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

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Abstract

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 percent increase in test scores (approximately one standard deviation) is associated with a 3.5 percent increase in house prices. Our result is in line with private school tuition costs, and accords with prior research from Britain and the United States. Estimating the effect of school quality on house prices provides a possible measure of the extent to which parents value better educational outcomes.

JEL Codes: I22, R21

Keywords: housing demand, school quality

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 United States, 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 United States. 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. 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 policymakers. 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. And 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 policymakers 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 percent increase in high school test scores (approximately one standard deviation) is associated with a 3.5 percent 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 organized 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 compares the magnitude of the results with private school tuition fees. Section IX 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 and Quigley, 1975; Mingche and Brown, 1980; Jud and 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, Staiger, and Riegg (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 capitalization effects associated with the 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, Ferreira and McMillan (2003), 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.

[1] In the United States, 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 later, see Bogart and Cromwell (1997)

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

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

How large are the existing estimates of the effect of school quality on house prices? In Table 1, we summarize the results from 10 prior studies (four from the United Kingdom and six from the United States). For reasons of comparability, we translate all studies to a common metric – the percentage effect on house prices of a one standard deviation 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 nonlinearities identified by some studies (*e.g.* Cheshire and Sheppard 2002; Bayer, Ferreira and McMillan 2003), 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 United Kingdom estimates are smaller for secondary schools (0.05 and 2 percent), but primary school estimates are in the range of 2.1 and 10 percent, with a median around 4 percent. The United States estimates range from 1 to 14 percent, centred around 5 percent.

Table 1: Studies Estimating the Effect of School Quality on House Prices
Measured as the effect of a 1 standard deviation increase on house prices

Study	Effect	Sample	School quality measure
Australia			
Davidoff and Leigh (2007) *[this study]*	3.5 percent	Secondary schools in the Australian Capital Territory	Median year 12 test score
United Kingdom			
Cheshire and Sheppard (2002)	2.1 percent	Primary schools in Reading, England	Sum of 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 percent	Secondary schools in Reading, England	Proportion of 15 year olds who pass 5 or more General Certificate of Secondary Education subjects at grade C or better
Gibbons and Machin (2003)	3 to 10 percent	Primary schools in England	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 percent	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 percent	Secondary schools in England	Proportion of 15 year olds who pass 5 or more General Certificate of Secondary Education subjects at grade C or better
United States			
Bayer, Ferreira and McMillan (2003)	2.4 percent	San Francisco Bay Area, CA	Average student test scores in mathematics, literature and writing for grades 4, 8 and 10.
Black (1999)	2.5 percent	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 percent	Middle schools in Chicago, IL	Average district/school eighth grade reading component of the Illinois Goals Assessment Program tests
Kane, Staiger, and Reigg (2005)	10 percent	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 to 7.7 percent	Elementary, middle and secondary schools in Minnesota	Index based on 7 district-level tests, covering grades 3 to 10
Weimer and Wolkoff, (2001)	1.0 to 8.3 percent	Elementary schools in Monroe County, NY	4th grade English Language Arts exam

III. BACKGROUND

The ACT, home to the Australian national capital, Canberra, is an ideal location to study the capitalization 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 (DET, 2004). 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 (ABS, 2001a).

The ACT government education system is normally split up into five phases: pre-school, 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 percent of the

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

students who were enrolled in year 7 in 1999 being enrolled full-time in year 12 in 2004 (ABS, 2004). 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 percent nationally, and 41 percent in the ACT, higher than any other state or territory[6]

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 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 capitalized price of school quality.

At the same time, 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 Britain and the United States, 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 on-going 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 capitalization effect (Figlio and Lucas 2004), the ACT's restricted information regime is a further factor which might limit the capitalization of test score results into house prices.

[6] The percentage of students attending non-government schools is consistent across all year levels, with the exception of years 7-10, where the rate is 7 percentage points higher (ABS 2005).

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 fifteen 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 sub-divisions 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 meters 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 neighborhoods 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.

Figure 1: An Example of Two Contiguous High School Attendance Zones

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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.

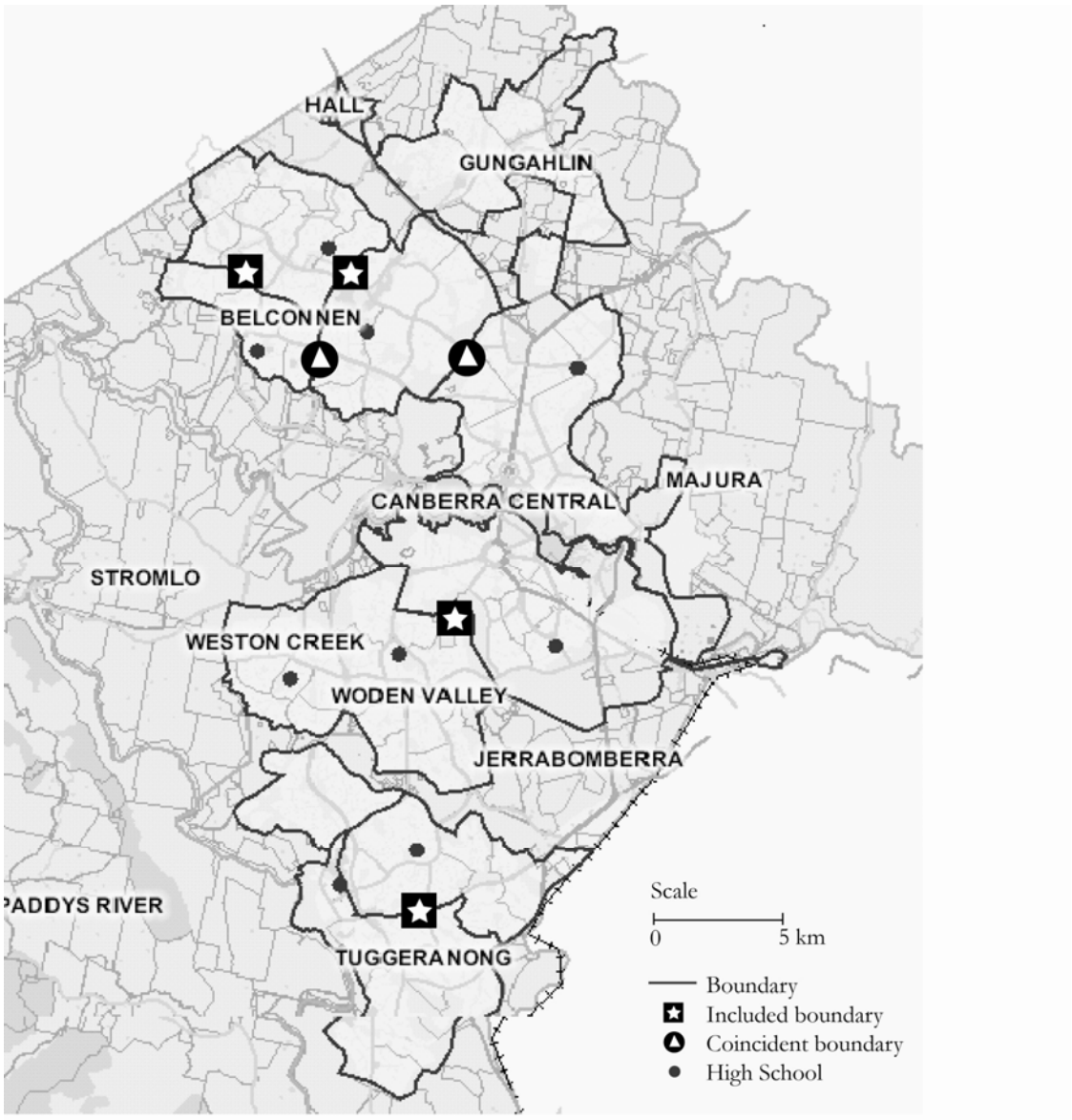
Second, not all boundaries are contiguous, meaning that there is not a designated school zone on either side of the boundary. This is especially true of boundaries on the outer perimeter of Figure 2, which are at the urban fringe. Non-contiguous boundaries are also excluded from the sample.

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.[7]

[7] 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 that quality of the high and middle schools on either side of the attendance boundary are *positively* correlated.

Figure 2: All High School Attendance Zones in the ACT



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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 standardized measure which is comparable across schools, evidence suggests that test scores—especially year 12 test scores—are a highly valued indicator of school quality.[8] 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 (DET, 2006).[9] 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 tests 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 standard deviation of $185,083. The average median UAI in the ACT across all schools and all years is 74.6 with a standard deviation of 5.6. A number of census variables are also presented to capture more detailed neighbourhood

[8] While not all students received a UAI score because they did not all opt to undertake the pre-requisite 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-drop out 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.

[9] 40 percent of students selected this option. Other possible answers included: 'preparation for life and work, not just university' (6 percent); and 'choice of vocational sources' (25 percent).

characteristics. At the postcode level, 22 percent 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:			
No of students per school	755.5	203.3	580
Yr 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 8 government high schools in ACT, all represented in the data (DET 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 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, Todd and Van der Klaauw 2001.)

To see how the boundary discontinuity approach addresses the problem of reverse causality, suppose that: (a) school quality has no causal effect on house prices; (b) areas with higher house prices have better schools (*e.g*. because richer parents contribute more to the running of the school); and (c) 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 (a), 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:

$$\ln(\text{House Price})_{ijbt} = \alpha + \beta \text{Test}_{jt} + \lambda X_{ijbt} + \delta Z_{ijb} + \Phi_b + \gamma_t + \varepsilon_{ijbt} \qquad (2)$$

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, X_{ijbt} is a vector of house-specific characteristics, and 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 one percentage point increase in test scores is associated with a 0.7 percent 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) to (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.

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 sqd		-0.575	-0.109	-0.34
		(0.508)	(0.501)	(0.756)
Log Lot size cbd		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-squared	0.53	0.83	0.86	0.86

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

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 meters of the boundary, while column (2) restricts it even further, to parcels within 200 meters of a given boundary. The results indicate that for narrowly defined samples, a one point increase in test scores is associated with 0.5 percent increase in house prices.

Table 4: Robustness Checks
Dependent Variable is Log(House Price)

	(1)	(2)	(3)	(4)	(5)
	Restrict Distance to Boundary		Control for Neighbourhood Demographics		Use Mean UAI
	<500m	<200m	Migrant Share	Migrant Share & Income	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-squared	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, 2002-03 for 2004, and 2002-04 for 2005).

Another issue of potential concern is that better schools may be located in better neighbourhoods. 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 capitalization 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 percent level, indicating that the capitalization 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 quality variable may lead to attenuation bias (see Gibbons and 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 three-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

three or more 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.[10] 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 3 or less bedrooms is higher than for the full sample (0.009), while that for houses with 4 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 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.

[10] 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 and Miller: 2003: 65).

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

	(1) **Using Actual Numbers of Bedrooms**	(2) **Predicting Numbers of Bedrooms from Lot Size**
Test score*(3 or less bedrooms dummy)	**0.009****	**0.005***
	(0.003)	**(0.003)**
Test score*(4 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-squared	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.

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 percent 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 neighborhood characteristics, one will overestimate the capitalization of higher test scores into property prices (Black 1999; Kane, Staiger and Riegg 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. MAGNITUDE OF RESULTS AND A COMPARISON WITH PRIVATE SCHOOL TUITION

Our preferred estimate of the impact of school quality on house prices (column 1 of Table 3), suggests that a 1 percentage point increase in test scores raises property values by 0.7 percent. It shows that a 5 percent increase in year 12 test scores (approximately one school-level standard deviation) leads to an increase in marginal resident's willingness to pay of 3.5 percent—or $13,000 at the median 2005 house price. All else being equal, parents would need to pay approximately 2.5 percent more to move from a bottom quartile school zone to a top quartile school zone—or approximately $9,500 at 2005 house prices.[11]

As noted above, parents in the ACT do not have to send their child to a government high school—and, in fact, many choose not to. We can therefore compare our estimates of the cost of public schools (via house prices) with the tuition cost of non-government schools. We first look at private tuition fees as an upper bound on parents' willingness to incur additional capital costs, on the margin, when purchasing

[11] Note that while Black's estimate of the capitalization rate per standard deviation is 2.5%, she finds that a move from a school in the 25th percentile of her sample to one in the 75th percentile would result in a house price increase of 2.9 percent.

a property. Year 12 tuition fees at non-government schools in the ACT in 2005 averaged $4777.[12] Assuming that there is a superior private school option at this price, a parent in the ACT should therefore not be willing to pay more than approximately $4777 on the margin in additional annual mortgage payments for a house in a neighbourhood with a better quality public high school. With a 20-year mortgage and interest rate of 5 percent an additional $4777 per annum could service a home loan that is $58,000 greater in total value. However, our results suggest that parents would only need to pay an additional $13,000 to live in a high quality school zone.[13]

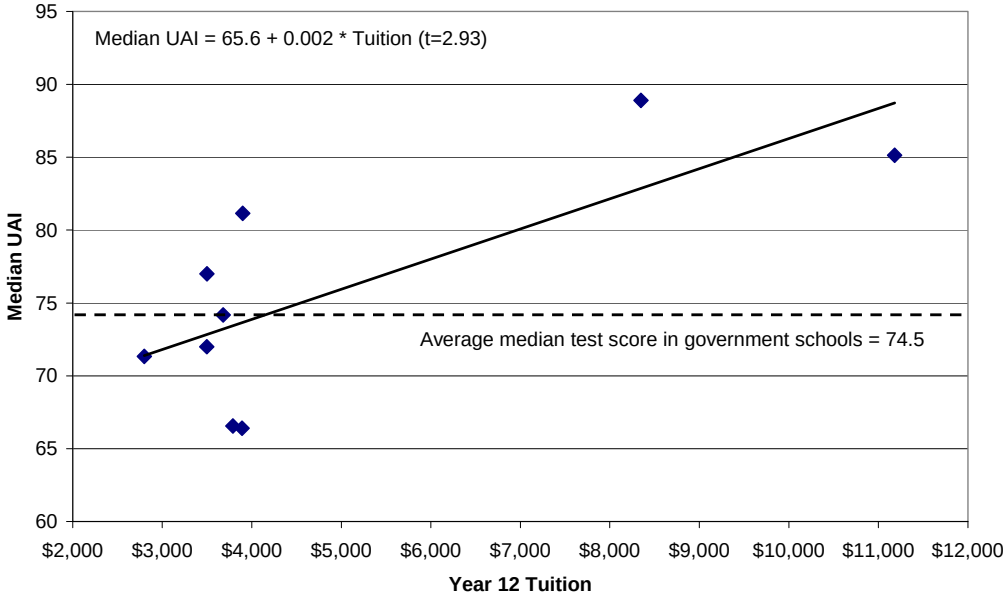
In the context of the ACT, such a comparison is complicated by two factors however. First, the comparison assumes that the tuition fee savings are realizable for the full length of the home loan. In fact, these savings are only likely to be realized as long as the child is in grades 11-12 of high school.[14] Second, with only two exceptions (Marist College and St. Francis Xavier College), all non-government schools in the ACT which charge *average* tuition fees (ie $4777) produce test score results which are no better than that of the average public school. As discussed immediately below, parents would typically need to pay higher fees to access superior private schools, and thus $4777 may not be an accurate capital cost benchmark.

In light of these complications, Figure 3 presents an additional means of benchmarking these capitalization estimates against private school choices. The figure relates year 12 tuition fees at all non-government schools in the ACT in 2005 to median test scores from the same year. Among high schools in the non-government sector, each $1000 in tuition is associated with test scores that are approximately 2 UAI points higher. Taking account of the intercept, our results suggest that the marginal parent would need to pay approximately $7000 in annual tuition fees to send their child to a private school producing results that are approximately 5 percentage

[12] The estimate of average private school tuition fees is based on data from the *Good Schools Guide NSW and ACT 2005*, supplemented where necessary by telephone calls to school administrators.
[13] Kane, Steiger and Riegg reach a similar conclusion. Specifically, they find that an upper limit to a family's willingness to pay for a good school of U$120,000 in additional mortgage value, compared with only $14,000 difference in house prices between schools at the 25th and 75th percentiles.
[14] Although enrolment in some private middle schools, which include years 11 and 12, require that the child be enrolled from year 7 onwards. In this situation, the implied savings from not sending a child to a private school would span 6 years.

points higher than those recorded at the average public high school.[15] Based on two years of tuition, our capitalization estimates suggest that a family with *one* child would therefore 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.

Figure 3: Tuition and Median Test Scores in Non-Government Schools



Note: Test scores are 2005 year 12 test scores measured at the high school level; Tuition is for 2005, from Good Schools Guide (2005) and schools.

The relationship between school quality and housing prices presented above is thus plausible when benchmarked against two estimates of the costs associated with private school tuition: one based on implied additional capital costs; the other based on direct equity savings.

IX. 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

[15] Specifically, the tuition would be equal to (5+74.5-65.6)/0.002 = $6950.

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 percent 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 (ABS 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. These results are quite 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 United States. 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 Britain and the United States.

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 policymakers 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 maximize 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 equalize education opportunities, government funding should be directed towards schools with less talented teachers and substandard facilities.

REFERENCES

Abelson, P. (1997), 'House and Land Prices in Sydney from 1931 to 1989'. *Urban Studies*, 34(9), 1381-1400.

Australian Bureau of Statistics (2001a), *Socio-Economic Indexes for Areas, Australia*, ABS, Canberra.

Australian Bureau of Statistics (2001b), *Census CData2001*, ABS, Canberra.

Australian Bureau of Statistics (2005), *Education in the ACT, Cat No 1344.8.* ABS, Canberra.

Australian Bureau of Statistics (2006), *House Price Indices: Eight Capital Cities, Cat No 6416.0*. ABS, Canberra

BBC (2006). 'Parents paying 'postcode premium'', *BBC On-line.* Available at: http://news.bbc.co.uk/go/pr/fr/-/1/hi/education/4744104.stm. (Accessed March 17 2006)

Bayer, P. J., McMillan, R. and Ferreira, F.V. (2003), 'A Unified Framework for Measuring Preferences for Schools and Neighborhoods'. Yale University Economic Growth Center Discussion Paper No. 872, Yale University, New Haven, CT.

Bellamy, E. (2006), 'ACT students among brightest in nation, but still room for improvement,' *The Canberra Times*, 11 March.

Black, S. (1999), 'Do Better Schools Matter? Parental Valuation of Elementary Education', *The Quarterly Journal of Economics*, 114(2), 577-599.

Bogart, W.T. and Cromwell, B.A. (1997), 'How much more is a good school district worth?' *National Tax Journal*, 50(2), 215-232.

Bradley, S., Draca, M. and Green, C. (2004), 'School performance in Australia – is there a role for quasi-markets?', *Australian Economic Review*, 37(3), 271-286.

Cheshire, P. and Sheppard, S. (2002), 'Capitalizing the Value of Free Schools: The Impact of Land Supply Constraints', Lincoln Institute of Land Policy Conference Paper.

Department of Education and Training (2005), *Enrolment in Colleges,* DET, Canberra. Available at http://www.det.act.gov.au/policies/pdf/collegeenrolment.pdf. (accessed April 1 2006).

Department of Education and Training (2006), *Review of Government Secondary Colleges*, Report Prepared by Atelier Learning Solutions, DET, Canberra.

Downes, T. A. and Zabel. J.E. (2002), 'The impact of school characteristics on house prices: Chicago 1987–1991', *Journal of Urban Economics*, 52 (1), 1-25.

Epple, D. and Romano, R.E. (1998). 'Competition Between Private and Public Schools, Vouchers and Peer Group Effects', *American Economic Review*, 88(1), 33-62.

Figlio, D and Lucas, M. (2004). 'What's in a Grade?' School Report Cards and House Prices', *American Economic Review*, 94(3), 591-604.

Gibbons, S. and Machin, S. (2003), 'Valuing English primary schools', *Journal of Urban Economics*, 53, 197–219.

Gibbons, S. and Machin, S. (2006), 'Paying For Primary Schools: Supply Constraints Popularity or Congestion', *The Economic Journal*, 116, C77–C92.

The Good Schools Guide NSW and ACT (2005), Hobsons, Sydney.

Government School Education Council, (2004). *Review of Government School Reporting*, GSEC, Canberra.

Hahn, J., Todd, P. and Van der Klaauw, W. (2001), 'Identification and Estimation of Treatment Effects with a Regression-Discontinuity Design', *Econometrica*, 69(1), 201-209.

Jud, G.D. and Watts, J.M. (1981), **'**Schools and Housing Values', *Land Economics*, 57(3), 459-470.

Kain, J.F. and Quigley, J.M. (1975), *Housing Markets and Racial Discrimination*, Columbia University Press, New York.

Kane, T., Staiger, D. and Riegg, S. (2005), 'School Quality, Neighborhoods and Housing Prices: The Impacts of School Desegregation', NBER Working Paper 11347, NBER, Cambridge, MA.

Le, A.T. and Miller, P.W. (2003), 'Choice of School in Australia: Determinants and Consequences', *Australian Economic Review*, 36(1), 55-78.

Marks, G.N., Cresswell, J. and Ainley, J. (2006), 'Explaining Socioeconomic Inequalities in Student Achievement: The Role of Home and School Factors', *Educational Research and Evaluation,* 12(2), 105-128.

Mingche M.L., and Brown, H.J. (1980). **'**Micro-Neighbourhood Externalities and Hedonic Housing Prices', *Land Economics*, 56(2), 125-141.

Nechyba, T. J. (2003), 'Introducing School Choice into Multidistrict Public School Systems' in Hoxby, C. (ed.), *The Economics of School Choice*, University of Chicago Press, Chicago.

Reback, R. (2005), 'House Prices and the Provision of Local Public Services: Capitalization Under School Choice Programs', *Journal of Urban Economics*, 57, 275-301.

Rosen, S. (1974), 'Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition', *Journal of Political Economy*, 82, 34-55.

Rosenthal, L. (2003), 'The Value of Secondary School Quality', *Oxford Bulletin of Economics and Statistics,* 65(3), 329-355.

Weimer, D.L and Wolkoff, M. (2001), 'School Performance and Housing Values: Using Non-contiguous District and Incorporation Boundaries to Identify School Effects', *National Tax Journal,* 54(2), 231-254.