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House and Land Prices in Sydney from 1931 to 1989

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Summary. This paper describes and explains house and land prices in Sydney from 1931 to 1989. Throughout this period, house and land prices fell, generally exponentially, with distance to the CBD. However, the price gradients were not constant. Between 1931 and 1968 the gradients flattened. On the other hand, between the mid 1970s and 1989 they became steeper again. The changes in the gradients were caused mainly by changes in travel times and costs by road and rail. Real travel costs fell in the early period and rose later on. Other factors that affected the price gradients were changes in car ownership and the supply of urban services in the early period and gentrification of inner-city areas and the greater increase in housing supply on the urban fringe in the later period. The paper also shows how house size and environmental factors influenced house prices in the 1970s and 1980s.

1. Introduction

This paper describes and explains the distribution of residential property prices in Sydney from 1931 to 1989. In order to do this, the paper draws on data from two main sources. The first is the writer's research study of house and land prices in Sydney from 1931 to 1968. (See Abelson (1985) for a discussion of average house and land prices over this period.) The second is a consultancy study of house prices in Sydney, Melbourne and Adelaide from 1970 to 1989, directed by the writer (Applied Economics and Travers Morgan, 1992).

Because the paper is based on two separate sets of data, it is not possible to provide a unified empirical analysis for the whole period. However, a common theme—the negative exponential relationship between residential property prices and access to the central business district (CBD)—runs through the paper. Moreover, the two periods provide interesting contrasts. From 1931 to 1968, and especially after 1948, the price gradients flattened. More recently, from the mid 1970s to 1989, the price gradients became steeper again. The paper explains both phenomena.

The paper starts with a general model of house and land prices within cities. Sections 3–5 discuss and explain the distributions of house and land prices between 1931 and 1968. Sections 6–8 deal with the period to 1989. There is a brief concluding section.

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2. The Determination of House and Land Prices in Cities

House Prices in Cities

The paper outlines below what may be regarded as the standard model of house prices within an environmentally homogeneous city (Mills and Hamilton, 1994) and then introduces local variations. Households are assumed to purchase standard units of housing services, h, at an annual price p^h. Most workers are employed in the CBD. In choosing their residential location, households balance housing costs against transport (commuting) costs.

Let households have a utility function, $U = f(g,h)$ where g is goods other than housing. The household budget constraint is given by:

$$Y = p^g g + p^h(u)h + T(u, Y) \quad (1)$$

where, Y is household income, which here includes the value of leisure time foregone in commuting; p^g is the price of other goods; and T is the cost of commuting to the CBD including time costs.

Both p^h and T vary with distance to the CBD, represented by u. T also rises with household income. Maximising household utility subject to the budget constraint, the following first-order Langrangean condition is obtained with respect to changes in distance from the CBD:

$$dL = -\ \lambda(hp^h{}_u + T_u) = 0 \quad (2)$$

where the subscripts denote the partial derivatives,

$$\text{for example, } p^h{}_u = \frac{\partial p^h}{\partial u} \quad (3)$$

Equation 2 indicates that:

$$-p^h{}_u h = T_u \quad (4)$$

In equilibrium, a household must be compensated for an increase in transport costs with u by a fall in housing costs. Since $h > 0$ and $T_u > 0$, $p^h{}_u$ must be negative. Moreover, if the marginal cost of commuting falls with distance from the CBD, the price of housing also falls with u, but at a decreasing rate.

However, as p^h falls, households purchase more h. Therefore house prices (total housing expenditures) may not fall with u. Whether they do, or not, depends in this simple model on the price elasticity of demand for housing services. Muth (1975) argues that because this price elasticity is about unity, a fall in p^h leaves total housing expenditures unchanged.

This somewhat abstract theoretical model assumes unrealistically that the units of housing services are homogeneous and observable. In practice, houses provide a range of housing services, but fortunately most of these services are observable. Houses are in effect a collection of attributes. House prices are determined by the quantities of each housing attribute and their implicit prices.

Variations in local amenities must be reflected in house prices so that in equilibrium households are indifferent between locations. Also, any variation in transport costs besides access to the CBD—for example, access to rail services or major radial roads—is likely to affect relative house prices. Of course, over time housing services are likely to expand and improve, as they have done in Sydney. To explain changes in house prices over time, we need to determine whether housing attributes or their prices, or both, have changed.

Another important issue is the monocentric nature of the model. This may well be considered a "very poor representation of modern cities" (Richardson, 1978, p. 48). And it is true that in cities with large employment sub-centres, as in San Fransisco, house prices can rise close to these centres (Muth, 1975). However, this is exceptional. If prices were to rise close to small sub-centres, CBD commuters would be doubly penalised by high house prices and long commutes and would move closer to the CBD. In equilibrium, housing prices close to sub-centres must reflect the city-wide housing price gradient even when the CBD provides only a minority of jobs, as in Sydney. In a free market system, equilibrium in the labour market is achieved by a wage gradient that declines with distance from the CBD. As Mills and Hamilton (1994, p. 119) observe, the introduction of a wage function "preserves the applicability of the monocentric model in the face of decentralised employment".

Finally, note that household income may affect house prices for two main reasons independently of the relationship between household income and house size. First, for a given supply of local public goods, local tax rates are lower in higher-valued areas. Therefore, house prices in these areas must rise until the higher cost of housing offsets the advantages of a lower tax rate or access to more local public goods. Secondly, positive externalities—for example, better local property maintenance or gentrification—are likely to be positively related to household income levels.

In summary, at any given time, house prices are determined mainly by distance from the CBD, house and lot size and other housing attributes including local environmental amenities. They may also be determined by access to employment and local household income levels. Relative house prices may alter with changes in household preferences or the stock of housing or its attributes in any location.

Land Prices in Cities

The land price gradient depends on the housing price gradient and the share of land in housing. Following Muth (1969), housing services are assumed to be produced in a competitive market by firms using land (L) and non-land (N) inputs, so that $h = h(L,N)$. Producers aim to maximise profits (F):

$$F = P^h h(L,N) - P^L L - p^N N \tag{5}$$

where, P^h and P^L are the capital prices of housing and land inputs respectively; and p^N is the price of non-land inputs.

Profits must be equal at each location, but the prices and combinations of inputs may vary with location. Setting the total differential for equation 5 to zero and substituting in the first-order (maximisation) conditions, we obtain:

$$\frac{dP^L}{P^L} = \left[\frac{P^h h}{P^L L} \times \frac{dP^h}{P^h} \right] - \left[\frac{P^N N}{P^L L} \times \frac{dp^N}{p^N} \right] \tag{6}$$

where, dP^L/P^L is the land price gradient.

Letting S_L and S_N be the shares of land and non-land factors in housing, the land price gradient becomes:

$$\frac{dP^L}{P^L} = \left[\frac{1}{S_L} \times \frac{dP^h}{P^h} \right] - \left[\frac{S_N}{S_L} \times \frac{dp^N}{p^N} \right] \tag{7}$$

Because the gradient of the non-land factors (dp^N/p^N) is usually negligible, in effect the land price gradient is given by the first expression on the right-hand side. That is, the land price gradient is approximately the product of the inverse of the share of land and the housing price gradient. Further, because the share of land is nearly always less than 50 per cent and sometimes below 10, the land price gradient is generally much steeper than the housing price gradient.

As the value of land rises towards the CBD, housing producers substitute capital for land and the share of land in housing falls. Given equation 7, the land price gradient is steeper close to the CBD. Mills and Hamilton (1989, App. A), working with rents rather than capital values, demonstrate that under certain conditions (most notably that housing is produced in competitive markets with a Cobb—Douglas production function and that the price elasticity of demand for housing is -1) the land rent gradient takes the negative exponential form:

$$r(u) = ae^{-bu} \tag{8}$$

where, a is the residential land rent in the CBD; $e = 2.718$; and b is the percentage change in land rent per km from the CBD which is to be estimated.

Of course, as land prices fall with u, households consume more land. Therefore lot prices ($P^L L$) fall by less than land prices, and may even increase, with distance from the CBD.

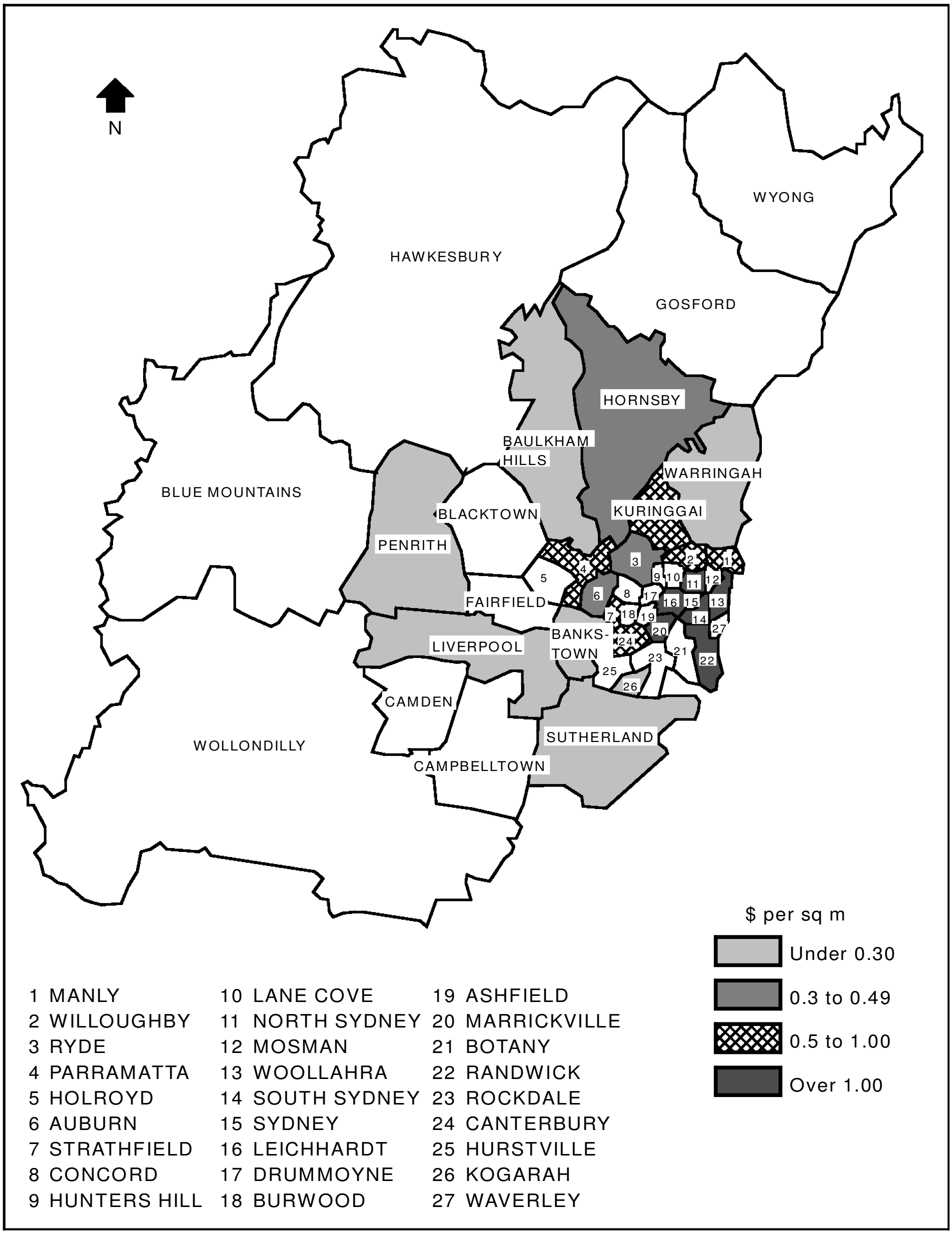

Figure 1. Land values in Sydney in 1931, in Au$ per sq m.

3. House and Land Prices in Sydney, 1931–68

Valuation and sale data were collected for houses and land for about 4400 properties in 22 local government areas (LGAs)—about half the LGAs in Sydney. The LGAs were chosen to ensure that the distribution of the sample properties represented the actual distribution with respect to both distance to the CBD and geographical sectors over the study period. Properties within the LGAs were selected randomly. The analysis below draws on the valuations because of insufficient sales data. However Abelson (1991) shows

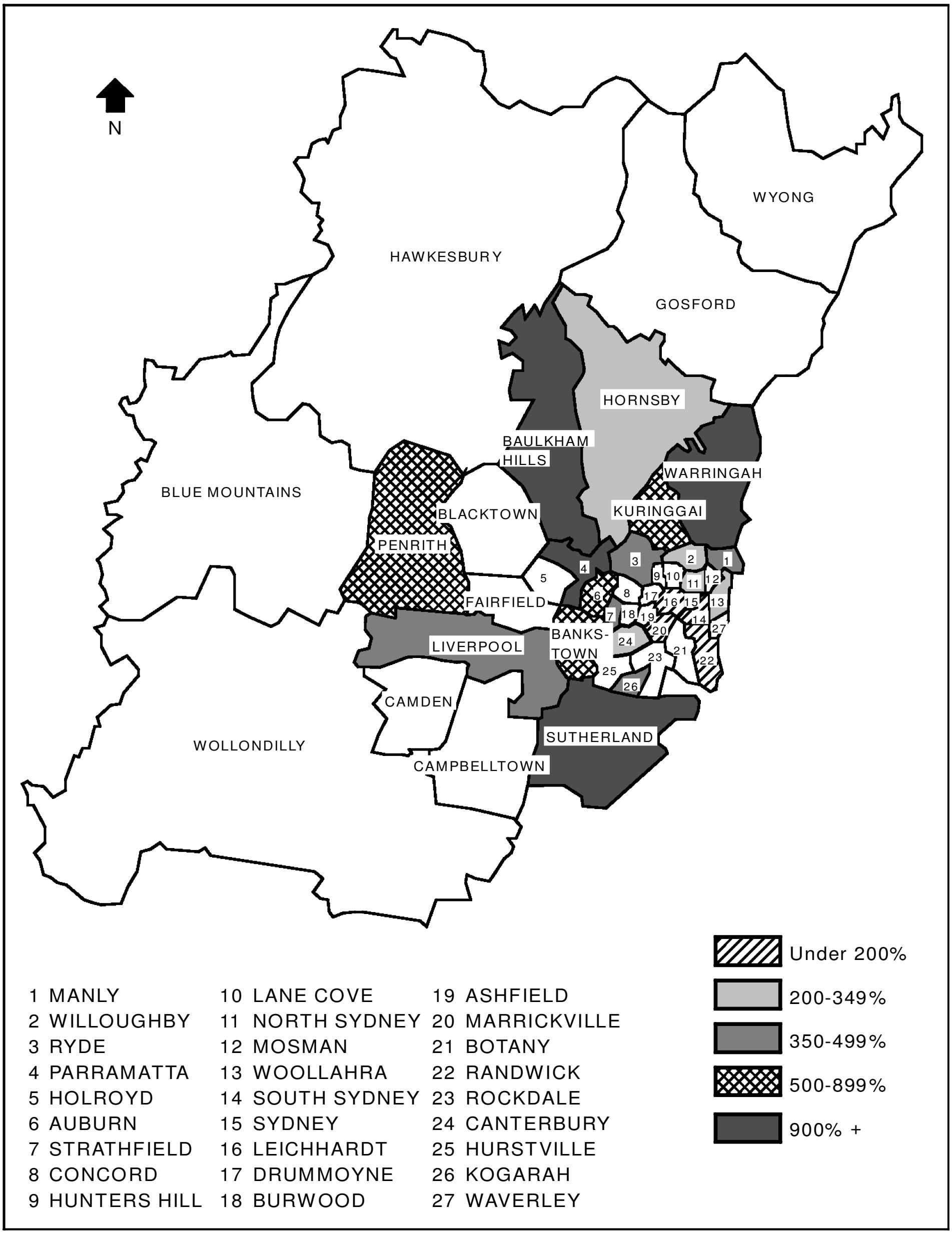

Figure 2. Real percentage increases in Sydney land values, 1931–68.

that, for this sample, the valuations are a reasonable guide to prices.

Two other issues should be noted. First, all houses and lots in the sample were valued between 1930 and 1932, between 1947 and 1949, and between 1966 and 1970. In order to standardise the valuations to selected years (1931, 1948 and 1968), the valuations were factored up or down by the estimated changes in the Sydney house or land price index in the relevant years. Secondly, to allow for differences in lot size, the land value per sq m was estimated for each property and median land values for each LGA.

Table 1. Median values in selected years, in current $S[a]

Distance to CBD (km)	*UV*/sqm			*UV*/lot			*IV*/lot		
	1931	1948	1968	1931	1948	1968	1931	1948	1968
0–8	1.58	1.64	18.23	436	522	5980	1483	1523	8122
8–16	0.72	0.78	11.19	417	460	6522	1649	2034	13 333
16–24	0.29	0.35	7.36	214	264	5135	1345	533	12 173
24 +	0.24	0.25	7.15	171	189	5058	823	1090	11 941
All Sydney	0.92	1.02	9.95	360	410	5100	1400	1650	11 920

Note: *UV* is unimproved, or land, value, *IV* is improved, or house, value.
Source: Abelson (1993).

Table 2. Real changes in median values

Distance to CBD (km)	*UV*/sqm		*UV*/lot		*IV*/lot	
	1931–48	1948–68	1931–48	1948–68	1931–48	1948–68
0–8	− 27	+ 331	− 17	350	− 18	+ 108
8–16	− 24	+ 457	− 23	+ 453	− 14	+ 156
16–24	− 16	+ 723	− 14	+ 662	− 20	+ 209
24 +	− 27	+ 1013	− 23	+ 948	− 8	+ 330
All Sydney	− 22	+ 274	− 20	+ 382	− 18	+ 182

Source: Nominal values in Table 1, deflated by CPI.

Estimated median land values in 22 LGAs in 1931 are shown in Figure 1 and changes in land values between 1931 and 1968 are shown in Figure 2. Some land and house values are given in the next section. More details are given in Abelson (1993).

4. Property Values and Access to the CBD, 1931–68

Descriptive Overview

Median land and house values in four rings around the CBD (0–8 km, 8–16 km, 16–24 km and 24 + km to the CBD) in 1931, 1948 and 1968 are shown in current prices in Table 1. The real changes in values are shown in Table 2.

Table 1 shows that, in each selected year, land values (*UV*/sq m) declined significantly from the centre and at a decreasing rate. Table 2 brings out the sharp flattening of the land price gradient after 1948. Lot values also tended to fall with distance from the CBD. But because lot size generally increased with distance, the lot price gradients were shallower than the land price gradients.

Explanations should perhaps be given for two apparent anomalies in Table 2. First, average city property values rose less than values in each part of the city because the centre of residential gravity moved away from the CBD. Secondly, the median Sydney lot value rose by more than the median value per sq m. As the city expanded, average lot size increased by one-quarter from 407 sq m in 1931 to 513 sq m in 1968. This occurred even though the average lot size fell by around 10 per cent in 6 of the 22 LGAs in the sample and stayed fairly constant in the remainder (Abelson, 1993).

House prices (*IV*s) were like land prices in some respects. Except for some low, inner-area house prices, house prices generally declined with distance. Also, the house price gradient flattened considerably between 1948 and 1968. However, as expected, the house price gradient was always much flatter than

Table 3. Real increases in property values by sector: percentage price increases, 1931–68

	UV/sqm				*UV*/lot				*IV*/lot			
Distance to CBD (km)	Inner –East	S–SW	W–NW	N	Inner –East	S–SW	W–NW	N	Inner –East	S–SW	W–NW	N
0–8	292	276	—	340	767	282	—	332	254	187	—	187
8–16	—	378	5555	424	—	376	501	462	—	222	210	226
16–24	—	615	1202	702	—	608	993	736	—	252	313	241
24 +	—	1152	897	732	—	1051	790	854	—	474	342	400

Source: Abelson (1993).

Table 4. Residential property prices and distance from the CBD

	UV/sqm			*IV*		
Year	*a*	*b*	R^2	*a*	*b*	R^2
1931	1.60	− 0.061 (− 6.9)	0.71	1 808	− 0.018 (− 3.1)	0.33
1948	1.68	− 0.058 (− 7.1)	0.71	1 808	− 0.012 (− 1.47)	0.16
1968	18.92	− 0.036 (− 9.4)	0.81	13 359	− 0.0065 (− 1.51)	0.11

Notes: Figures are based on 22 average LGA values, using equation 8. Figures in parenthesis are *t*-statistics.

the land price gradient. Further, house prices rose everywhere by less than land prices. This happened because house prices rose by more than non-land factor costs, so that the price of the residual input (land) rose faster than house prices.

Real price changes are shown by geographical sector in Table 3. This provides sectoral support for the finding that both house and land prices increased by more further from the CBD. The only exception was the outer part of the W–NW sector where land values in the relatively inaccessible and inhospitable inland areas rose by less than in more accessible areas.

Property Prices and Distance from the CBD, Based on Median LGA Prices

Still drawing on median LGA prices, we now examine how much of the variation in property prices is explained by distance from the CBD. Abelson (1991) tested linear, negative exponential and semi-log forms of land price—distance equations and found that the negative exponential form (equation 8) usually gave the best results.[1] Table 4 summarises some results for land and housing.

As shown, distance to CBD explains a high percentage of the variation in average LGA land prices; the *b* coefficients in the land equations are highly significant; and the land price gradient fell significantly between 1948 and 1968. In 1931 and 1948, land prices fell with distance from the CBD by an estimated 6 per cent per km; in 1968, they fell by about 3.5 per cent per km.

In 1931, distance from the CBD explained about one-third of the variations in average LGA house prices. After that, the house price gradient declined and distance, though still exerting a negative influence on house prices, became barely significant and explained only

Table 5. Land values and distance from the CBD

	1931			1948			1968		
Sector	a	b	R^2	a	b	R^2	a	b	R^2
North	0.39	− 0.055	0.20	1.35	− 0.063	0.33	59.7	− 0.012	0.13
		(− 10.4)	409		(− 20.9)	878		(− 3.98)	1123
West	0.40	0.075	0.31	0.84	− 0.049	0.36	49.4	− 0.029	0.32
		(− 13.0)	387		(− 18.7)	625		(− 23.4)	1181
South	0.64	− 0.092	0.44	2.16	− 0.092	0.59	67.4	− 0.021	0.13
		(− 16.0)	327		(− 32.9)	764		(− 12.3)	991
East	0.58	− 0.033	0.02	1.78	− 0.057	0.06	19.1	− 0.071	0.12
		(− 2.9)	320		(− 5.0)	361		(− 7.4)	393
Inner	1.73	− 0.030	0.30	3.69	− 0.024	0.19	83.1	− 0.120	0.11
		(− 11.5)	313		(− 9.1)	350		(− 0.75)	430
All	0.65	− 0.094	0.55	1.75	− 0.078	0.53	69.4	− 0.032	0.28
		(− 46.3)	1756		(− 58.4)	2987		(− 40.1)	4118

Notes: Using equation 8. Figures shown below R^2 statistics are sample sizes.
Figures in parenthesis are t-statistics.

10–15 per cent of the variations in house prices. In 1931, house prices fell by about 2 per cent per km from the CBD; in 1968, they fell by about 0.5 per cent per km.

Land Values and Distance from the CBD, Based on Individual Land Values

Drawing on all the properties in the sample and again using equation 8, the relationships between land values and access to the CBD in each sector are shown in Table 5. The main results are:

—The value of a, residential land close to the CBD, rose over time in each geographical sector.
—The b parameter is always negative and highly significant. That is, in each sector, in each year, the land price gradient is well represented by a negative exponential function.
—In all sectors except the Eastern one (which has some unusual characteristics), the land price gradient declined significantly between 1948 and 1968. Also distance from the CBD became a less important influence (the value of R^2 fell) between 1948 and 1968.
—Similar results were obtained for the whole of Sydney. Despite the marked differences between sectoral environments in Sydney, distance from the CBD explained over 50 per cent of the differences in land values in Sydney in 1931 and 1948, and 28 per cent in 1968.
—The estimated land price gradients in 1931 and 1948, based on individual lot assessments, were higher than those based on average LGA figures in Table 4. Since the former embody more information and are better specified, they would generally be preferred.

Finally, an international comparison. In Chicago, one of the few cities for which comparable data exist, the estimated land rent gradient was just over 20 per cent per mile in 1928 and 11 per cent per mile in the 1960s (Mills and Hamilton, 1989). The comparable figures for Sydney are approximately 15 per cent per mile in 1931 and 5 per cent per mile in 1968. A major reason for Sydney's lower rent gradient was its smaller population, which was less than half that of Chicago between 1928 and 1968, and consequently its lower density. This lower density is likely to be associated with lower congestion and transport costs and hence a lower price gradient.

5. Causes of Changes in Relative Property Values

We consider now the main causes of real land price changes between 1931 and 1968. First, some of the underlying causes of the changes are observed. Then an examination is made of the effects of changes in road and rail services and urban services as proxied by changes in the provision of sewerage services. A more comprehensive statistical analysis of the determinants of property price changes—for example, including employment data—is not feasible because of data constraints.

Various factors tend to flatten the residential price gradient. On the demand side, rising income increases the demand for housing space and environmental amenities. This usually increases the demand for fringe properties where land is cheap and environmental conditions are good. Also, decentralisation of employment reduces the demand for inner-city housing. On the supply side, it is easier to improve land in undeveloped areas—for example, by improving urban services. Transport improvements are often radial and benefit fringe areas more than established areas.

In Sydney increases in population, income and car ownership were major causes of the rise in demand for housing and land values in outer urban areas. Between 1930 and 1970, the population of Sydney more than doubled from 1.3 million to 2.8 million (an average rate of growth of over 2 per cent per annum). Most growth occurred after 1940—the population grew by 10 per cent in the 1930s, 34 per cent in the 1940s, 28 per cent in the 1950s, and 24 per cent in the 1960s. Over the whole period 1928–68, per capita income in Australia rose by 150 per cent (nearly 3 per cent per annum). Registered motor cars in New South Wales rose from 145 000 in 1931 to 188 000 (one in three households) in 1948, to 1.11 million (over one car by household) in 1971.

Writing about the US, Muth (1975, p. 73) observed:

> Empirically, differences in marginal transport costs, as reflected in car registrations per capita, are the other major factors in addition to population differences leading to differences in the degree of population dispersion at a given time. More important, though, the increase in car registrations per capita that took place in the fifties decreased the relative rate of decline in population densities by more than one half. These same changes caused the land area occupied by cities to increase by about 45 per cent, and central city populations fell by about 10 per cent. Thus there is good economic reason why the suburban parts of cities grew so rapidly during the 1950s.

Car usage in Sydney was encouraged by the end of petrol rationing in 1950, the decline in the real price of petrol in the 1950s and 1960s, and the large road construction programme. Between 1956 and 1968 the real price of petrol fell by about 20 per cent (Abelson, 1993). This represented an annual saving of $22 per annum for a 20-km commuter or a capital saving of $440, assuming a real rate of discount of 5 per cent, which equated to 9 per cent of average land value (including improvements to land) in the outer areas of Sydney in the late 1960s.

As described in detail in Abelson (1993), 1931–68 was a period of major road building in Sydney. Before the NSW Main Roads Board was created in 1924, local authorities were responsible for all road construction. After 1924, large expenditures were committed to five major city radials (to the north, north-west, west, south-west and south). Also, many large bridges were constructed including the Sydney Harbour bridge which was completed in 1932. The main beneficiaries were commuters to the CBD and property owners in the outer areas.

Unlike the road infrastructure, Sydney's rail infrastructure was nearly complete by the mid 1920s (Abelson, 1993). Between 1930 and 1970, peak-hour rail travel times to the CBD from most areas in Sydney stayed constant or increased. Moreover, although the frequency of peak-hour services to inner-city areas tended to decline and the frequency to

Table 6. Percentage of properties with mains sewer service

Distance to CBD (km)	1931	1968	Percentage change 1931–68
0–8	92	100	8
8–16	50	93	43
16–24	22	90	68
24 +	3	37	34

Source: Sydney Water Board.

other areas to increase, changes in service frequency per capita were usually small. Of more significance for land values, many real rail fares fell, in several cases by over 25 per cent. Moreover, fare reductions were greatest for longer journeys. For some areas, real fares fell by a dollar or more per week (in 1970 $s). Assuming a real 5 per cent interest rate, this represented a capital value of $1000. This represented a 20 per cent increase in land values in outer urban areas in the late 1960s.

Another feature of the 1931–68 period was the increase in urban services—especially mains sewer services (see Table 6). In 1931, only 22 per cent of properties between 16 and 24 km from the CBD were sewered. By 1968, 90 per cent were sewered. These services generally increased, like land values, with distance from the CBD. Admittedly, only modest improvements in sewerage services occurred in the 24 + km areas. However, by the late 1960s, most urban-fringe residents expected to receive sewer services in the next few years. Of course, improvements in sewer services often occurred in the same period as improvements in drainage, kerb and guttering, so that the separate effects on land values are difficult to isolate.

In order to quantify the separate influences (if any) of distance, improved roads and sewerage services on land values, the percentage changes in land values (*CHUV*/sq m) in each LGA were regressed on the log of distance to the CBD (*LOGCBD*), dummy variables for road improvements (1 for significant improvements and 2 for very large improvements) and the increase in the proportion of properties receiving mains sewer service. The results were as follows:

$$\begin{aligned} &CHUV/\mathrm{m}^2 = -34 \\ &(1931\text{–}48) \quad + 2.0\ LOGCBD \\ &\qquad\qquad (0.66) \\ &\qquad\quad + 8.59\ RD \\ &\qquad\qquad (2.21) \\ &\qquad\quad + 0.11\ SEW \\ &\qquad\qquad (0.64) \\ &R^2 = 0.32 \end{aligned} \tag{9}$$

$$\begin{aligned} &CHUV/\mathrm{m}^2 = 18 \\ &(1948\text{–}68) \quad + 155\ LOGCBD \\ &\qquad\qquad (1.24) \\ &\qquad\quad + 379\ RD \\ &\qquad\qquad (2.12) \\ &\qquad\quad - 0.38\ SEW \\ &\qquad\qquad (-0.10) \\ &R^2 = 0.45 \end{aligned} \tag{10}$$

$$\begin{aligned} &CHUV/\mathrm{m}^2 = -161 \\ &(1931\text{–}68) \quad + 184\ LOGCBD \\ &\qquad\qquad (1.84) \\ &\qquad\quad + 308\ RD \\ &\qquad\qquad (2.49) \\ &\qquad\quad - 3.39\ SEW \\ &\qquad\qquad (-1.36) \\ &R^2 = 0.49 \end{aligned} \tag{11}$$

where, *RD* and *SEW* are road and sewerage improvements respectively; ($t-$ statistics in parenthesis).

Clearly, road improvements had a major effect on land prices. Although distance by itself is a significant determinant of land price changes, *LOGCBD* is not significant in the two sub-periods when road improvements are included. This doubtless reflects multicollinearity between road improvements and *LOGCBD*. On the other hand, the sewerage coefficient is twice negative and never significant. This is probably due to the lack

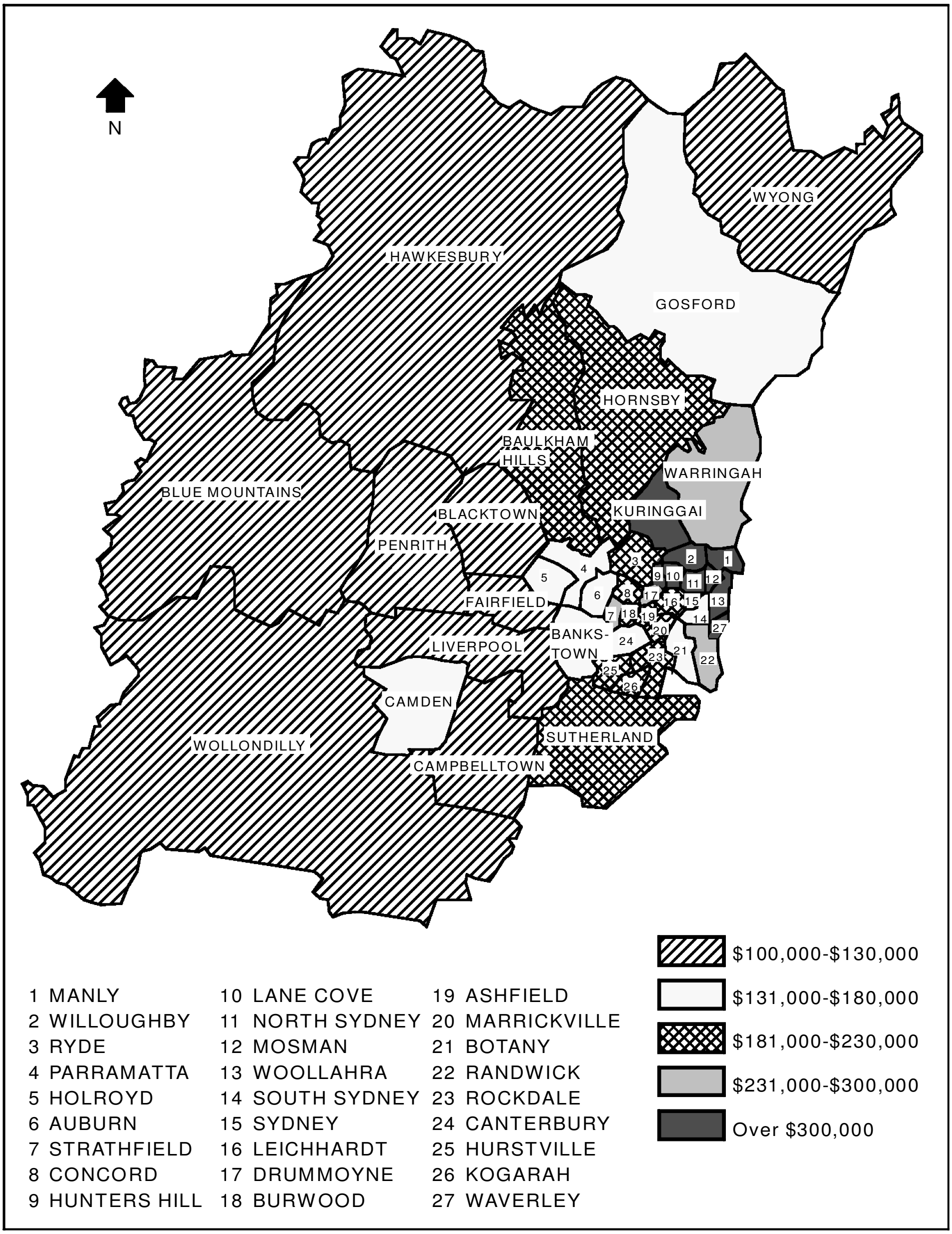

Figure 3. Median house prices in Sydney, 1989.

of an expectations factor for sewer supply and some multicollinearity in the equation.

Finally, a brief observation on the impact of regulatory policies on land values. During the study period, local authorities held main responsibility for land-use zoning policies. Generally they adopted exclusionary policies that prevented the substitution of capital for land and retained lot sizes at historic levels. Consequently, lot sizes in inner areas were larger than they would have been in a freer market. Such policies increase house prices in established areas, but reduce land prices (per sq m). Therefore, land-use controls

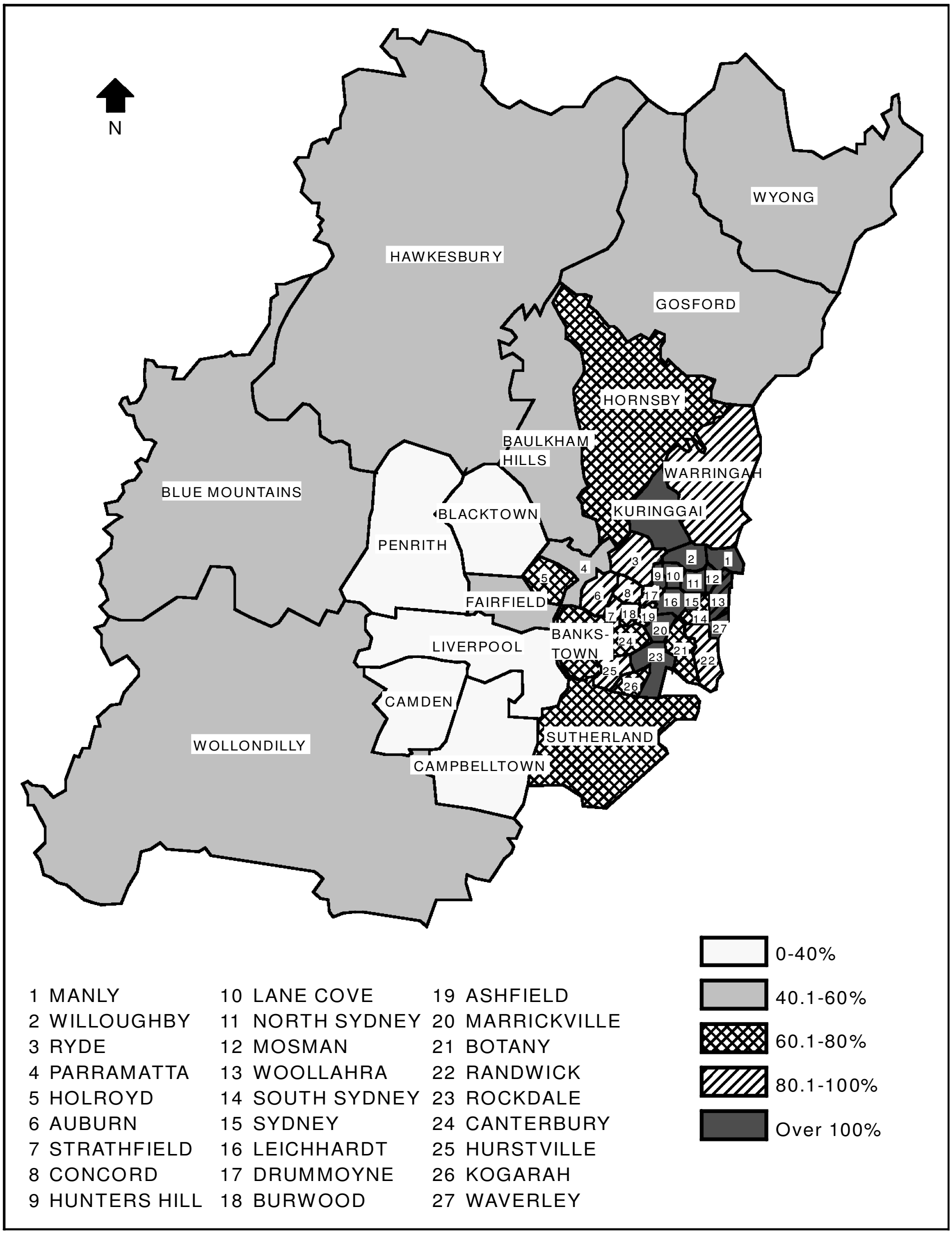

Figure 4. Real percentage change in house prices in Sydney, 1977–89.

flattened the land rent gradient below that which would have occurred in a freer market.

6. House and Land Prices, 1977–89

Our data on house prices in the later period are based on actual sales. The 1977 data are derived from all sales in that year. The 1989 data are derived from a random sample of 10 per cent of sales in 1989. However, the 1977 data are available from the Australian Bureau of Statistics only in the form of average (mean) house prices in each LGA. The analysis is therefore based on an aggregated

Table 7. Land values and distance from the CBD, 1983

	a	b	R^2	Equation
For 22 LGAs	215	− 0.048 (− 7.7)	0.75	(12)
For 2349 properties	221	− 0.052 (− 52.4)	0.54	(13)

Note: t-statistics in parentheses.
Source: Kirwan (1989).

Table 8. LGA variables used in hedonic house price equations

Land and buildings[a]
Typical lot size estimated on three-point scale: (1) over 750 sq m; (2) 550–750 sq m; (3) under 550 sq m.
Average house size: proxied by average number of bedrooms in 1976.
Percentage of brick houses in 1976.
Percentage of houses with mains sewer services in 1976.
Age of typical house based on decade of most building, e.g. 1910 or earlier = 1; 1910–20 = 2; etc.

Accessibility
Distance (km) from centre of LGA to centre of CBD.
Distance (km) from centre of LGA to nearest regional centre.
Whether LGA contained a rail station in 1989 (dummy 1–0 variable).
Whether LGA received a ferry service in 1989 (dummy 1–0 variable).

Environment
LGA environmental quality estimated on four-point scale; (1) low-quality, generally flat, with few views; (2) undulating with some local views; (3) undulating/rolling with some more extensive views; (4) high-quality landscapes with high-quality views.
Average distance (km) to the coast; this reflects climatic comfort as well as access to recreation.
Whether LGA contained a major industrial area (dummy 1–0 variable); this could be an access benefit or amenity disbenefit.
Population density (in 1986); a possible environmental disamenity.

[a] Data on dwellings only available in 1976 Household Census.

LGA data set rather than on individual house prices.

Figures 3 and 4 show average LGA house prices in 1989 and the price changes between 1977 and 1989 respectively. Figure 3 shows that house prices declined with distance from the CBD in 1989. Figure 4 shows that, between 1977 and 1989, house prices increased most closest to the CBD. Detailed statistics are given in Abelson (1993).

Comparable data on land prices are not available for this period. However, the discussion in section 2, suggests that land prices are likely to follow house prices and work by Kirwan (1989) confirms this. Kirwan obtained land valuations in 1983 for this author's 1968 sample of properties and estimated the negative exponential land value equations (for UV/sq m) for 1983, as shown in Table 7. The b coefficients in equations 12 and 13 are significantly higher than the comparable figures in Tables 4 and 5. This indicates that the land price gradient became significantly steeper between 1968 and 1983.

7. Causes of House Price Distributions, 1977 and 1989

Average LGA house prices may be explained in two main ways: by hedonic price models or by housing market models of the demand for, and supply of, housing in each LGA. The hedonic price approach focuses directly on the determinants of house prices. The housing market approach models the forces underlying house prices, but requires more data and more complex modelling. This paper draws mainly on hedonic price explanations.

As shown in Abelson (1991), the following six sets of factors are usually the most important determinants of house prices: the size of land and dwellings; the age and quality of dwellings; accessibility, especially to employment; environmental attributes; neighbourhood attributes other than the environment (such as crime/safety); and fiscal variables. Also, some studies include household income or socioeconomic status as an explanator.

For this study, LGA data were collected for the first four sets of factors plus income data. Due to resource constraints, no data were collected for neighbourhood or fiscal variables. However, local differences in expenditure and tax levels in Sydney are minor compared with the US. Table 8 summarises the data collected. Most of the data are objective. However, the environmental quality data reflected the assessments of professional town planners.

A linear hedonic price model was adopted for most variables. Although many hedonic studies adopt a log-linear model, this was inappropriate with so many dummy variables. However, for the crucial variable—distance from the CBD—various non-linear transformations were tested and it was found that the log form usually gave the best results (Abelson, 1991).

The main results are shown in Table 9. The 1977 regressions show comparable results using 1977 and 1989 prices. The latter were estimated by factoring up LGA prices by the general house price inflation between 1977 and 1989. Despite Sydney's irregular topography, the models provide a high level of explanation of LGA prices. The applicability of a single hedonic price structure for the city was treated by using dummy variables for seven sub-regions. Only one dummy variable, that for the outer south-western LGAs, was significant.

Turning to the main explanators, *LOGCBD* is the most significant variable; it improves the specification and the goodness-of-fit significantly. Drawing on typical coefficients, in 1989 house prices declined by about 3 per cent per km between 5 and 10 km from the CBD; by 2 per cent between 10 and 20 km from the CBD; and by 1.5 per cent per km between 20 and 30 km from the CBD. These declines are higher than the typical 2 per cent per mile in US cities estimated by Jackson (1979). This is most likely to be due to the high transport costs over Sydney's irregular topography and the failure of transport infrastructure to keep pace with transport demands. In fact, the access coefficients rose substantially between 1977 and 1989. By comparing equation S2 and equation S5b, which is estimated in 1989 prices, we can see that the cost of distance nearly doubled in 12 years. The causes are discussed below.

It may also be observed that the Sydney house price gradient is consistent with estimated values of travel time savings. In 1989, typical commuting speeds 10–30 km from the CBD were about 30 kph. Allowing an average value of travel time of $9 per hour (Hensher, 1989), the time cost of commuting 20 km would be $6. Add marginal vehicle operating costs of $2 per 20 km and the total commuting cost would be $8 per 20 km. The estimated annual cost for a return trip of 20 km would be $3250. Allowing a 5 per cent real rate of interest, this is equivalent to about $70 400. This is approximately equal to the price premium for medium-priced houses 10 km from the CBD, compared with those 30 km from the CBD.

The three other key determinants of house prices are quality of the environment, house size and distance to the coast. The environmental premium in a high-quality LGA is about $100 000 compared with a low-quality LGA. Again, the premium on the environment rose significantly between 1977 and

Table 9. Sydney house prices: determinants of differences between LGAs

	1989				1977[a]	
	S1	S2	S3	S4	S5a	S5b
Constant	381 760	363 570	355 600	214 900	55 810	277 934
LOGCBD	− 75 856 (− 8.9)	− 55 675 (− 5.2)	− 32 677 (− 4.3)	− 49 379 (− 2.7)	− 5 801 (− 4.4)	− 28 889 (− 4.4)
ENVIRON	28 524 (3.3)	24 144 (2.9)		36 947 (3.2)	3 152 (3.2)	15 697 (3.0)
COAST		− 1 575 (− 2.8)	− 1 878 (− 4.9)	− 1 392 (− 2.2)	− 191 (− 2.8)	− 951 (− 2.8)
INDUSTRY				17 391 (0.8)		
LOTSIZE				7 834 (0.5)		
BEDROOMS	296 450 (5.9)	323 350 (6.8)	358 360 (11.3)	294 930 (5.1)	51 541 (9.0)	256 674 (9.0)
BRICK				172 (0.3)		
SEWER				675 (1.6)		
FERRY			88 473 (5.2)			
SUB-CENTRE			3 135 (2.7)			
S.W.LGAS			− 78 348 (− 4.3)			
R^2	0.80	0.83	0.92	0.85	0.86	0.86

[a] S5a is in 1977 prices; S5b is in 1989 prices (based on house price inflation).
Note: *t*-statistics in parentheses.
Source: Author's research.

1989. The coefficient for *BEDROOMS* suggests that average house prices in LGAs with large houses are about \$75 000 higher than those in LGAs with small houses. To interpret the estimated coefficient, note that the average number of bedrooms per house in an LGA is usually between 2.80 and 3.10. Thus given a coefficient of say \$250 000, a 0.1 variation in average bedroom number implies a difference of \$25 000 in the average house price. However, this may include some value that should be attributed to lot size or house quality. Comparing similar specifications for 1977 and 1989, the coefficients for *BEDROOMS* (unlike those for *LOGCBD* and environment) did not change by much.

Variables which were generally not significant were lot size, access to a sub-centre, age of houses, access to rail, and population density. Of course, these findings do not necessarily mean that these variables are insignificant. For example, lot size almost certainly affects house prices. However, in this study only crude estimates of average lot size in each LGA were available. In unreported results, there were weak findings that house prices were positively related to the percentage of brick and sewered houses and inversely related to the presence of industry in an LGA.

Finally, it may be noted that Abelson and Tonkin (1993) tested the effect of income on house prices. Although household income is strongly correlated with house prices, the addition of household income to the hedonic price equations did not improve their specification or explanatory power.

Table 10. Changes in house prices, 1977–89: attribute models

	Equation S6	Equation S7	Equation S8
Constant	41	113	48
CBD	− 0.59	− 0.91	
	(− 2.1)	(− 4.8)	
Price 1977			0.0011
			(2.9)
Environment	3.2		
	(0.9)		
Brick	0.54		
	(2.2)		
Newrail		− 6.0	− 14.0
		(− 0.3)	(− 0.7)
Road improvements		− 19.9	− 25.5
		(− 2.6)	(− 2.9)
Urban improvements		− 0.2	4.1
		(0.2)	(0.5)
R^2	0.56	0.57	0.44

Note: *t*-statistics in parenthesis.

8. Causes of Changes in House Prices, 1977–89

Relative house prices may change because of changes in the quantities of housing services or changes in the implicit prices of these services. Both possibilities are examined below.

Most hedonic price studies analyse the effects of changes in housing services on prices. This approach presumes unchanged housing preferences. On the other hand, if housing services are constant, we can test for changes in preferences by regressing house prices at different points in time against the constant attribute levels and interpret the changes in the coefficients as demand changes. For example, the environment coefficients increased significantly between 1977 and 1989. Given that environmental rankings did not change, it may be inferred that the premiums attached to the environment increased.

If the demand for and supply of housing services both change, sorting out the effects on the prices is more complex. For example, a change in the access premium could reflect increased values of travel time or more congested travel conditions, or both. These access issues are examined in more detail below.

Hedonic Price Models

We consider first whether the changes in Sydney house prices were related to changes in the supply of local services or to a change in implicit prices. To assess the services effect, data were collected on three key factors: improvements (if any) from a new rail service; a major road upgrade in the area; or a major local urban development between 1977 and 1989. In each case, the improvement was represented by a dummy.

The principal result (Table 10) is that changes in house prices were related strongly and inversely with distance from the CBD. They were also related positively with house prices in 1977. But this relationship is less significant than that of access to the CBD. Although the coefficients for environment were positive, none was significant at the 95 per cent level. The coefficient for brick houses was positive, as expected, and significant.

On the other hand, no significant positive relationship was found between house prices and local (rail, road or urban) improvements.

This probably reflects the lack of major local improvements in infrastructure between 1977 and 1989 (the state government for most of this period was strongly opposed to major new roads). The major local improvement was the state government's billion dollar expenditure in Sydney's Darling Harbour, adjacent to the CBD, which benefited all the most accessible inner areas more than other areas.

Clearly, there is a need to explain the rise in the access gradient. The most direct explanation is that access costs themselves increased because of increased congestion, higher values of travel time or increased vehicle operating costs. Secondly, housing improvements (alterations and additions) may be inversely related to distance to the CBD. Thirdly, house prices in outer areas may be depressed by new housing supply in these areas.

Changes in Access Costs

Between 1983 and 1989, average variable speeds on six major routes into the Sydney CBD fell from about 32 kph to 24 kph in the morning peak hours and from 38 kph to 32 kph in the afternoon peak hours (Abelson, 1993). Overall, travel times increased by about 25 per cent between 1983 and 1989. Detailed traffic speed data are not available before 1983. However, given the increases in car ownership and the lack of major road projects (then government policy) between 1977 and 1983, traffic speeds probably also declined in this earlier period. Although conjectural, an order of magnitude increase in travel times of one-third between 1977 and 1989 seems plausible.

Typically the value of commuting time is considered to be a constant percentage of (hourly) income and to rise proportionately with income. Accepting this, the value of travel time would have risen by about 25 per cent between 1977 and 1989.

Moreover, the retail price of petrol rose from 17.2 cents per litre in 1977 to 54.7 cents per litre in 1989, a real price increase of about one-quarter. With a constant real price, commuters would have saved about 3 cents per km in 1989 and annual saving on commuting trips would have been an estimated \$13.2 per km. Capitalised at the then prevailing real rate of interest of about 7 per cent, this represented about 7.5 per cent of the access cost per km in Sydney in 1989.

In summary, assuming that commuting costs are made up of 80 per cent travel time costs and 20 per cent fuel costs, commuting costs rose by about 55 per cent between 1977 and 1989. Therefore increased travel costs accounted for about half of the increases in the access premium between 1977 and 1989.

Housing Alterations and Additions

To test the gentrification effect, data were collected on alterations and additions (AA) expenditure for each LGA from 1985/86 to 1987/88. In these years, AA expenditure averaged \$1474 per house per annum. Extrapolating this result and allowing for price changes, AA contributed an estimated 11.6 per cent to house values in the 13 years from 1976 to 1989.

Not surprisingly, AA were also found to be larger in inner-city areas with high land values and much old housing stock. Equations 14 and 15 show two relationships between AA expenditure and distance from the CBD.

$$AAEXP = 2291 - \underset{(3.6)}{31.8}\, CBD \quad R^2 = 0.24 \tag{14}$$

$$AAPER = 13.8 - \underset{(2.5)}{0.088}\, CBD \quad R^2 = 0.13 \tag{15}$$

where, *AAEXP* is average annual AA expenditure per house in each LGA in 1989 dollars; *AAPER* is AA expenditure from 1977 to 1989 as a proportion of average house prices in each LGA, and *CBD* stands for distance in km from the CBD.

Equation 14 shows that distance from the CBD explains 24 per cent of the variations in AA. Equation 15 indicates that total AA expenditure between 1977 and 1989 fell by 1 per cent of house price for each 11 km distance from the CBD. Given that the access

Table 11. Changes in house prices, 1977–89: market models

	Equation S9	Equation S10	Equation S11
Constant	77	81	93
CHHINC	1.6 (3.2)		
CHPOP		0.51 (1.17)	
CHEMP	− 0.3 (− 1.0)		
CHHOUSE	− 0.38 (− 1.3)	− 0.29 (− 1.2)	− 0.65 (− 5.3)
ETHNIC	2.3 (0.2)		
VACANCIES 1976		1.4 (1.6)	
R^2	0.53	0.45	0.40

Note: t-statistics in parenthesis.

premium increased by about 1 per cent per km, housing improvements accounted for about 10 per cent of the change in the access premium.

Changes in Relative House Prices: Housing Market Equations

Finally, we consider briefly the effects of changes in housing demand and supply (see Table 11). Demand factors are represented by the percentage changes in household income (*CHHINC*), population (*CHPOP*) and employment (*CHEMP*) and supply by the percentage change in houses (*CHHOUSE*). The potential role of ethnic concentrations on house prices was also examined (*ETHNIC* stands for more than 5 per cent of LGA population coming from one overseas country), together with the impact of the initial vacancy rate which would be expected to be inversely related to changes in house prices.

The main result is that house price changes are positively correlated with changes in household income. This is consistent with gentrification. However, the correlation does not necessarily entail a causal relationship. House prices may have risen, not because local incomes increased, but because the areas became relatively more accessible and attracted higher-income households.

More significantly, changes in housing supply explained negatively 40 per cent of the changes in house prices (Equation S11). Although *CHHOUSE* is not significant when population or income is introduced into the model, the causal relationship is probably from houses to population and theory supports the notion that an increase in housing stock would depress house prices.

9. Conclusions

From 1931 to 1989, Sydney land and house prices declined exponentially with distance from the CBD. Between 1931 and 1968, both price gradients became flatter. But after 1970 both gradients became steeper again.

Land prices fell by about 9 per cent per km from the CBD in 1931, by 8 per cent per km in 1948, and by just over 3 per cent per km in 1968. The land price gradients for each major geographical sector in Sydney were also significantly negative and flattened over this time.

House prices related less uniformly to distance to the CBD. Nevertheless, house prices fell by an estimated 2 per cent per km from the CBD in 1931, by 1 per cent per km in 1948, and by 0.5 per cent per km in 1968. The small and irregular house price gradient is consistent with the theory that, although the price gradient for standard housing units is likely to be negative (to compensate households for higher access costs), actual house prices may not decline because households further from the CBD purchase larger and newer houses.

Also, the land price gradient was predicted to be the product of the housing price gradient and the inverse of the share of land in housing. Thus, given a typical land share of 20 per cent, the land price gradient would be five times the housing price gradient. This is approximately the result obtained.

The main causes of the flattening of the land price gradient between 1931 and 1968 were: the increased demand for housing and land as population and incomes more than doubled; the trebling in car ownership per household between 1948 and 1968; the major road construction programme over the whole period; and the substantial falls in real rail fares and petrol prices, especially after 1948. About half of the changes in LGA land prices were explained by distance to the CBD and by road or bridge improvements.

For the post-1970 period, the analysis switched to house prices for which there were more data. Over 80 per cent of the variations in house prices were explained by distances to the CBD and the coast, house size and local environmental quality. In 1989, house prices fell with distance to the CBD by about 3 per cent per km between 5 and 10 km from the CBD, and by about 1.5 per km some 20–30 km from the CBD. These declines broadly reflected commuting costs. Environmental factors explained variations in average LGA house prices in the order of $100 000 in Sydney (over 50 per cent of the median house price).

Between 1977 and 1989, increases in house prices were strongly related to access to the CBD with the access premium more than doubling. There was also some evidence that changes in relative house prices reflected increased environmental premiums. Local improvements were not found to influence house prices. This probably reflects the nature of city development over this period or measurement difficulties, rather than a fundamental lack of such relationships.

The access effect reflects various factors. First, higher access costs due to increased congestion and increased travel time values accounted for slightly over half the increase in the access gradient. Secondly, housing improvements in established areas accounted for a further 10 per cent change in the access premium. Thirdly, the greater supply of new houses in fringe areas significantly reduced house prices in those areas. House price increases were also correlated positively with high-priced areas and with high increases in household incomes. However, the nature of the causal relationship between house price and household income increases is not established.

Note

1. This assumes that the value of a parcel and its lot area are directly proportional. However, there is evidence that lot price is an increasing concave function of size (Brownstown and De Vany, 1991). If this is so, then the rate of decline in land price with distance will be overestimated in a model that constrains the price and parcel size relationship to be proportional.

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