schools to identify better middle schools. The assumption might be that better high school results partly reflect more able student bodies, which in turn suggests that the calibre of the children/parents in the neighbourhood where the school (and other schools) are located must be high. Under this scenario, parents would effectively be assuming that the quality of the high and middle schools on either side of the attendance boundary are positively correlated.

FIGURE 1
An Example of Two Contiguous High School Attendance Zones

FIGURE 2
All High School Attendance Zones in the ACT



Due to concerns about potential neighbourhood differences on opposite sides of attendance boundaries, each house in the sample is also matched to postcode-level neighbourhood characteristics from the 2001 quinquennial census. In general, postcodes are not contiguous with attendance boundaries.

Ideally, our measure of school quality would be a value-added measure, reflecting the ability of a given school to raise students' achievement. However, since such a measure is not available, we instead use each school's median University Admissions Index (UAI). The measure is derived from students' ongoing assignments and exams spanning through both years 11 and 12. The UAI ranks students on a nationally equivalent scale out of 100. The scale is designed to allow comparisons within an age cohort (e.g. a UAI of 75 means that the student is at the 75th percentile of his or her age cohort). Its main purpose is to allow universities to choose between applicants. The Australian UAI (known in other states and territories as an ENTER or TER score) carries more significance than final year exams in many other countries, as it is the sole criterion for entrance into most university programs.

In addition to being a standardised measure which is comparable across schools, evidence suggests that test scores – especially year 12 test scores – are a highly valued indicator of school quality.[7] A recent survey of high school students in the ACT found that 'preparation for university entrance' was the primary reason why students chose to enrol in a government high school (Department of Education and Training, 2006).[8] Even if parents are not considering test scores specifically when evaluating a high school but are instead looking at characteristics that are correlated with test scores, test scores will still be an appropriate measure. To reflect the information that parents had at their disposal, the test scores assigned to each sale are those publicly reported in mid-December of the previous year.

The full sample includes 580 houses. These houses span six boundaries which capture the school attendance zones associated with each of the eight public high schools in the ACT. Table 2 presents summary statistics. The mean house price in our sample is \$367 011 with a SD of \$185 083. The average median UAI in the ACT across all schools and all years is 74.6 with a SD of 5.6. A number of census variables are also presented to capture more detailed neighbourhood characteristics. At the postcode level, 22 per cent of the sample population was born overseas, and median weekly household income is \$509.

Table 2
Summary Statistics

	Mean	SD	*N*
House characteristics			
House price (\$)	367 011	185 083	580
ln(house price)	12.716	0.450	580
ln(lot size) (m^2)	6.712	0.294	580
Bedrooms	3.535	0.753	303
Bathrooms	1.679	0.711	280
Parking spaces	1.788	0.666	269
Distance from boundary	225.597	148.022	580
School characteristics			
Number of students per school	755.5	203.3	580
Year 12 test score (0–100)	74.557	5.608	580
Neighbourhood characteristics			
Median household income	508.620	73.722	580
ln(median household income)	6.222	0.134	580
Fraction born overseas	0.221	0.025	580

Notes: House prices are drawn from allhomes.com.au. Test scores are year 12 test scores measured at school level, taken from the *Canberra Times* (various years). There are eight government high schools in ACT, all represented in the data (Department of Education and Training, 2005). Neighbourhood characteristics are measured at the postcode level, sourced from ABS (2001b).

V *Estimation Strategy*

To estimate the relationship between school quality and housing prices, we exploit boundary discontinuities. Our strategy is similar to that of Black (1999), in that we compare the prices of houses that are close to, but on opposite sides of, a school attendance boundary. By comparing a sample of houses on opposite sides of a school attendance boundary, such an approach controls for unobserved neighbourhood characteristics that may be correlated with both school quality and house prices.

To better understand how the boundary discontinuity approach operates, imagine two identical houses that are on opposite sides of the same street, in a neighbourhood where the school zone boundary runs down the middle of the street. In this example, the two houses have access to all the same local amenities, such as shops, parks and transport networks. The only difference between these houses is that children in one house can attend a better school than children in the other house. As such, any observed difference in house

[7] While not all students received a UAI score because they did not all opt to undertake the prerequisite subjects, the resulting bias on school-level achievement is likely to be small. The proportion of students not receiving a UAI at government schools is small (approximately 5 percentage points) and the schools with higher median UAIs report higher compliance rates. The bias is also difficult to sign. A low dropout rate may mean that the school's real value-add is lower than a school with a high drop out rate. Alternatively, parents may prefer the lower dropout rate in its own right.

[8] 40 per cent of students selected this option. Other possible answers included: 'preparation for life and work, not just university' (6 per cent); and 'choice of vocational sources' (25 per cent).

prices can be attributed solely to differences in school quality.

A key assumption underlying the boundary discontinuity approach is that neighbourhoods change continuously over space, but that school quality changes discretely at the boundary. Under this assumption, the boundary discontinuity approach makes it possible to estimate the causal impact of school quality on house prices. (For a more detailed discussion of the regression discontinuity approach – of which the boundary discontinuity approach is a special case – see Hahn *et al*., 2001.)

To see how the boundary discontinuity approach addresses the problem of reverse causality, suppose that: (i) school quality has no causal effect on house prices; (ii) areas with higher house prices have better schools (e.g. because richer parents contribute more to the running of the school); and (iii) house prices change continuously over space. In such a situation, we would observe a positive relationship between school quality and house prices in aggregate (i.e. if we were to sample evenly throughout the school zone), but no discrete change in house prices at the school zone boundary. The reason there would be no change at the school zone boundary is that, as noted in (i), parents in this example do not pay more in order to live in a better school zone.

To ensure that our results are identified from differences in house prices on opposite sides of the same boundary, all our specifications include boundary fixed effects. To further isolate the effect of school quality on housing prices, we also control for a vector of other characteristics of each house, such as lot size and the number of bedrooms. A vector of quarter × year dummies are also added to control for the surge in housing prices in the ACT over the period under study. Including these additional variables, our main estimating equation is:

$$\ln(\text{House Price})_{ijbt} = \alpha + \beta \text{Test}_{jt} + \lambda \mathbf{X}_{ijbt} + \delta \mathbf{Z}_{ijb} + \Phi_b + \gamma_t + \varepsilon_{ijbt}, \tag{1}$$

where $\ln(\text{House Price})_{ijbt}$ is the log price of house i in attendance zone j adjacent to boundary b at time t. Test_{jt} is the median year 12 test score of the government high school in that attendance zone, $\mathbf{X}_{ijbt}$ is a vector of house-specific characteristics, and $\mathbf{Z}_{ijb}$ are neighbourhood characteristics (migrant share and average income). Since the neighbourhood characteristics are taken from the 2001 Census, they do not vary over time. Φ_b and γ_t are boundary fixed effects and quarter × year fixed effects, respectively.

VI Main Results

Table 3 presents the primary results of the paper. Although the sample consists of detailed information about the lot size, number of bedrooms, and other characteristics of properties, individual unit records in the database do not uniformly include information on all of the listed property characteristics. In column (1), we control only for quarter × year dummies, boundary fixed effects and lot size, and find that a 1 percentage point increase in test scores is associated with a 0.7 per cent increase in housing values. (Both sets of fixed effects are highly significant, with an F-statistic of 92.25 for the boundary fixed effects and 3.88 for the time fixed effects.) In columns (2–4), we add a cubic in lot size, and other house characteristics: indicator variables for the number of bedrooms, bathrooms and parking spaces. The coefficients on these controls accord with expectations: sale prices are higher for houses on larger lots, as well as for houses with more bedrooms and bathrooms.

VII Robustness Checks

To test the robustness of the results presented in Table 3, a number of sensitivity checks were performed. One issue of concern is the implied width of the attendance boundaries used in the sample. The key assumption of our estimation strategy is that unobserved neighbourhood quality is the same on the opposite sides of each attendance boundary. While looking at homes within a narrow band along attendance boundaries ensures that these neighbourhood qualities are most similar, using a wider band allows the use of more data, which provides for more precise estimates. To test whether houses on opposite sides of the boundaries in the sample are in fact similar in all respects other than in the high school to which they are assigned, we restrict our sample to houses that are closer to the attendance boundaries. (We do not include controls for number of bedrooms, bathrooms and parking spaces in the robustness checks, since these data are missing for a significant number of houses, and this would unduly restrict the sample size.) The results are presented in Table 4. Column (1) restricts the sample to parcels within 500 m of the boundary, while column (2) restricts it even further, to parcels within 200 m of a given boundary. The results indicate that for narrowly defined samples, a one point increase in test scores is associated with 0.5 per cent increase in house prices.

Another issue of potential concern is that better schools may be located in better neighbourhoods.

TABLE 3
Main Results
Dependent Variable is Log(House Price)

	(1)	(2)	(3)	(4)
Test score (UAI)	0.007***	0.008***	0.007***	0.007***
	(0.002)	(0.002)	(0.002)	(0.002)
Log lot size	0.296***	2.984	0.161	1.545
	(0.055)	(3.133)	(3.084)	(4.616)
Log lot size squared		–0.575	–0.109	–0.34
		(0.508)	(0.501)	(0.756)
Log lot size cubed		0.036	0.011	0.023
		(0.027)	(0.027)	(0.041)
Bedrooms (3)		0.184**	0.079*	0.064
		(0.071)	(0.047)	(0.059)
Bedrooms (4)		0.355***	0.214***	0.201***
		(0.076)	(0.046)	(0.057)
Bedrooms (5)		0.499***	0.356***	0.332***
		(0.094)	(0.079)	(0.098)
Bedrooms (6)		0.487***	0.303***	0.276***
		(0.099)	(0.071)	(0.078)
Bedrooms (7)		0.372***	–0.181	–0.226**
		(0.098)	(0.113)	(0.100)
Bathrooms (2)			0.073***	0.072***
			(0.025)	(0.025)
Bathrooms (3)			0.197***	0.200***
			(0.049)	(0.049)
Bathrooms (4)			0.558***	0.587***
			(0.103)	(0.090)
Park spaces (1)				–0.023
				(0.070)
Park spaces (2)				–0.005
				(0.069)
Boundary fixed effects	Yes	Yes	Yes	Yes
Quarter × year fixed effects	Yes	Yes	Yes	Yes
Observations	580	303	277	254
R^2	0.53	0.83	0.86	0.86

Notes: Robust standard errors in parentheses. * Significant at 10%; ** significant at 5%; *** significant at 1%.

This may be especially true where a given boundary also represents a division between suburbs of different names, as happens along a number of boundaries in the sample. To the extent that neighbourhoods at or around the boundary edges go from bad to good, it is possible that capitalisation observed at or around school attendance boundaries may be picking up not just differences in school quality, but also differences in neighbours. As a check to see whether this might be the case, we control for the percentage of the population in the postcode born overseas (since people may be willing to pay more for homogeneity or heterogeneity), and the log of the mean household income in the postcode (since people may be willing to pay more for richer neighbours). Columns (3) and (4) show the results from these specifications. Including percentage born overseas, the test score coefficient falls from 0.007 to 0.006, while adding an income control causes it to fall to 0.004. Note that while the latter is a non-trivial decrease, including income may be regarded as ‘overcontrolling’ (if school quality is a normal good, those who consume more of it will be richer). In any case, our estimate remains statistically significant at the 1 per cent level, indicating that the capitalisation estimate is not merely picking up differences in non-school neighbourhood characteristics.

Thus far, we have been using the previous year’s test score as our measure of school quality. If underlying school quality changes little from year to year, then measurement error in the school

TABLE 4
Robustness Checks
Dependent Variable is Log(House Price)

	Restrict distance to boundary		Control for neighbourhood demographics		Use mean UAI
	(1) <500 m	(2) <200 m	(3) Migrant share	(4) Migrant share and income	(5) Average UAI from previous years
Test score (UAI)	0.005**	0.005*	0.006***	0.004**	0.011***
	(0.002)	(0.003)	(0.002)	(0.002)	(0.003)
ln(lot size)	Yes	Yes	Yes	Yes	Yes
Other house characteristics	No	No	No	No	No
Boundary fixed effects	Yes	Yes	Yes	Yes	Yes
Quarter × year fixed effects	Yes	Yes	Yes	Yes	Yes
Observations	556	344	580	580	580
R^2	0.56	0.24	0.53	0.54	0.54

Notes: Robust standard errors in parentheses. * Significant at 10%; ** significant at 5%; *** significant at 1%. Migrant share is the share of people in that house's postcode who were born overseas by postcode. Income is the log median weekly income in the postcode. Mean UAI uses the average UAI for previous years (2002 for 2003, 2002–2003 for 2004, and 2002–2004 for 2005).

quality variable may lead to attenuation bias (see Gibbons & Machin, 2003 for a discussion of this issue). In such a case, a better metric may be the average test score over a number of years. In column (5), we therefore replace the annual test score variable with the average test score of the previous years' results. (Though note that since test score data was only published from 2002 onwards, the 'average' test score assigned to 2003 house prices is just the 2002 score.) We find that this increases our estimate of the relationship between school quality and house prices (the test score coefficient is 0.011). Whether this estimate should be preferred over our primary specification depends on whether underlying school quality (for which the annual test score is a noisy proxy) changes over a 3-year period. If underlying school quality does not change at all over this interval, then the estimate of 0.011 should be preferred. However, we adopt a more cautious stance, and use 0.007 as our primary estimate, on the basis that true school quality may vary from year to year.

Does the willingness to pay for school quality vary across housing types? To test this, we interact the test score measure with the numbers of bedrooms in the house. Houses with more bedrooms are more likely to be owned by families with children who either have or will attend high school than those with few bedrooms; while houses with a greater number of bedrooms are also more likely to be the homes of families with multiple children. This suggests that the school quality premium may be higher for larger houses.[9] Given that only a portion of the unit records in the sample report on bedroom numbers, we subsequently predict the bedroom number for the full sample of houses, by regressing the lot-size of each property with a full set of reported characteristics on bedrooms (we do this on a boundary-by-boundary basis to account for the difference in subdivisions across different suburbs).

The results are presented in Table 5. The first column reports on the samples where actual number of bedrooms is known, which accounts for only about half of the full sample. The coefficient on test scores interacted with houses with three or less bedrooms is higher than for the full sample (0.009), while that for houses with four of more bedrooms is lower but not statistically significant. To address the problem that the number of bedrooms is not known for many houses in the sample, the second column uses the full sample, but this time using the log of the lot size to predict the number of bedrooms (which is then rounded to

[9] A recent study on school choice in Australia shows that as family size increases (over a range of one to four children) there is a direct switch between high-priced independent schools and more moderately priced Catholic schools, suggesting that family size does predict financial decisions related to school choice (Le & Miller, 2003: 65).

Table 5
Does the Effect of School Quality Differ by House Size?
Dependent Variable is Log(House Price)

	(1)	(2)
	Using actual numbers of bedrooms	Predicting numbers of bedrooms from lot size
Test score*(three or less bedrooms dummy)	0.009**	0.005*
	(0.003)	(0.003)
Test score*(four or more bedrooms dummy)	0.005	0.009**
	(0.003)	(0.003)
F-test. H0: Effect does not differ by number of bedrooms	0.87	1.14
(*P*-value)	(0.353)	(0.286)
ln(lot size)	Yes	Yes
Other characteristics	Bedroom fixed effects	Predicted bedroom fixed effects
Boundary fixed effects	Yes	Yes
Quarter × year fixed effects	Yes	Yes
Observations	303	580
R^2	0.82	0.55

Notes: Robust standard errors in parentheses. * Significant at 10%; ** significant at 5%; *** significant at 1%. Number of predicted bedrooms are rounded to the nearest integer.

the nearest integer). We then interact the test score coefficient with variables denoting whether the predicted number of bedrooms in a house is three or fewer, or four or more. The coefficient on test scores interacted with three or less bedrooms is similar to that for the full predicted sample (0.005) while, as expected, the coefficient on the interaction of test score and four or more bedrooms is higher (0.009). However, an *F*-test cannot reject the hypothesis that the effect of school quality on house prices does not vary by house size.

In addition to the robustness checks presented in Tables 4 and 5, we estimated five other models, the results of which are not shown in the tables (due to space constraints). First, as a check on sample selection, we weight the boundaries evenly, to account for differences in the number of house sales around each boundary in the sample period. With such weighting, the coefficient on test scores increases to 0.009. However, in reality boundaries with more sales are conceivably longer boundaries, or those in more densely populated areas, and should therefore not be weighted evenly.

Second, we estimate the relationship between test scores and housing prices without boundary fixed effects, and find that a one percentage point increase in test scores is associated with a 1.5 per cent increase in housing values ($t = 4.4$). This result is consistent with earlier literature relating house prices to test scores, which similarly finds that if one does not properly control for neighbourhood characteristics, one will overestimate the capitalisation of higher test scores into property prices (Black, 1999; Kane *et al*., 2005).

Third, on the suggestion of a referee, we estimate the models by re-defining the dependent variable as the difference between a particular house price and the mean house price adjoining that boundary. The results from this specification are close to those shown in Table 3. Fourth, we transform the UAI variable in the same manner (so as to regress house price differences on UAI differences). The results from this specification are also very close to those shown in Table 3.

Fifth, we experiment with estimating the models using propensity score matching methods. Within each boundary, however, the sample size is small relative to the number of covariates (e.g. in a given quarter × year, there is not always a sale on both sides of the same boundary). As a result, it is not feasible to match on a boundary-by-boundary basis using the full set of covariates. When we estimate propensity score matching models using a more limited set of covariates, we obtain UAI coefficients that are somewhat higher than those shown in Table 3 (in the range of 0.01–0.015).

VIII Conclusion and Implications

This paper poses a critical question which has not yet been asked in the Australian public finance literature: how much do parents value better public schools? By comparing sale prices of houses on opposite sides of school attendance boundaries of adjacent public high schools in the ACT between 2003 and 2005, we find that much like their British and American counterparts, parents in the ACT do place a premium on better public school education. Specifically, the marginal parent is willing to pay 3.5 per cent more for a house associated with a school whose median year 12 test score is 5 percentage points higher. These results are robust to a number of sensitivity checks.

At the median 2005 sale price of $375 000 (Australian Bureau of Statistics, 2006), our estimates suggest that parents are willing to pay an additional $13 000 for a 5 percentage point increase in the test scores of their local school. In Davidoff and Leigh (2007), we check whether our results are plausible when compared with private school fees in the ACT. We find that the home equity 'cost' of public schooling is somewhat lower than the cost of private school fees. Under certain assumptions, we estimate that a family with one child would save approximately $1000 in potential housing equity if instead of sending their child to the superior private school, they chose to purchase a property in a school zone with a public school of equal quality. For families with more than one child, the savings are larger still.

At the outset, we noted three institutional factors that should lead the relationship between house prices and school quality to be weaker in the ACT than in the USA. First, ACT parents typically have little or no access to school average test scores. Second, school zone boundaries are 'soft', meaning that being on the wrong side of the boundary merely sends a child to the bottom of the enrolment list. And third, a substantial number of children attend non-government schools. Yet despite these factors, we find that the elasticity of house prices with respect to school quality in the ACT is not much lower than estimated elasticities from previous studies in the UK and the USA.

There are three caveats to interpreting these results. Although we have sought to disentangle neighbourhood characteristics from school quality by comparing houses that are close to school boundaries, our sample includes houses a short distance from the boundary, and therefore the possibility of omitted variable bias cannot be categorically ruled out. The second caveat is that parents' estimation of school quality may be determined by more than test scores, and may also be affected by factors such as discipline standards or sporting facilities. To the extent that these are positively (negatively) correlated with test scores, our results should be regarded as an overestimate (underestimate) of the impact of broadly defined school quality on house prices. The final caveat is that differences in scores between schools could be the result of policy-driven variables, such as principals or teachers; or they could be driven by variables that are less amenable to change, such as parents or peers. By relating house values to raw test score results, this reduced-form exercise may capture either effect; but nevertheless still helps decision makers evaluate policies aimed at raising test scores.

Our findings and estimation strategy provide policy-makers with the means by which to assess the net benefit of various policies designed to improve the performance of public schools. The costs associated with a proposal aimed at raising the test score standards at public schools can now be usefully pitted against the social benefit evaluation of the intended policy outcome. With such rational social accounting practices, education policy-makers should be better placed to maximise social welfare.

The results carry other key policy implications. Since houses in better school zones are more expensive, high-quality public education is not costless. The price of buying into a good school zone may prevent poor families from accessing the public schools of their choice. Given that education can transform the social and economic opportunities of the underprivileged, such social exclusion may perpetuate cycles of disadvantage if left unaddressed. To the extent that the achievement gap between schools is driven by inherent school quality more than it is by peers, our findings suggest that in order to equalise education opportunities, government funding should be directed towards schools with less talented teachers and substandard facilities.

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