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A HEDONIC MODEL OF INTERREGIONAL WAGES, RENTS AND AMENITY VALUES

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ABSTRACT

This paper develops a general multimarket hedonic model appropriate for a national, interregional study of wages, housing prices and location-specific amenities. The model encompasses the effects of interregional location, intraurban location and city size. Typically, hedonic studies focus on a single market such as labor or housing and ignore interactions implicit in a more global compensation mechanism. Examination of the comparative statics of our model indicates that single market differentials are partial prices and are unreliable measures of amenity values in an interregional context. Unbiased amenity values are estimated for a comprehensive set of amenities using data on housing prices for 34,414 households and wages for 46,004 workers from the 1980 Census of Population and Housing. Statistically significant differences in housing prices and wages are found due to amenities.

The hedonic approach values location-specific amenities by measuring the price differentials that arise across certain market goods. The basic concept is simple: If individuals are to locate in both desirable and undesirable locations, undesirable locations must carry lower prices. Applied to interregional amenity differences, a standard hedonic analysis estimates amenity prices by regressing interregional wages on local amenities. Regression coefficients are then interpreted as marginal amenity values.

Two major difficulties arise in interpreting these wage-based, interregional results. First, recent research suggests that land rent or housing price differentials play an important role in compensating for interregional amenity differences. Graves (1983) rejects the artificial dichotomy between interregional job-related moves and intraurban housing-related moves. Graves' empirical analysis demonstrates the significant impact of housing prices on interregional location decisions. Rosen (1979) and Jones (1980) suggest that urban locations are best viewed as tied bundles of wages, amenities, and rents. Roback (1982) constructs an analytical model to show that interregional amenity differences are indeed bid into interregional differences in both wages and rents. Nevertheless, the general relevance of these results to hedonic analysis remains unclear. The Roback model, for instance, ignores the potentially important compensating role of intraurban commuting costs. Henderson (1982) argues that the costs of intraurban commuting -- even within a relatively simple monocentric city -- tend to cancel out the interregional housing price effect.

A second difficulty of interpretation stems from the relation between market price differentials and the amenity values held by individuals. As suggested by Cropper (1981), the hedonic coefficients obtained in a conventional wage based analysis are unlikely to be unbiased estimates of marginal amenity values. In a general interregional setting, wage and rent gradients may be a mixture of demand and supply effects and are not necessarily interpretable as amenity values. Roback develops a procedure for deriving unbiased amenity values from measured wage and rent differentials but its validity within an urban structural model has not been established.

The objective of this paper is to clarify the role of wages and rents in an interregional hedonic analysis of amenity values. The analysis is organized in three sections. The first section develops an analytical model that combines a model of interregional location with a conventional model of intraurban structure. The resulting model captures the essential features of location discussed by Rosen and Jones. The analytical model is used to determine whether both wage and land rent differentials are likely to arise across interregional amenity differences.

The second section uses the identified price gradients to construct a policy-relevant, unbiased estimator of net amenity values. To facilitate empirical application, the estimator is extended to include housing price differentials. An unbiased estimate of amenity value can be computed from estimates of (1) the wage differential and (2) the housing price differential.

The third section implements the interregional amenity valuation procedure using microdata from the 1980 Census of Population and Housing. Benefit estimates based on the unbiased estimator are compared with estimates of the wage and housing price differentials. The unbiased valuation procedure is shown to resolve a number of empirical contradictions that would occur with either a simple wage or rent based approach.

Wages, Rents, and Interregional Amenities

In a general model of location, the opportunities offered by a particular location are viewed as a tied package of wages, rents, and local amenities. As individuals attempt to access a favorable set of amenities, local wages are discounted and local rents are bid up. Individuals remain at a particular location as long as they cannot improve their well-being by an appropriate move. At equilibrium levels of wages and rents, individuals are indifferent across the wage, rent, and amenity packages offered by different locations. In the models of both Rosen (1979) and Jones (1980), firms also play a role: If wage differentials are to persist, there must be some productivity advantage to higher wage locations. Otherwise, interregional product price competition would force higher wage or higher product price firms to shut down.

Within the general model of location, however, the interaction between intraurban structure, rents, and amenities is not clear. Jones suggests that intraurban commuting costs create a fundamental inelasticity in the local supply of desirable sites.[1] This inelasticity leads Jones to conclude that interregional amenity differences are -- at least in part -- bid into land rents. Henderson (1982), however, views intraurban structure in a somewhat different light. He considers the example of two monocentric cities with equal radii and equal opportunity costs to land at the rural-urban fringe. Since individuals within each city are, by assumption, indifferent to an intraurban move, rent gradients within each city are anchored by the opportunity cost of land at the rural-urban fringe. Given that the opportunity cost of land is fixed by nonurban forces, any amenity difference between the two cities is bid solely into wages. Land rents are determined by commuting costs and the opportunity costs of land at the rural-urban fringe.

Thus, for Henderson, intraurban structure ensures that interregional amenity differences are bid into wage differentials alone.

The remainder of this section seeks to clarify the role of intraurban structure and land rents in compensating for interregional amenity differences. The analysis begins by developing a simple general equilibrium model of wages, rents, and local amenities.[2] The model's interregional structure parallels the framework discussed by Rosen (1979) and specified by Roback (1982). In addition, the model also accounts for the intraurban features discussed by Jones (1980), Henderson (1982) and Haurin (1982).

Intraurban Structure and Interregional Location

The objective is to develop a model that identifies the price mechanism that compensates for interregional differences in amenities. To allow for interregional migration, individuals and firms are presumed - at least at the margin - to be freely mobile across urban areas. Once located within a particular city, however, firms and individuals are restricted to the opportunities offered by the local labor market, the local land market, and the level of local amenities.

Each urban area is composed of a central business district (CBD) and a residential zone that encircles the CBD. Firms locate within the CBD, purchase local labor, and produce a consumption commodity that is priced in international markets. Individuals purchase land within the residential zone, commute to the CBD, and sell labor at the local wage. For simplicity, local amenities are distributed uniformly across the urban area.

An interregional equilibrium implies that firms cannot reduce their costs and individuals cannot improve their well-being by relocation. With (internally) constant returns to scale, technology and free mobility, firms earn zero equilibrium profits and individuals attain equal utility. The equilibrium conditions are used to solve for wage and rent gradients as a function of local amenities. To derive these results, individuals and firms are described in additional detail.

Individual well-being is defined by a utility function

$$(1) \qquad u = u(x,s,e,L)$$

where x is the composite consumption good, s is an index of amenities, e is leisure time, and L is residential land. Each individual is endowed with one unit of labor and a fixed amount of leisure time, e. An individual locates within an urban area by purchasing residential land, L_r, at a distance r from the CBD. In an urban area of radius r*, land prices, p_r, vary from p_0 at the edge of the CBD to p_a at the rural-urban fringe. The price p_a is the opportunity cost to residential land at the rural-urban fringe.

Once located within a residential zone, an individual enjoys the level of amenities, s, available within the particular urban area. To earn the local wage, the individual commutes to the CBD. Commuting reduces available leisure time at a rate of t units of leisure per unit of distance traveled. Earnings not spent on a residential location are used to purchase the consumption good, x, at a price, p_x, fixed by international markets. For simplicity, prices are normalized so that p_x equals one. Overall, an individual that locates in an urban area defined by w, s, and p_r, $p_r \in [p_0,\ldots,p_a]$, attains a level of utility

$$u_r = \max[\ u(x,s,e,L_r)\ |\ w = p_rL_r + x,\ e = \bar{e}-tr\ ]$$
$$= v(\bar{e}-tr,p_r,w,s) \tag{2}$$

where p_x is suppressed since it always equals one. Utility is increasing in w ($v_w > 0$) and decreasing in both r and p_r ($v_r,v_p < 0$). Utility is increasing in s ($v_s > 0$) if s is an amenity and decreasing ($v_s < 0$) if s is a disamenity.

A residential intraurban equilibrium is reached when, for a given wage, the utility of any individual within the residential zone cannot be improved by relocating within the city. Therefore, rents at radius r,p_r, must rise or fall until

$$u^0 = v(\bar{e}-tr,p_r,w,s) \tag{3}$$

for all $r \in [0,r^*]$ where u^0 is the intraurban level of utility and r^* is the rural boundary of the residential zone. Letting p_a be the opportunity cost of rural land, equation (3) implies that the rural-urban boundary adjusts until

$$u^0 = v(\bar{e}-tr^*,p_a,w,s)\ . \tag{4}$$

Thus, with the overall system, the rural-urban boundary is endogenous along with wages and rents.

The population of an urban area is also endogenous and depends upon the density of settlement within the residential zone. At a distance r from the CBD, the quantity of land demanded by an individual is

(5) $L_r = -v_p/v_w = L_r(\bar{e}-tr,p_r,w,s)$.

Since the total amount of land at radius r is $2\pi r$, the population residing at radius r is $2\pi r/L_r$. The total population residing within the urban area is

(6) $N = \int_0^{r^*} (2\pi r/L_r)dr$

Assuming that land is a normal good, the partial equilibrium effect of a wage increase is to reduce both residential density and population size ($N_w \leq 0$). Moreover, if an intraurban equilibrium is to be maintained, equations (3) and (4) imply that the rent gradient must shift upward with an increase in r^*. Thus, an increase in r^* implies a partial equilibrium increase in the urban population ($N_w > 0$).

Local firms provide the demand for local labor. Firms locate within the CBD and produce a consumption good x with technology that is constant returns to scale in labor and capital. By assuming a point CBD, land does not enter into production. As in the Roback (1982) specification, the consumption good is sold and capital is acquired at constant prices in an international market. At equilibrium, unit production costs within the CBD equal the unit product price.

(7) $1 = g(s,N)c(w)$

where $g(s,N)c(w)$ is a firm's unit cost function with the price of capital left implicit. Both amenities and the agglomeration effects of city size may shift the productivity of individual firms. Unit costs decrease if s is an amenity to firms ($g_s < 0$) and increase if s is a disamenity ($g_s > 0$). Agglomeration effects may be productivity enhancing for small city sizes ($g_N < 0$ for some $N < N^0$) and may eventually reduce productivity for large city sizes ($g_N > 0$ for some $N > N^0$).

At an interregional equilibrium, firms earn zero profits and individuals attain the same level of well-being within each urban area. Denoting the equilibrium level of utility as u^0 and supposing that the amenities of each urban area are described by some choice of s, the equilibrium wage, rents, residential radius, and population size of each urban area satisfy equations (3), (4), (6), and (7). Rewriting these equations reversing the order of equations (3) and (4), the system of equations, S1, that describes the interregional equilibrium is

$$\text{(S1)} \qquad \begin{aligned} u^0 &= v(\bar{e}-tr^*,p_a,w,s) \\ u^0 &= v(\bar{e}-tr,p_r,w,s) \\ N &= \int_0^{r^*} (2\pi r/L_r)dr \\ 1 &= g(s,N)c(w) \end{aligned}$$

The first equation in S1 describes utility possibilities at the rural-urban fringe for an urban area offering amenities s. The second equation describes utility possibilities at an arbitrary radius r within a residential zone. The third equation summarizes local labor supply conditions and the fourth equation embodies local labor demand conditions. Using S1, one can solve for: (1) the comparative static effects of a change in s on w, p_r, r^*, and N, and (2) the implicit price of s appropriate for amenity valuation.

Interregional Wage and Rent Differentials

The effects of a marginal change in s are derived by taking the total differential of S1 and then solving the resulting system of equations for dr^*/ds, dp_r/ds, dw/ds, and dN/ds. To demonstrate the major features of these comparative static results, two simplifying assumptions are imposed.[3] First, it is assumed that the utility function is additively separable in w and s.[4] Second, population size -- local labor supply -- is assumed to increase with an increase in the local wage. From equation (6), the wage-induced effect on local labor supply is $N_w^S = N_r(dr/dw) + N_w$ where dr/dw can be determined from equation (4). The assumption that $N_w^S > 0$ implies that the wage-induced change in population at the rural-urban fringe offsets the effect of a change in population due to a wage-induced change in residential density. Subject to these two assumptions, the comparative static results are

$$(8) \qquad dw/ds = -(v_w^*/v_r^*)[g_s c v_r^*/v_w^* - p_s^* g_N c N_r]/D,$$

$$(9) \qquad dp_r/ds = (1/L_r)[p_s(gc_w + N_w g_N c) - g_s c]/D,$$

$$(10) \qquad dr^*/ds = -(v_w^*/v_r^*)[p_s^*(gc_w + N_w g_N c) - g_s c]/D, \text{ and}$$

$$(11) \qquad dN/ds = -(v_w^*/v_r^*)[p_s^* N_r g c_w + g_s c N_w^S v_r^*/v_w^*]/D$$

where $v = v(\bar{e}-tr, p_r, w, s)$, $p_s = v_s/v_w$, $v^* = (\bar{e}-tr^*, p_a, w, s)$, $p_s^* = v_s^*/v_w^*$, and $D = g_N c N_w^0 + gc_w$. By the separability assumption, $p_s = p_s^*$. The determinant D is positive as long as the local labor market is Walrasian stable.[5] Lastly, note that N_w^S -- assumed to be positive -- enters only in the determination of dN/ds.

Equations (8) through (11) describe the differences in wages, rents, residential zone radii, and urban population that arise due to interregional amenity differences. Each differential depends on a rather complex interaction of structural effects. Note that since an individual's marginal valuation of an amenity change is simply $p_s = v_s/v_w$ (or $p_s^* = v_s^*/v_w^*$ at the rural-urban fringe), neither the wage nor rent differential is directly interpretable as an amenity valuation. Additionally, there is no straightforward structural assumption that leads to a zero rent differential as long as s is an amenity (or disamenity) to either individuals or firms. Generally, the empirical sign and size of both the rent and wage differentials depend on the specific elements that comprise equations (8) and (9).

Table 1 presents comparative static results for a range of possible assumptions regarding (1) agglomeration effects, (2) the effect of amenities on individual well-being, and (3) the effect on firm productivity. In reviewing the results, note first that by the column under $v_s = 0$, scale effects operate only in conjunction with the amenity impacts on individuals. Second, if s is an amenity to both individuals ($v_s > 0$) and firms ($g_s < 0$), N is certain to increase -- more amenable cities have larger populations. However, in terms of wages and rents, if agglomeration effects reduce productivity ($g_N > 0$), the increase in city size tends to offset the beneficial productivity impact of s. Therefore, with s an amenity to both individuals and firms and with $g_N > 0$, wages, rents, and the city's boundary may either increase or decrease with a change in s.

In the case where s is beneficial to individuals but neutral with regard to unit costs, city size also increases unambiguously with s. Again, a more amenable city is larger. Given the neutrality of s on production, wages rise

Table 1. The Impact of a Small Change in Amenities (ds>0) on Equilibrium Values of r*, p_r, w, and N

Impact on Unit Costs	Differential	Impact on Individuals[a]			
		$v_s > 0$			$v_s = 0$
		$g_N < 0$	$g_N = 0$	$g_N > 0$	$g_N \gtrless 0$
$g_s < 0$	dw	+	+	- +	+
	dp_r, dr*	+	+	- +	+
	dN	+	+	+	+
$g_s = 0$	dw	+	0	-	0
	dp_r, dr*	+	+	- +	0
	dN	+	+	+	0
$g_s > 0$	dw	- +	-	-	-
	dp_r, dr*	- +	- +	- +	-
	dN	- +	- +	- +	-

a

A "+" ("-") indicates that $dz/ds > 0$ ($dz/ds < 0$). A "- +" indicates that the sign of dz/ds may be positive or negative.

or fall solely with the impact of agglomeration on productivity. However, if wages decline, the decline in income leads to a lower residential density. Lower population density, in turn, leads to a decrease in both p_r and r^*.

In the case where s is an amenity to individuals but detrimental to productivity, most of the comparative static effects are ambiguous. Population, wages, and rents may rise or fall in almost all cases. However, if $g_N = 0$, only the disamenity effect on unit costs is operative and the outcome is a lower wage. If $g_N > 0$, detrimental agglomeration effects combine with the disamenity impact of s on productivity to produce a lower wage.

The results displayed in Table 1 underscore the importance of accounting for both the wage and rent differentials when valuing an amenity change. For example, with s an amenity to both firms and individuals ($g_s < 0$, $v_s > 0$) and $g_N < 0$, an independent consideration of the wage differential alone would seem to indicate that s is a disamenity when in fact it is an amenity. The independent evaluation of wage differentials overlooks entirely the compensatory impact of the rent differential.

Estimating Amenity Values

Wage and rent differentials compensate individuals for interregional amenity differences. Because they are mixtures of a number of structural elements, measured market price differentials are not unbiased estimators of amenity values. The objective of this section is to describe an unbiased estimator of amenity value that is based upon the price differentials of the last section. To facilitate empirical application, the estimator is also extended to encompass housing price differentials in place of land rent differentials.

Amenity Values Based on Wage and Land Rent Differentials

To develop the amenity value estimator, consider two urban areas that differ in amenities by a small amount, ds. In equilibrium, utility opportunities within each urban area are equal.[6] Taking the total differential of equation (3) this difference implies that

$$(12) \qquad du = 0 = v_p dp_r + v_w dw + v_s ds.$$

Rearranging, the marginal valuation of the change in s is

$$(13) \qquad f^r = v_s/v_w = -(v_p/v_w)(dp_r/ds) - dw/ds = L_r(dp_r/ds) - dw/ds \ .$$

By equation (13), an unbiased amenity value estimator is the sum of (1) a residential land expenditure differential, $L_r(dp_r/ds)$, and (2) the wage or earnings differential, dw/ds.[7]

Except for the notation to denote location within the residential zone, the general estimator, f^r, is virtually identical to the interregional estimator proposed by Roback (1982). Moreover, if utility functions are additively separable in s and w, f^r and the land expenditure differential are constant across an urban area. In this case the notation for intraurban location may be dropped and equation (13) rewritten as

$$(14) \qquad f = dz/ds - dw/ds$$

where $dz/ds = L_r(dp_r/ds)$ is a constant for all r within the residential zone. Overall, then, the amenity valuation results of Roback's pure interregional case carry over to the case involving urban structure.

An Amenity Value Estimator Based on Housing Price and Wage Differentials

Housing price differentials are of interest both empirically and conceptually. An estimator based on housing price differentials facilitates empirical application since housing prices are more easily observed than land rents. Conceptually, since consumers usually deal directly in the housing market, it is more appropriate to consider housing prices. Land is one of the attributes of housing. Local housing production introduces an additional compensatory mechanism into the local economic context; see Tolley (1974). As local wages rise, increasing labor costs lead to an increase in the price of housing. The resulting increase in housing prices dampens the impact of a wage increase. To capture the structural effects of housing price differentials, two refinements in the system of equations S1 are required: (1) a housing cost function is required to link wages and rents to housing prices and (2) the utility function of equations (3) and (4) must be defined on housing prices.

In a given urban area, housing costs are subject to local wage, rent, and amenity conditions. To describe the housing cost function, it is assumed that inputs are requisitioned at the CBD and transported for assembly and sale at a particular point r within the residential zone. Unit production costs are the sum of two components: (1) the costs of assembly, $h(w,p_r,s)$ where s is a factor neutral shifter, and (2) the costs of transportation to point r, d(r), where the marginal costs of additional distance are assumed to be positive.

Free entry and exit of firms ensures that the product price of the local good, q_r, equals unit costs, or

$$(15) \qquad q_r = h(w,p_r,s) + d(r) .$$

At the rural-urban fringe, unit costs are

$$(16) \qquad q_* = h(w,p_a,s) + d(r^*) .$$

Individuals locating in the city now maximize utility subject to the local wage, the disutility of commuting, the constant price of the consumption good, and local housing prices. An individual that locates at a distance r from the CBD enjoys a utility level

$$(17) \qquad u^0 = v(\bar{e}-tr,q_r,w,s) .$$

An intraurban equilibrium is achieved when individuals at the rural boundary obtain the same level of utility,

$$(18) \qquad u^0 = v(\bar{e}-tr^*,q_*,w,s) .$$

Equations (6), (7), (15), (16), (17), and (18) form a system of equations that determines equilibrium levels of wages, land rents, housing prices, city population size, and the rural boundary. The system can be reduced in size by substituting equation (15) into equation (17) and equation (16) into equation (18). The result is a system

$$(S2)\qquad u^0 = v(\bar{e}-tr^*,h(w,p_a,s)+d(r^*),w,s)$$

$$u^0 = v(\bar{e}-tr,h(w,p_r,s)+d(r),w,s)$$

$$N = \int_0^{r^*}(2\pi r/L_r)dr$$

$$1 = g(s,N)c(w)\ .$$

Once equilibrium wages and land rents are found by means of S2, q_* and q_0 can be computed by equations (15) and (16).

The comparative static effects of a change in s on wages, land rents, the rural boundary, and city population size can also be computed using S2. With these effects computed using S2, comparative static results in housing prices can be computed using the total differential of housing production costs. Specifically, using equations (16) and (15),

$$(19)\qquad dq_*/ds = h_w dw/ds + h_p dp_a/ds + h_s$$

and

$$(20)\qquad dq_r/ds = h_w dw/ds + h_p dp_r/ds + h_s\ .$$

Equations (19) and (20) demonstrate that the housing price differentials are weighted sums of the wage and land rent differentials. The compensatory impact of a wage increase may indeed be dampened by a subsequent increase in local prices. Moreover, given the impact of wages and the amenity effect, h_s, the comparative statics of land rents cannot be translated directly to the comparative statics of housing prices.

Empirically, it is possible to use measured housing price and wage differentials to compute the implicit prices of amenities. Taking the total differential of equation (17) and rearranging, the marginal value of s at any given point r within the residential zone is

$$(21) \qquad f^r = v_s/v_w = k_r dq_r/ds - dw/ds$$

where $k_r = -v_{q_r}/v_w$ is the quantity of housing purchased at radial point r. Once again the marginal value of s can be measured in terms of the sum of market price differentials. The first term on the right hand size of equation (21) is the change in housing expenditures due to the change in amenities. The second term on the right hand size is total earnings differential.[8] Given an estimate of the equilibrium housing expenditure differential ($k_r dq_r/ds$) and an estimate of the earnings differential (dw/ds), f^r can be computed without explicit reference to the land rent gradient, dp_r/ds. The full hedonic price (f^r), equation (21), captures the global compensatory mechanism of wages, rents, and location. As such, the hedonic price measures the benefit of an improvement in amenities.

An Empirical Analysis

The hedonic model of interregional wages, rents and amenity values is used to estimate marginal amenity values for a comprehensive set of location-specific amenities. Amenity values for 16 amenities are based on coefficients from housing hedonic and wage hedonic equations which estimate the $k_r dq_r/ds$ and dw/ds.

The core of the data set is composed of individual records from the 1 in 1000 Public Use "A" Sample of the 1980 Decennial Census. The starting sample size is approximately 225,000 individuals and 88,000 households located in 285

Standard Metropolitan Statistical Areas (SMSAs). More aggregate variables which pertain to climatic, environmental, urban conditions and the labor market are merged to this core. The unit of observation for these merged variables is the county, SMSA or industry.

The dependent variable in the housing hedonic equation is actual or imputed monthly housing expenditures for 1980. Census-based nonamenity control variables included are: units at address, age of structure, stories, rooms, bedrooms, bathrooms, condominium status, central air, sewer, lot size exceeds 1 acre, renter status, and renter interaction terms for each of these variables. The dependent variable in the wage hedonic equation is computed as annual earnings divided by the product of annual weeks worked and usual hours per week. The sample is restricted to wage and salary earners with positive reported total earnings. Census-based nonamenity control variables included are: experience, experience squared, gender, gender interactions with experience and experience squared, race, gender interaction with race, marital status, gender interaction with marital status, gender interaction with children under 18, schooling, disabled, school enrollment status and occupation dummies for 5 of 6 occupations. The percent of the industry covered by unions as reported by Kokkelenberg and Sockell (1985) is also included.

The amenity variables are common to both hedonic equations. Six variables for climatic conditions are taken from Comparative Climatic Data prepared by the National Climatic Data Center. Coast is one if the county touches an ocean or a Great Lake and central city is one if the individual resides in the central city according to the Census. The teacher-pupil ratio is based on school district and county data on enrollment and salaries found in Volumes 3 and 4 of the 1982 Census of Governments. The crime variable is based on figures reported in the U.S. FBI Uniform Crime Reports for the United States. The environmental variables are based on data from four different sources. The ambient concentration of total suspended particulate (TSP) for each county is calculated from U.S. E.P.A. SAROAD data. Visibility data were obtained from reports by Trijonis and Shapland (1979) and daily weather observations supplied by the National Climatic Center. The number of Superfund sites in the individual's county is based on information published in the Council on Environmental Quality report, Environmental Quality 1982. Two of the last three variables are counts of activity in the individual's county of residence and are based on information available on the Resource Conservation and Recovery Act (RCRA) Application for Hazardous Waste Permit Tape which was obtained from the U.S. E.P.A. The counts are for the number of treatment, storage and disposal (TSD) facilities for hazardous wastes, and the number of National Pollution Discharge Elimination Systems (NPDES) water pollution dischargers in the county of residence. The landfill waste variable also comes from the RCRA tape and is the total quantity of licensed waste for landfills in the county.

Housing and wage hedonic equations are estimated for 34,414 households and 46,004 workers. A limited Box-Cox search was done over functional forms of $\frac{Y^{\lambda}-1}{\lambda} = b_0 + \sum_{i=1}^{n} b_i \frac{X_i^{\gamma}-1}{\gamma} + \varepsilon$, where Y is either rent or wage, the X_i are the independent variables, λ was varied from +1.2 to -0.4, and γ was either 1 (linear) or 0 (logarithm). The best functional form for the housing hedonic was for $\lambda = 0.2$ and $\gamma = 1$ and the best form for the wage hedonic was $\lambda = 0.1$ and $\gamma = 1$. These functional forms yielded the highest values of the log likelihood functions. The amenity variables make statistically significant contributions to the hedonic equations. For the housing hedonic regression the R^2 increases from 0.5870 to 0.6624 with the addition of amenity variables. A test for the joint significance of the amenities gives a calculated F value of 480.0. For the wage hedonic regression the R^2 increases from 0.3078 to 0.3138 and a joint significance test results in an F value of 25.0. The hedonic regressions indicate that significant differences in housing prices and wages arise due to amenities.[9]

The parameter estimates for the 16 amenity variables included in each equation are used to construct the price differentials and amenity values for the amenities. Market price differentials and unbiased estimates of amenity values are reported in Table 2.[10] For sunshine, coast and teacher-pupil ratio the partial implicit prices and the corresponding full amenity values indicate that these factors are amenities. For humidity the two partial prices and the full amenity value indicate that humidity is a disamenity. For the other 12 amenity factors, the two partial prices for each factor are of opposite signs and the net amenity effect is determined by the magnitudes of the partial prices. Consistent with the interregional model virtually all of the full amenity values which account for compensation in both markets, result in intuitively appealing classifications. For example, the partial prices from the housing market indicate that windspeed and Superfund sites are amenities, but these prices are more than offset by the partial prices from the labor market. The full amenity values, which include the partial prices from the labor market, indicate that windspeed and Superfund sites are marginal disamenities, as expected. Only visibility, which has a standard error more than two times as large as the full amenity value, appears to be misclassified. Perhaps this result is due to multicollinearity with TSP, humidity and precipitation.

The benefits of a policy which moderately improves amenities can be estimated using the estimated amenity values. For instance, consider a national policy which increases by 10 percent the teacher-pupil ratio and visibility and decreases by 10 percent the violent crime rate, TSP, water pollution dischargers, Superfund sites, landfill waste, and toxic disposal sites. The annual value per household of this improvement is given by the sum of the values for these amenity factors shown in the last column in Table 2, $262.87 per household per year. An estimate of the aggregate benefit can be made by multiplying $262.87 times the number of households. Since there were 80,776,000 households in 1980 the estimated aggregate benefit is $21.2 billion per year.[11] If the estimate were based on the housing differentials alone instead of the conceptually correct amenity values, the estimated aggregate benefits would be approximately $3.3 billion per year - 84 percent too low. If the estimate were based on the wage differentials alone, the estimated benefits would be $18.0 billion per year - 15 percent too low. The valid estimate of amenity values accounts for compensation in both housing and labor markets. Also, the amenity values are useful for estimating the benefits of a policy which moderately improves only some of the amenities. For instance, consider a national policy which decreases by 10 percent the number of Superfund sites, and number of toxic disposal sites and amount of landfill waste. The annual value per household is given by the sum of the values for these three disamenities shown in the last column of Table 2, $17.43. The estimated benefit of the decreases for all households in 1980 is approximately $1.4 billion per year. If only the wage differentials were used, the estimated benefit would be approximately $4.0 billion per year -- 186 percent

Table 2. Market Price Differentials and Amenity Values for an Average Household[a] (1980 dollars per year)

Amenity (mean and units)	Market Price Differentials one unit change: Housing Expenditure Differential[b]	Market Price Differentials one unit change: Wage Differential[c]	Amenity Values[d]: One Unit Change	Amenity Values[d]: Ten Percent Change
Climate				
Sunshine (61.1 percent of total days)	$ 25.62 (2.82)	$ 22.90 (15.17)	$ 48.52 (15.43)	$ 296.52
Precipitation (32.0 in./yr.)	- 12.56 (1.78)	36.06 (9.54)	23.50 (9.71)	75.20
Humidity (68.3 percent)	- 25.52 (3.01)	- 17.89 (16.01)	- 43.42 (16.29)	-296.52
Windspeed (8.89 mph)	142.61 (10.40)	-240.13 (54.55)	- 97.51 (55.54)	- 86.73
Heating Degree Days (4326 degree days)	- 0.17 (0.01)	0.09 (0.06)	- 0.08 (0.06)	- 34.59
Cooling Degree Days (1162 degree days)	- 0.91 (0.03)	0.55 (0.13)	- 0.36 (0.13)	- 41.44
Coast (yes=1, 0.33)	390.17 (29.63)	77.54 (158.34)	467.72 (161.09)	-
Urban Conditions				
Central City (yes=1, 0.29)	-489.00 (30.43)	1134.02 (162.26)	645.02 (165.09)	-
Teacher-Pupil Ratio (0.08 teacher/pupil)	7,620 (859)	13,620 (4,619)	21,250 (4,698)	169.76
Violent Crime Rate (647 crimes/100,000 people)	0.51 (0.04)	- 1.55 (0.19)	- 1.03 (0.19)	- 66.83
Environment				
Total Suspended Particulate (73.2 μ/m^3)	- 6.42 (0.69)	6.06 (3.71)	- 0.36 (3.77)	- 2.64
Visibility (15.8 miles)	- 9.97 (1.32)	6.55 (6.90)	- 3.41 (7.03)	- 5.39

(Continued next page)

Table 2. Market Price Differentials and Amenity Values for an Average Household[a] (1980 dollars per year) - (Continued)

Water Pollution Dischargers (1.51 dischargers in county)	- 89.49 (5.53)	12.81 (30.06)	- 76.68 (30.56)	- 11.60
Superfund Sites (0.88 sites in county)	161.09 (8.32)	-267.16 (42.91)	-106.07 (43.70)	- 9.36
Landfill Waste (477 hundred million metric tons in county)	0.12 (0.01)	- 0.23 (0.05)	- 0.11 (0.05)	- 5.38
Toxic Disposal Sites (46.4 sites in county)	2.62 (0.29)	- 3.20 (1.53)	- 0.58 (1.56)	- 2.69

[a] A positive amenity value indicates an amenity. A negative amenity value indicates a disamenity.

[b] The annual housing expenditure differential is computed as:

$$b^h_{s_i}(12)(\overline{Rent})^{1-\lambda_h}$$ where $b^h_{s_i}$ is the coefficient for amenity i in the housing hedonic regression, λ_h is the power transformation from a Box-Cox search and equals 0.2, $\overline{Rent}$ is the sample average monthly housing expenditure of $462.93, and 12 is the number of months per year. The standard errors shown below the rent differentials are calculated assuming Rent and λ_h are constants.

[c] The annual wage differential is computed as:

$$- b^w_{s_i}(\overline{Workers})(\overline{Hours})(\overline{Weeks})(\overline{Wage})^{(1-\lambda_w)}$$ where $b^w_{s_i}$ is the coefficient for amenity i in the wage hedonic regression, λ^w is the power transformation from a Box-Cox search and equals 0.1, $\overline{Wage}$ is average hourly earnings and equals $8.04, $\overline{Workers}$ is the average number of workers per household and equals 1.54, $\overline{Hours}$ is the average number of hours worked per week and equals 37.85, $\overline{Weeks}$ is the average number of weeks worked per year and equals 42.79. The standard errors shown below the wage differential are calculated assuming Workers, Hours, Weeks, Wage and λ_w are constants.

[d] The full amenity value is the sum of the wage and housing price differentials. Rounding of the differentials causes minor differences between the sums of the differentials and the full amenity values. The standard errors shown below the full prices are calculated assuming the covariance between the partial prices is zero.

too high. If only the housing expenditure differentials were used, the estimated benefit would be approximately negative $2.6 billion per year. The toxic reduction policy illustrates how misleading estimates based on partial differentials can be and how important it is to use conceptually correct values.

Conclusions

In this paper we adapt the hedonic model to an interregional, multimarket context. Earlier single market hedonic analyses focus on subsets of the tradeoffs that individuals may make concerning amenities. Intraurban housing models focus on the local tradeoffs between housing prices and amenities and ignore the possibility of compensating intercity variations in both rents and wages. Interregional labor market models focus on variation in wages and amenities across regions and tend to ignore compensating variations in intercity and intraurban rents. Our interregional, multimarket, hedonic approach recognizes a more global compensating mechanism which allows for interaction between the interregional markets for labor and housing and accommodates intraurban differences in rents and amenities.

The interregional, multimarket, hedonic approach has an important implication for the valuation of amenities: a conceptually valid measure of amenity values includes compensating differentials from both the labor and housing markets. In general the full implicit price of an amenity is the sum of two components, an earnings differential and a housing price differential. A valuation based only upon the housing price differential or only upon the earnings differential is likely to be misleading in both size and sign. The more general approach captures the net effect of the housing and wage differentials and in an interregional context should more reliably indicate the true value of location-specific amenities.

Market price differentials and amenity values for 16 amenities were estimated on a sample based on individual records from the 1980 Decennial Census of Population and Housing. Data on school quality, crime, air quality, water quality, and toxic substances were matched to the individual Census records. Results show that significant differences in housing prices and wages arise due to amenities. Valid amenity value estimates indicate the serious bias of estimates based on single market price differentials and the credibility of multimarket value indicators. To illustrate this bias, national aggregate benefits were estimated for a subset of eight amenities which can be influenced by public policy. For a 10 percent improvement in the teacher-pupil ratio, violent crime rate, total suspended particulate, visibility, water pollution dischargers, Superfund sites, landfill waste and toxic disposal sites, the annual value per year is estimated to be $21.2 billion based on the full amenity values. If the estimate is based on either set of market price differentials alone, then the benefits are underestimated - by 85 percent with housing expenditure differentials and by 15 percent with wage differentials. The results demonstrate that in an interregional context single market differentials are unreliable indicators of amenity values and that compensation for amenities should be analyzed in a multimarket framework.

FOOTNOTES

1 See Jones (1980), p. 340. Also, Jones uses the more general notion of intraurban "distance costs" rather than that of commuting costs.

2 The analysis treats the economy of an urban area in a manner similar to the economy of a small country engaged in international trade. Analytical techniques are similar to those described by Dixit and Norman (1980).

3 The general derivations are given in an Appendix which is available upon request. The simplifying assumptions do not affect the conclusion regarding interregional differences in wages and rents.

4 Additive separability implies that equations (3) and (4) could be rewritten as

(3a) $u^0 = v(\bar{e}-tr,p_r) + v(w) + v(s)$ and

(4a) $u^0 = v(\bar{e}-tr^*,p_a) + v(w) + v(s)$.

5 Walrasian stability means essentially that the slope of the local labor demand curve is less than the slope of the local labor supply curve.

6 If instead amenities were increased by a small amount everywhere, then a new spatial equilibrium would be reached at a new higher level of utility. For a discussion of adjustments of consumers and firms to small and large changes in amenities and the implications for benefit estimation, see Bartik (1986).

7 To demonstrate that the sum of the wage and land expenditure differentials does indeed reduce to f^r, substitute equations (8) and (9) for dw/ds and dp_r/ds, respectively. Appropriate cancellations demonstrate that the sum of the wage and land expenditure differentials provides an unbiased estimator of f^r.

8 Individuals supply one unit of labor in this model. However, the amenity valuation equation is easily generalized to a case where individuals choose between labor and leisure. In this case, the implicit price of s is again the housing expenditure differential minus the earnings differential, or

$$f^r = k_r dq_r/ds - n_r dw/ds$$

where n_r is the quantity of labor supplied by an individual located at r.

9 A less limited Box-Cox search using, say, a quadratic form would consider a different γ_i for each X_i and interaction term. With a large number of observations and variables a limited search seemed prudent. Results for the housing and wage hedonic regressions are available upon request.

10 The change estimated in the housing hedonic equations is the change in monthly housing expenditures. The change in housing expenditures equals $k_r dq_r/ds$ if the quantity of housing does not change due to a change in amenity. In notation we have: $d(k_r q_r)/ds = k_r(dq_r/ds)$ if $q_r(dk_r/ds) = 0$. We use $d(k_r q_r)/ds$ as an approximation to $k_r(dq_r/ds)$ since q_r is not observable.

11 See U.S. Statistical Abstract, 1985, 105th ed., p. 40, for the number of households.

REFERENCES

Bartik, Timothy J., "Measuring the Benefits of Amenity Improvements in Hedonic Price Models." Mimeo. Department of Economics, Vanderbilt University, February 1986.

Cropper, M.L., "The Value of Urban Amenities," Journal of Regional Science, 21(3):359-372, 1981.

Dixit, Avinash and Norman, Victor, Theory of International Trade, Cambridge, London, 1980.

Graves, Philip E., "Migration with a Composite Amenity: The Role of Rents," Journal of Regional Science, 23(4):541-546, 1983.

Henderson, J. Vernon, "Evaluating Amenities and Interregional Welfare Differences," Journal of Urban Economics, 11:32-59, 1982.

Haurin, Donald R., "Urban Structure, Wage Rates, and Regional Amenities" in Douglas B. Diamond, Jr. and George S. Tolley (eds.), The Economics of Urban Amenities, Academic Press, 1982.

Jones, Donald W., "Location and the Demand for Nontraded Goods: A Generalization of the Theory of Site Rent," Journal of Regional Science, 20(3): 331-342, 1980.

Kokkelenberg, Edward C. and Sockell, Donna R., "Union Membership in the United States, 1973-1981," Industrial Labor Relations Review, 38:497-543, 1985.

Roback, Jennifer, "Wages, Rents, and the Quality of Life," Journal of Political Economy, 90(6):1257-1278, 1982.

Rosen, Sherwin, "Wage-Based Indexes of Urban Quality of Life," in Peter Mieszkowski and Mahlon Straszheim (eds.), Current Issues in Urban Economics, Johns Hopkins University Press, 1979.

Tolley, George S., "The Welfare Economics of City Bigness," Journal of Urban Economics, 1:324-345, 1974.

Trijonis, John and Shapland, Dawn, "Existing Visibility Levels in the United States," Technology Services Corp., Santa Fe, New Mexico, for USEPA (EPA-450 15-79-010), 1979.

Appendix

The comparative static results discussed in the text are the result of taking the total differential of system S1 about the equilibrium values of w, p_r, r^*, and N, and then solving for dw/ds, dp_r/ds, dr^*/ds, and dN/ds. In this appendix, the general comparative static results are derived and then simplified by using the two assumptions introduced in the text.

The differential system is

$$(A1)\quad \begin{vmatrix} -v_s^* \\ -v_s^o \\ -c_s \\ -N_s \end{vmatrix} = \begin{vmatrix} v_w^* & 0 & v_r^* & 0 \\ v_w & v_p & 0 & 0 \\ gc_w & 0 & 0 & g_N c \\ N_w & 0 & N_r & -1 \end{vmatrix} \begin{vmatrix} dw/ds \\ dp_r/ds \\ dr^*/ds \\ dN/ds \end{vmatrix}$$

In deriving the differential system, equations (3) and (4) are used to solve for p_r as a function of w, p_a, s, $\bar{e}$, and r^*. The resulting function, $p_r(w,p_a,s,\bar{e},r^*)$, is substituted for p_r in equation (6) with the result that N_p equals zero.

By multiplying (A1) by the inverse of the coefficient matrix, one can solve for

$$(A2)\quad \begin{vmatrix} dw/ds \\ dp_r/ds \\ dr^*/ds \\ dN/ds \end{vmatrix} = \begin{vmatrix} -N_r v_p g_N c & 0 & v_r^* v_p & v_r^* g_N c v_p \\ N_r v_w g_N c & A & -v_r^* v_w & -v_r^* g_N c v_w \\ B & 0 & -v_p v_w^* & -v_w^* g_N c v_p \\ N_r v_p g c_w & 0 & C & -v_r^* g c_w v_p \end{vmatrix} \begin{vmatrix} -v_s^*/\hat{D} \\ -v_s/\hat{D} \\ -c_s/\hat{D} \\ -N_s/\hat{D} \end{vmatrix}$$

where $A = v_r^{*} g c_w - v_w^{*} g_N c N_r + v_r^{*} g_N c N_w$, $B = g_N c v_p N_w + v_p c_w$, $C = v_r^{*} v_p N_w - N_r v_p v_w^{*}$, and $\hat{D} = v_r^{*} v_p [g c_N N_w^S + g c_w]$.

In general, the sign of both the wage and rent differentials depends upon the relative sizes and signs of the structural elements that are included on the righthand side of system (A2). Notably, there is nothing in system (A2) to suggest that the rent differential generally vanishes. To derive the specific cases given in Table 1, the text introduces two assumptions. The first assumption is that the utility functions are additively separable. Additive separability implies that $p_s = p_s^{*}$ and that N_s (the partial equilibrium effect) is equal to zero. This first assumption allows one to cancel a number of conflicting terms in system (A2) and, thereby, to derive the simplified system given by equations (8) through (11). The second assumption is that local labor supply increases with an increase in the local wage ($N_w^S > 0$). The second assumption is used to identify the sign of dN/ds.

REFERENCES

Bartik, Timothy J., "Measuring the Benefits of Amenity Improvements in Hedonic Price Models." Mimeo. Department of Economics, Vanderbilt University, (February 1986).

Cropper, M.L., "The Value of Urban Amenities," Journal of Regional Science, 21(3):359-372, 1981.

Dixit, Avinash, and Victor Norman, Theory of International Trade, Cambridge, London, 1980.

Graves, Philip E., "Migration with a Composite Amenity: The Role of Rents," Journal of Regional Science, 23(4):541-546, 1983.

Henderson, J. Vernon, "Evaluating Amenities and Interregional Welfare Differences," Journal of Urban Economics, 11:32-59, 1982.

Haurin, Donald R., "Urban Structure, Wage Rates, and Regional Amenities" in Douglas B. Diamond, Jr. and George S. Tolley (eds.), The Economics of Urban Amenities, Academic Press, 1982.

Jones, Donald W., "Location and the Demand for Nontraded Goods: A Generalization of the Theory of Site Rent," Journal of Regional Science, 20(3):331-342, 1980.

Kokkelenberg, Edward C. and Sockell, Donna R., "Union Membership in the United States, 1973-1981," Industrial Labor Relations Review 38:497-543, 1985.

Roback, Jannifer, "Wages, Rents, and the Quality of Life," Journal of Political Economy, 90(6):1257-1278, 1982.

Rosen, Sherwin, "Wage-Based Indexes of Urban Quality of Life," in Peter Mieszkowski and Mahlon Straszheim (eds.), Current Issues in Urban Economics, Johns Hopkins University Press, 1979.

Tolley, George S., "The Welfare Economics of City Bigness," Journal of Urban Economics, 1:324-345, 1974.

Trijonis, John and Shapland, Dawn, "Existing Visibility Levels in the United States," Technology Services Corp., Santa Fe, New Mexico, for USEPA (EPA-450 15-79-010), 1979.