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Property Prices and the Value of Amenities[1]

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Implicit hedonic prices of amenities are estimated by means of a study of the variation in house prices in Sydney. The results include estimated hedonic prices for aircraft noise, road traffic, road widening, good views, spacious streets, good access to shops, and high quality neighborhoods. Since hedonic prices are the response of the market at the margin to supply as well as demand forces, they do not necessarily reflect average household willingness to pay prices. However, the paper concludes that they provide a basis from which the values of amenities to be used in benefit cost studies can be estimated.

1. INTRODUCTION

The main purpose of the paper is to describe the results of a study of the hedonic prices of various amenities implicit in the variation in property prices in Sydney. Of particular interest are the negative prices for aircraft noise, road traffic, planned road widening, and railway noise, and the positive prices for a good view, a spacious street, good access to shops, and a high quality neighborhood.[2] Despite the number of property price studies now made, much remains to be learned about hedonic amenity prices. Thus Ball [1] in his summary article on 11 house price studies noted that "Only two studies, Kain and Quigley, and Messell and Stewart, calculated disaggregated environmental indices for each house, the rest used census tract wide surrogates such as predominant socio-economic group or percentage of old housing in the area. These variables can only give broad indications of some aspects of environmental quality and hide many within area environmental variations." In the narrower field of aircraft noise, Walters [2] reported on a number of studies of the relationship between house prices and aircraft noise, but he concluded that "little faith can be vested in the result

[1] This study started when the author was working with R. Travers Morgan and Partners, Consulting Engineers, and was completed with the aid of a grant from the Bureau of Transport Economics, Canberra. I wish to acknowledge especially the assistance of David Hawes, Dick Bullock, and Michael Moore of R. Travers Morgan and of Murray Aitken, June Crawford and Bernie Ludecke of Macquarie University. I was also assisted by comments by two referees on an earlier draft of this paper. Naturally I am responsible for any errors that remain in the paper.

[2] It is of course often arbitrary whether we speak of a positive price for amenity or a negative price for disamenity. For example, we may say that a good view has a positive price or a bad view a negative one.

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[that house price depreciates linearly with NNI or any other noise annoyance scaling system] until it has undergone more stringent and extensive tests."

To put the empirical work into perspective, the meanings and use of hedonic amenity prices are also discussed. Like other prices, hedonic prices are the response at the margin to supply as well as demand factors, and they do not necessarily reflect average household willingness to pay prices. However, I argue that hedonic prices do provide a basis from which approximate willingness to pay prices can be generated and used in benefit cost studies.

In Section 2 I discuss house price models and the data base used to establish hedonic amenity prices in the study. The main results of the study, i.e., the hedonic prices, are reported in Section 3 and interpretation and application of these results in benefit cost and similar studies are discussed in Section 4. A very brief summary concludes the paper.

2. DESCRIPTION OF THE STUDY

House Price Models

The hedonic price approach which underlies this study has been succinctly summarized by Rosen [3] in the following terms.

> The hedonic hypothesis [assumes] that goods are valued for their utility-bearing attributes or characteristics. Hedonic prices are defined as the implicit prices of attributes and are revealed to economic agents from observed prices of differentiated products and the specific amounts of characteristics associated with them. They constitute the empirical magnitudes explained by the model. Econometrically, implicit prices are estimated by the first step regression analysis (product price regressed on characteristics) in the construction of hedonic price indexes.

In general, the utility of a house, or what households are prepared to pay for a house, depends on the size of the land, the size and quality of the house, accessibility to work and recreation, and environmental factors including the quality of the neighborhood. Of course each of these major utility-bearing elements can be broken down into smaller utility-bearing components, the quality of the house, for instance, depending upon the central heating, the modernization of the kitchen, the garage, and so on. It may be noted, however, that if changes in land use are contemplated, the land may have investment as well as consumption value. In order to estimate the value of amenities, it was considered desirable therefore to exclude from the study properties which had undergone, or were likely to undergo, significant land use change following their sale.

Under certain extremely restrictive, perfect market conditions—including similar household preferences and incomes in different cities, costless household movement between cities, and a free competitive market in the supply of land and housing—the prices households would be willing to pay for the utility-bearing characteristics of a house would be similar in different cities. In practice, needless to say, such conditions do not prevail and both house prices and hedonic attribute prices vary between cities. Likewise household preferences vary, household movement is costly, and housing is not supplied in a perfectly competitive market even within a city. Moreover, from an econometric point of view, it is not easy to measure the differences in all utility-bearing characteristics in different parts of a city. For example, differences between localities in accessibility, in the quality of the view, and in the supply of public sector goods are often difficult to model on a city wide basis. Consequently our study of the implicit prices of amenities was based on differential house prices within two large neighborhoods. Limiting the area of study in this way increases the precision of the study and hence confidence in the results. But it has the limitation that implicit amenity prices in other areas may be different from those estimated in this study as the demand and supply conditions, which determine prices, vary from area to area.

Turning to the detailed specification of the house price model, four regression models were used in our study. The first one, the ordinary linear regression, can be expressed as

$$P_i = a + \sum_{j=1}^{n} b_j x_{ij}, \tag{1}$$

where the P_i are house prices and the x_{ij} are the set of j attributes for the ith house. In the linear model, property attributes have absolute dollar values regardless of the other characteristics of the property; for example, a single garage would be worth the same amount in a \$20,000 or \$30,000 house.

In the second model, some of the independent variables are expressed in log or exponential rather than in linear form. Dummy variables are of course unchanged. Taking the log of an independent variable implies diminishing marginal costs or benefits; for example, a sixth room in a house would be worth less than the fifth room. The exponential implies increasing costs or benefits; thus $P_i = f(e^{\mathrm{NEF}}i)$ implies that house prices fall by increasing amounts for each increment in NEF (Noise Exposure Forecast, see below). This model can therefore be expressed as

$$P_i = a + \sum_{k=1}^{n^1} b_j x_{ik} + \sum_{L=n^1+1}^{n^{11}} c_k e^{x_{iL}} + \sum_{m=n^{11}+1}^{n} d_m \ln x_{im} \tag{2}$$

where $n^1 < n^{11} < n$.

In the third model, the log of house price is a function of linear variables. In this model, housing attributes are valued at a given percentage of house price; thus a single garage would be x percent of house price, for all levels of house prices.

$$\ln P_i = a + \sum_{j=1}^{n} b_j x_{ij}. \tag{3}$$

In the fourth model, the log of house price is a function of log variables as well as linear ones. The double log relationship shows the percentage increase in house price for a 1% change in the independent variable.

$$\ln P_i = a + \sum_{r=1}^{n^{11}} b_j x_{ir} + \sum_{m=n^{11}+1}^{n} c_k \ln x_{im}. \tag{4}$$

The results reported below draw on all four regression models.

Data Collection and the Nature of the Independent Variables

The two Sydney municipalities of Marrickville and Rockdale were chosen as the study areas as they are close to the airport and lie partly under the N–S and

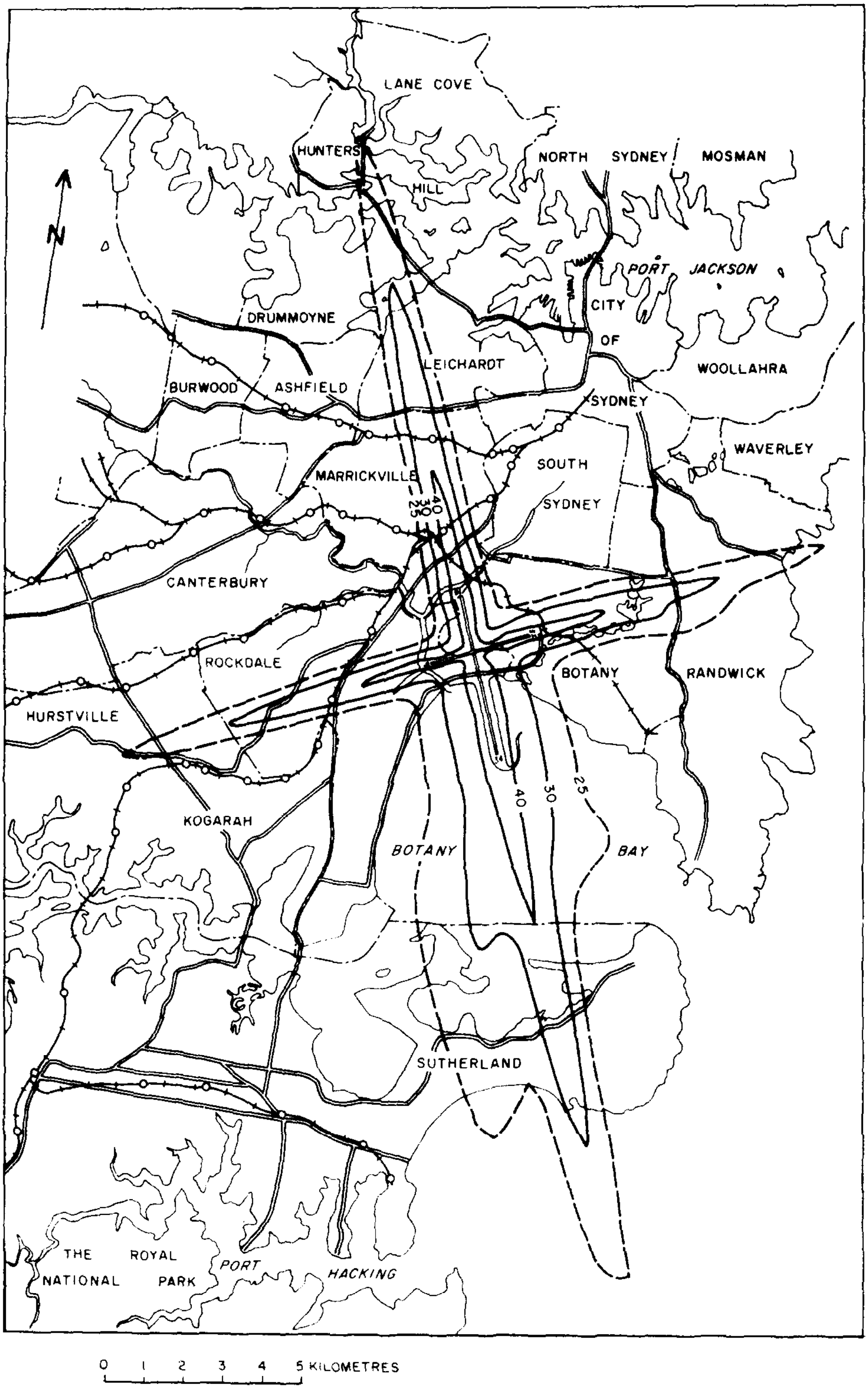


FIG. 1. Aircraft flight paths and noise exposure forecasts in Sydney, 1973.

E–W flight paths, respectively (see Fig. 1). Marrickville is an inner city municipality whereas Rockdale is suburban, but both municipalities rank amongst the poorest six out of the 40 in Sydney, with an average income of less than $5000 per household per annum in 1971 [4].

The study included all houses sold in the two municipalities between January 1972 and September 1973, excepting a few with highly unusual features, e.g.: very extensive modifications, or subdivision into flats. Purpose built flats were excluded because of special difficulty of predicting their prices without internal examination of the property. The sample finally included 592 house sales in Marrickville and 822 house sales in Rockdale. The data collected for each house and the main data sources are shown in Fig. 2.

By way of introducing the independent variables, it may be noted that they were measured in three ways. First, some variables were measured on an objective cardinal scale, for instance, the *number of rooms* was described by such a scale. Second, some variables were measured on a subjective scale, also intended, however, to be cardinal. For instance, *road traffic* levels were measured on a three-point scale of noisy, normal, and quiet, and *views* were measured similarly on a three-point scale of good, average, and poor.[3] Third, the existence or nonexistence of some attributes could be objectively described by dummy variables. For example, dummy variables were used to represent a carport, a single garage, a double garage, or no garage, respectively.

The second of these methods of measurement, which involved subjective judgments, was probably the most contentious. The main requirements were that the field researchers would simulate the house buyer's perception of the traffic noise or view, etc., and that their attributions were consistent. Tests were made to ensure consistency, but accurate simulation of buyer's perceptions cannot be guaranteed, especially as it is the perception of the marginal purchaser not of the average person which determines the hedonic price. The important conclusion is drawn that if an attribute based on a subjective scale is not a statistically significant determinant of house price, this may be due to an imperfect scaling rather than to the inherent insignificance of the attribute. Despite this potential problem, most of the subjectively measured attributes were significant for either Marrickville or Rockdale houses.

The main independent variables used in the hedonic regression equations, other than those already mentioned are described briefly below.

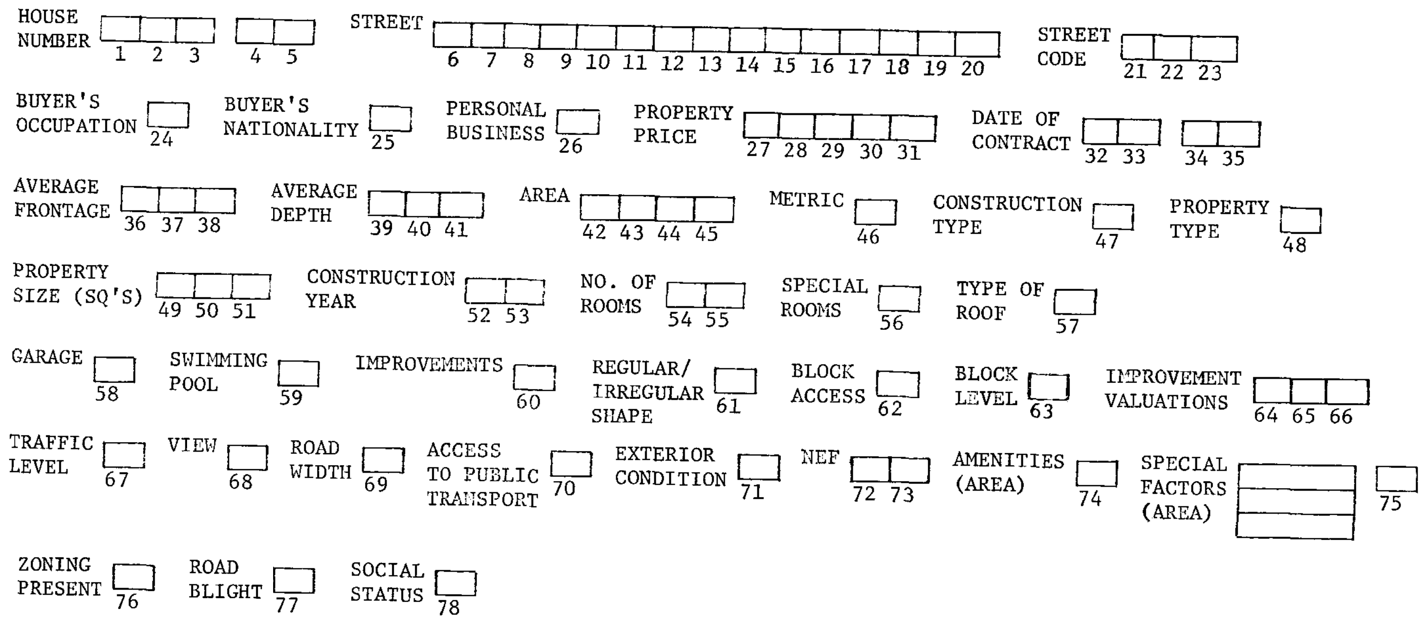
The *date of contract* for the sale was important because of the high rate of property price inflation in 1972–1973. The data were transformed into a monthly scale, with January 1972 = 1, February 1972 = 2, etc., so that the variable came to represent the monthly inflation rate.

The *frontage and depth* of the land, which were measured in feet, have obvious significance.

Construction type meant a brick or nonbrick building.

Property types, classed as detached and semidetached and as one or two stories, were represented by dummy variables. They were intended to reflect the quality

[3] It may be noted that in the field the researchers actually used a five-point scale for traffic levels and a seven-point scale for the quality of the view. But when the more detailed scale was used in the regressions, the coefficients were not significant.



Sources: Valuer General, Field Inspection, Zoning Maps.

FIG. 2. The data collection form.

of the building, but they are partly correlated with the size of the land and number of rooms, so that some regressions were run without them.

The *construction year* was estimated and converted in the regression analysis to the estimated age of the house, for which a negative coefficient was of course expected.

The *type of roof* included tile, slate, and other roofs.

Significant *improvements* were represented by a dummy variable. Typically these would show up in modernized windows or extensions at the back of the house, and would doubtless be correlated with renovation of the inside of the house.

Block access other than normal included either rear access, which is generally regarded as an advantage for parking, or a corner position, which would be noisy.

A dummy variable for *block level* indicated a house on the top side of a sloping street or one built well above street level.

Road width was measured on a three-point scale of wide, normal, and narrow, reflecting the spaciousness of the environment, which we would expect to be an attractive attribute, having of course allowed separately for the amount of road traffic.

The quality of *public transport service* was represented by a dummy variable, distinguishing households living within half a mile of a public transport service from others. It transpired, however, that virtually all households in Marrickville and most in Rockdale lived close to public transport. Therefore this was not a significant discriminating factor in house prices.

The *exterior condition* of each house was measured on a four-point scale—very good, good, average, and poor.[4]

NEF stands for *Noise Exposure Forecast,* which is the model most often used to represent aircraft noise nuisance in the United States and Australia. The model incorporates the diverse effects of aircraft noise on households into an index of noise annoyance and attempts to explain this annoyance by the number and noisiness of aircraft movements.[5] With the NEF formula, a household living under the flight path close to the airport will be in the 35 to 45 NEF area, whereas a household experiencing little annoyance from aircraft noise will tend to be at least outside the 25 NEF area and possibly outside the 20 NEF area. It should be said, however, that the correlation between the NEF measure and household annoyance with aircraft noise is not high, $r = 0.42$ [5], and that as noted above the relationship between them is not necessarily a linear one. Given these observations, relationships between house prices and various forms of the NEF variable were tested. These forms included NEF -25, which gives all NEF scores of 25 or less a value of zero and assumes a linear relationship between house prices and NEF scores of greater than 25, NEF -30, which is calculated

[4] To be precise, external conditions and area amenities were measured on a five-point scale but there were very few houses indeed in the very poor category.

[5] The total noise exposure (NEF) is defined at a point as $\text{NEF} = 10 \log [\sum_i \sum_j \text{antilog} \times (\text{NEF}_{ij}/10)]$ in which $\text{NEF}_{ij} = \text{EPNL}_{ij} + 10 \log (\text{Nd}_{ij}/20 + \text{Nn}_{ij}/1.2) - 75$. In this formula NEF_{ij} is the noise exposure forecast value of aircraft class i along flight path j and EPNL_{ij} is the effective perceived noise level of aircraft class i on flight path j. Nd_{ij} and Nn_{ij} are the numbers of movements of the ith aircraft type on the jth flight path by day and night (2200 hours to 0700 hours), respectively.

in similar manner, and $e^{\mathrm{NEF}-25/10}$ and $e^{\mathrm{NEF}-30/10}$, which suggest that for a given increment in NEF house prices fall more at higher levels of NEF.

Area amenities meant primarily access to shops, which was measured on a three-point scale in Marrickville and a four-point scale in Rockdale.

Present zoning reflects the allowable land uses in a subarea of a municipality. Each council had some five codes allowing different residential densities and commercial uses.

Road blight means here the cost to a house of a plan to widen the road at some future time.

Social status, measured on a three-point scale of high, average, and low, reflected the quality of the neighboring houses in the street and their effect upon house prices.

One other variable, not shown in Fig. 2, *proximity to the sea* (within half a mile of it) was added for Rockdale but was not relevant to Marrickville.

Despite the large number of variables included, some important ones were perforce excluded or were included crudely. Characteristics of the interiors of the houses, for example, were excluded. Nor was any allowance made for such attributes as privacy, the amount of sun in winter, or air pollution, though the last of these would be strongly correlated with road traffic. The public transport variable was also rather crude. It may be noted that distance to the central business district was not included as an independent variable since it was considered a relatively unimportant determinant of property price differences within the municipality—partly because of the uniform quality of public transport and partly because of the availability of local jobs. But distance to work would surely be an important determinant of property price differences between municipalities.

Brief Description of Properties

Marrickville house prices in 1972–1973 ranged from \$14,000 to \$35,000 and averaged \$21,000.[6] Some $\frac{3}{5}$ of the 592 sample houses were detached dwellings, and $\frac{2}{5}$ were terraced or semidetached properties, but in style and quality the houses were a fairly homogeneous group. Over 90% were brick and most were considered to be in good condition. Over $\frac{3}{4}$ were judged to have been built before 1914. And fully $\frac{3}{4}$ of the houses were considered to have an average inner city view. However, significant differences between houses were noted for both road traffic, over $\frac{1}{3}$ of properties experiencing heavy traffic conditions, and aircraft noise, with over $\frac{2}{5}$ of the properties standing within the 25 NEF. Furthermore, over 10% of the houses stood on roads scheduled for significant widening.

House prices in Rockdale varied from \$13,000 to over \$45,000 in 1972–1973, with the average in our survey being \$24,000. Although over 90% of the 822 sample houses were detached, in other respects they displayed more heterogeneous characteristics than Marrickville houses. Only about $\frac{2}{3}$ of the houses were of brick construction. Some $\frac{1}{3}$ of the houses were built before 1914 and the rest during the intervening years up to the present day. The views, with some houses overlooking the Pacific Ocean, also vary greatly in quality. About $\frac{1}{6}$ of the houses experience heavy road traffic and $\frac{1}{3}$ stand with the 25 NEF.

It is generally thought that the attributes of houses are interrelated. Houses

[6] All monetary figures are in 1972–1973 Australian dollars.

TABLE I

Some Correlations between Variables: Marrickville

	Road traffic	View	External condition	NEF	Road blight	Social status
Road traffic	1.0	0.152	0.077	−0.298	−0.087	0.325
View		1.0	0.156	−0.135	−0.077	0.271
External condition			1.0	−0.102	−0.046	0.198
NEF				1.0	−0.082	−0.331
Road blight					1.0	−0.123
Social status						1.0

with good views and peaceful surroundings tend to be kept in good condition. The quality of the neighboring houses tends to be in keeping with the qualities of the environment, and so on. In practice, however, it turned out that multicollinearity between the variables was lower than might have been expected. Some examples of correlations are given in Tables I and II, which show that multicollinearity is slightly higher in Marrickville than in Rockdale. In particular, "social status" tends to be correlated with other positive amenities of a house, and houses suffering from aircraft noise tend to experience high road traffic levels. However, most of the correlations between the independent variables are low and the regression coefficients are not significantly affected by the inclusion of other variables in the equations.

3. RESULTS OF THE HOUSE PRICES STUDY

General Results

The major results for Marrickville and Rockdale are reported in Tables III and IV, respectively. Regressions with the log of the house price as well as those with ordinary house price as the dependent variable are included for both municipalities. Likewise regressions in which certain independent variables, such as age and frontage, are expressed in log rather than linear form are included. Also reported are regression results for equations in which such variables as road traffic, social status, and property types are omitted in order to examine the effects of removing such multicollinearity as exists between the variables. For

TABLE II

Some Correlations between Variables: Rockdale

	Road traffic	View	External condition	NEF	Road blight	Social status
Road traffic	1.0	0.315	0.076	0.011	−0.000	0.126
View		1.0	0.004	0.034	−0.001	0.080
External condition			1.0	−0.036	−0.021	0.159
NEF				1.0	−0.056	0.064
Road blight					1.0	−0.009
Social status						1.0

TABLE III

Marrickville: Summary of Regression Results[a]

	Equation					
	(5)	(6)	(7)	(8)	(9)	(10)
R^2	0.68	0.66	0.68	0.66	0.66	0.62
House price	Linear	Log	Linear	Log	Linear	Linear
Constant	5365	9.3	4998	9.1	7860	8450
Monthly inflation	253 (21)	0.012 (0.001)	253 (21)	0.012 (0.001)	256 (22)	265 (23)
Frontage (ft)	35 (12)	0 002 (0.0006)	34 (13)		52 (13)	88 (11)
Log frontage				0.074 (0.017)		
Depth (ft)	9 (4)	0.0004 (0.0002)	9 (4)		13 (5)	13 (5)
Age (years)	−14 (5)	−0.0009 (0.0003)	−14 (5)			−16 (6)
Log age (years)				−0.062 (0.017)		
Not brick	−2525 (431)	−0.121 (0.020)	−2532 (431)	−0.127 (0.021)	−3179 (421)	−2155 (426)
No. rooms	1137 (102)	0.050 (0.005)	1140 (102)		1073 (103)	1359 (107)
Log no. rooms				0.291 (0.031)		
Road traffic	713 (202)	0.028 (0.010)	716 (202)	0.025 (0.010)		700 (227)
Road blight	−1923 (323)	−0.093 (0.016)	−1914 (323)	−0.083 (0.016)	−2052 (335)	−1709 (349)
Road width	459 (150)	0.029 (0.007)	458 (150)	0.030 (0.007)	432 (149)	440 (162)
External conditions	515 (133)	0.020 (0.006)	519 (133)	0.018 (0.006)		426 (143)
Area amenities	305 (138)	NS	307 (138)	NS		273 (149)
Improvements	1258 (401)	0.054 (0.019)	1275 (401)	0.051 (0.019)	1427 (415)	1366 (433)
$e^{(NEF-25)/10}$	−382 (114)					−330 (126)
NEF-25	NS	−0.004 (0.001)	−74 (23)	−0.004 (0.001)	−120 (22)	
Zoning C_1 (higher density)	−559 (223)	−0.020 (0.010)	−569 (223)	NS	−726 (229)	−562 (241)
Rear access	955 (277)	0.045 (0.013)	953 (277)	0.045 (0.013)	924 (288)	1075 (299)
Corner access	−1048 (399)	−0.040 (0.019)	−1048 (398)	0.040 (0.019)	−999 (412)	−1132 (429)
Property—detached one story double front	1699 (318)	0.057 (0.015)	1696 (319)	0.056 (0.015)	1747 (330)	
Property—detached two stories	3866 (773)	0.168 (0.038)	3884 (775)	0.170 (0.037)	3491 (803)	
Property—semidetached one story	−6573 (761)	−0.287 (0.038)	−6597 (762)	−0.290 (0.038)	−6412 (792)	
Property—semidetached two stories	NS	0.040 (0.020)	NS	0.046 (0.020)	NS	
Single garage	1019 (260)	0.045 (0.013)	1010 (260)	0.045 (0.012)	1111 (269)	1316 (270)
Carport	−1083 (424)	−0.064 (0.020)	−1086 (425)	NS	−1171 (442)	−1366 (433)
Roof, galvanized iron	−630 (298)	−0.042 (0.015)	−626 (298)	NS	NS	NS
Roof, slate	921 (310)	0.052 (0.015)	912 (310)	NS	NS	NS
Social status						867 (277)

[a] A blank means that the variable was excluded from the run. NS means that it was included but was not significant at the 95% level. The figures in brackets are the standard errors.

Rockdale, where there is greater dispersion of house prices than in Marrickville, regressions were also run separately for low and high price houses to investigate whether household incomes affect implicit amenity prices.

When most of the independent variables were included in the Marrickville regressions, Eqs. (5) to (9), the R^2 varied from 0.66 to 0.68. This compares reasonably with the amount of explanation obtained in the studies reported by Ball [1] especially given the relatively large number of observations in our study and the exclusion of internal house characteristics other than the number of rooms from our study. A slightly higher R^2 was normally obtained with ordinary house price rather than the log of house price as the dependent variable, but the residuals were more biased in the former case, being higher for the higher prices houses. On these grounds it could be argued that the latter dependent variable, the log of house price, provides a better basis for model specification.

TABLE IV

Rockdale: Summary of Regression Results[a]

	Equation				
	(11)	(12)	(13)	(14)	(15)
R^2	0.61	0.62	0.37	0.37	0.46
House price	Linear	Log	Linear	Log	Log
Houses in regression	All	All	$P > \$25,000$	$P > \$25,000$	$P < \$25,000$
Constant	13,254	9.6	19,591	9.9	9.8
Monthly inflation	330 (26)	0.013 (0.001)	166 (41)	0.005 (0.001)	0.009 (0.001)
Frontage (ft)	72 (12)	0.003 (0.0005)	34 (17)	0.002 (0.0006)	0.002 (0.006)
Depth (ft)	11 (4)	0.0003 (0.0001)	23 (6)	0.001 (0.0002)	
Not brick	−3,000 (297)	−0.134 (0.012)			−0.100 (0.012)
Age (years)	−129 (10)	−0.005 (0.0004)	−108 (12)	0.003 (0.0004)	−0.002 (0.0005)
No. rooms	252 (48)	0.008 (0.002)	163 (49)	0.005 (0.002)	
Above road	1,390 (606)	0.055 (0.025)	3,042 (1,122)	0.104 (0.037)	
View	440 (220)	0.017 (0.009)	887 (425)	0.035 (0.014)	
Road width	416 (222)	0.018 (0.009)			
External condition	392 (134)	0.015 (0.005)	427 (211)	0.104 (0.007)	0.013 (0.006)
Road blight	−3,241 (1,566)				
Area amenities	352 (145)	0.016 (0.006)	396 (222)	0.014 (0.007)	0.016 (0.006)
Close to railway					−0.121 (0.011)
Close to sea	502 (263)				
Social status	936 (379)	0.043 (0.015)			
Improvements	812 (292)	0.033 (0.012)			
$e^{(\mathrm{NEF})/10}$			−916 (575)		
NEF-25				−0.0022 (0.0016)	
Roof, galvanized iron	−1,728 (400)	−0.092 (0.017)			−0.084 (0.015)
Roof, slate					−0.083 (0.027)
Roof other (not tile)	3,522 (755)	0.152 (0.031)			
Single garage	1,504 (328)	0.073 (0.014)		0.036 (0.024)	0.049 (0.012)
Double garage	2,751 (619)	0.099 (0.026)	1,791 (676)	0.056 (0.022)	
Carport	−3,510 (713)	−0.145 (0.029)	−1,815 (902)	−0.060 (0.030)	−0.054 (0.017)
Property detached, one story, double front					0.037 (0.013)
Property detached, two storys	9,075 (1,446)	0.265 (0.059)	6,994 (1,376)	0.180 (0.046)	0.081 (0.021)
Property semidetached, one story	−11,663 (1,566)	−0.374 (0.064)	−14,694 (3,540)	−0.485 (0.118)	

[a] In these runs all variables were included throughout, and blanks indicate a lack of any significant result. The figures in brackets are the standard errors.

However, all the coefficients reported for each Marrickville equation are significant at the 95% level and possess the expected signs.

The R^2 for the equations including all properties in Rockdale was normally slightly lower than in Marrickville, being around 0.62, due probably to the larger sample in Rockdale as well as to the wider price and quality range. It may be noted that a marginally higher level of explanation was obtained with the log of house price rather than with ordinary house price as the dependent variable, Eq. (11) compared with Eq. (10). As can be seen from Table IV, nearly all coefficients were significant at the 95% level and all possessed the expected signs.

To round off this summary, the major determinants of house price differentials within municipalities, as shown in Table V, were house quality and size, land size, and inflation. Environmental factors and neighborhood effects explained a smaller proportion of house price differences. The significance of the individual variables in Eqs. (5) and (11) is shown in Table VI. Of course "significance" is relative to the context, which is the explanation of intramunicipality house price differentials. A low score for any factor, for example, accessibility, in Table V or VI does not mean that it is always unimportant with respect to house

TABLE V

Explanation of House Price Variations (%)

	Marrickville (%)	Rockdale (%)
House quality and size	43	45
Land size	10	7
Inflation	8	6
Environmental factors	6	3
Neighborhood effects[a]	1	1
Accessibility	Neg.	Neg.
Total	68	62

[a] Includes residential zoning, local amenities, and social status.

prices. Moreover as described in the following section, the estimated hedonic prices of amenities were far from negligible.

Hedonic Prices for Amenity Attributes

Aircraft noise. As shown in all the equations in Table III, aircraft noise was a significant determinant of house prices in Marrickville. The values of the coeffi-

TABLE VI

Variables in Order of Entry

Marrickville	R^2	Rockdale	R^2
No. rooms	0.28	Construction year	0.24
Frontage	0.37	Construction type	0.35
Month of contract (inflation)	0.45	Frontage	0.41
Construction type	0.49	Month of contract (inflation)	0.47
Property—semidetached terrace 1 story	0.53	Single garage	0.50
Property—detached single story double front	0.56	No. rooms	0.51
Road blight	0.58	Property semidetached 1 story	0.52
$e^{(\mathrm{NEF}-25)/10}$	0.60	Property detached 2 stories	0.55
External condition	0.61	Roof, galvanized iron	0.56
Property—detached 2 stories	0.62	Roof, other	0.57
Single and garage	0.63	Improvements	0.57
Construction year	0.64	External condition	0.58
Depth	0.65	Block level	0.58
Improvements	0.65	Depth	0.59
Road width	0.66	Area amenities	0.59
Road traffic	0.66	Double garage	0.59
Carport	0 67	Carport	0.60
Corner and rear access	0.67	Social status	0.60
Corner access only	0.67	Road width	0.61
Residential zone C_2	0.68	Road blight	0.61
Area amenities	0.68	View	0.61
Roof, slate	0.68	Closeness to sea	0.61
Roof, galvanized iron	0.68		

cients for different forms of the aircraft noise variable can be summarized as follows.

Form of variable	Coefficient	Order of entry in stepwise regressions	Approx. price difference between quiet and very noisy houses
$x = e^{\text{NEF-25}/10}$	-382	1	\$1340
$x =$ NEF-25	-74	2	\$1100
$x =$ NEF-30	-125	3	\$1250

These Marrickville results suggest that the relationship between house prices and the NEF measure of aircraft noise is better represented by a nonlinear than by a linear function. The variable $e^{\text{NEF-25}/10}$ always entered the stepwise regressions before other forms of the noise variable and the coefficient for the NEF -30 variable was higher than for the NEF -25 variable. It is also possible, I believe, to infer from the results that there is some minor house price depreciation due to aircraft noise outside the NEF. Within the 25 NEF, the price of aircraft noise was estimated at 0.4% of house price per NEF, which implies a total price difference of some 6.0% between a quiet and a noisy house.[7] This was rather less than the difference found in the studies reported by Walters [2], most of which suggested that house prices fell by 1.0% or more per NEF over 25. One reason for this difference may be the larger number of variables included in our study. For instance, when traffic noise and exterior condition are dropped, as in Eq. (9), the NEF coefficient rises by 60%. It may be argued, however, that if aircraft noise causes a reduction in home maintenance and hence in property values, this fall in value may reasonably be ascribed to aircraft noise. A second possible reason for our relatively low depreciation due to aircraft noise is that Marrickville residents, who have chosen an inner city lifestyle and who have low incomes, have a relatively low preference for peace and quiet.

Some support for the hypothesis that the relationship between house prices and NEF is nonlinear was also found in analyzing the higher priced houses in Rockdale (see Eq. (13)), where the variable $e^{\text{NEF-30}/10}$ was significant at about the 90% level. The equation implied that noisy higher priced houses experienced about \$3250 or 10% price depreciation compared with high priced quiet houses.

No significant relationship could be established, however, between NEF and house prices for the sample of all houses, or for lower priced houses, in Rockdale. This negative finding may have occurred because the houses experiencing severe aircraft noise have some countervailing attribute, such as access to work, which was inadequately represented in our model of house prices. But it is more likely to have arisen, I believe, because the NEF model is not always a good measure of annoyance at aircraft noise, especially at low numbers of aircraft movements when the peak aircraft noise assumes disproportionate importance in the NEF formula. The NEF model was calibrated at busy airports in the United States [5] but there were only six aircraft flight movements per hour over Rockdale in

[7] The percentages quoted here and below are derived where possible from equations with the log of house price as the dependent variable. They are not necessarily the same as would be obtained by dividing the average house price in the municipality by the value of the coefficient, in say, Eqs. (5) and (11).

1972–1773, so that aircraft noise was probably less serious in Rockdale than would be inferred from the NEF model. However, it would be absurd to suggest that there is no aircraft noise problem in Rockdale. A survey [6] of households in Rockdale and Marrickville found that 80% of households underestimated aircraft noise before they moved into the area and 20% positively regretted buying their house because of the noise, which is strong evidence that the adverse effects of aircraft noise are not always fully reflected in house prices.[8]

Road traffic and road widening. The price difference between a house on a quiet road compared with one on a noisy road in Marrickville was estimated at $1400 or 5.6% of house price. In addition to this, houses on corners sold for $1000 or about 4% less than other houses, some of which depreciation would doubtless be attributable to traffic noise. However, no statistical relationship between road traffic and house prices was established in Rockdale.

The price of a house on a road scheduled for widening in Marrickville was estimated to fall by $1923 or by 9.3% of the average house price. The comparable figures for Rockdale were $3241 and 13.5% of house price, respectively.

Views, block levels, spacious roads, and other environmental amenities. The values of a good view, of a house built above road level, and of a house on a spacious road are most evident in Eqs. (11) and (12) for all houses in Rockdale. A good view in Rockdale was valued at about $440 compared with an average view, which was in turn worth $440 more than a poor view. In addition a house built above road level was estimated to be worth $1450 or 5.5% more than a house at road level or below it, and a house on a wide road was estimated to be worth $832 or 3.6% more than a house on a narrow road. And in addition to all this, a house in a good neighborhood ("social status") was estimated to be worth about $1900 or 8.6% more than a house in a poor neighborhood, and a house close to the sea was worth a further $550. A house which combined all these environmental qualities would sell at an estimated premium of some $5500 more than a house with none of these qualities, which would constitute nearly 25% of the value of the average house in Rockdale in 1972–1973.

There is also clear evidence from the Rockdale Eqs. (11) to (15) that the demand for a good view and for a house built above the road level is income elastic. A good view compared with a poor one was estimated to be worth 7.0% of the price for high priced houses compared with 3.5% of the price for all houses, and was not significant for lower priced houses. A house built above the road was estimated to be worth about 10.0% of the price for high priced houses compared with 5.5% of the price for all houses, and was also not significant for lower priced houses.

Unlike Rockdale houses, most houses in Marrickville are built on flat terrain and have a rather uniform inner-city view, so that not very surprisingly, no statistical relationship between block level or views and house prices was established. However, houses on wide spacious roads in Marrickville were estimated to be worth about $900 or 6% more than houses on narrow roads. Indeed this differential is percentage wise significantly larger than that estimated for Rockdale, which may be seen as a slight compensating factor for the lack of views.

[8] This point is of course not particular to Rockdale. Note, moreover, that it would also be possible for public alarm over aircraft noise to cause excessive depreciation of noisy house prices.

The quality of a good neighborhood compared with a poor one was estimated to be worth $1700 or about 9.0% of house price in Marrickville, which was similar to the valuation for a good neighborhood in Rockdale.

Other related amenities. Unlike the attributes discussed above, garages are not amenities in the sense that amenities are normally external to the property, but as roads have figured prominently in our discussion, the value of garages is perhaps of interest. Single garages in Marrickville were valued at approximately $1000 or 4.5% of house price. In addition, rear access to a house was worth an estimated $1000, some of which value was probably attributable to its utility as a parking space or as leading to parking facilities in the back garden. Single garages in Rockdale were valued at $1500 and double garages at $2250. As a percentage of house price this would be 7.3% and 10.0%, respectively. However, carports at the front of houses actually reduced house values by nearly $1000 in Marrickville and by an estimated $3500 in Rockdale.

Good access to shops and commercial entertainments was estimated to be worth $600 per house in Marrickville or about 3% of house price, and about $1000 in Rockdale, or about 5% of house price. It may be noted further that good access to shops was also worth about 5% of the value of both high and low priced houses in Rockdale, when they were examined separately (Eqs. (14) and (15)).

Finally it may be noted that being close to the railway reduced the price of low priced houses in Rockdale by an estimated 12% (Eq. (15)). Proximity to rail was meant to reflect the advantage of access to public transport, but apparently this was outweighed by the disamenity, chiefly noise, of living close to the railway.

4. HEDONIC AMENITY PRICES AND WILLINGNESS TO PAY VALUES

One of the main motivations for the attempt to establish hedonic amenity prices has been the desire to use them as willingness-to-pay values in benefit cost analyses. Such was the motivation of the Roskill Commission, for instance, when it attempted to establish property price depreciation due to aircraft noise around Heathrow and Gatwick [7]. The validity of the assumption that hedonic prices represent willingness to pay values, or alternatively the circumstances in which this assumption can be considered to hold, have now been widely discussed in the literature, and I discuss these issues below mainly to put the empirical work described in this paper into a policy perspective rather than to raise fresh theoretical issues, especially as by and large I follow the approach taken by Freeman [8] and Rosen [3]. Of course, benefit cost analysis is not the only use to which hedonic equations and prices may be put; they may be useful also for purposes of valuation or for predicting the effect of amenity changes on property prices, both of which may be important issues in their own right but which are not discussed below.[9]

[9] See the Polinsky and Shavell paper [9] for a discussion of the effect of changes in amenities on property prices.

In order to determine whether estimated implicit amenity prices reflect willingness to pay values, it is convenient to ask two main questions. First, do the estimated prices reflect equilibrium prices, determined by willing buyers and sellers? And second, to what extent do equilibrium prices reflect general willingness to pay values? Four reasons are advanced below, some of which have already been noted above, for considering that estimated implicit prices may not be in equilibrium. But in each case reasonable allowance can probably be made.

(i) In the house price model, household attitudes toward certain amenities and disamenities are represented by scales, for example, the NEF scale. Estimated implicit prices derived from this model reflect buyer preference only if the scales accurately represent household attitudes. Since the scales are sometimes quite simple, they can do only rough justice to the complexity of individual preferences, but nevertheless, the orders of magnitude obtained with the use of such scales are probably reasonable rerpresentations of preferences.

(ii) Markets may be imperfect because of buyer ignorance. In this case survey information may indicate the approximate amount by which house price depreciation due to the disamenity is an understatement of the household's true preferences.

(iii) Additional costs arise in disequilibrium situations after major land use changes. Some households will be living where they do not wish to and will incur losses of householder surplus and possibly movement costs. Neither of these is reflected in implicit (or explicit) prices but both are part of the costs of negative amenity changes.

(iv) Hedonic prices do not capture the indirect or dynamic secondary effects of amenities or disamenities. Heavy road traffic may, for instance, reduce property values both directly and indirectly as neighborhood values fall and house maintenance expenditures are reduced. To determine these effects, it would be necessary to examine the interrelationships between the "independent" variables in the house price model.

Let us assume now that hedonic prices are equilibrium prices paid by informed, willing buyers, and consider to what extent they can be taken as general willingness-to-pay prices.[10] Our starting point is Rosen's comment that "here [hedonic prices] as elsewhere, price differences generally are equalizing only on the margin and not on the average. Hence estimated hedonic price-characteristics functions typically identify neither demand nor supply" [3]. Freeman argues similarly that "the observed relationship between property values and air quality is not a demand curve for clean air, but rather represents an opportunity locus or a sort of supply curve for households" [8]. But both writers argue that hedonic prices provide a basis for estimating the demand for amenities.

Figure 3A, taken from Freeman, depicts the annual rent $V(Q)$ as a function of air quality (Q). Figure 3B, also from Freeman, shows the change in property values with the change in air quality as a function of air quality $R(Q)$ and the demand for air quality $D_i(Q)$ and $D_j(Q)$. The $R(Q)$ function is the marginal purchase price of air quality and "can be interpreted as the locus of the equilibrium marginal willingness to pay amounts of all households" [8]. If all house-

[10] The amenities or disamenities of an area will generally have a price to nonresidents as well as to residents of an area, but it is only the latter price which is considered in this paper.

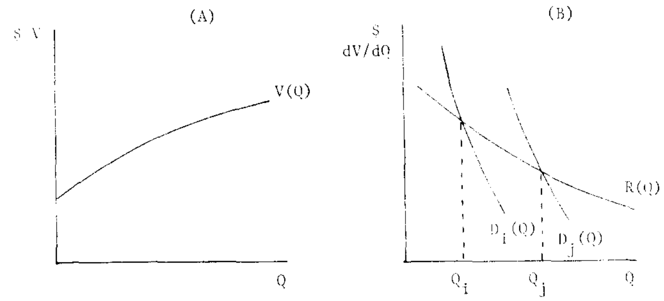


FIG. 3. The rent function and household demand curves for air quality.

holds have the same preferences, the slope of the demand curve will be the same as the marginal price curve. More likely, however, preferences will differ, as shown in Fig. 3B. Given this situation, how can the real demand for amenities be estimated?

Rosen and Freeman have described similar two-stage procedures for estimating demand curves for amenities. Following here the Freeman version, the first step is to estimate amenity prices as in this paper. Second,

> it is hypothesized that the air quality chosen by the ith household in the jth city depends upon the marginal purchase price of Q in that city, $R(Q)$, and household socioeconomic characteristics such as income, age, etc.
>
> Specifically, for the ith individual living in the jth city,
>
> $$Q_i = f[R^j(Q_i), Y_i, \text{age}_i \ldots].$$
>
> This equation can be estimated from the pooled data for all cities. The inclusion of the marginal purchase price function amounts to an experimental shifting of the supply curve or opportunity locus, to obtain price variation, while controlling for income, age, etc. The coefficient on the variable, $R^j(Q_i)$, is either the slope or the elasticity of the demand curve for clean air, depending on whether the equation was estimated in the log or linear form. If the changes in Q are small enough so that the marginal utility of income can be assumed to be approximately constant, then the estimated demand function can be used to calculate the benefits of air quality improvement [8].

Freeman goes on to show that given such a demand function, for a marginal change in amenity level affecting all households, the sum of the individual households' marginal willingness to pay is a precise measure of the aggregate marginal benefit. However, for nonmarginal amenity improvements (or deterioration) multiplying the marginal willingness to pay times the change in amenity summed over all households will result in an upper bound (or a lower bound) of the true benefits (or costs).

To summarize, hedonic prices may not represent willingness to pay amenity values because markets are imperfect or in disequilibrium or because preferences vary and average values do not equal marginal values. One result of this is that hedonic prices may vary between areas. Most of these difficulties can be resolved and relevant willingness to pay prices estimated with plausible assumptions about market imperfections and disequilibrium effects, and with survey data about consumer preferences. Alternatively, if the hedonic prices represent equilibrium situations, willingness to pay prices may be calculated with the aid of a Freeman-type two-step econometric model to estimate the demand curve for amenities, the first step of which is obtaining amenity prices along the lines shown in this paper.

5. SUMMARY

The paper describes a study of house price transactions for over 1400 properties in two municipalities in Sydney, analyzed in terms of some 30 independent variables. Plausible hedonic amenity prices were estimated for aircraft noise, road traffic, road widening, railway noise, the quality of view, block level, the spaciousness of the roads, proximity to the sea, access to shops, and the quality of the neighborhood. Moreover, these hedonic prices were generally statistically significant at the 95% level, though the two municipalities are amongst the poorest in Sydney and therefore contain many households that might be expected to place a relatively low valuation on amenities.[11]

Hedonic amenity prices represent average willingness to pay values only if markets are assumed to be perfect and in equilibrium and if all household preferences are similar. However, the paper argues that the demand price for amenities can be derived from hedonic prices either with plausible assumptions and survey data on market behavior and attitudes or with a fuller two-stage econometric study. Such a study typically would first obtain hedonic amenity prices, and second would estimate the amounts of amenities purchased as a function of their prices as well as the socioeconomic attributes of the purchasing household.

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[11] No significant disequilibrium existed for Marrickville or Rockdale municipalities in 1972, although Marrickville households may not have adjusted fully to the extension of the N–S runway which was completed in 1968.