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HEDONIC PRICING FOR A COST BENEFIT ANALYSIS OF A PUBLIC WATER SUPPLY SCHEME*

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During the 1950s and 1960s pipelines were built to provide water to many farms in the central wheatbelt of Western Australia using public funds. The resulting network has become known as the Comprehensive Water Supply Scheme. The expansion of the Scheme is currently under consideration. An *ex ante* cost benefit analysis of the proposed expansion is undertaken. An earlier analysis which focused on the benefits of the reduced necessity to cart water was rejected by farmer groups because of the inability of the analysis to properly account for domestic benefits and risk reduction. To overcome these criticisms a hedonic model of farm land values is formulated in which the independent variables are the characteristics of a property, including whether or not the property is connected to the Scheme. The implicit marginal price (or value) of Scheme connection is then derived. An advantage of this technique is that it estimates the value that the farmers allocate to Scheme water in the market place. The conclusion is that the benefits of Scheme water are considerably less than the costs.

In the 1950s and 1960s the Comprehensive Water Supply Scheme (hereafter termed Scheme), funded by the Commonwealth and Western Australian governments, brought piped water to some areas in the wheatbelt and Great Southern areas of Western Australia. Water is piped as far east as Southern Cross (Fig. 1). This water is used to

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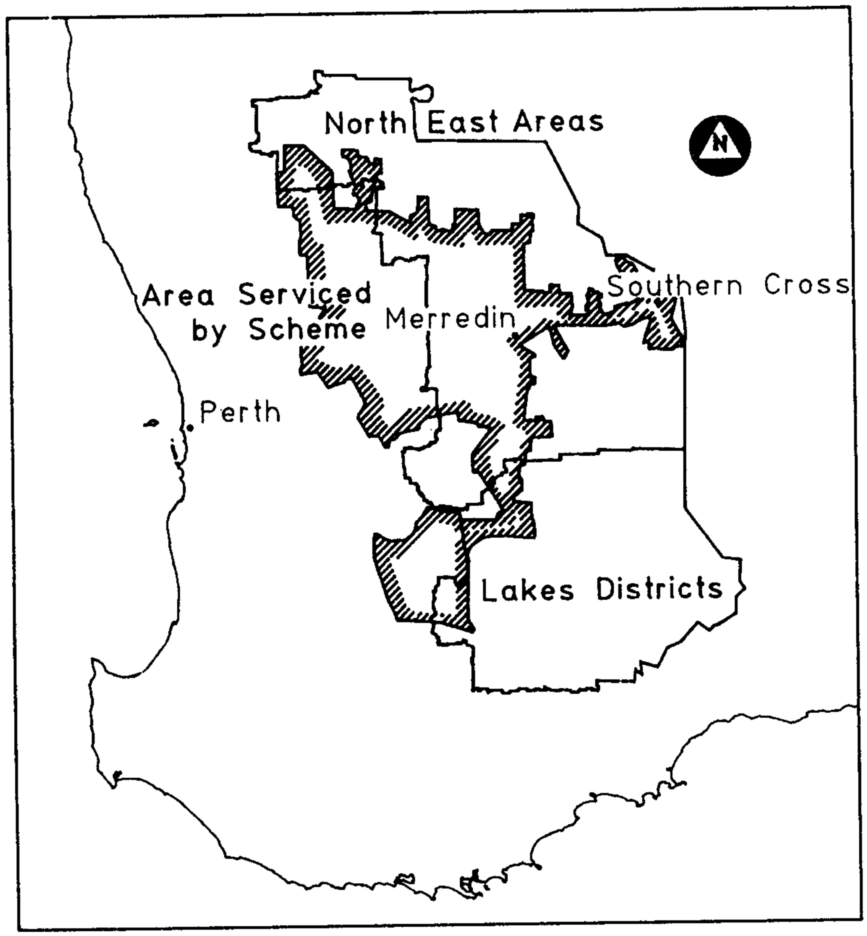
FIGURE 1
Area Serviced by the Comprehensive Water Supply Scheme in South Western Australia
(scale 1 : 4,000,000)



supplement on-farm supplies, for stock watering and domestic purposes (both in-house consumption and irrigation of house gardens, etc. which improve the quality of life). The volumes supplied are not sufficient for commercial irrigation. The capital costs of the Scheme were borne entirely by the Governments and subsequent running costs have been heavily subsidised by the State Government.

In the 1980s the Commonwealth Government appeared reluctant to fund additional expansion of the Scheme. Nevertheless Western Australian governments of the 1980s have publicly supported the concept of expanded Scheme supply. A cost benefit analysis (CBA) of one proposed project (Agaton, 1981) was not favourable.

Bores, dams, dams enhanced by roaded catchments and rainwater tanks are the principal sources of on-farm water supply in south western Australia. In years of on-farm scarcity farmers can truck water from regional sources developed and maintained by the State Government. The value of Scheme water is derived from the increase in quantity and reliability of water supply over the on-farm methods. Scheme water is, however, considerably more expensive than on-farm supplies due to the high capital and operating costs of moving water from sources which are located in higher rainfall areas near the west coast. One CBA showed benefits to be only about 25 percent of costs (Agaton, 1981).

This finding is disputed by farmers, who claim that Scheme water would be much more beneficial than their present on-farm supplies and a much better way of expanding water supplies than expanding supplies from on-farm sources. This view may be largely the result of farmers having received Scheme water at no capital cost and at a subsidised operating cost while on-farm supply costs and water carting costs are largely borne by the farmers.

The Agaton Study gave farmers some scope for criticism because it concentrated on the benefits of reduced carting for stock purposes, and did not account for the additional domestic benefit nor the reduced risk that results from a Scheme supply of water.

Representing all these benefits in an expanded version of the Agaton analysis posed methodological difficulties because of the subjective nature of the assumptions relating to domestic benefits and the benefit of reduced water supply risk. Hence it is important to seek alternative sources of information on the value of Scheme water to farmers; ideally information relating directly to farmer willingness to pay for water.

Rural land prices can be used to provide an estimate of the market value of Scheme water. The hedonic technique is used to extract the implicit marginal price of Scheme water from the price of rural land.

Hedonic Pricing Models

The implicit marginal price or hedonic price approach to the analysis of a market for a differentiated good explores the relationship that exists between the price of a good and the bundle of characteristics (or attributes) which the good possesses, to explain variations in the prices of the differentiated goods under consideration. Though many applications of the method appeared in the 1960s, it was not until Rosen (1974) that a widely accepted theoretical model was developed for the methodology. Rosen proposed a two stage procedure, the first stage of which involves the estimation of a hedonic price function of the form:

$$P_i = f(Z_i) + u_i\,, \qquad i = 1,\ldots,n. \tag{1}$$

where P_i is price of the i-th good (i.e. the i-th observation); Z_i is a (kx1) vector of the k characteristics of the i-th good; and u_i is a random disturbance term.

Upon estimation of the above function, the partial derivative of price with respect to the j-th characteristic yields the implicit marginal price of the j-th characteristic. That is, the partial derivative may be interpreted as the additional amount that the marginal buyer would have to pay (and that the marginal seller is willing to accept) to obtain (or to sell) one more unit of the j-th characteristic, all other things held constant.

Rosen's second stage involves the specification of a system of supply and demand equations of the attributes (2k equations in all). The system is defined by:[1]

(2) $P_j = G_j(Z, Y_1) + v_j, \qquad j = 1,\ldots,k.$

(3) $P_j = H_j(Z, Y_2) + w_j, \qquad j = 1,\ldots,k.$

where P_j is the (unobservable) price of the j-th attribute; Y_1 and Y_2 are vectors of buyer and seller characteristics, respectively; and v_j and w_j are random disturbance terms.

The system of (2k) equations defined by (2) and (3) would be estimated simultaneously with the unobservable P_js replaced by the implicit marginal prices calculated from the estimated hedonic function. That is, the predictions calculated from the partial derivatives of the hedonic function estimated in the first stage.

Assumptions regarding the homogeneity of the characteristics of buyers and sellers influence the way in which Equation 1 may be interpreted and hence has implications for the second stage analysis. Rosen (1974) identifies four possible cases: i) identical sellers (the Y_2 drop out of Equation 3) — implying Equation 1 is an estimate of the sellers' offer function; ii) identical buyers (the Y_1 drop out of Equation 2) — implying a buyers' bid function; iii) both buyers and sellers are identical — providing a trivial solution in which only one product quality appears on the market (i.e. no product differentiation exists); and iv) the most general case in which a distribution of both buyers and sellers are observed — implying Equation 1 defines the intersections of a number of individual offer and bid functions. King and Sinden (1988) in their study of land prices in the Manilla Shire in New South Wales identify a number of farmer characteristics relating to utility functions, production functions and income. They conclude that buyers are heterogeneous while sellers are identical in their application, based mostly upon the notion that buyers enter the market from other shires with different ideas. In the study area the assumption that sellers are identical would be unrealistic as the methods and technologies employed by these wheat sheep farmers vary greatly. Some concentrate on cropping while others are predominantly graziers, some grow wheat in a lupin rotation employing direct drill methods while others retain conventional cultivation methods. It is thus assumed that Rosen's fourth case listed above is relevant to this analysis.

[1] From this point on the subscript i will be implicit.

The hedonic approach has been used regularly in the analysis of land prices. A large number of analyses of urban real estate prices have been conducted. Of most interest to agricultural economists have been those analyses which have studied the balance between agricultural productivity and residential demand on the urban rural fringe (Dunford, Marti and Mittelhammer 1985, Hepner 1985, Chicoine 1981 and Liesch and Musgrave 1979). Although not as numerous as the urban studies, there have been a number of hedonic analyses of rural land prices including Lloyd-Smith (1987), Peterson (1986), Warmann, Nelson and Kletke (1985) and Blase (1973). More recently, with land degradation becoming a topical issue, a number of studies have attempted to measure the degree of capitalization of soil conservation works into farm land prices through hedonic price functions (King and Sinden 1988, Ervin and Mill 1985, Gardner and Barrows 1985 and Miranowski and Hammes 1984). In a similar fashion to these studies, which focus upon the value of soil conservation, the hedonic technique is used to value a particular attribute of rural land, namely connection to Scheme water supply.

It is evident that there is a multiplicity of factors that may be involved in the determination of rural land values. These can be classified into five main categories: external forces, expectations about future conditions, seller characteristics, buyer characteristics and land characteristics (Dunford et al, 1985). The external forces include both economic and governmental influences that are likely to affect the use and profitability of the farm. These range from general economic conditions to government action to influence commodity prices or limit production.

The expectations about future conditions are simply the expectations regarding future prices, yields, costs and other factors likely to affect the value of the farm land. These may include for example changes in population size and distribution with a concurrent urban sprawl into rural areas, rezoning and likely changes to road or rail access.

The characteristics of the buyers and sellers relate to the individual differences of the economic agents and affect the way in which the buyers' bid function and the sellers' offer function, that is their willingness to pay or the prices that they will accept for varying characteristics of the good, converge. King and Sinden (1988) note that farmer characteristics may include factors relating to production functions and incomes as well as any number of factors influencing utility functions, such as whether the sale was forced (through death, bankruptcy, etc.) or whether the buyer was a neighbour.

Of Dunford's five categories of factors affecting rural land values, the first two factors, external forces and expectations are of most interest in temporal or wide-ranging spatial analyses, descriptions which do not apply to our analysis. The second two categories listed, those of buyer and seller characteristics, are also discarded as this hedonic analysis does not proceed to Rosen's second stage for reasons outlined later in the paper.

Thus, in this study it is Dunford's fifth category, the specific attributes or characteristics of individual farms, which are the focus of attention. These characteristics may include soil quality, arable areas, buildings or other improvements (in particular water supply quality and quantity), topography, climate as well as the locational characteristics of distance to town, road access and specific to this study, availability of Scheme water.

King and Sinden (1988), recognising that the family farm is often both a source of income and a place of residence, divide the farm characteristics into three groups. Namely, those which influence productivity (e.g. rainfall, soil quality), those which influence consumption (e.g. housing) and location factors. Most likely, locational factors were treated as a separate group by King and Sinden because of their potential to influence both farm profitability and residential amenity. In this analysis it is recognised that Scheme water is similar to location in this way and hence the third group is renamed 'characteristics influencing both production and consumption' with Scheme water included in it.

Functional form

Economic theory rarely offers strong direction as to the correct functional form to be used. As noted by Graves et al (1988), in the particular case of '. . . hedonic gradients, which are by theory already in reduced form and hence are the solution of several equations, even less can be presumed'. Many studies have assumed a linear form for the hedonic price function (Equation 1). The practice of assuming a linear specification without testing any alternative specifications is not unique to hedonic studies: it occurs in almost all areas of applied economics. In the specific case of hedonic functions the assumption could be most unrealistic as it implies the implicit prices of attributes (the first partial derivatives) are constants and thus independent of the quantity of an attribute the good possesses (Rosen, 1974).

Halvorsen and Pollakowski (1981) suggested the use of the quadratic Box Cox functional form. This is a flexible functional form which embodies many of the popular functional forms as special cases. Parameter restrictions in the quadratic Box Cox may be tested to determine whether any of the simpler forms should be preferred in a particular application.

Cropper, Deck and McConnell (1988) use simulation to test the performance of various functional forms when some attributes are unobserved or replaced with proxies. They conclude that under these conditions the simpler forms, the linear, log-linear, log- log and linear Box Cox outperform the quadratic and quadratic Box Cox functional forms in reliably predicting the implicit prices.

Graves et al (1988) in a study investigating the value of urban air quality, unintentionally provide an excellent example to support the findings of Cropper et al (1988). Graves et al (1988) use their application to illustrate the wide range of estimates of the value of urban air quality that may be derived under alternative model specifications. They investigate a list of functional forms similar to that in Cropper et al (1988). They tabulate the mean predicted value of air quality estimated under several different assumptions on functional form and under two slightly different sets of regressors. Of the functional forms considered, it is the quadratic Box Cox, the most general functional form, which produces the greatest change in the predicted mean value of air quality when the regressor set is altered. In their conclusion they recommend the quadratic Box Cox functional form (because it provided the best 'fit' to the sample data) and also note that the above mentioned volatility is evidence of the importance of choice of included variables. In the light of the results of Cropper et al (1988), it is concluded that the results presented in Graves et al (1988) support the use of simpler functional forms rather than the converse.

A concise summary of points for and against the use of the quadratic Box Cox in hedonic studies may be found in Williams (1989). In the light of these arguments, it was decided that the overriding consideration was the possibility of variable misspecification or omission in the data set. The danger of obtaining poor predictions of implicit prices under such conditions led us to consider the linear, log-linear and log-log functional forms only. Once estimated, model selection is based on using the modified J-test of McKinnon (1981) and the Ramsey Reset test (Ramsey, 1969).

Application

A map of south western Australia is presented in Figure 1. The region of the State in which farms presently have access to Scheme water is partially shaded. Properties in the area bordering the existing Scheme water region to the north east and the east were judged to be those most likely to realise significant benefits from the expansion of the Scheme. This assessment was based on Laing, Pepper and McCrea (1988), who identified particular problem areas in the establishment of on-farm water supplies in south western Australia. Data for the eastern and north eastern wheatbelt and the Lakes Districts were therefore used (refer Fig. 1). The Valuer General's Office (VGO) of Western Australia provided data on 129 land sales recorded between March 1987 and June 1989. Sixty two of the sales were of farms connected to Scheme water.

The rural land market in the study area is deemed to be suitable for the application of the hedonic technique as it is characterised by a differentiated product (rural land) being sold in a competitive market. The flow of information in the market is excellent with a number of real estate agents advertising within the region, intrastate and interstate. There are no large buyers or sellers in the market who could singularly influence this market for rural land. There are no barriers to entry other than the obvious one of insufficient finance. In developing the theoretical model, Rosen (1974) assumed the existence of the text book case of pure competition. In this case, the degree of competition is sufficiently high for the same assumption to be made.

VGO records every rural land sale made in Western Australia. Along with the price paid, other information is recorded by the valuers. From this information the following variables were specified.

AREA	— area of cleared land (hectares)[2]
PRICE	— price per (cleared) hectare ($)
RAIN	— average annual rainfall (mm)
SCHEME	— connection to scheme water (1 = yes, 0 = no)
BUILD	— value of buildings ($)
HOME	— presence of seller's home on property (1 = yes, 0 = no)
DIST	— distance to nearest town (km)
PASTURE	— quality of pasture (valuer's rating: 1, 2 or 3, 3 being above average)
FENCE	— quality of fencing (valuer's rating: 1, 2 or 3, 3 being above average)
WATER	— quality of farm water supplies (valuer's rating: 1, 2 or 3, 3 being above average)
HEAVY	— proportion of property with heavy soil
MEDIUM	— proportion of property with medium soil
LIGHT	— proportion of property with light soil

The VGO was the sole source of data. It would have been preferable to have collected the data through a direct farmer survey but time and funding restrictions prevented this. There are additional and differently defined variables which would have been used in the analysis had the information been available. The most obvious example of this is information on the characteristics of the individual buyers and sellers. This lack of data was the primary reason for us not proceeding to the second stage of the hedonic analysis.[3]

[2] There was a choice between cleared area and total area. The two variables were quite similar in the sample. Cleared land was opted for as in many cases any land left uncleared was not deemed economically viable to clear and hence would unlikely to add to the productive capacity of the property.

[3] The results of this analysis suggest that benefits are substantially less than costs. If they had been closer it may have been of interest to define the precise nature of the demand and supply conditions influencing the implicit value of Scheme water in order to identify those instances in which it is valued at a level greater than the costs. These factors may then be used to develop a selective policy on Scheme expansion. It was decided that the gulf between benefits and costs would be unlikely to be bridged in enough instances to warrant the commitment of further resources to collect the data necessary to extend the analysis to the second stage.

The variables PASTURE, FENCE and WATER could be incorporated directly into a regression model but this would require assumptions regarding the relative marginal values of the ratings within each of these ordinal variables. To avoid imposing such restrictions, each ordinal variable was replaced with two dummy variables. The six dummy variables defined are:

PASTURE1 — 1 if PASTURE = 1, 0 otherwise
PASTURE2 — 1 if PASTURE = 2, 0 otherwise
FENCE1 — 1 if FENCE = 1, 0 otherwise
FENCE2 — 1 if FENCE = 2, 0 otherwise
WATER1 — 1 if WATER = 1, 0 otherwise
WATER2 — 1 if WATER = 2, 0 otherwise

One variable not supplied by the VGO which may be potentially important is the influence of salinity. The Lakes District of Western Australia is so named because of a number of large salt lakes in the area. By observing the proximity of the properties to these salt lakes a dummy variable SALT was defined (1 if adjacent to a salt lake, 0 otherwise).

The above farm attributes may be divided into three general categories: those influencing profitability, those influencing residential amenity and those influencing both production and consumption. In the first category is RAINFALL, AREA, SALT, PASTURE, FENCE AND WATER; in the second we place HOME and in the third are the remaining variables, BUILDINGS, SCHEME and DISTANCE.

Production characteristics

The relationship between PRICE and AREA is expected to be negative. This expectation is based upon the premise that in the more productive areas (i.e. those areas with higher rainfall and better soil types) the farms tend to be smaller because less area is needed to support the family business. Land is more expensive in the more productive regions, thus a negative relationship would be observed between farm size and price per hectare. In essence AREA could be viewed as an inverse proxy for the productivity potential of a hectare of land. Other factors could influence the relationship between farm size and price per hectare. For example, there are generally more buyers who can afford smaller parcels of land in the market place. This is likely to contribute to the negative relationship between PRICE and AREA. There is a possibility of the conflicting influence of an economies of scale effect on the coefficient of AREA but this effect is unlikely to overpower the other effects.

The primary limiting factor to agricultural productivity in the Western Australian wheatbelt is rainfall. The sample mean of RAIN in our study is 324 mm. The vast majority of the properties in the sample are wheat/sheep farms. Low rainfall adversely affects wheat yields, pasture production and results in dam levels insufficient for livestock. RAIN is therefore expected to have a strong positive influence upon land values.

The productivity of properties adjacent to salt lakes may be affected in two primary ways. Firstly through the poor quality of the soils resulting from 'blow' from the surface of the lakes when the lakes are dry and the winds strong. Secondly, the high saline water table makes the establishment of dams of reasonable depth a difficult task. Hence we expect SALT to have a negative influence upon farm productivity and hence land value.

PASTURE is a measure of the quality of improved pasture on the property. It should add to the productivity of the sheep enterprise thus the coefficients of PASTURE1 and PASTURE2 are expected to be negative. The quality of fencing and on-farm water supplies (FENCE and WATER) should also favourably affect the sheep enterprise, therefore the dummy variables defined for them are also expected to have negative coefficients.

After rainfall, soil quality was viewed as the next most important characteristic influencing production. Unfortunately the available data only detailed the proportions of heavy, medium and light soils on each property. Though soil density is by no means the only soil property influencing the productive potential of a soil in this region of Western Australia it was expected that on average the heavier soils would be preferred because of their greater water-holding capacity. Heavy soils may not result in significantly higher yields but in less variable wheat yields since high stored moisture reserves mean that the crop is less reliant on the timing of the rainfall (pers. comm. Steve Hossen — WADA, August 1990).

Consumption characteristics

The only variable included in this group is HOME. It is a dummy variable indicating whether the seller's home was on the property. It is expected to have a positive influence upon the property value.

Characteristics influencing both production and consumption

DIST specifies the distance in kilometres that each property is from the nearest town. This distance is expected to have a negative influence upon the profitability of the farm enterprise through higher costs of carting wheat, wool and sheep to market and of bringing in inputs such as fuel, fertiliser, etc. DIST is also expected to reduce the consumption or residential value of the farm through the greater distances that must be travelled to schools, shopping and social gatherings. It is recognised that the nearest 'town' as specified by the VGO may be very small and contain few of the services mentioned above. Given the opportunity to collect primary data, other variables such as grain transport charges from farm gate to port or distance to nearest town with a school would have been more relevant. It should be noted that in the area from which the data has been collected there is no centre of population larger than 5,000. Thus the 'hobby farm' effect, noted in many other studies of rural land values, is likely to be minimal.

The variable of most interest to this paper is SCHEME, a dummy variable reflecting the presence of a connection to public water supply. It is expected to add to the value of a property both through the improved quantity and reliability of water supply for stock watering and is also expected to improve the quality of life of those living on the property through the benefits of being able to maintain a garden or swimming pool and so on, through times of water shortage.

The value of buildings, BUILD, on a property is classed as both a production and consumption characteristic as it includes estimates of the value of any houses, shearing sheds, silos, machinery sheds, etc.[4]

Estimation of Model

Price per hectare is used as the dependent variable in the analysis in preference to total property price, for intuitive reasons. Farmers and property agents generally express property values in per hectare rather than per farm terms as farm sizes tend to vary greatly. The choice of price per hectare as the dependant variable was further supported by preliminary analysis of total price functions which exhibited significant heteroskedasticity. The error variances of the total price functions were observed to be positively related to property size thus implying transformation through division by area could be warranted.

Some degree of multicollinearity was expected in this analysis particularly between such variables as BUILD and HOME. As a result the correlation coefficients between each of the property attributes were calculated. All those correlations which exceeded the arbitrarily chosen figure of 0.4 are listed in Table 1. With the main concern being the accurate estimation of the coefficient of SCHEME it is reassuring to note that SCHEME does not appear in this table. The expected correlation between HOME and BUILD exists and furthermore correlation is observed between these two variables and AREA. Larger properties require larger shearing sheds, more silos and such, and are also more likely to contain a home. Thus this result appears reasonable. The remaining three correlations in the table are simply an artifact of the way the variables are constructed. For example, LIGHT is negatively related to HEAVY because a property with a large percentage of heavy soil must obviously have a small percentage of other soil types. The multicollinearity question was not acted on, for reasons which are outlined later in this section.

[4] The BUILD variable is in terms of 1988/89 dollars having been deflated by the CPI. The PRICE variable is also expressed in 1988/89 dollars having been deflated by an index of rural land values for the 300 to 350 mm region of Western Australia supplied by the VGO.

TABLE 1
*Sample Correlation Coefficients Between Attributes**

Attribute A	Attribute B	Correlation
BUILD	HOME	.6708
AREA	BUILD	.5784
AREA	HOME	.4375
PASTURE1	PASTURE2	–.5399
HEAVY	LIGHT	–.6567
MEDIUM	LIGHT	–.4211

* All correlations not listed were less than the arbitrarily chosen level of 0.4 (in absolute value).

OLS estimates of the three functional forms are presented in Table 2. The log-log functional form is the only one for which all of the F-values of the Ramsey Reset test are insignificant.[5] The Ramsey Reset test, being a general test of misspecification, thus supports the choice of the log-log form.

A modified J-test may also be used to attempt to choose between the models. The J-test is a test of non-nested hypotheses. Its calculation (for the case of two models) involves two steps. Firstly each model is estimated and their predictions stored. Then each prediction is included as a regressor in the competing model.[6] Three conclusions can be drawn from a J-test: i) If the t-ratios of the included predictions are either both significant or both insignificant neither model is preferred to the other; ii) If predictions of model 1 in model 2 is significant and the converse insignificant then model 1 is preferred; and iii) If predictions of model 2 in model 1 is significant and the converse insignificant then model 2 is preferred. The t-ratios relevant to this test are presented in Table 3 and it can be concluded that the linear model is superior to the log-linear model and that the log-log model is superior to the linear model. Given this, it is concluded that the log-log model is superior overall.[7] This result is in agreement with the Ramsey Reset test results presented in Table 2 which indicated misspecification in the log-linear and linear models.

[5] All hypothesis tests in this paper assume a 5 percent level of significance unless otherwise stated.

[6] The J-test needs to be modified when the dependent variables are not the same (e.g. one may be the logarithm of the other) by suitably transforming the predictions of one model before including them as a regressor in the other. For a concise discussion of the J-test, Ramsey Reset test and many other specification tests see Kennedy (1985) Chapter 5.

[7] The result of the J-test between the log-linear and log-log models was inconclusive. This does not discredit the conclusion though a result in favour of the log-log would have added greater weight to the choice of model.

Given the spatial nature of the data, the possible existence of heteroskedasticity in the models was considered. The SHAZAM package of White, et al (1990) provides numerous tests of various forms of heteroskedasticity.[8] All but one of the calculated statistics indicated significant heteroskedasticity in the linear model. Conversely, all tests were insignificant for the log-linear and log-log models. Thus our choice of the log-log form is not altered by these heteroskedasticity test results.

Lloyd-Smith (1987) found residual autocorrelation to be a problem in a similar analysis conducted over a longer time period. The problem was also suspected in this application but the structure of the data did not lend itself easily to testing for autocorrelation. The data were not observed at regular time intervals, with different numbers of sales observed in the different months with a number of months having no observations at all. Given these data limitations, pursuing the autocorrelation question was deemed to be beyond the scope of this study.

As already noted, the estimated coefficients of the log-log model are presented in Table 2. All coefficients which are statistically significant have the expected sign. A large number of coefficients have t-ratios of less than one. The model was re-estimated with these variables omitted (except SCHEME for obvious reasons). This involved deleting PASTURE1, PASTURE2, FENCE1, FENCE2, WATER2, LMEDIUM AND LLIGHT. The poor performance of the five dummy variables omitted could be due to either the relative unimportance of these factors in determining land values or the approximate way in which the information is defined. Most likely it is a combination of the two. The insignificance of the soil variables was not unexpected as soil density is only one characteristic of soil quality.

The restricted model is presented in the first column of Table 4. The joint test of the seven restrictions yields an insignificant F-value of 0.52. Thus the restricted model is preferred.

The variables AREA, BUILD and HOME were all retained in the model even though they were observed to be correlated to a degree (refer Table 1). One common approach to correcting multicollinearity is the deletion of the variable. This often cannot be justified. In this study the sole aim is estimation of the value of Scheme. Omitting one of these variables could introduce unnecessary misspecification bias to our SCHEME coefficient estimate. The best approach is to retain the correlated variables, especially given that their t-ratios are reasonable despite the effect of multicollinearity and there are strong *a priori* reasons for their inclusion. However, little weight is given to the reliability of their estimated coefficients.

[8] For a discussion of the many forms of heteroskedasticity for which SHAZAM provides tests refer to Chapter 9 of Judge et al (1988).

TABLE 2

OLS Estimates of Three Alternate Functional Forms[a]

Linear depn var = price		Log-Linear depn var = log (price)		Log-Log depn var = log (price)	
SCHEME	23.66	SCHEME	.0730	SCHEME	.0242
	(0.96)		(1.05)		(0.35)
AREA	–.0533	AREA	–.0002	Log	–.3070
	(3.26)		(4.59)	(AREA)	(5.67)
RAIN	4.007	RAIN	0.120	Log	3.807
	(7.52)		(8.04)	(RAIN)	(8.37)
BUILD	.0010	BUILD	3.8E-6	Log	.0168
	(2.10		(2.91)	(BUILD)	(2.32)
HOME	–25.41	HOME	.0110	HOME	.1743
	(0.89)		(0.14)		(2.45)
PASTURE 1	–.0269	PASTURE 1	.0145	PASTURE1	.0522
	(0.01)		(0.14)		(0.49)
PASTURE2	–33.30	PASTURE2	–.0917	PASTURE2	–.0650
	(1.11)		(1.09)		(0.78)
FENCE1	–31.03	FENCE1	.0231	FENCE1	–.0045
	(0.59)		(0.16)		(0.03)
FENCE2	–7.971	FENCE2	–.0281	FENCE2	.0069
	(0.30)		(0.37)		(0.09)
WATER1	–30.43	WATER1	–.2190	WATER1	–.2689
	(0.60)		(1.54)		(1.98)
WATER2	–20.89	WATER2	–.0579	WATER2	–.0558
	(0.73)		(0.72)		(0.71)
DIST	–.7735	DIST	–.0020	log	–.0408
	(0.95)		(0.89)	(DIST)	(1.22)
HEAVY	62.65	HEAVY	.0140	log	.0508
	(0.38)		(0.03)	(HEAVY)	(1.50)
MEDIUM	–64.69	MEDIUM	–.2897	log	–.0014
	(0.37)		(0.59)	(MEDIUM)	(0.05)
LIGHT	–36.86	LIGHT	–.2063	log	–.0066
	(0.23)		(0.46)	(LIGHT)	(0.24)
SALT	–100.8	SALT	–.2722	SALT	–.3114
	(2.28)		(2.20)		(2.50)
intercept	–881.4	intercept	2.142	intercept	–14.21
	(4.02)		(3.49)		(5.18)
R-square	0.64		0.71		0.72
R-square-adj	0.59		0.67		0.68
Ramsey Reset test using powers (2, 3 & 4) of the predictions:					
F(1,111)	7.81		0.18		0.21
F(2,110)	11.13		6.44		0.70
F(3,109)	7.65		4.44		0.95

[a] T-ratios are in parentheses.

TABLE 3
T-Ratios for the J-Test for Functional Form

Model from which Predictions were Derived	Model into which Predictions are Included		
	linear	log-linear	log-log
linear	****	2.65	0.19
log-linear	1.69	****	2.22
log-log	6.22	3.61	****

Results and Discussion

It was hypothesized that the same hedonic price function may not apply across both the north east areas and the Lakes districts (refer Fig. 1). This was due to inherent differences in soil and water characteristics which cause farming practices to vary. It can be observed from shire statistics that shires in the south of the study area have a higher ratio of grazing to cropping on the average farm. Table 4 includes estimates of the preferred model derived from data from each region separately as well as for the whole study area. The Chow test[9] provided a calculated F-value of 2.06, indicating a significant difference in the model across regions. The two regional models were therefore used in preference to the aggregate model to provide estimates of the implicit marginal price of Scheme.

All estimated coefficients in Table 4 are of the expected sign. All Ramsey Reset test statistics are insignificant, thus indicating the absence of misspecification. The coefficient of SCHEME varies markedly between regional models from 0.0712 in the north eastern model to 0.1847 in the Lakes Districts model.[10] These coefficients may be multiplied by the sample mean prices ($259 and $419) to provide average per hectare values of $18.44 and $77.39. These figures may be further multiplied by the sample mean farm areas (1,278 and 1,087) to provide per farm values of $23,566 and $84,123, for the north east and Lakes, respectively. The large size of this difference was unexpected.

A number of explanations of the observed difference have been proposed. The first relates to the variation in farming practices between the regions. In the Lakes districts stocking rates and total sheep numbers per farm are higher and areas of crop are smaller than in the north east areas. Thus, as Scheme water removes the need for graziers

[9] For more information on the Chow test refer to Judge et al (1988), Chapter 10.
[10] The t-ratios on the coefficients of SCHEME in the equations in Table 4 are all less than 1.96. Thus the implicit marginal value of the Scheme is not significantly different form zero at the five percent level. This choice will not alter the conclusions of this paper.

to cart water in drought years, it is likely to be of greater value to the farmers of the Lakes districts.

TABLE 4
OLS Estimates of Preferred Log-Log Model[a]

	North East and Lakes Districts (n = 129)	North East (n = 85)	Lakes Districts (n = 44)
SCHEME	.0383 (0.59)	.0712 (0.84)	.1847 (1.66)
Log (AREA)	-.3080 (5.88)	-.2601 (3.68)	-.1970 (2.18)
log (RAIN)	4.023 (10.11)	3.951 (6.42)	1.801 (1.91)
log (BUILD)	.0169 (2.37)	.0063 (0.68)	.0153 (1.22)
HOME	.1809 (2.68)	.2516 (2.77)	.0340 (0.35)
WATER1	-2.132 (2.22)	-.1439 (1.25)	-.3226 (1.83)
log (DIST)	-.0401 (1.31)	-.0162 (0.46)	-.0879 (1.43)
log (HEAVY)	.0608 (2.08)	.1000 (2.42)	.0016 (0.04)
SALT	-.3060 (2.55)	b	-.2849 (2.27)
intercept	-15.50 (6.40)	-15.45 (4.14)	-3.122 (0.58)
R-square	0.71	0.68	0.67
R-square-adj	0.69	0.64	0.58

Ramset Reset test using powers (2, 3 & 3) of the predictions:

F(1, 122)	0.71	F(1, 75)	1.95	F(1, 33)	0.66
F(2, 111)	0.95	F(2, 74)	0.97	F(2, 32)	0.36
F(3, 110)	0.70	F(3, 73)	0.73	F(3, 31)	0.23

[a] T-ratios are in parentheses
[b] No farms in the north east were adjacent to salt lakes.

Secondly, the on-farm water supply technology is much less suited to the Lakes districts. This is for two reasons, firstly groundwater suitable for stock watering (i.e. with acceptable salt levels) is rarely found in the Lakes districts while in the north it supplies non-Scheme farms with approximately half their water supplies. During drought when surface water is minimal, groundwater is an important source of water for stock. It is not surprising that Scheme connection is valued more highly in areas without suitable groundwater. Secondly, the establishment of dams and roaded catchments in the Lakes district is on average much more difficult than in the north east areas. Laing, Pepper and McCrea (1988), with reference to the Lakes districts, note the problems of 'instability of soils used for catchments and dams, and poor potential for deep dams due to the common occurrence of salt watertables and to poor water holding soils in some situations'.

Cost Benefit Analysis and Policy Implications

The foregoing analysis has provided estimates of the mean value of Scheme water as provided by the interaction of what buyers are willing to pay and sellers willing to accept for this attribute in the market place. Unlike previous synthetic estimates, this estimate includes farmers' perceptions of the additional benefits that Scheme water may provide in terms of improved quality of life from an expanded water supply for domestic purposes and the perceived reduction in risk of Scheme rather than on-farm supply. The analysis therefore overcomes the major objections raised by farmers to the cost benefit analysis previously conducted.

Benefits and costs attributable to the Scheme are presented along with the estimated Net Present Values (NPV) and benefit Cost Ratios (BCR) in Table 5. Benefits are much less than costs, with the BCR varying from 0.09 for the north east region to 0.25 for the Lakes districts. The costs presented in Table 5, which are taken from Stone (1989), are an estimate of the present value of the average capital cost of providing Scheme water connections to each farm in the region. The size of these costs is largely a consequence of the expense of piping water from a distant source and distributing it to a widely dispersed population of users.

TABLE 5
Net Present Values and Benefit Cost Ratios[a]

	North East	Lakes Districts
Capital cost of Scheme per farm[b]	$265,000	$331,000
Benefits per farm	$24,000	$84,000
Net present value	–$241,000	–$247,000
Benefit cost ratio	0.09	0.25

[a] All figures are in 1988/89 dollars.
[b] Source is Stone (1989).

It is noteworthy that the benefit cost ratios are respectively much less than and the same as the 0.25 calculated in the previous cost benefit study. Thus the results do not support farmer claims about the inadequacy of the previous study. The finding of the Agaton study that the expansion of the Scheme cannot be justified on economic grounds is thus supported by this analysis.

Consideration of the assumptions behind the figures presented in Table 5 reveals three factors, not accounted for, which may reduce these already unfavourable results even further. Firstly, the hedonic estimate of Scheme (an ex post measure) may be an overestimate of the correct value that should be used in an *ex ante* cost benefit analysis of Scheme expansion. The reason for this is the investment by farmers in on-farm reticulation to pipe water from the Scheme pipeline to the farmhouse and elsewhere around the farm. Such capital would exist on many if not all of the properties in our sample which are connected to the Scheme. Thus when a buyer values a property with Scheme water, he/she is not only valuing the Scheme connection but also any associated investment in on-farm reticulation. Thus the benefit figure in Table 5 could be regarded as an upper bound of the value of a Scheme connection alone.

The second unaccounted for factor relates to the concept of opportunity cost. The estimate of costs in Table 5 relates to the capital cost of piping water from dams near the west coast. The calculations assume, however, that the water taken from these dams has no opportunity cost. This assumption is unlikely to be valid given the water shortages which have been experienced in Perth in recent years as its population expands rapidly. There are many alternative uses to which the water could be put. The estimate of costs could thus be regarded as a lower bound to the true social cost of providing Scheme water.

The last unaccounted for factor relates to the as yet unmentioned operating and maintenance costs of the Scheme. Historically the water charges paid by farmers have not been sufficient to cover these costs. If this is to continue in the future then the estimate of costs (which only involves capital costs) will be an underestimate. Alternatively, if farmers are to bear the full operating and maintenance costs in the future, then the hedonic estimate of benefits will be an overestimate as the farmers in the sample do not presently face such high charges. Either way the benefit cost ratio will be an overestimate.

Conclusions

The hedonic pricing model proved a useful method for estimating the value of piped Scheme water. Unlike a previous study it directly measures the value farmers attribute to Scheme water in the marketplace, providing an estimate which met criticisms of a previous analysis by allowing for the higher reliability of Scheme supply and benefits from increased domestic supplies.

Benefit cost ratios calculated on the basis of these estimates are less than or similar to those found previously. Thus they support the previous finding that Scheme expansion cannot be justified on economic grounds.

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