Estimating the value of undergrounding electricity and telecommunications networks

Ben McNair[a,*] and Peter Abelson[b]

[a] (Corresponding author) Crawford School of Economics and Government, The Australian National University, Canberra ACT 0200, Australia. Phone: +61 400 342 613. Email address: ben.mcnair@anu.edu.au

[b] Faculty of Economics and Business, University of Sydney, NSW 2006, Australia.

* The authors thank Jeff Bennett, Ross Williams and two anonymous referees for helpful comments, and ActewAGL Distribution for allowing use of its network maps. Funding for this research is from ARC Industry Linkage Grant LP0669754.

Abstract

Underground low-voltage electricity and telecommunications networks have a number of advantages over overhead networks including reliability of supply, safety and improved visual amenity. This paper investigates the value of these benefits to households by estimating the relationship between house prices and type of network service in three suburbs in Canberra. This is possible because each suburb has broadly similar houses but a mix of overhead and underground infrastructure. Thus we avoid the problems that arise in estimating network effects across suburbs in a city-wide sample where other attributes of housing may confound the results. Holding other house and neighbourhood characteristics constant, we find that underground networks increase house prices by 2.9 per cent. Although Canberra has some unusual features, this approach can provide valuable information to policy-makers considering undergrounding programs in residential areas.

Short description

Data from three suburbs in Canberra are used to demonstrate a method for estimating the relationship between house prices and type of electricity and telecommunications network service (overhead or underground).

Keywords: House prices; electricity networks; hedonic analysis.

JEL code: L94, Q51

1. Introduction

A number of cities around the world have implemented or are considering programs to replace overhead low-voltage electricity and telecommunications networks with new underground infrastructure.[1] Undergrounding these networks provides benefits to both utility businesses and households. Underground networks generally provide a more secure and reliable service. They greatly reduce the risks of damage from fires, strong winds and other severe weather events, which can cause extended power outages and risks of electrocution. They lead to more aesthetically pleasing residential areas and savings from lower network energy losses, avoided pole maintenance costs and avoided costs of trimming trees away from power lines.

However, undergrounding networks in established residential areas usually costs between $10,000 and $20,000 per property. The savings to utility businesses in terms of lower energy purchases and network maintenance costs are usually only a small percentage of these costs. The expense of undergrounding must be justified primarily by the benefits to households. The estimated value of benefits to households is therefore a key component in the economic evaluation of undergrounding programs.

But herein lies a major problem. There appear to be no complete estimates of the value of undergrounding electricity supply to households and most economic evaluations to date have categorised this value as unquantifiable (DCITA 1998, InfraSource Technology 2007, IPART 2002). Some stated preference (SP) studies have valued supply reliability improvements using contingent valuation (Carlsson and Martinsson 2007, Layton and Moeltner 2005) and choice experiments (Accent 2008, Beenstock et al. 1998, Carlsson and Martinsson 2008). But, as far as we are aware, very few SP studies have attempted to value the overall household benefit from undergrounding, including amenity and safety benefits (McNair et al. 2010).

Turning to revealed preference studies, many hedonic property price studies have estimated the impacts on house prices of various other urban disamenities and pollutants, such as noise (Nelson 1982) and poor air quality (Brookshire et al. 1982). However, apparently none have estimated the impact of overhead distribution wires. A possible reason is that cities are typically divided into newer areas with underground wires and older areas with overhead wires. This makes it difficult to separate out the effects of underground wires from other effects, such as building age, access to the central business district and other neighbourhood characteristics.[2]

This paper has two main objectives. The first is to show how the value of underground wires in cities can be derived using the hedonic property price approach. By limiting the sample to areas with a mix of underground and overhead infrastructure where the neighbourhood and housing stock are otherwise relatively homogeneous, we can control for unobserved neighbourhood characteristics that could be correlated with type of infrastructure in a city-wide sample. This approach is similar to the boundary discontinuity approach used by Black (1999), Davidoff and Leigh (2008), and Gibbons and Machin (2003) to value school quality in that it involves comparison of the prices of houses that are broadly similar to each other, but on opposite sides of boundaries between adjacent areas serviced by underground and overhead wires. This approach can be employed when investigating the costs and benefits of a *potential* undergrounding program, whereas other possible approaches, such as the difference-in-difference (natural experiment) approach, can be employed only after some retro-fit undergrounding has taken place.

Secondly, we provide an estimate of the implicit price of underground wires in a specific study. This is a contribution towards addressing the research gap identified above, although we also note some differentiating features of the Canberra housing market.

The paper is set out as follows. Section 2 relates the theory of hedonic prices to the case study and sets out the estimation approach. Section 3 describes the data. The results of the study are presented in Section 4 and Section 5 concludes.

2. Method

Lancaster (1966), Rosen (1974) and others have argued that many goods and services can be characterised as a bundle of attributes. Differing levels of those attributes lead to the availability of many different ‘versions’ of a good. The hedonic pricing technique uses observed market prices for a good and observed attribute levels to estimate implicit prices for the attributes. Houses are an example of such a good and many studies have used the hedonic pricing technique to estimate implicit prices for different house attributes including energy efficiency (Dinan and Miranowski 1989), noise (Nelson 1982), air quality (Brookshire et al. 1982), quality of schools (Black 1999) and urban wetlands (Mahan et al. 2000). This study estimates the implicit price for underground low-voltage electricity distribution and telecommunications wires.

The theoretical framework for the estimation is as follows. The market price for a house is $p = p(UG, Z)$, where UG indicates whether the house is serviced by underground wires and $Z = z_1, z_2, \ldots, z_n$ is a vector of the amounts of n other attributes (for example number of bedrooms, block size, distance to central business district). Households spend their income, y, on housing and a composite good, x, whose price is normalised to unity. Households maximise their utility, $U = U(x, UG, Z)$ by choosing x, UG, and Z subject to their budget constraint $y = x + p(UG, Z)$. The first order conditions of this constrained optimisation are $\partial p/\partial UG = U_{UG}/U_x$ and $\partial p/\partial z_i = U_{Zi}/U_x$ for $i = 1, \ldots, n$. For attributes with continuous levels, these conditions mean that households purchase the quantity of each attribute up to the point at which their marginal willingness to pay (WTP) for an additional unit of the attribute is just equal to the marginal implicit price of a unit of the attribute.

However, the attribute of interest in this study, *UG*, is a discrete attribute taking one of two values. Consequently, a household's WTP for underground lines (which is the appropriate measure of economic benefits) is not necessarily equal to the implicit price for underground lines. Figure 1 illustrates the optimal discrete choice in the *x*-*UG* plane cut at *Z**. In order to purchase a house serviced by underground lines, a household must forgo $P_{UG}(Z^*)$ units of *x*. This is the implicit price of underground lines. Two households are shown, both with income *Y**. One has a utility function U_A and the other U_B. The indifference curves for the optimal utility levels of each household, U_A^* and U_B^*, are shown in the diagram.[3] The household with utility function U_B chooses a house serviced by underground lines but the other household does not.

[Figure 1 near here]

The implicit price, $P_{UG}(Z^*)$, reveals limited information about the underlying demand function.[4] A household's WTP for underground wires is less than the implicit price if the household purchases a house serviced by overhead lines. It is equal to or more than the implicit price if the household purchases a house serviced by underground lines. Assuming a continuous distribution of WTP across households, the implicit price represents the WTP of the marginal purchaser of the underground lines attribute. To demonstrate this, consider the value function $\theta(UG, Z; y, u)$ where $u = U(y - \theta, UG, Z)$ (Rosen 1974). The WTP for underground wires, holding all other house attributes constant at *Z**, is $\theta_{UG}(Z^*; u^*, y)$ where *u** is the optimum quantity given *Z**. A demand function for underground wires in the market for houses of type *Z** can be constructed by arranging these WTP amounts in descending order across all households. Figure 2 demonstrates that the implicit price of underground wires depends not only on the WTP of households but also on the supply of houses serviced by underground wires, *S*, for each given type of house as characterised by *Z*.[5]

[Figure 2 near here]

The boundary discontinuity approach, which is a special case of the regression discontinuity approach (Hahn et al. 2001), can be applied where housing attributes change continuously over space, but the attribute of interest changes discretely at a boundary. In our study, we selected houses close to changes in the type of network service (from overhead to underground or vice versa) but where the neighbourhood and housing stock are relatively homogeneous across the boundary. This allows comparison of prices for houses with similar access to shopping centres, recreational areas and transport facilities, but different types of network service. As well as controlling for unobserved neighbourhood characteristics, this intra-suburb approach minimises correlations that might occur between underground infrastructure and some house characteristics in a city-wide study. However, because a number of variables are likely to affect house prices, we employ multivariate analysis to analyse the impact of undergrounding electricity.

The main equation to be estimated (Model 1) is:

$$\ln P_{ijt} = \alpha + \beta.UG_{ij} + \gamma.Z_{ijt} + \delta_j + \lambda.T_t + \varepsilon_{ijt} \qquad (1)$$

where:

- $\ln P_{ijt}$ is the log of real price of house *i* in area *j* at time *t*;

- UG_{ij} is a dummy variable for indicating that house *i* is serviced by underground wires;
- Z_{ijt} is a vector of other house attributes;
- T_t is a vector of time trend variables and;
- δ_j are area fixed effects.

β is the parameter that is used to establish the implicit price of underground wires. This is the focus of our study. Other house attributes are included where they are thought likely to be significant or where they may be correlated with type of infrastructure in our sample areas. The semi-log model specification is commonly used in hedonic house price regressions. It fits with the *a priori* expectation implied by microeconomic theory that model prices are homogeneous of degree one in the general consumer price level, which is not true of a linear model. It also allows the use of variables that take the value zero, which a log-log specification does not (Diewert 2001). In the semi-logarithmic model specification, the coefficients on the explanatory variables are interpreted as the percentage change in real house price associated with a unit change in the relevant explanatory variable holding all other variables constant. However, we also test for other specifications, for example for a log-log relationship between house prices and distance from the CBD.

3. Data

This study uses detached house sales data for Canberra between January 2004 and September 2008. Low-voltage distribution lines have been placed underground in new housing developments in Canberra since around 1990. Before then, network operators generally installed overhead wires on poles, usually reticulated through backyards to preserve streetscapes. However, a few areas in some suburbs were developed in the

1980s where underground installation was starting to become a standard condition in land development deeds. These suburbs contain a mix of sections serviced by overhead and underground wires.[6] Following site visits and advice from valuers with extensive experience in the city, we selected three of these suburbs (Calwell, Florey and Macarthur) for analysis due to the relative homogeneity of neighbourhoods and housing stock across sections with overhead and underground wires. Appendix A shows the areas serviced by underground wires in each suburb.

The sample selection is central to our estimation approach. To see this, consider an expansion of the sample. Almost all of the introduced data would fall into one of two categories: sales of older houses in inner suburbs serviced by overhead wires; and, sales of newer houses in outer suburbs serviced by underground wires. Disentangling the price effect of underground wires from those of building age and distance to central business district (CBD) may not be possible due to near-perfect correlations. However, the risk when using a selective sample is that the data are not representative of the broader population. Table 1 presents a comparison of the characteristics of individuals and households in the three sample suburbs and Canberra as a whole. Importantly, the sample suburbs are representative of Canberra in terms of unemployment and the distributions of household income and house size (measured as the number of bedrooms).

[Table 1 near here]

The variables employed in the analysis and their sources are shown in Table 2. The variables were chosen based on a review of the literature (for example, Ball 1973, Kain and Quigley 1970) and discussions with experienced valuers. The housing attributes found to be most significant in recent house price studies in Canberra by Davidoff and Leigh (2008) and DEWHA (2008) were included. Quality of view was included because of its significance in several studies (for example Benson et al. (1998)).[7] Land characteristic data collected were: the size of the block, the distance to the central business district (CBD), a 3-point scale rating of the quality of views[8], and dummy variables for high road traffic and for servicing by underground wires.[9] Structure characteristics collected were: the number of bedrooms, the number of bathrooms and ensuites, and the number of car parking spaces in garages and carports. The quality of landscaping and the external condition of the house were rated jointly on a 3-point scale.[10] Data were not collected for building age or other neighbourhood characteristics because, within each of the three suburbs, houses are of similar vintage and neighbourhoods are relatively homogeneous (for example, they have similar access to town centres and transport infrastructure).[11] These effects are captured using indicator variables for suburb.

[Table 2 near here]

Most of the data were obtained from allhomes.com.au, a website containing a database of all property sales in the ACT. Other data were collected during field work between November 2008 and January 2009. Any measurement error resulting from the time between the house sale and the field work is expected to be uncorrelated with type of network infrastructure. Data on the number of bedrooms, bathrooms and car accommodation were available from allhomes.com.au for 436 of the 863 sales of detached houses in the period of interest. Deleting eight “battle-axe” blocks that could not be inspected in the field and one price outlier, the final sample was 427 observations. Of these, 132 were serviced by underground wires, as described in Table 3.

[Table 3 near here]

Summary statistics for the data used in the main regression are set out in Table 4. The log of distance from CBD (*DIST_LN*) and the square of block size (*SIZESQ*) were found to be the best-fitting transformations of the *CBDDIST* and *SIZE* variables respectively. Both *TIME* and *TIMESQ* (equal to *TIME* squared) were included in the final regression to account for a non-linear movement in average real prices over the period. Interactions between the indicator variable for underground wires and other house characteristics such as quality of views and road traffic were found to be statistically insignificant and omitted from the final model.

[Table 4 near here]

A regression explaining the indicator variable for underground wires (*UG*) in terms of the other explanatory variables from the main regression showed that *UG* is unrelated at the 0.05 significance level to house sale date, the number of bedrooms and the presence of high quality views, garages and ensuites. However, underground wires are negatively related to external condition, block size and the presence of high road traffic and 'some view'. An F-test showed the explanatory variables to be jointly significant at the 0.05 level indicating that housing characteristics differ between areas serviced by overhead and underground wires in the sample. This result means that the data cannot be treated as a randomised controlled trial. A simple comparison of average house sale prices across the two groups will not suffice. Rather, a hedonic regression is required to control for the differences between the groups. Importantly, the correlations between *UG* and the other explanatory variable are low. The highest correlation is 0.27 and all but two are correlated at less than 0.2, suggesting that it will be possible to disentangle the effect of underground wires on house price from the effects of the other variables.

4. Results

The main results of the study are presented in Table 5. The R-squared value of 0.83 indicates a model fit similar to recent house price studies in Canberra by Davidoff and Leigh (2008) and DEWHA (2008). All coefficient estimates, including the coefficient on the undergrounding indicator variable, are significant at the 0.05 level and with the expected sign. In fact, all but three of the coefficient estimates are highly significant with p-values less than 0.005.

The variable of interest, *UG*, has a coefficient of 0.029, indicating that the presence of underground wires increases house prices by 2.9 per cent holding all other explanatory variables constant. The 95 per cent confidence interval around this estimated implicit price is 0.3 per cent to 5.5 per cent.

[Table 5 near here]

Five additional models are estimated to test the sensitivity of this result to various aspects of the estimation. Model 2 includes an untransformed dependent sale price variable to test the sensitivity of results to specification of functional form. In Model 3, the sample is reduced by removing observations located in three ABS collection districts (one in each of the three suburbs) that do not contain a mix of underground and overhead infrastructure. Thus, Model 3 tests the impact of excluding observations that are furthest from underground-overhead boundaries. In Model 4, the natural logarithm of block size is included rather than the *SIZESQ* variable used in Model 1. Testing sensitivity to specification of the block size variable is important because it is correlated (albeit weakly) with underground wires. In Model 5, the continuous time variables are replaced with quarterly dummy variables, and, in Model 6, the suburb dummy variables are replaced with ABS collection district dummy variables. The results of the models are presented in Table 6.

[Table 6 near here]

The estimated implicit price of undergrounding of 2.9 per cent of house value is robust to all but one of the model variations presented in Table 6. In Model 2, the estimated implicit price of undergrounding is around $20,000. At approximately 5 per cent of the median real house price in the sample, this is a higher point estimate than that from Model 1. The other models estimate the implicit price at between 2.6 per cent and 4.0 per cent of house value. Model 2 has a lower R-squared value than the other models suggesting that the semi-log specification explains the data better than the linear specification. The underground infrastructure variable is significant at the 0.05 level in all models except Models 3 and 6, in which its p-value is 0.06.

We turn now to the relationship between the implicit price and WTP. According to the theory presented in Section 2, the implicit price of underground wires, $P_{UG}(Z) \approx 0.029 \times P(Z)$, is the WTP of the *marginal purchaser* of the underground wires attribute in the market. Given that 31 per cent of houses in the sample are serviced by underground wires, it may be inferred that 31 per cent of households are willing to pay at least 2.9 per cent of house price for this attribute. Figure 3 shows the relationship between the implicit price and WTP, θ_{UG}, of households that purchased houses with average attribute levels from the sample, Z^*. The mean real house price in the sample is $426,000, so the implicit price of undergrounding for this house type is approximately $12,350. If the sample is representative of the population, then 31 per cent of households would be willing to pay $12,350 or more for underground wires. On the other hand, if the supply of underground wires increases, the marginal valuation of $12,350 is likely to fall.

[Figure 3 near here]

5. Conclusions

This paper offers two contributions. First, it demonstrates how estimates of the value of undergrounding electricity and telecommunications distribution wires can be derived using the hedonic property price approach in cities where overhead to underground network conversion has yet to take place. The method, which utilises house price data from areas with a mix of overhead and underground infrastructure where neighbourhoods and housing stock are relatively homogeneous, was successful in isolating the impact of overhead distribution wires on property prices in Canberra.

Second, the paper provides an estimate of the implicit price of underground electricity and telecommunications distribution wires. Undergrounding was found to increase house price by 2.9 per cent holding other property characteristics constant. At the median real house price in the sample, this equates to approximately $11,700 per property. This result is robust to several model specifications. The value lies within the range of 0 to 5 per cent of house prices predicted by the State Valuers-General of Australia (see DCITA 1998). It is much lower than the estimated property price impacts of proximity to high-voltage overhead transmission lines reported in the literature, which range from 5 to 17 per cent of property price (Colwell 1990, Des Rosiers 2002, Hamilton and Schwann 1995, Ignelzi and Priestley 1991, Sims and Dent 2005). Turning to households' willingness to pay for underground wires, we observe that 31 per cent of households in our sample chose to pay the price premium for a house serviced by underground wires. This is remarkably consistent with evidence from the recent stated preference study by McNair et al. (2010), which found that 32 per cent of Canberra home-owners currently serviced by overhead wires are willing to pay $11,700 or more for undergrounding in their suburb.

The key question from an economic evaluation perspective is whether households' willingness to pay for undergrounding exceeds the difference between the capital cost of undergrounding and the present value of ongoing cost savings for network operators. This seems most plausible if capital costs are similar to those experienced in Perth of approximately $10,000 per property. However, if capital costs exceed $20,000 per property as they have in South Australia (ETSA Utilities 2009), then the economic viability of widespread undergrounding would depend on wider community benefits and avoided costs from related projects such as the roll-out of the National Broadband Network.

We acknowledge that the usefulness of this estimate for benefit transfer to other cities may be limited. In Canberra, most overhead electricity and telecommunications networks are reticulated along the rear boundary of properties rather than the much more common street verge reticulation. The estimated implicit price is also influenced by the middle-income socio-demographic composition of the selected suburbs and the relative scarcity of houses serviced by underground wires in older suburbs in Canberra. Values in other cities may differ with different social features and different supply conditions. Despite these limitations, the estimate derived from this study may provide useful information to policy-makers considering the economic merits of an undergrounding program where little or no information was previously available.

Appendix 1: Maps

[Figure A1 near here]

[Figure A2 near here]

[Figure A3 near here]

References

Accent 2008, *Expectations of DNOs and WTP for improvements in service,* A report for OFGEM, July.

Ball M. 1973, 'Recent Empirical Work on the Determinants of Relative House Prices', *Urban Studies*, vol. 10, pp. 213-233.

Beenstock M., Goldin E. and Haitovsky Y. 1998, 'Response bias in conjoint analysis of power outages', *Energy Economics*, vol. 20, pp. 135-156.

Benson E., Hansen J., Schwartz A. and Smersh G. 1998, 'Pricing Residential Amenities: The Value of a View', *Journal of Real Estate Finance and Economics*, vol. 16, pp. 55-73.

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

Brookshire D., Thayer M., Schulze W. and d'Arge R. 1982, 'Valuing Public Goods: A Comparison of Survey and Hedonic Approaches', *American Economic Review*, vol. 72, pp. 165-177.

Carlsson F. and Martinsson P. 2008, 'Does it matter when a power outage occurs? A choice experiment study on the WTP to avoid power outages', *Energy Economics*, vol. 30, pp. 1232-1245.

____ 2007, 'Willingness to Pay among Swedish Households to Avoid Power Outages: A Random Parameter Tobit Model Approach', *The Energy Journal*, vol. 28, pp. 75.

Colwell P. 1990, 'Power lines and land value', *The Journal of Real Estate Research*, vol. 5.

Davidoff I. and Leigh A. 2008, 'How Much do Public Schools Really Cost? Estimating the Relationship between House Prices and School Quality', *Economic Record*, vol. 84, pp. 193-206.

DCITA 1998, *Putting cables underground,* A report for the Minister for Communications, Information Technology and the Arts, November.

Des Rosiers F. 2002, 'Power lines, visual encumbrance and house values: A microspatial approach to impact measurement', *The Journal of Real Estate Research*, vol. 23, pp. 275.

DEWHA 2008, *Energy Efficiency Rating and House Price in the ACT,* A report for Minister for the Environment, Water, Heritage and the Arts.

Diewert E. 2001, 'Hedonic Regressions: A Consumer Theory Approach', Discussion Paper No. 01-12, Department of Economics and NBER, University of British Columbia.

Dinan T. and Miranowski J. 1989, 'Estimating the implicit price of energy efficiency improvements in the residential housing market: A hedonic approach', *Journal of Urban Economics*, vol. 25, pp. 52-67.

ETSA Utilities 2009, 'Undergrounding powerlines', In ETSA Utilities Fact Sheet.

Gibbons S. and Machin S. 2003, 'Valuing English Primary Schools', *Journal of Urban Economics*, vol. 53, pp. 197-219.

Gregory R. and von Winterfeldt D. 1996, 'The Effects of Electromagnetic Fields from Transmission Lines on Public Fears and Property Values', *Journal of Environmental Management*, vol. 48, pp. 201-214.

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

Hamilton S. and Schwann G. 1995, 'Do high voltage electric transmission lines affect property values?', *Land Economics*, vol. 71, pp. 436-444.

Ignelzi P. and Priestley T. 1991, *A statistical analysis of transmission line impacts in six neighbourhoods*, A report for Pacific Consulting Services, February.

InfraSource Technology 2007, *Undergrounding assessment phase 1 final report*, A report for Florida Electric Utilities, February.

IPART 2002, *Electricity Undergrounding in New South Wales*, A report for the Minister for Energy, May.

Kain J. and Quigley J. 1970, 'Measuring the Value of Housing Quality', *Journal of the American Statistical Association*, vol. 65.

Kinnard W. and Dickey S. 1995, 'A primer on proximity impact research: Residential property values near high-voltage transmission lines', *Real Estate Issues*, vol. 20, pp. 23-29.

Lancaster K. J. 1966, 'A New Approach to Consumer Theory', *The Journal of Political Economy*, vol. 74, pp. 132-157.

Layton D. and Moeltner K. 2005, 'The cost of power outages', in *Applications of Simulation Methods in Environmental and Resource Economics*, (eds) Scarpa R and Alberini A, Springer, Dordrecht.

Mahan B., Polasky S. and Adams R. 2000, 'Valuing urban wetlands: a property price approach', *Land Economics*, vol. 76, pp. 100-113.

McNair B., Bennett J. and Hensher D. A. 2010, 'Strategic response to a sequence of discrete choice questions', paper presented at 54th Annual Conference of the Australian Agricultural and Resource Economics Society, Adelaide, South Australia, 10-12 February 2010.

Nelson J. P. 1982, 'Highway Noise and Property Values: A Survey of Recent Evidence', *Journal of Transport Economics and Policy*, vol. 16, pp. 117-138.

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

Sims S. and Dent P. 2005, 'High-voltage overhead power lines and property values: A residential study in the UK', *Urban Studies*, vol. 42, pp. 665-694.

Witte A., Sumka H. and Erekson J. 1979, 'An Estimate of a Structural Hedonic Price Model of the Housing Market: An Application of Rosen's Theory of Implicit Markets', *Econometrica*, vol. 47.

Tables and figures

Figure 1 Household Consumption Decision

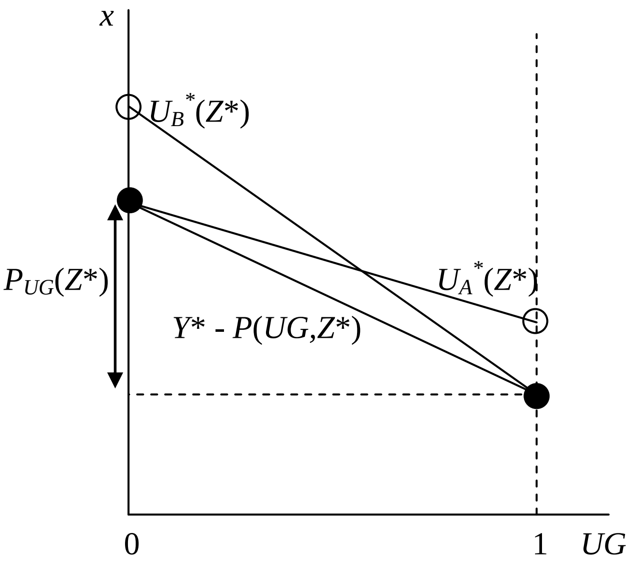

Figure 2 Implicit Price and WTP

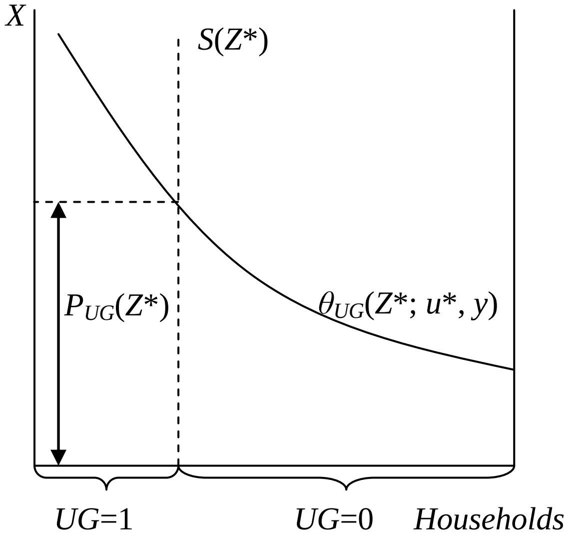

Table 1 Comparison of individual and household characteristics

	Sample suburbs (per cent)	Canberra (per cent)	χ^2 tests for differences (p-value)
Weekly household income:			
$0-$1,699	49.9	50.9	0.20
$2,500 or more	21.0	21.6	0.53
Unemployment rate	3.4	3.4	0.81
Age:			
0-14 years	22.6	19.1	0.00
65 years and older	5.3	9.7	0.00
Separate houses - household size:			
5 or more persons	16.4	14.0	0.00
Separate houses - building size:			
3 bedrooms	44.2	45.3	0.24
4 bedrooms	52.7	51.2	0.11

Source: Australian Bureau of Statistics (ABS) 2006 Census Data

Table 2 Data Sources

Data from allhomes.com.au:	
	Sale price
	Date of sale
	Suburb
	Size of land
	Distance to CBD
	Number of bedrooms
	Number of bathrooms and ensuites
	Number of car parking spaces in garages and carports
Data from field visits to properties:	
	Quality of view (3-point scale)
	External condition of yard and building (3-point scale)
Data based on address of property:	
	High road traffic (dummy variable)
Data based on ActewAGL network maps:	
	Underground wires (dummy variable)

Table 3 Final Sample by Suburb, Year and Type of Network Infrastructure[a]

Period	Calwell	Macarthur	Florey	Total
2008[b]	20 (5)	3 (1)	8 (2)	31 (8)
2007	56 (18)	13 (1)	31 (15)	100 (34)
2006	55 (15)	15 (3)	32 (16)	102 (34)
2005	51 (17)	20 (3)	31 (12)	102 (32)
2004	46 (10)	17 (0)	29 (14)	92 (24)
Total	228 (65)	68 (8)	131 (59)	427 (132)

[a] Number of observations with underground wires are in parentheses
[b] to September 2008

Table 4 Descriptive Statistics[a]

	Min.	Max.	Mean	S.D.
Continuous variables:				
Real sale price (AUD 2008 ‘000s) (*PRICER*)	262	964	426.0	106.4
Number of days sale occurred after 11/01/2004 (*TIME*)	1	1696	791.6	448.4
Block area in m^2 (*SIZE*)	232	1561	813.8	223.8
Distance to Canberra General Post Office (*CBDDIST*)	8	19	14.7	4.0
Dummy coded variables:				
3 bedrooms (*BED3*)	0	1	0.47	
4 bedrooms (*BED4*)	0	1	0.43	
5 or more bedrooms (*BED5UP*)	0	1	0.07	
At least one garage (*GARAGE*)	0	1	0.71	
At least one ensuite (*ENSUITE*)	0	1	0.63	
Underground wires (*UG*)	0	1	0.31	
Situated on a distributor road (*TRAFFIC*)	0	1	0.15	
Some view (*VIEW2*)	0	1	0.38	
Spectacular view (*VIEW3*)	0	1	0.06	
Average external condition (*COND2*)	0	1	0.63	
Above average external condition (*COND3*)	0	1	0.11	
Suburb of Calwell (*CALWELL*)	0	1	0.53	
Suburb of Macarthur (*MACARTH*)	0	1	0.16	

[a] Sample size, N=427.

Table 5 Model 1

Variable	Coefficient	t-stat.
(Constant)	6.937	(16.13)
BED3	0.110	(5.82)
BED4	0.289	(11.51)
BED5UP	0.379	(10.22)
GARAGE	0.032	(2.89)
ENSUITE	0.067	(4.32)
UG	0.029	(2.19)
TRAFFIC	-0.051	(-3.77)
VIEW2	0.040	(3.10)
VIEW3	0.163	(5.55)
COND2	0.058	(4.61)
COND3	0.177	(7.15)
TIME	0.000	(7.44)
TIMESQ	0.000	(-2.94)
DIST_LN	-0.553	(8.31)
SIZESQ	0.000	(2.37)
CALWELL	0.283	(2.35)
MACARTH	0.186	(16.13)
Dep. var.	*PRICERLN*	
R^2	0.83	
N	427	

Table 6 Model Sensitivity

	Model 2		Model 3		Model 4		Model 5		Model 6	
Variable	Coef.	t-stat.	Coef.	t-stat.	Coef.	t-stat.	Coef.	t-stat.	Coef.	t-stat.
(Constant)	1005.3	(4.95)	6.908	(13.65)	5.978	(14.33)	6.953	(16.40)	7.169	(6.33)
TIME	-0.130	(-5.06)	0.000	(-4.55)	0.000	(-5.86)			0.000	(-5.27)
BED3	32.309	(4.75)	0.118	(6.05)	0.051	(1.66)	0.118	(4.18)	0.115	(3.88)
BED4	108.89	(10.49)	0.289	(10.74)	0.228	(6.69)	0.295	(9.48)	0.296	(9.10)
BED5UP	163.45	(8.57)	0.391	(9.59)	0.324	(8.26)	0.391	(10.62)	0.381	(10.15)
GARAGE	11.995	(2.52)	0.032	(2.52)	0.029	(2.33)	0.027	(2.17)	0.027	(2.15)
ENSUITE	20.554	(2.96)	0.066	(3.85)	0.066	(4.55)	0.065	(4.62)	0.064	(4.48)
UG	20.408	(3.08)	0.026	(1.91)	0.040	(3.07)	0.031	(2.50)	0.031	(1.87)
TRAFFIC	-26.765	(-4.20)	-0.054	(-2.85)	-0.055	(-3.75)	-0.044	(-3.05)	-0.047	(-3.03)
VIEW2	18.960	(3.20)	0.051	(3.19)	0.039	(3.02)	0.041	(3.26)	0.046	(3.37)
VIEW3	93.062	(5.34)	0.164	(5.01)	0.183	(7.78)	0.159	(6.79)	0.163	(6.67)
COND2	20.656	(3.50)	0.059	(4.20)	0.050	(3.79)	0.063	(4.98)	0.058	(4.38)
COND3	84.650	(6.19)	0.176	(5.88)	0.163	(7.87)	0.181	(8.74)	0.169	(8.06)
TIMESQ	0.000	(6.55)	0.000	(6.10)	0.000	(7.50)			0.000	(6.82)
DIST_LN	-312.78	(-3.53)	-0.545	(-2.46)	-0.610	(-3.18)	-0.560	(-3.03)	-0.534	(-1.39)
SIZESQ	0.000	(7.25)	0.000	(7.21)			0.000	(9.10)	0.000	(7.71)
CALWELL	170.705	(3.05)	0.277	(1.97)	0.318	(2.58)	0.283	(2.38)		
MACARTH	107.710	(2.92)	0.183	(2.01)	0.212	(2.61)	0.180	(2.29)		
SIZELN					0.189	(8.44)				
Quarterly dummy var.	No		No		No		Yes		No	
ABS CD dummy var.	No		No		No		No		Yes	
Dep. var.	*PRICER*		*PRICERLN*		*PRICERLN*		*PRICERLN*		*PRICERLN*	
R^2	0.79		0.83		0.82		0.84		0.83	
N	427		342		427		427		427	

Figure 3 Estimated Implicit Price and WTP

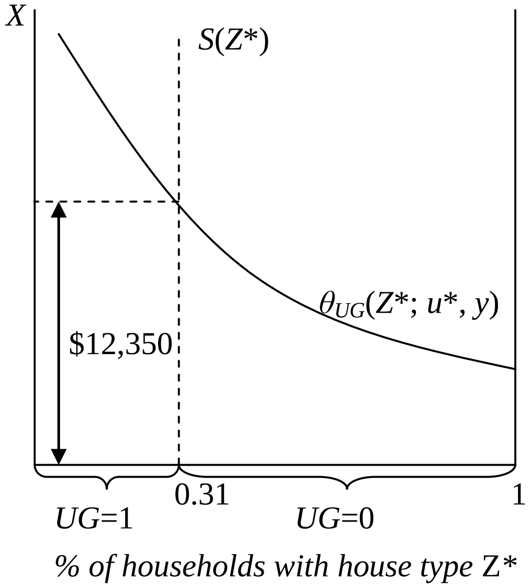

Figure A1 Map of Florey

Figure A2 Map of Calwell

Figure A3 Map of Macarthur

[1] The Australian cities of Perth, Darwin and Adelaide and the New Zealand cities of Auckland and Wellington have implemented undergrounding programs. In the United States, undergrounding is gradually taking place throughout California and in specific locations in Florida, Maryland and Virginia. In the United Kingdom, undergrounding programs are focussed on distribution lines in national parks and areas of outstanding natural beauty.

[2] Studies of households' revealed disutility from proximity to high-voltage overhead transmission lines and towers are of limited benefit due to significant differences in the nature of the infrastructure including the perceived health risks associated with electromagnetic fields from high-voltage wires (Colwell 1990, Des Rosiers 2002, Gregory and von Winterfeldt 1996, Hamilton and Schwann 1995, Kinnard and Dickey 1995, Sims and Dent 2005).

[3] These functions are undefined for $0<UG<1$, but lines are shown for illustrative purposes.

[4] Identification problems and costly data requirements meant that, like many other hedonic price studies, this study does not proceed to the second stage in hedonic estimation suggested by Rosen (1974) in which estimated implicit prices and data on the characteristics of individual suppliers and

demanders are used to estimate supply and demand functions simultaneously (for example Witte et al. 1979)

[5] In Canberra, this supply is exogenously determined by Australian Capital Territory (ACT) government via development regulations. Consequently, there are a number of house 'types', *Z*, in the ACT housing market for which $S = 0$. For example, detached houses that are both serviced by underground wires and close to the central business district are scarce. In general, the supply of houses serviced by underground wires varies significantly across different *Z*.

[6] The decision to install wires underground appears to be unrelated to zoning.

[7] The selection of variables was further validated by the strength of the estimation results.

[8] The rating of view quality was based on elevation and the amount of land visible from the property. The presence of overhead power lines was not a factor in the rating.

[9] By coding underground wires as a single dummy variable, we assume that wires do not impose externalities on adjacent properties. A violation of this assumption would result in boundaries that are 'soft' in the sense that properties serviced by overhead wires would be more valuable where they are adjacent to a boundary and properties serviced by underground wires would be less valuable where they are adjacent to a boundary. If these opposing effects are equal then our assumption will not bias the implicit price estimate.

[10] We expect that the measures of external quality would be strongly correlated with unobserved internal quality, effectively serving as a proxy. The estimate of the implicit price of external quality would then reflect the implicit prices of both external and internal quality.

[11] There are very few knock-down-rebuilt houses in these suburbs. All three suburbs were developed in the late 1970s and 1980s.