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Hedonic Price Analysis and Selectivity Bias: Water Salinity and Demand for Land

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Abstract

Hedonic valuation of quality attributes can be misleading when the assumption that these attributes are exogenous to sample selection is violated. This paper considers the simultaneity between hedonic valuation and sample selection in the context of a model of producer behavior and investigates empirically the case where land is demanded for use as an input either in agricultural production or in touristic development. The empirical analysis suggests that failing to correct for sample selection results in a biased valuation of the effect of water salinity on agricultural land.

JEL Classification: Q15

Keywords: quality, resource environmental valuation, sample selection bias, separability

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1 Introduction

Groundwater scarcity has an important qualitative dimension that further limits the supply of usable water. Groundwater quality may affect the productivity of land as an input in agricultural production. Were this is so, the structure of land rents and prices will reflect these environmentally determined productivity differentials. Hence, by using data on land rent or land value for different properties we can in principle identify the contribution which the attribute in question, fresh groundwater quality, makes to the value of (willingness to pay for) the traded good, land. This identifies an implicit or shadow price for the attribute fresh groundwater quality, which in turn can be interpreted as an estimate of the in situ scarcity value of the marginal unit of the environmental resource. Methods commonly used to implement this approach include (i) the hedonic technique pioneered by Griliches (1971) and formalised by Rosen (1974); and (ii) the travel cost valuation methods first proposed by Hotelling (1931), and subsequently developed by Clawson (1959) and Clawson and Knetsch (1966). The relationship between land prices and surface and groundwater access (both in quantity and quality terms) has been studied in the hedonic framework by Miranowski and Hammes (1984), Gardner and Barrows (1985), Ervin and Mill (1985),King and Sinden (1988), Caswell and Zilberman (1986) and Toell et al (1990). Travel cost techniques employed to measure the welfare effects to changes in water quality of recreational sites include Binkley (1978), Freeman (1979), Caulkins et al (1986), Smith and Desvousges (1986) and Bockstael et al (1987).

This paper considers the case where the quality characteristic of an input influences not only the output value but also the usage of the input itself. It is argued that failure to account for alternative uses of an input can give rise to a sample selection problem resulting in misleading parameter estimates reflecting the shadow prices of the quality characteristics of the input in question. The sample selection problem here is analogous to the one considered in travel cost models where the endogeneity of the decision to visit a recreational site is shown to result in estimated demand that exaggerates the consumer surplus associated with the trip (Miller and Hay 1981, Russell and Vaughau 1982, Hellerstein and Mendelsohn 1992 and Hausman et al 1992).

Our investigation is motivated by the fact that the decision whether to pay for a particular input or not is endogenous to the price paid, as it is the decision how much input to purchase. This is because certain quality characteristics can be responsible for an observation being included in or excluded from the sample. We demonstrate this argument in a model where land close to the seaside is demanded for use as an input either in agricultural production or in touristic development. In the context of this model this selection decision is investigated together with the hedonic valuation of the quality characteristics of the land parcel to avoid the sample selection bias of the type described above. The proximity to the sea, in particular, decreases the probability of land usage for farming due to salination of groundwater supplies and increases the probability of tourism usage due to attractiveness to tourists. Yet, land parcels closed to the seaside may continue to be used in agriculture (is spite of the poor quality of their underwater supplies) because they are still below the touristic development reservation price.

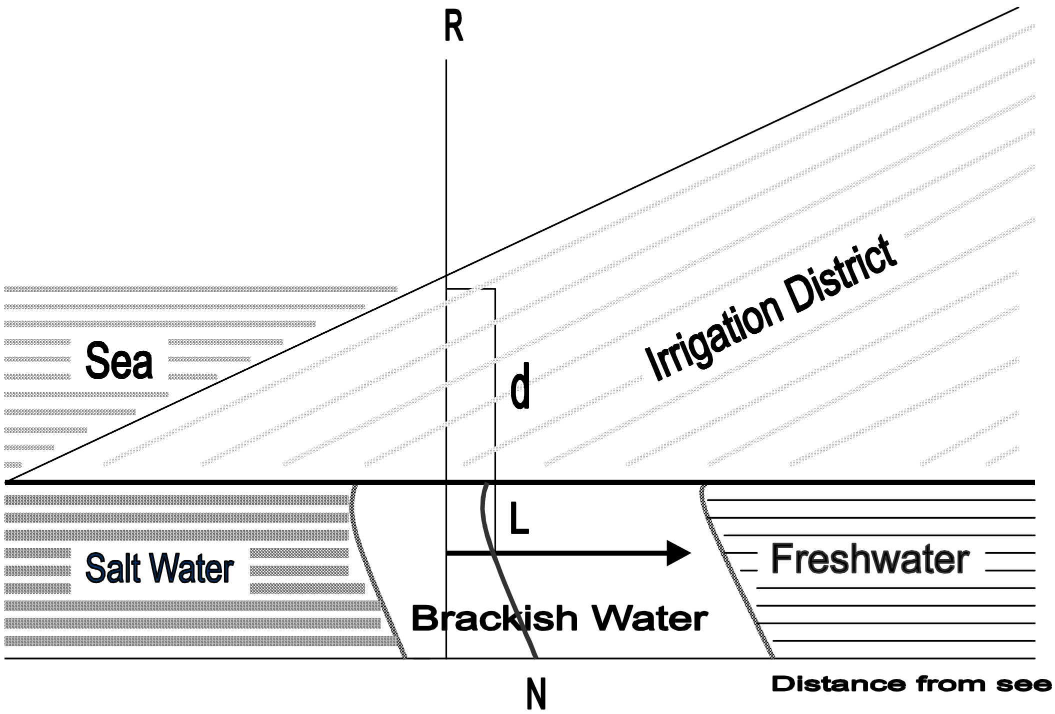
We investigate empirically how this selectivity problem affects the hedonic valuation of the effect of water salinity on agricultural land. The outcome of this empirical investigation is that hedonic valuation techniques might give rise to misleading conclusions about the effect of an environmental attribute on producers (or consumers) welfare if potential biases from inappropriate sample selection criteria are ignored.

The structure of the paper is as follows. Section 2 describes the decision environment in which the selectivity problem of interest arises. Section 3 considers a model of producer demand for package factors of production and discusses the behavioral effects of characteristics reflecting quality. Section 4 reports the results obtained from the empirical analysis and section 5 concludes the paper.

2 Decision environment

In coastal fresh groundwater systems seawater intrusion is a common form of quality deterioration of groundwater resources that diminishes the water's usefulness for certain purposes. Figure 1 presents a simplified description of the movement of intruding seawater into an aquifer. Consider a coastal irrigation district. A reference boundary R is defined. This can be the coastal perimeter of the irrigation district, the seaward limit of agricultural activity, or an arbitrarily defined line. The object of R is to provide a point of reference from which to measure the length of intrusion. For an arbitrarily given depth d measured at R, we define the length measure of saltwater intrusion, L. Note that the interface and the point of measuring L is not between saltwater and freshwater. In as much as saltwater and freshwater are miscible fluids, a transition zone will exist between the two fluids. The maximum level of salt concentration for irrigation water is usually around 3000 TDS[1] mg/l. Hence as far as the agricultural sector is concerned interest lies in the interface between water with total salinity greater than 3000 and water with total salinity less than 3000, (the interface between 'brackish water' and 'fresh-water'), as shown in Figure 1.

Figure 1: Representation of seawater intrusion.



To understand the movement of saltwater intrusion imagine a district that is divided into n zones. The dimensions of each zone depend on the impact of saltwater intrusion on pumping activity. For example, starting at R, an inland movement

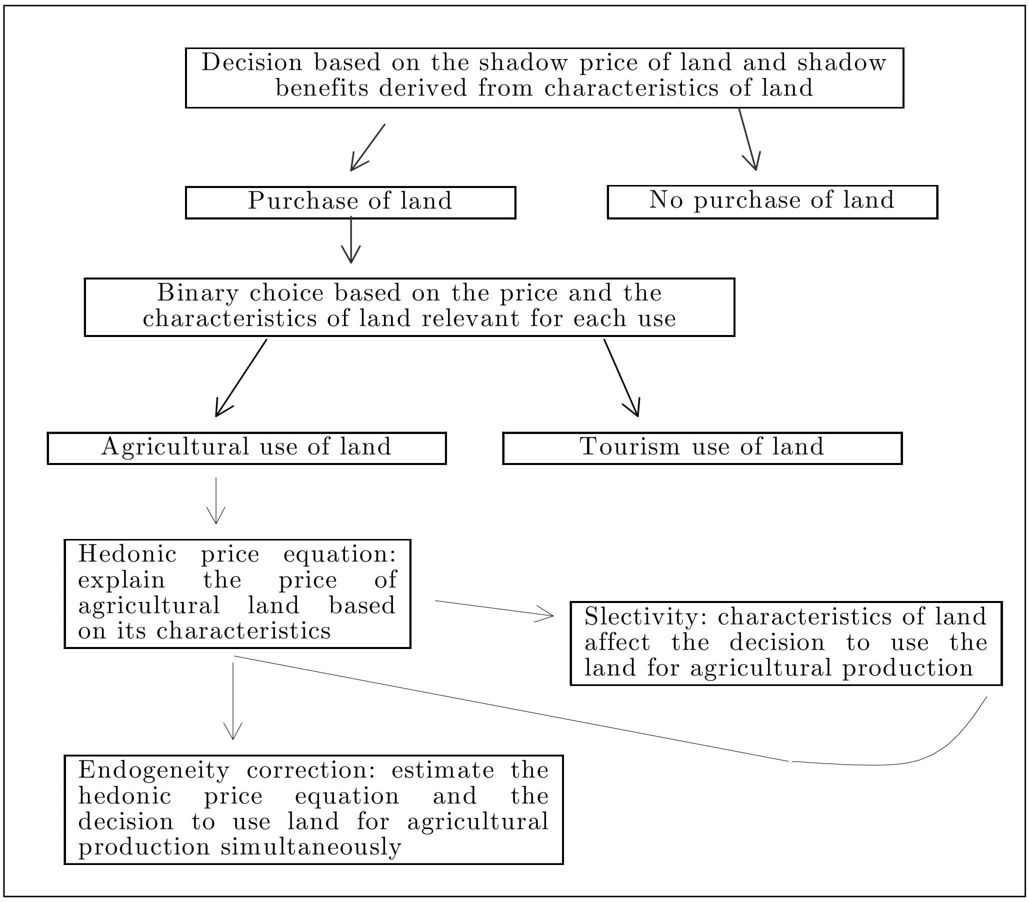
[1]Although the effects of particular ions on crop productivity vary, the usual approach is to lump all salinity into a macro measure called "total dissolved solids" (TDS).

of the saltwater interface to a distance N results in the loss of pumping activity in a given area. This arc would be zone 1. The impact of further movements of the interface is usually treated discretely, with each succeeding zone defined in terms of the impact of intrusion on pumping potential. Thus the location of a parcel of land with respect to its proximity to the sea, defines the quality of groundwater supplies accessible to owners of the parcel under consideration: the further away from the sea the parcel is, the lower the impact of seawater intrusion on its groundwater supplies. It is also worth noting that in terms of freshwater stock, instability in the interface between salt water and freshwater causes a widening of the transition (diffusion) zone. Thus as the aquifer is mined, saltwater not only replaces freshwater, but relatively larger quantities of freshwater become brackish. Instability of the interface is directly related to the rate of mining of the aquifer given a level of freshwater stock.

Proximity of a land parcel to the sea can be a proxy for the existence and extent of saltwater intrusion in the parcel's groundwater supplies. As groundwater supplies are contaminated, if other sources for irrigation water are not readily available, new wells must be drilled, coastal injection wells installed, and/or brackish groundwater treated with costly osmosis or catalysis methods. All these imply additional costs for the agricultural producer. Moreover, if salinated water is applied for irrigation, dissolved soils become concentrated in irrigated soils as part of the applied water evaporates through plants and adversely affect crop productivity. Crops vary in their sensitivity to salinity. Generally speaking however, the least sensitive crops are also the least valuable, so areas irrigated with highly saline waters tend to emphasize low-valued types of crops. Thus proximity to the sea decreases the benefits from agricultural use of a parcel of land. As a result, proximity to the sea decreases the probability of land usage for farming. That is, owners of land close to the sea substitute away from fresh groundwater as an input in their production because fresh groundwater becomes more expensive to access due to saltwater intrusion. Hence sea proximity does not only affect the value of agricultural land, but also the decision to use a parcel of land as an input in agricultural production. As shown in the empirical analysis in section 4, when this endogeneity problem is ignored, a hedonic valuation can understate the effect of groundwater salinization on the price of agricultural land. To correct for this problem we adopt a Heckman (1976, 1979) type sample selection process, as described in the next section.

The decision tree relevant for understanding the above argument is graphically presented in Figure 2, where we provide a stylized exposition of the decision process which we model theoretically and estimate empirically in this paper. Notably, for the construction of this figure, we adopt two of the assumptions that will be employed in the theoretical model of this chapter, to be presented in the following section. Firstly, we assume that the cost function is weakly separable in land, so that prices of other goods can be excluded from the decision to buy a parcel of land (Deaton and Muellbauer, 1980, pp 122-37). Secondly, we assume that each individual producer purchases only one land bundle.

Figure 2: The purchase decision and the price of agricultural land



3 Selectivity and input demand

We assume that firm specific production sets over packaged inputs of production are described by the separable cost function

$$C(p, Y_{\ell}) = G_{\ell}\left[c_{1}\left(p_{11}, ..., p_{1K}\right), ..., c_{I}\left(p_{I1}, ..., p_{IK}\right), Y_{\ell}\right], \tag{1}$$

where Y_{ℓ} the units of output produced by the ℓ^{th} producer (firm) from the use of all the packaged inputs of production, $c_{i}(.)$ a sub-function reflecting the unit cost of the i^{th} package and p_{ik} the price of the k^{th} input in this package.

In this context, producer $\ell = 1, .., L$ obtain the $k = 1, ..., K$ input indirectly, through purchasing the package $i = 1, .., I$. Applying Shephard's lemma to (1) we obtain demand for the k^{th} input in the i^{th} package by the ℓ^{th} producer,

$$q_{ik\ell} = \frac{\partial C\left(p, Y_{\ell}\right)}{\partial p_{ik}} = \frac{\partial G_{\ell}\left[.\right]}{\partial c_{i}\left(.\right)}\frac{\partial c_{i}\left(.\right)}{\partial p_{ik}}, \tag{2}$$

where $\partial G_{\ell}\left[.\right] / \partial c_{i}\left(.\right)$ represents the demand for the i^{th} package and $\partial c_{i}\left(.\right) / \partial p_{ik}$ the conditional demand for the individual k^{th} factor of production in this package, i.e. demand for k^{th} input subject to the expenditure of the i^{th} package being decided.

Here we focus on the case where producers purchase only one input package at a time, i.e. the outcome of the above optimization problem is a 'corner solution'. We therefore drop the i^{th} subscript for convenience and incorporate the selection aspect in the analysis by writing expenditure on the selected package by the ℓ^{th} producer as

$$\begin{aligned} y_{\ell} &\equiv \Sigma_{k} q_{\ell k} p_{k} = \Sigma_{k}\left(\frac{\partial G_{\ell}\left[.\right]}{\partial c\left(.\right)}\frac{\partial c\left(.\right)}{\partial p_{k}}\right) p_{k} \\ &= \frac{\partial G_{\ell}\left[.\right]}{\partial c\left(.\right)}\Sigma_{k}\frac{\partial c\left(.\right)}{\partial p_{k}} p_{k} = \frac{\partial G_{\ell}\left[.\right]}{\partial c\left(.\right)} c\left(.\right), \end{aligned} \tag{3}$$

where $\partial G_{\ell}\left[.\right] / \partial c\left(.\right) = 1$ if the package is selected by the ℓ^{th} firm and $\partial G_{\ell}\left[.\right] / \partial c\left(.\right) = 0$ otherwise.

We model the package selection decision using a simple Heckman (1976, 1979) type process,

$$I_{\ell} = g\left(x_{\ell}\right) + v_{\ell}, \tag{4}$$

where $x_{\ell} = x_{1\ell}, x_{2\ell}, ...x_{M\ell}$ is a vector of variables affecting the package choice, including quality characteristics and other firm-specific production characteristics like farming skills etc; v_{ℓ} is an error term.

Each firm has a 'reservation' value I_{ℓ} below which it does not purchase the package in question. As I_{ℓ} increases (due to quality improvements, increases in firm efficiency etc.) so does the probability of selecting this package. Using the dummy variable $D_{\ell} = 1$ when the i^{th} package is selected by the ℓ^{th} firm and $D_{\ell} = 0$ otherwise we can write

$$\begin{aligned} D_{\ell} &= 1 \text{ if } g(x_{\ell}) + v_{\ell} > I_{\ell} \\ \text{and } D_{\ell} &= 0 \text{ otherwise.} \end{aligned} \tag{5}$$

Turning to the modelling of quality heterogeneity of land parcels used by different producers, recall that $c_i(.)$ in (1) is the unit cost of the i^{th} package and define the quality augmented price of the k^{th} input in the package selected by the ℓ^{th} producer as $p^*_{k\ell} = \theta_{k\ell} p_k$, where $\theta_{k\ell} \geq 1$. Then quality heterogeneity is introduced in the analysis by writing the unit cost of the package under consideration as

$$c\left(p^*_{1\ell}, ..., p^*_{K\ell}\right) = c(\theta_{1\ell} p_1, ..., \theta_{K\ell} p_K). \tag{6}$$

At base period prices $p_k = 1$, all k, and (6) obtains the form $c(.) = c(\theta_{1\ell}, ..., \theta_{K\ell})$. Then expenditure on the package by the ℓ^{th} producer incorporating the selection decision can be written as

$$\begin{aligned} lny_{\ell} &= lnc(\theta_{1\ell}, ..., \theta_{K\ell}) + u_{\ell} \quad \text{if } D_{\ell} = 1 \\ \text{and} \quad lny_{\ell} &= 0, \text{ otherwise.} \end{aligned} \tag{7}$$

Truncation from below at $g(x_{\ell})$ implies that

$$E[u]_{D_{\ell}=1} = \sigma \frac{\phi_{\ell}(.)}{1 - \Phi_{\ell}(.)}, \tag{8}$$

where $E[.]$ denotes expectations, $\phi_{\ell}(.)$ and $\Phi_{\ell}(.)$ are the values of the probability density and cumulative functions at $g(x_{\ell})$, respectively. The simultaneity in the participation and hedonic equations is reflected by $\sigma = cov(v_{\ell}, u_{\ell})$. If $\sigma = 0$ then selectivity problems are nonexistent, and as a result the hedonic valuation of the effect of water salinity on agricultural land is statistically correct. Therefore, for $D_\ell = 1$ we may write (7) as

$$lny_\ell = lnc(\theta_{1\ell}, ..., \theta_{K\ell}) + \sigma M_\ell + \eta_\ell, \tag{9}$$

where M_ℓ is the inverse Mill's ratio[2] and η_ℓ a random error term. This equation can be estimated by OLS methods by replacing the unknown M_ℓ values with those computed at $\hat{b}(x_\ell)$, the predictions obtained from the selection equation (4).

4 Empirical analysis

The empirical analysis focuses on demand for land parcels by individual agricultural production units. The data are drawn from a Survey of Production (1999) in Kiti, a coastal region located in the island of Cyprus. Data on usage (agriculture or tourism) and price (y_ℓ, $\ell = 1, ..., L$) are collected for 193 land parcels. Also collected for these land parcels are many characteristics ($\theta_{K\ell}$, $k = 1, ..., K$) reflecting the quality of land, such as the groundwater and soil quality, fragmentation, distance from the sea, distance from the town centre and other environmental and location characteristics.

Property prices, of course, normally capture the marginal value of all possible effects of environmental and location characteristics. As discussed earlier in the paper, proximity to the sea can give rise to two opposite effects on the price of land used as an input in agricultural production: (a) the probability of land usage for farming decreases and (b) the probability of land usage for tourism development increases. To separate these two effects in our empirical analysis, we use two continuous index variables specifying the proximity of each parcel of land to the coast and the town center of the region under consideration, respectively. These indexes equal one if the parcel is located on the seaside or on the reference point chosen for the town center; and equal zero if the parcel is located at the furthest distance point relevant for the sample of data under consideration.[3]

[2]The inverse Mill's ratio is given by $\phi_\ell(.)/[1-\Phi_\ell(.)]$, where $\phi_\ell(.)$ and $\Phi_\ell(.)$ are defined as in the text. This function also represents the hazard function of the truncated normal distribution. As the truncation point increases so does $\Phi_\ell(.)$ and the greater proportion of the population (in the left-hand tail) is discarded and so the mean rises accordingly.

[3]Given that (i) Kiti (the town of the region under consideration) is located on the coast and

Assuming that $lnc(\theta_{1\ell}, ..., \theta_{K\ell})$ has the Translog form, we write expenditure on the package by the ℓ^{th} producer at base period prices (9) as

$$lny_\ell = a_0 + \Sigma_k a_k ln\theta_{k\ell} + \tfrac{1}{2}\Sigma_k\Sigma_j\gamma_{kj} ln\theta_{j\ell} ln\theta_{k\ell} + \sigma M_\ell + \eta_\ell, \qquad (10)$$

where $M_\ell = \phi_\ell\,(.)\,/[1 - \Phi_\ell\,(.)]$ predicted from a probit equation

$$D_\ell = \lambda_0 + \Sigma_s\lambda_s x_{s\ell} + v_\ell, \qquad (11)$$

where $D_\ell = 1$ when the i^{th} package is used for farming and $D_\ell = 0$ otherwise and $x_{s\ell}$ includes the $\theta_{k\ell}$ quality characteristics plus years of experience in farming (reflecting farm-specific production skills).

Table 1 reports the parameters obtained from applying (10), the hedonic rental function, to the individual land parcel data described above. The dependent variable is the natural logarithm of the per hectare price of land in Cyprus pounds. Under the heading 'selectivity correction' are the results obtained from the unrestricted version of (10) and under the heading 'no selectivity correction' are the results obtained subject to the restriction $\sigma = 0$.

Commending on the results reported in the first half of table 2, all variables in the regression model with selectivity correction have effects conforming to expectation. Expenditure on fertilizers, which serves as a proxy for the quality of soil of the parcel, has a significant negative effect on per hectare price of land, apparently indicating the effect of poor soil quality on the selling price of land. Proximity to the town centre has a strongly significant positive effect, a result conforming to the argument that this variable reflects the potential switch of land usage from agricultural production to touristic development. The positive effect of proximity to the town centre on the value of land can also reflect reduction in transportation costs for firms, since the town center is the location where trading of agricultural products takes place.

The variable of interest here, proximity to the coast, does not appear to be significant in the model where a correction for sample selection (farming versus tourism) is made by including the Mill's ratio among the explanatory variables.

(ii) touristic development is traditionally more intense closer to the town centre, the distance from the town centre serves as a proxy for the effect of sea proximity on the decision to switch land usage from agricultural production to touristic development.

Without this correction however, proximity to the coast appears to have a significant positive effect on the value of agricultural land, apparently indicating that ignoring selectivity correction ignores the fact that the costs of salinization can be offset by an increasing probability of switching to the more lucrative tourism industry. The estimated coefficient indicating the marginal shadow value of groundwater toxicity is not statistically significant at the 95% confidence level in both models (with and without correction for selectivity bias). This result suggests that the cost of increased groundwater toxicity to agriculture cannot be offset by an increasing probability of switching to tourism because, unlike proximity to the sea, this characteristic is not relevant for tourism development.

Table 1: Parameter estimates of demand for land

Variable	No selectivity correction		Selectivity correction	
	Parameter	t-ratio	Parameter	t-ratio
Intercept	9.116	32.247	8.233	20.584
Area (0.1 hectares)	-0.686E-02	-2.958	-0.638E-02	-2.803
Existence of House (dummy)	0.495	1.309	0.504	1.364
Existence of Well (dummy)	0.164	1.110	0.131	0.904
Expenditure on Fertilizers (Θ)	-0.469E-03	-2.014	-0.478E-03	-2.099
Value of Investment* (Θ)	-0.134E-04	0.891	0.162E-04	1.097
Proximity to Town (km)	0.224E-02	6.867	0.230E-02	7.200
Groundwater Extraction (m^3)	0.316E-06	1.050	0.390E-06	1.338
Groundwater Toxicity (dummy)	-0.257	-1.641	-0.227	-1.479
Proximity to Coast (km)	0.142	4.316	-0.066	-1.634
Mill's ratio	-	-	3.004	3.053
Diagnostic statistics (model with selectivity correction):				
Number of observations	193			
Mean of dependent variable	7.767			
Adjusted R-squared	0.457			
Ramsey's RESET test	0.876 [F-critical = 1.25]			
LM heteroskedasticity test	0.168 [x^2-critical = 53.7]			

* NPV of construction works and other investments, excluding machinery

Regarding the diagnostic tests reported in the lower part of Table 1, it is also worth notingRamsey's (RESET) specification test suggests correct specification of the estimated model. Also is also worth noting that the LM-test for heteroscedasticity suggests acceptance of the null hypothesis of homoscedastic residuals.

In interpreting the empirical results above recall that in the environmental valuation literature the marginal implicit price of a productive characteristic of land can be derived by differentiating the hedonic value function with respect to that characteristic. In this paper, the marginal implicit price for coast proximity measures the producer's equilibrium marginal willingness to pay (MWTP) to avoid the marginal increase in the salinization of fresh groundwater supplies beneath her/his land.[4] This MWTP for avoiding coast proximity is estimated to be equal to $10.7 per hectare of land in the model with selectivity correction whereas the model without selectivity correction indicates that the agricultural producer is willing to pay $11.5 per hectare of land to gain a marginal increase in groundwater salinization. Of course, the latter result indicating positive willingness to pay by the average farmer in order to "gain" marginal degradation in one of the environmental attributes of his land, is counter intuitive. However, it can be explained by the fact that the model without selectivity correction estimates the MWTP for sea proximity which increases the value of land for prospective touristic uses.

5 Conclusion

The argument put forward in this paper is that hedonic valuations can be misleading when the quality characteristics intended for this valuation have sample selection implications. We consider this argument in the case of land close to the seaside that can be used either as an input in agricultural production or for touristic development. In this case, proximity to the sea can reduce the quality of land as an input in agricultural production, due to salinization of groundwater supplies, but increases the probability of switching the land usage from agriculture to the lucrative tourism market. Deterioration of the groundwater supplies can then appear to have a positive effect on the price of agricultural land.

In the empirical analysis of the paper the quantifiable water quality attribute is groundwater salinity. Salinity is ceteris paribus increasing with sea proximity, the latter being an attribute itself valued in tourist development but not agricul-

[4]This leads us naturally to the question of whether producers' inverse demand functions for factor inputs can be identified from observations of marginal implicit prices and quantities. The answer depends on the circumstance of the case. In the model estimated in this paper the hedonic price function is nonlinear and as a result, different producers selecting different bundles of characteristics will have different marginal implicit prices for groundwater quality.

tural production. This is the source for sample selectivity bias. The empirical econometric analysis, based on data collected from surveying 282 owners of land parcels, uses Heckman's two step estimation procedure and validates the hypothesis that failing to correct for sample selection results in a biased valuation of groundwater salinity as an attribute of agricultural land. The estimated marginal WTP by the average farmer for fresh groundwater derived from the econometric estimation when correcting for sample selection bias, is statistically not different from zero, whereas without this correction this value appears to have a significant positive effect on the value of land. This result indicates that ignoring selectivity correction ignores the fact that the cost of lower groundwater quality can be offset by an increasing probability of switching to the more lucrative tourism industry. Furthermore, it shows that in a model where the selection and hedonic valuation aspects of agricultural land are modelled simultaneously, low quality groundwater supplies do not have a positive effect on the price of agricultural land.

The overall conclusion of this paper is that researchers and policy makers in environmental valuation must be careful when employing hedonic techniques to derive willingness to pay for environmental and/or resource quality; it is possible for these techniques to give rise to misleading conclusions about the effect of an environmental attribute on producers (or consumers) welfare if potential biases from inappropriate sample selection criteria are ignored.

The arguments raised in the paper have implications for hedonic price analysis applied to other goods whose quality characteristics can affect sample selection. For example, the approach followed in this paper may be used to correct for traffic noise appearing to have a potentially positive valuation effect on residential housing because houses in main roads have a high probability of being converted to business properties.

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