ENVIRONMENTAL IMPACTS OF MINING

ON GREEN VALLEY, ARIZONA

by

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As members of the Final Examination Committee, we certify that we have read the dissertation prepared by Hyo-Sun Kim

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Final approval and acceptance of this dissertation is contingent upon the candidate's submission of the final copy of the dissertation to the Graduate College.

I hereby certify that I have read this dissertation prepared under my direction and recommend that it be accepted as fulfilling the dissertation requirement.

Prof. DeVerle Harris
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STATEMENT BY AUTHOR

This dissertation has been submitted in partial fulfillment of requirements for an advanced degree at The University of Arizona and is deposited in the University Library to be made available to borrowers under rules of the Library.

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Finally, I thank my husband for his patience and understanding.

DEDICATION

This dissertation is dedicated to my parents and my lovely little sister, Insoo.

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ABSTRACT

The purpose of this dissertation is to estimate an empirical model of demand for environmental characteristics for the Green Valley community and to evaluate environmental impacts of mining on the community.

Environmental impacts are estimated by two different methodologies: An hedonic price model for housing and a contingent valuation based upon a sample survey of Green Valley residents. Variables that serve as proxies for environmental characteristics in hedonic prices and willingness to pay equations are distance from mining complex and orientation of house (viewscape). These variables are proxies for environmental air quality and scenic quality.

Inverse demand equations for environmental variables are derived from the hedonic and contingent valuation analysis. Using these demand relations, environmental impact of mining is estimated as the consumers surplus from environmental quality improvements in Green Valley.

In this dissertation, consumer surplus is an approximation to the sum of individual surpluses, which allows for variations in specific levels of the variables across the individual households.

Based upon the number of detached single family homes, the environmental impact of mining on the Green Valley community is estimated by the contingent valuation to be approximately $ 44,000,000 and by the hedonic price approach to be approximately $ 94,000,000. When impact is based upon total units (detached and

nondetached), the environmental impact is estimated by contingent valuation to be approximately $ 88,000,000 and by the hedonic price approach to be approximately $ 191,000,000. Perhaps, these estimates bound the actual impact.

CHAPTER 1.

INTRODUCTION

Section 1. Statement of Problem

Description of Green Valley Residential Area and Nature of the Externalities at Duval and Pima Mines

Established in March, 1964, Green Valley is a retirement community located 25 miles south of Tucson, Arizona. The community, which is approximately 8 miles long and 2 miles wide, grew steadily at an average annual growth rate of 4% , reaching a population of 21,087 in 1992. Warm sunshine and Madera Canyon, which is located on the east side of Green Valley, attract people from cold or urban areas. Green Valley provides great year-around activities, including golf courses, year-around swimming, tennis, bird watching, hiking, exercising, and over 200 social clubs. Green Valley's small-town atmosphere gives a safe and protective environment, one with a low crime rate. Most subdivisions have neighborhood watching systems to prevent crime. Green Valley is an unincorporated community, governed by a community co-ordinating council to save taxes. Property tax is assessed at 10% of the full cash value and 11% on residential rental property. Arizona state sales tax is 5%, and Green Valley sales tax is 0%.

Unlike other retirement communities such as Sun City, Arizona, Green Valley is located near (southeast of) the Duval and Pima open pit copper mines. Infrastructure, such as roads, shopping malls, and health care facilities that serve the mining complex, provides a convenience to Green Valley residents. On the other hand, the mines can be considered as a source of environmental externalities for residents in Green Valley. The copper mining companies have made progress in controlling dust, as indicated in a 1994 survey in which most of residents in Green Valley indicated that dust control has been improved. However, dust still comes from the mine dump or from tailing ponds when it is very windy or dry. Noise and dust problems appear to be most serious in the area near the Duval mine road, which crosses the nothern part of Green Valley. This is a very busy road, as it is used by heavy trucks in the mining operation.

The tailings ponds have high banks in order to improve dust control, but these banks are tall enough that they diminish scenic values for nearby residents. For example, since the tailings ponds are located on the west side of Green Valley, they interfer with the scenic values of the landscape and sunset. For those who are located on the west side of Green Valley very near the ponds, there is nothing to see but the banks. On the other hand, those living in the eastern and southern parts of Green Valley are farther from the mine and are near Madena Canyon and more than ten nice golf courses. Everything else being equal, the locations near the mine-related complex are expected to be less desirable for living in than those that are farther from the mine because of poorer scenic views.

Hypothesis

The major hypothesis of this dissertation is that the mine complex significantly affects house values in Green Valley. A secondary hypothesis is that positive welfare changes for residents in Green Valley can be generated by environmental quality improvement.

Section 2. The Statement of Objective and Scope

The objective of this dissertation is to estimate qauntitative measures of the impacts of mining on house values in the Green Valley community. Two different methodologies are employed to estimate these environmental impacts: indirect and direct. The direct approach employs contingent valuation methods, based upon a survey of Green Valley residents. The indirect approach estimates a Hedonic model of house values using recent real estate transactions.

The Hedonic model will be used as a means to estimate the demand for environmental improvement. Hedonic price is defined as a function of housing and nonhousing factors. The Hedonic approach requires strong assumptions and provides what some consider to be upper bound values. Because the hedonic equation is based on the assumption that the house market is at equilibrium, hedonic prices can be considered as the locus of willingness to pay (Freeman, 1979).

The contingent valuation method poses questions directly to Green Valley respondents about how much they are willing to pay for postulated substantial environmental improvements. Being based upon a survey of opinion about postulated improvements, this method must contend with strategic behavior of respondents and possible biases of respondents, such as hypothetical bias, reality bias, information bias, starting point bias, vehicle bias, instrument bias, and item non-response bias. On the other hand, contingent valuation does not require the strong assumption of market equilibrium, and it is a format that permits the consideration of income effects. More importantly, the use of contingent valuation as well as a Hedonic model provides a means to compare estimates by two very different methodologies and to see if relative comparisons made in other studies differ from those for the environmental impacts of mining. For example, are estimates by the Hedonic approach larger than those by contingent valuation, an approach which is considered by some to provide a lower bound of estimate of willingness to pay?

In summary, this dissertation will estimate the environmental impact of the mine complex on the community of Green Valley using an hedonic model of house values and an open-ended contingent valuation method. The demand for environmental quality from both hedonic and willingness to pay equations will be derived and used to calculate consumers surplus for the entire Green Valley community, which environmental impact of mining on the whole Green Valley community.

This study is not a benefit-cost analysis of mining, because it does not estimate the benefits of mining to the Green Valley community. The neglect of the benefits represents nothing more than a restriction of scope to a manageable dissertation topic, and it should not to be construed to imply that these benefits are inconsequential or that the environmental impacts outweigh the benefits. Although such comparison is not done in this study, the magnitude of the environmental impact suggests that benefits probably considerably outweight the environmental costs, especially when consideration is given to the real value of the local park and local high school which were sponsored by the mining companies.

Section 3. Literature Review

Literature on Hedonic Prices

The Hedonic model, which is a new approach to analyzing consumer demand was pioneered by Houthakker (1952), Becker (1965), and Lancaster (1966). Hedonic prices are defined as the function of attributes of differentiated products, rather than product quantities directly. Econometrically, implicit prices are estimated by the first-step regression analysis of hedonic price indexes. The hedonic approach to benefit evaluation has been used in a number of recent empirical studies since Lancaster (1966) and Rosen (1974) presented a general theoretical framework. Lancaster (1966) extended consumption activity analysis based on the assumptions that the goods possess multiple characteristics and that consumer's preferences depend only on the characteristics of the goods. This fundamental notion is the basis for a new technique to analyze consumer behavior. Newcomb (1969) extended the method to intermediate inputs in production activity analysis based on the assumptions that the input materials possess multiple characteristics and the user technology as well as consumers preferences for these characteristics are demand side factors in derived materials demands.

Buttner and Runckle (1969) first displayed elasticities of material demands in space age metals as a function of vehicle design, and hedonic demand techniques are central to multi-attribute utility analysis of advanced materials by Clark et al. (1989). Rosen (1974) described a model of product differentiation based on the hedonic hypothesis that goods are valued for their utility-bearing characteristics.

Freeman(1974) interpreted empirical property value studies and calculated the aggregate benefits for marginal changes in air quality directly from the hedonic equation because the first derivative of the observed rent function is a locus of equilibrium marginal willingness to pay. Lucas (1975) provided a theoretical basis for evaluation of alternative interpretations and applications of Hedonic price functions, and he compared Lancaster's theory with Houthakker's (1952) consumer theory.

Freeman (1979) reviewed the theoretical basis and assumptions for a hedonic price equation and provided the general interpretation of hedonic regression coefficients. This indirect approach has been criticized as leading to overestimation of the benefits of amenities caused by necessary strong assumptions, such as homogeneity in income and preference, and market equilibrium, e.g., Bartik (1987). The utility level is unobservable, and in order to avoid the identification problem the supply function is assumed to be fixed or perfectly inelastic. Harrison and Rubinfeld (1978) estimate a hedonic price function in which the level of concentration of nitrogen oxides is used as a proxy for air pollution level. They found the hedonic house price to be insensitive to air quality. However, as Freeman (1979) comments, Harrison and Rubinfield (1978) did not clarify the rationale behind their procedure. The implicit market for a residential environmental amenity is a function of the demand and supply of housing in equilibrium. If the supply of housing with air quality is inelastic with respect to the implicit price in the short run, it is possible to treat supply as exogenous. Then, the inverse demand function is identified by regressing marginal implicit price on the variables. If the sample area has a rapid speed of adjustment, greater care must be given to the specification of the supply equation.

Goodman (1978), and Halvorsen and Pollakowski (1978) provided improved methods for selection of hedonic forms. Goodman (1978) suggests that the use of linear Box-Cox transformation is an explicit likehood ratio functional form. Bender, et al. (1979) take the Chicago sample and estimate hedonic price using the linear Box-Cox transformation. The work of Bender, et al (1980) employed a quadratic Box-Cox transformation, and these results are compared with the previous studies in terms of price and income elasticities. The results are consistent and give evidence of the efficacy of the two-step methodology for air quality research. Since demand is derived from the implicit price of hedonic results relation, the estimates are sensitive to the particular hedonic form adopted. The observed implicit price is a locus of a reduced form equilibrium vector, reflecting both supply and demand influences.

Quigley (1982) adopted non-linear budget constraints to estimate the compensated demands for particular housing attributes based on the non-linear hedonic nature of housing prices by assuming that the utility function is a generalized CES form, and he measure Hicksian benefits of housing subsidy in developing countries. Kanemoto and Nakamura (1986) compared their study with Quigley (1982) in terms of the marginal rates of substitution (MRS) between the composite nonhousing good and housing characteristics by using Japanese housing data, which show that the MRS's between the nonhousing goods and the living area of their estimate (MRS= 24.1) is higher than that of Quigley's method. They found that the preference structure is not homothetic and MRS becomes higher as the amount of nonhousing good is increased with living area, which is fixed in Quigley's method, but MRS becomes lower by their method. Kanemoto (1988) examined the short-run benefit estimation with fixed lot size and shows that the hedonic measure does not always provide correct estimates in the short run when lot size is fixed. His results suggest that hedonic measures can be used as an upper bound estimate, and consumer's surplus of bid price is preferable to that of hedonic price because the bid price function is equivalent to the hedonic function in a homogenous population case. Anderson and Crocker (1971) demonstrated a linear programming assignment routine for equilibrium house values, but their work was criticized by Straszheim (1974), who emphasized that geographic disaggregation in cross-section estimation should be required in a general equilibrium analysis.

Brookshire, et at. (1982) presented the theoretical framework for validity of surveys in general. Brookshire, et al. (1982) included nitrogen oxide (NO2) and total suspended particulate (TSP) in both hedonic and survey approaches under homogeneous income and preference assumptions. Their survey approach followed Bohm (1972) and Davis (1963) in gathering information for estimation of bid curve. However, investigator's bias, in other words, the starting point bias, was still expected because the initial bid price appeared to be dependent on the investigator's decision. And, because perception about the level of NO2 and TSP is not easy to convey to survey respondents, they showed supporting pictures to respondents, which generated instrumental bias. The hypothesis that the average rent differential equals or exceeds the average survey bid for a marginal air quality improvement requires an important assumption that the hedonic approach perfectly represents the exact values of rent differentials in order to examine the validity of the survey approach. Brookshire, et al. (1985) demonstrated that information on earthquake hazards released from 1974 state law creates a new market for safe housing and showed that the expected utility hypothesis is useful to describe consumer's behavior, given information in the Los Angeles and San Francisco areas. Thayer, et al. (1985) estimated the reductions in housing prices in Mammoth, California which is an earthquake and volcanic Hazard zone. Kohlhase (1991) analyzed the impacts of toxic waste sites on housing prices in the Houston area and found that a premium to live farther from a waste site disappears after a site is cleaned. Craig, et al. (1991) distinguished among alternative regression specifications, based on the BDS test of Brock, Dechert, and Scheinkman (1987), and detected the presence of nonlinearity in microeconomic data, which was reviewed in the study by Starrett (1972).

Literature on Survey Approaches

In normal markets, a consumer responds to changes in prices of goods and in his income. On the other hand, the prices of public goods such as national parks, drinking water, air quality, and other environmental and natural resources are not observable in normal markets. Contingent valuation is one of the methods to value nonmarket goods. Subjects are asked for their willingness to pay or willingness to accept compensation based upon hypothetical scenarios. Since the late 1950's and early 1960's, contingent valuation methods have been used by decision makers, policy analysts, and social scientists who deal with public goods.

Since Davis (1963) started the bidding game to reveal the maximum amount of willingness to pay for recreational planning, Ridker (1967) evaluated air pollution benefits using the contingent valuation method. Hammack and Brown (1974) used open-ended questions that allow respondents to fill in their own values on a mail survey asking waterfowl hunters about willingness to pay for the right to hunt and willingness to accept compensation for giving up hunting. After Ridker's air pollution study, Randall et al. (1974, 1978) estimated the benefits in the Four Corners Region of visibility reductions and showed empirical divergences between compensating and equivalent surplus measures of consumer surplus in the same area. Kahneman and Tversky (1979) reformulated expected utility theory, which is replaced by a value function that evaluates changes in income from the current level. Increases in income are weighted by a relatively smaller marginal utility than decreases in income. Compared with the studies of Randall et al. (1974) and Brookshire et al. (1976), which had $1.00 starting bids and used $0.25 and $1.00 bidding increments, respectively, Rowe et al. (1980) tried three starting bids ($1, $5, $10). Besides the starting bids and amounts of bidding increments, the average income of the Brookshire et al. (1976) sample was much higher and the supporting pictures of Brookshire et al. (1976) were more relevant to respondents than those of Rowe et al. (1980), which leads to higher bids. Rowe et al.(1980) emphasized that the structure of the survey instrument, such as starting bids and information presented, can be important factor, because the results can be varied by different structures of a survey instrument, although it is conducted in the same area. Bishop et al. (1983) discussed the several biases that can occur when a survey is conducted and measured the average Hicksian surplus. They took a random sample of people in central Wisconsin with an incentive of $5 per questionnaire in order to improve response percentage and ask them the value of a permit to hunt Canada geese. When travel-cost results were used as rough standards for comparison, simulated market and contingent market take-it -or-leave-it willingness to sell showed parallel construction and contingent valuation willingness to pay measures appeared to underestimate the value of a permit. These findings are consistent with that of Brookshire et al. (1985), which showed contingent valuation willingness to pay for air quality improvement is less than property value differentials in Los Angeles Basin. Brookshire et al. (1985) tested the validity of the survey approach based on the criterion that the average rent differential equals or exceeds the average marginal willingness to pay by the survey approach. Bishop et al. (1983) reported that open-ended contingent valuation estimates yield the lowest value of willingness to pay among the estimates, and the open-ended contingent valuation method is expected to have a high percentage of no response. Sellar et al. (1986) specified a logit model for estimation of recreational boating demand. They suggested that the noniterative bidding approach is preferable because it shows the expected results with less cost.

Starting point is a tool for initiating the bidding process, and ideally, it should not affect respondents final bids. In other word, the respondents utility function should not be affected by the starting point. Randall and Brookshire (1978) found starting point bias in the items which are poorly perceived by respondents. Brookshire et al. (1981) analyzed the cause of this problem and suggest that the initial bid may suggest a certain range of final bids to the respondents. Mitchell and Carson (1981) pointed out that some tests do not have validity because of starting point bias. Desvousges et al. (1983) suggested that tests for starting point bias should be included in research. Boyle et al. (1984) explicitly test for starting point bias in bidding games, using indirect utility functions. Boyle, et al. (1984) tested previous studies for a significant relationship between starting points and final bids and suggested that bidding games are less preferable because of starting point problems.

Sellar et al. (1985) compared the values of welfare changes of recreational boating in Four Lakes in East Texas (lakes Conroe, Livingston, Somerville, and Houston) by the travel cost method, open-ended contingent valuation method, and close-ended contingent valuation method. The open-ended contingent valuation results showed the lowest percentage of responses (25%). The travel cost method provides estimates of Marshallian consumers surplus, whereas contingent valuation methods provide Hicksian equivalent measures of welfare change. They interpreted that the travel cost method provides an estimate of consumer's surplus for total recreation experience, while both contingent valuation methods give estimates of consumer's surplus for just the boating experience. The open-ended contingent valuation method provides lower estimates of consumer's surplus in each lake. On the other hand, the close-ended contingent valuation method estimate of consumer's surplus shows results that are much more comparable with the estimates from the travel cost method, rather than with the estimates from the open-ended contingent valuation method. The close-ended contingent valuation method is used to estimate marginal willingness to pay for a recreational fishing day in the study of Cameron and James (1987), which avoided intrinsic truncations. They identified the marginal influence of catch characteristics on value and distinguish the contribution from other factors which generate utility to anglers.

Knetsch and Sinden (1985) and Cummings, Brookshire and Schulze (1986) demonstrated a disparity between willingness to pay and willingness to accept measures of value, and concentrated on inconsistencies in individual responses to questions solicited outside of market situations. Psychological factors play a big role in large differences between the value of willingness to pay and the value of willingness to accept. Coursey, et al. (1987) interpreted the results of Knetsch and Sinden to reflect respondent's lack of experience in answering the questionaire. As noted by Knez, Smith, and Williams (1985), learning experience over time effects equilibrium behavior. Thus, the market-like learning experience causes the disparity to be reduced. Brookshire and Coursey (1987) compared and contrasted the values obtained from three survey procedures: contingent valuation methodology, field Smith auction process, and laboratory Smith auctions. The study suggests that hypothetical willingness to pay values may be both more accurate and more stable than hypothetical willingness to accept values.

Literature on Consumer's Surplus

Since Dupuit (1844) originated the concept of consumer's surplus, Marshall developed the idea of consumer's surplus as the area under the demand curve, given the assumption that the marginal utility of money is constant. If the marginal utility of money is constant, the consumer's demand schedule is unaffected by changes in his real income. Hotelling (1969) and Hicks (1956) suggested that the Marshallian measure of consumer's surplus can be a good measure if the income effect is small. However some researchers like Samuelson (1947) criticized consumer's surplus as a theoretical toy because of the nature of the unobservable utility function.

Willig (1976) settled the controversy surrounding consumer's surplus. As noted in his work, the compensating variation is an individual's cost-benefit concept which makes price changes perfectly commensurable with changes in income. When the indirect utility function is assumed to be a function of income (m) and price (p), the compensating variation can be defined as a level of income adjustment(C),

$u\ (p0,\ m0) = u\ (p1,\ m0 + C)$,

while the equivalent variation in income (E) can be defined by

$u\ (p0,\ m0 - E) = u\ (p1,\ m0)$,

where the -E is the income change which has the same welfare impact on the consumer as a price change from p0 to p1. His work provides the upper and lower bounds on errors of estimated compensating and equivalent variations with consumer's surplus. These bounds can be calculated from the observable demand data. The results of his study imply that consumer's surplus is a good approximation to the appropriate welfare measures. The ratio of consumer's surplus to consumer's base income ($|A|$ / m) is interpreted as a measure of the proportional change in real income due to the price change. Even though the income elasticity is considered, the ratio is small enough to permit substitution of consumer's surplus for compensating or equivalent variations in most studies of individual welfare. The demand curves for compensating and equivalent variations are not Marshallian because the income parameters are not constant, but they are Hicksian demand curves. When there is no income effect, the areas (equivalent variation and compensating variation) under Hicksian demand curves equal the area under the observable Marshallian demand curve (consumer's surplus). Willig (1976) shows how compensating and equivalent variations can be calculated from the observable demand when the income elasticity of demand is constant, and he establishes the formula for nonconstant income elasticity of demand.

Sellar et al. (1985) compare the values of welfare changes of recreational boating in Four Lakes in East Texas using a travel cost method, open-ended contingent valuation method, and close-ended contingent valuation method. The travel cost method provides estimates of Marshallian consumers surplus, while contingent valuation methods provide Hicksian equivalent measures of welfare change.

Section 4. Organization

This section outlines the structure of the dissertation.

Chapter 2 investigates the impacts of mining on the housing market in Green Valley using the hedonic approach. It identifies the hedonic price equation which is assumed to be a function of housing and nonhousing characteristics with environmental amenities variables and examines the hypothesis that the presence of the mine significantly affects house price. If the presence of mine is significant, the inverse demand function for environmental amenities can be derived from the hedonic implicit price equation.

Chapter 3 presents the survey study to estimate willingness to pay for a marginal change of environmental quality improvement. The open-ended contingent valuation method tests whether the variables used as proxies for environmental quality in the willingness to pay function demonstrate the same tendency as in the hedonic price equation.

Chapter 4 calculates and compares the values of the whole Green Valley consumers surplus from the change of each individual environmental variable by using the results from both the hedonic and open-ended contingent valuation methods. And, total welfare changes due to the environmental impact of the mine complex is estimated for the Green Valley community.

Chapter 5 interprets the results from chapter 2, 3, and 4, discusses the contribution of this study to the literature, and indicates areas for future study.

CHAPTER 2.

HEDONIC PRICES

In this chapter, the demand for environmental quality will be derived from an hedonic implicit price equation which displays consumer's behavior with respect to housing and nonhousing characteristics in residential housing markets. Conceptually, the house purchased by a consumer is a statement of his trade-off of the housing characteristics with environmental characteristics. Clearly, all houses are spatially located, so the choice of house also reflects the consumers trade-off of locational features and their relationship to environmental influences. The hedonic price equation relates the set of relevant considerations to house value as revealed by market transactions.

The demand for environmental amenities is derived from the estimated hedonic price equation and will be used in Chapter 4 to calculate welfare changes due to environmental quality.

Section 1. Conceptual Framework

Lancaster(1966), Rosen (1974), and Freeman (1979) developed a general model of implicit markets for quality characteristics. In Rosen's model, a rational consumer will purchase a good offering the combination of characteristics(z) that maximizies his utility function subject to his budget constraint. The utility function U $(x, z_1, z_2, \ldots, z_n)$ is assumed to be strictly concave and separable, which means U(x, z) = U(x) U(z). The vector x represents all other goods consumed with the price of x as unity. The budget constraint (y) equals x + p(z), where p(z), so-called hedonic price, is a market clearing price of a good reflecting the interaction of supply and demand and is assumed to be a function only of its characteristics(z). We can rewrite the utility maximization, $U = U(x, z_1, z_2, \ldots z_i, \ldots z_n)$ subject to the budget constraints, $y = x + p(z_1, z_2, \ldots, z_i, \ldots z_n)$ as,

$U(x, z_1, z_2, \ldots z_n) + \lambda[\, y - x - p(z)]$

The first-order necessary conditions are

$$\partial U / \partial x = Ux - \lambda = 0 \qquad \ldots\ldots\ldots\ldots(2 - 1)$$

$$\partial U / \partial z_i = Uz - \lambda\, (\partial p / \partial z_i) = 0 \qquad \ldots\ldots\ldots\ldots(2 - 2)$$

$$\lambda = Uz_i / (\partial p / \partial z_i) = Ux, \qquad \ldots\ldots\ldots\ldots(2 - 3)$$

where subscripts denote partial differentiation. The optimal characteristics, z_i^* can be obtained from eqautions (2 - 1), (2 - 2) and (2 - 3).

In order to use hedonic price estimation,an identical utility function across the households is assumed, whatever the structure of the utility function is. However, if a characteristic which affects the utility function is not included in the hedonic price equation, the coefficients of the other characteristics listed in the hedonic price equation will be biased.

Hedonic Model

The implicit hedonic price function is a reduced form equation reflecting the interaction of supply and demand at market equilibrium in time t. The buyer is a price taker. Since by assumption the housing market is at equilibrium, an hedonic price model can be used to study consumer behavior with respect to the events that cause losses in utility, such as earthquake, air pollution, and noise problem. Market equilibrium is necessary in order to isolate the role of housing and nonhousing factors on housing price. In this current study, there is no evidence that the assumption of market equilibrium is not resonabley well satisfied. For example, listing and selling prices did not differ greatly, as they may in a market that is far from equilibrium. Moreover, the data counted a short time span to mitigate market dynamics. In the hedonic approach, the price of a house is taken to be a function of both housing and nonhousing characteristics. Housing characteristics include features such as number of bedrooms, number of bathrooms, lot size, age of house, and type of air conditioner. Nonhousing characteristics can be divided into neighborhood characteristics and environmental characteristics. The hedonic price model is of the following general form:

$$p = p(h, n, Q) \qquad \text{....................(2-4)}$$

where

p = selling price of a house

h = a set of housing characteristics

n = a set of neighborhood characteristics

Q = the environmental characteristic

In order to derive the marginal implicit price for a characteristic, it is required to make some additional assumptions besides the basic hedonic assumption that the price of house is a function of its characteristics when the market is at equilibrium. First, the hedonic price equation is assumed to be continuous and differentiable:

$$mip = \partial p(h, n, Q)/ \partial Q. \qquad \text{....................}(2 - 5)$$

where

mip = marginal implicit price of the environmental characteristic, Q.

Second, a nonlinear form of implicit price function is desirable if the marginal implicit price of a characteristic is to be derived from the implicit hedonic price by differentiating the implicit price with respect to the characteristic. If the hedonic price is linear in the characteristics, the marginal implicit price for, say an environmental characteristic, is constant for all the households regardless of their current location. For the marginal implicit price of a characteristic to be functional, the hedonic price equation must be nonlinear in that characteristic.

Market Equilibrium

In the Figure 2-1, $C1 - C_o$ is required to improve the environmental quality from Q_o to $Q1$ maintaining equilibrium in the hedonic price equation, while $C_o' - C_o$

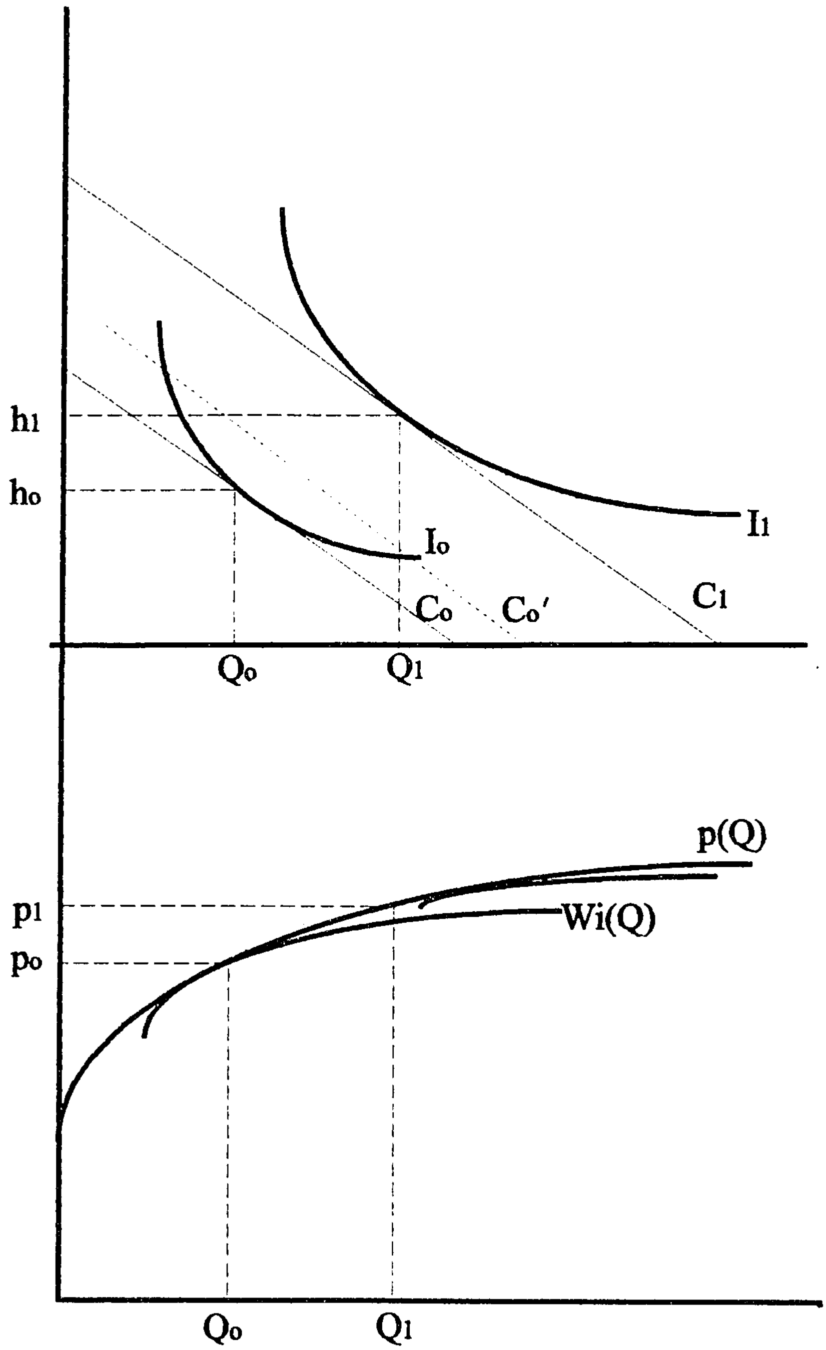


Figure 2 - 1. Hedonic Implicit Price Curve as an Equilibrium Price Under the Assumption of an Identical Utility Function Across Households.

is required to move from Q_0 to Q_1 maintaining the same indifference curve I_0 in the demand or willingness to pay curve, Wi. If all the other characteristics are constant, each household chooses a level of Qi where its marginal willingness to pay for Qi equals the marginal implicit price of Qi. In other words, the implicit price function is a locus of each household's marginal willingness to pay. Therefore, in order to interpret the observed marginal implicit prices by the hedonic approach as measures of marginal willingness to pay for housing, the assumptions are required that each household is a price taker and that the market is at equilibrium. Moreover, each buyer is assumed to have full information on all housing prices and attributes, and transactions and moving costs are assumed to be zero.

In short-run equilibrium, we can find a price function, p(z), when the market quantity of demand for housing with amenities or characteristics (z) equals the quantity of supply of housing with the characteristics (z):

$$Qd\ (z) = Qs\ (z). \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2 - 6)$$

The hedonic price function, p(z) can be used as a reduced form, representing the interaction of demand and supply in short-run equilibrium. Clearly, at market equilibrium, the features of the houses that are traded on the market implicitly reveal preferences of consumers. It is not always possible to use the hedonic price model. For example, in the long-run or across a sizeable time interval, determinants of demand and supply shift, creating an identification problem in the use of housing prices and features to estimate implicit prices of house and nonhouse features. When such circumstances exist, the estimated hedonic price equation will not represent the real world implicit prices, nor will the demand for features, e.g. enivronmental amenities, derived from the estimated hedonic price equation be credible.

In the Fig 2 - 2, the optimal level of z1 (z1*), is determined where marginal value of z1*, (θi(z1*)) equals the marginal cost (ϕi(z1*)). P1(z1) is the marginal price of z1 for all buyers, since the functions θi(z1) are compensated demand prices when real income is constant, in equilibrium. The speed of supply adjustment is required to be fast enough to maintain the equilibrium to avoid identification problems.

In this study, the supply of air quality is perfectly inelastic with respect to price at each residential location. Instant adjustment of supply is required in order to derive the fully identified inverse demand function from the observed equilibrium hedonic price, if demands are homothetic.

Inverse Demand Functions

Demands are homothetic under the assumption that all households have identical incomes and utility functions. With the market always at equilibrium and perfectly inelastic air quality supply with respect to the price, the marginal implicit price is the inverse demand function for air quality. In this study, this approximation will be used to obtain the inverse demand function instead of regressing the equilibrium price on determinants of demand, such as income and tastes. The device is taken because the data on these determinants are not available.

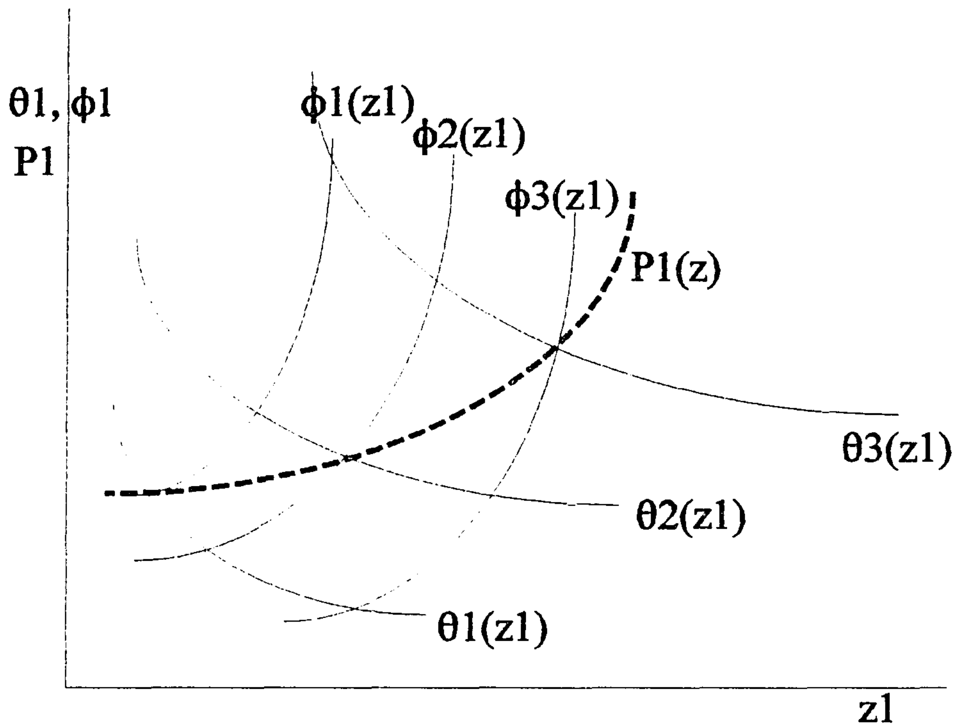


Figure 2-2. Identification Problem

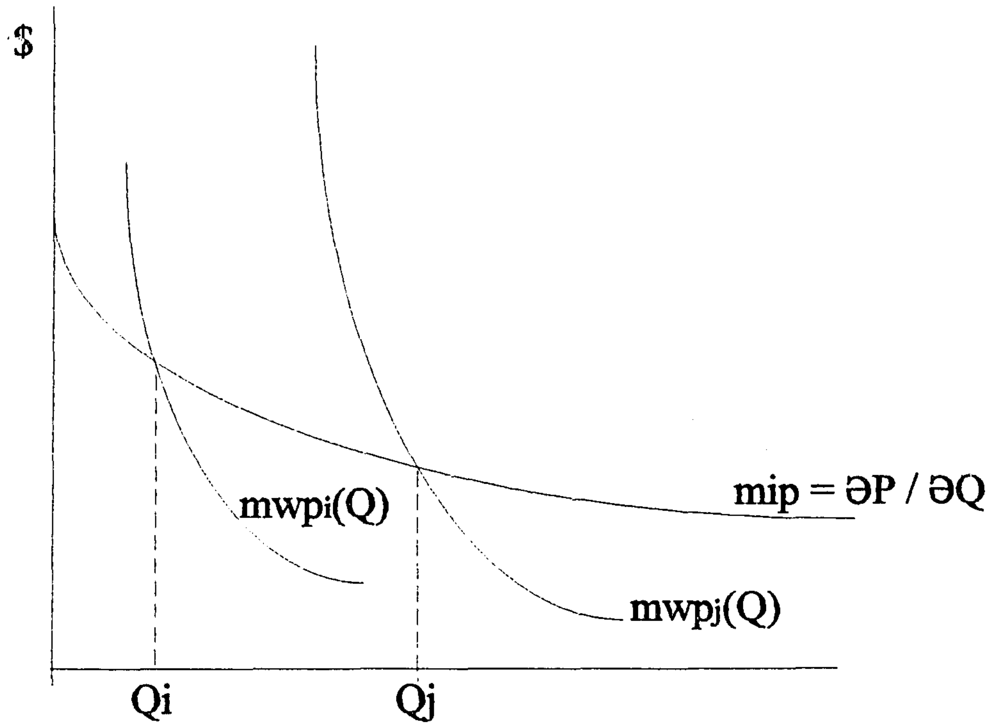


Figure 2 - 3. The Marginal Hedonic Implicit Price as the Equilibrium locus of Each Individual Household's Willingness to Pay

Section 2. Data and Methodology

Green Valley housing market data were obtained from the area MLS (Multi-Listing Services), which provides the information to buyers through the area real estate agencies. Since Green Valley is a small community, the number of houses sold in a specific period, especially in a period short enough to satisfy the market equilibrium assumption, is small, particularly when compared to number of market transactions for a large city, such as Los Angeles. Data on price and house charcteristics show only 20 houses were sold between July 1, 1993 and October 26, 1993 when the sample was restricted to single family houses. Single family houses are preferred because they provide buyers with a choice of location and are free of other spatial considerations, while town houses or condominiums encumber the choice of location. Several variables were available including living size, number of bathrooms, number of bedrooms, age of house, time on market, financing arrangements, listing price, selling price, type of air conditioning, type of dining room, guest room, capacity of garage, and location in the list of MLS (Multi-Listing Services). The exact distance from mine and orientation of house were identified by field study using topographic, photographic and local Green Valley maps.

In this study, neighborhood characteristics, such as race and age of household, were omitted because Green Valley is a typical retirement community which is relatively homogeneous in race and age of household.

The description of the variables used in the estimation of the hedonic equation are presented in Table 2-1. Selling price is used rather than the listing price because

Table 2 - 1. The Description of the Variables
in the Hedonic Approach.

Variable	Description
P	The Sales Price of the House ($).
SQ	The Size of Living Area of the House (sq. ft.).
TP	The Type of Payment to Purchase the House ; If Cash Payment, ln(TP) = 1, Otherwise, ln(TP) = 0.
Y	The Year When the House Was Built.
D	The Nearest Distance from the Mining Complex to the House ; When Hedonic Approach, the Distance is measured by cm in the Aerial Photo Map Provided by Landiscor Aerial Photo, Inc., Arizona.
DD	The Orientation of the House ; When the Backyard of the House Faces toward to the Mining Complex, ln(DD) = 1, Otherwise, ln(DD) = 0.

selling price is the price which a buyer and a seller actually agree upon and roughly reveal the equilibrium exchange price. The range of the sample selling price in this sample is from $44,900 to $249,500, while the price range of Green Valley single family houses $ 34,000 to $600,000. The average size of living area is 1,656.7 sq.ft., ranging from 851 sq.ft. to 3,228 sq.ft.. Since strong multicollinearities exist among the housing characteristics, several housing characteristics were excluded from the hedonic equation. For example, the number of bedrooms, number of bathrooms, and capacity of garage are highly correlated with the size of living area. The distance from mine and orientation of house were selected as proxies for environmental quality variables to in the hedonic price equation. The distance from mine is measured in cm scale in the aerial photo, which has scale of 1 inch = 1200 ft, after tranfering the location of the house from the local road map provided from the Century 21 realtor onto the topographic map. The aerial photo and topographic map precisely describe the location of mine dumps and tailing ponds, while the local road map identifies the location of houses. The distance from mine is taken as the nearest distance from the frontier of the mine-oriented complex, mine dump or mine tailing pond to the house. This study also considers the orientation of house, as well as distance to mine complex, as proxies for scenic view and other environmental qualities. If the backyard of the house faces toward the mine, the orientation variable is given a value of 1, being 0 otherwise.

The assumption is made that the backyard of the house represents the view of the house and that the front door is located opposite the backyard of the house.

Section 3. Empirical Results

This section estimates the hedonic implicit price equation using the variables which are available in MLS and derives the inverse demand function from the hedonic implicit price equation, given the assumptions that the all Green Valley residents have identical utility functions, the housing market is at equilibrium, and the supply of air quality and scenic view are inelastic with respect to the selling price.

It is assumed that buyers behave as price takers who are provided full information about property data. As the Green Valley community is homogeneous in income and age, some of the assumptions for the hedonic approach are better satisfied than for standard communities.

Hedonic Implicit Price

In this study, the equilibrium price, the selling price of house, is considered to be a function of housing and nonhousing characteristics:

$P = f(h, Q)$ ....(2 - 7)

where

P = actual selling price of house ($)

h = a set of housing characteristics

Q= a set of environmental characteristics

With consideration given to inter-correlations among the original variables and to weak association with selling price, the housing characteristics included in this hedonic price model are:

living area,

the year when the house was built,and

type of payment .

As mentioned in the previous section, the proxies for environmental variables are:

the distance of house from mine, and

orientation of house.

Clearly, these variables represent the proximity of the mine complex to the housing market.

The hedonic price equation selected and estimated depicts a nonlinear relationship between price and the explanatory (independent) variables, which has a log-log form, i.e., is linear in the log of each variable:

$$\ln(P) = -531.231 + 0.8239\ln(SQ) + 70.707\ln(Y) + 0.2872\ln(X) - 0.2253\ln(DD)$$

(-5.7603) (5.078954) (5.79439) (2.51603) (-2.25525)

$$+ 0.3117\ln(TP). \qquad \ldots\ldots\ldots\ldots(2-8)$$

(3.16997)

R square = 0.933868

F value = 39.53985

where

$X = 1.049942779 - (0.9947)^{D}$

D = distance from mine (cm in the map; 1 cm $\cong$ 0.09 mile)

SQ = size of living area (sq.ft.)

Y = year when a house was built

ln(TP) = logarithm of type of payment

= 1, if cash payment

= 0, otherwise

ln(DD) = logarithm of orientation of a house

= 1, if a house faces toward mine

= 0, otherwise

t-statistics are in parentheses

Based on these empirical results, the coefficients of all the variables in equation (2-8) are significant at the 5% level and have signs consistent with apriori expectations from economic theory.

The size of living area (SQ) represents physical features of the house, such as number of bedrooms, number of bathrooms, the capacity of garage, and presence of formal dining room and guest rooms. The year that the house was built (Y) directly represents the age of house and indirectly describes the condition of the house, and it represents indirectly the presence of modern appliances, for example, kind of type of air conditioner, or even whether the house includes a dishwasher. Compared with previous studies, this study avoids multicollinearity problems by excluding the unnecessary or highly correlated variables which were already represented. For example, Kohlhase (1991) used lot size, number of bedrooms, number of bathrooms besides square feet of whole house living area. As shown in her study, the R square of the hedonic result is relatively high when we compare the other previous studies, but some of t-statistic values of the coefficients of redundant variables were small.

The statistical results indicate that type of payment is a significant variable in the hedonic price equation at the 5 % level. Since type of payment (ln(TP)) is a dummy variable allowing having values of 1 or 0, it serves to shift the hedonic price equation. The reason is that the community like Green Valley is associated with retirees. People who want to buy a house already have a kind of fixed permanent nominal income. In other words, someone who has already enough money to afford the house can buy a house with a cash payment, while others who can't pay at once will finance the purchase through a payment schedule. Those who require financing may have less income than those who do not.

Another important factor in the type of payment for Green Valley is that when the age of buyer is over 55, he may find it difficult to obtain financing. Such buyers would choose a price range of house based on their current wealth + income level, because their real future income could decrease as they get older. There are, of course, complications and exceptions to the foregoing generalizations. Suppose there is someone who lives in Chicago and wants to have a winter house in Green Valley as a second house for the family. He (she) may or may not be able to purchase the second house by cash. Obviously, we can not compare the income level of someone who bought a house at $ 40,000 as a second house, and the income level of someone who purchases a house valuing exactly the same price as his sole residence. However, when we consider the case of the buyer who bought a second house in Green Valley, the price of the winter house may not exceed the price of his primary house in Chicago. Even further, when we compare only the cases of second houses, for example, the income of someone who bought a winter house valuing $ 40,000 by cash and the income of the other person who bought a winter house valuing the same price by finance can be compared. Therefore, the type of payment (TP) can not represent the income level of buyers in all cases, but it seems to be a useful shift variable in the Green Valley case.

The distance from mine (D) to house is used as a proxy for air quality. This variable was transformed into an asymptotic form in order to improve the model statistically and at the same time conform with postulated behavioural relations. Use of the transformed variable "X" rather than just "D" in the log-log form of hedonic price function results in an improved fit. It emphasizes the nonlinear form of the hedonic price function, which coincides with the common concept *and* the hypothesis of this dissertation. The (+) sign of the coefficient of "X" means that the house which is located nearer the mine tends to be cheaper than the house located farther away, when all the other variables are fixed. This is evidence that the presence of mine complex significantly impacts housing values in Green Valley. Stated differently, the presence of the mine affects utility of buyers negatively. However, the nonlinear (asymptotic) transformation implies that distance from mine becomes less important as distance increases.

The other variable which represents the presence of the mine complex is the orientation of house (DD= 2.7138 if the house faces the mine; 1, otherwise). This variable also is statistically significant in the hedonic price equation at the 5 % level. The (-) sign of the coefficient of "DD" shows the preference of buyers for better scenic view (away from the mine) with respect to the orientation of house. The orientation of house so that the backyard faces away from the mine increases the sales price of the house. Thus, there are two important environmental variables in the hedonic housing price model: D and DD, both of which reflect the proximity or visibility of the mine complex.

"D" and "DD" variable could to some degree substitute for each other: the people who buy a house located very near the mine would prefer to have their primary view away from the mine, while those located far from the mine may have weaker preferences for orientation. To examine this effect, the hedonic price model was re-estimated using as one variable the combination of D and DD, ln(DD/X):

$$\ln(P) = -\ 519.062 + 0.854675 \ln(SQ) + 69.07201 \ln(Y) - 0.25301 \ln(DD/X)$$

(-6.232) (6.361643) (6.272196) (-4.02434)

$$+\ 0.31845 \ln(TP) \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2\text{-}9)$$

(3.397722)

R square = 0.933243

F value = 52.4338

The statistical results are similar to those for the previous equation , including all variables being significant at the 5 % level with similar value of R square and greater F value. But, this model has a less good fit than equation (2 - 8). This suggests that the people who buy a house farther away from mine still prefer a better scenic view. This accords with the results of (2 - 9) as showin by the (-) sign in front of the coefficients of combination of "D" and "DD".

These results provide confidence in the hypothesis that the presence of the mine significantly impacts housing values. Although both equations support the same conclusion, the first equation is preferred because it separates the variables D and DD, permitting greater flexibility in modeling their impacts on housing values.

As shown in the study by Harrison and Rubinfeld (1978), heteroscedasticity often is a problem for estimated hedonic equations. But in this study, there is no heteroschedastic problem with the residuals. This too lends credence to the estimated hedonic housing model.

Inverse Demand Functions

The marginal implicit price for air quality can be derived from the hedonic implicit price equation (2 - 8).

$\partial P / \partial D = (\partial P / \partial X)(\partial X / \partial D)$

$= [(0.2872 P)/ X][0.0053141]$

$$\frac{\partial P}{\partial D} = 0.0015262 e^{-531.231}[1.10578-(0.928)^{D}]^{-0.7278}[Y^{70.71} SQ^{0.8239} TP^{0.3117} DD^{-0.2253}] \qquad \text{.........................(2- 10)}$$

The marginal implicit price for air quality is higher in case of the house nearer the mine than it is farther away from the mine. The closer a house is located to the mine, the stronger the desire to move away from mine, according to the results of the marginal implicit price for variable "D". On the other hand, the people who live far from the mine complex are not willing to move any further than their current location, because at these current locations, they do not mind the presence. The nonlinear form of the marginal implicit price equation implies that the sensitivity to the presence of mine is relatively high only when the mine is close. When the house is located beyond a certain distance, the distance from mine becomes irrelevant to the price of house.

When we compute the derivative of the hedonic price equation (1) with respect to the orientation of house(DD), we can obtain the marginal implicit price for better scenic view, as below:

$$\frac{\partial P}{\partial DD} = -0.2253e^{-531.231}[1.10578-(0.928)^{D}]^{0.2872}[DD^{-1.2253}Y^{70.707}SQ^{0.8239}TP^{0.3117}]$$

..................(2 - 11)

where

DD = 2.7138, if the house faces toward to mine

= 1, otherwise

Both marginal implicit prices --with respect to the distance from mine (D) and the orientation of house (DD)--describe premiums for associated environmental amenities. That is, the marginal implicit price for distance from mine (D) is the premium in housing values for moving away from the mine by a marginal increment of distance. Similarly, the marginal implicit price for the orientation is the premium for a house that presents natural (non-mine) viewscapes.

These marginal implicit prices are the locus of the marginal willingness to pay schedule. Therefore, under the market equilibrium assumption, these marginal implicit prices are themselves the demand for environmental quality, better air quality and better scenic view.

CHAPTER 3.

WILLINGNESS TO PAY

This chapter estimates the willingness to pay for environmental amenities by contingent valuation. Basically, this is done by surveying directly through questionnaire a sample of Green Valley residents for their willingness to pay for environmental amenities. The demand curve for environmental amenities can be derived by taking the first derivative of the estimated willingness to pay function with respect to the environmental characteristics. This will be used to obtain measures of the consumers surplus for comparison with the measures of the consumers surplus from the hedonic housing model described in the previous chapter.

Section 1. Conceptual Framework

Willingness to pay

One approach to valuing public goods is to ask households directly to answer hypothetical questions designed to elicit their willingness to pay for public goods. Especially, the survey technique is useful when there is no market for the good or when market data for hedonic price estimation is difficult to acquire or when the information on the specific amenities is not available. However, contingent valuation has been criticized because of the hypothetical nature of the questions and the fact that actual behavior is not observed. (Cumming et al. (1986), and Mitchell and Carson (1989)). And, when the respondents are asked the willingness to pay for a public good, their answers may reflect their expectations about how the results of the survey might affect their welfare. Unlike private goods, the same unit of a public good, such as clean air can be consumed by many, jointly without loss of utility to any one consumer. And, once a public good is provided for some individuals, it is impossible, or at least very costly, to exclude others from also enjoying the benefits of the good. In other words, free riders can exist in public good markets. Therefore, strategic behavior and the free rider phenomenon may lead to biased estimates of willingness to pay.

As shown in previous studies, such as Brookshire et al. (1982) and Sellar et al.(1985), the validity of the survey approach needs to be tested, because the survey approach is very subjective. Even though surveys have been conducted in the same place and on the same topic, the estimates vary with the choice of the functional forms. Brookshire et al. (1982) test the hypothesis that the survey bids are nonzero, and the average rent differential equals or exceeds the average survey bid using the t-statistic. The empirical results support the theoretical model and the hypothesis that survey responses will be bounded below by zero and above by rent differentials derived from the estimated hedonic rent gradient. And, as shown in Schulze et al. (1981), the survey estimates of the value of public goods, including environmental amenities, appear to be consistent with demand theory.

In this dissertation, willingness to pay is assumed to be a function of income and the housing and environmental characteristics used in hedonic implicit price function. All respondents are assumed to be rational and have full information about the housing market and amenities which are related to house, neighborhood and environment.

$$W = w(I, H, N, Q) \qquad \text{........................(3-1)}$$

where

W = willingness to pay

I = income of the whole family of the house

H = a set of housing characteristics

N = a set of neighborhood characteristics

Q = a set of environmental characteristics

Marginal Willingness to Pay

Differentiating the willingness to pay bid curves with respect to an environmental amenity provides a marginal willingness to pay for that amenity, conditional upon the values of the I, H, and N. For example, the marginal willingness to pay for environmental characteristic, Q1 can be described as follows:

$$mwp1 = \partial w\ (I, H, N, Q)\ /\ \partial Q1 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3\text{-}2)$$

where

mwp1 = marginal willingness to pay for Q1, conditional upon I,H, and N.

Q = a set of environmental characteristics, Q1, Q2, Q3.....Qn.

Q1 = one of the environmental characteristics.

The marginal willingness to pay curve assumes the same utility function across the residents. As stated in the review by Willig (1976),

$$U(p_o, m_o) = U(p', m_o + C) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3\text{-}3)$$

or

$$U(p_o, m_o - E) = U(p', m_o) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3\text{-}4)$$

where

$U(.)$ = the utility function

p_o = the initial price

p' = the alternative price

m_o = the initial income

m' = the alternative income

C = the compensating income variation

E = the equivalent income variation

That is, marginal willingness to pay moves on the same indifference curve with respect to the characteristics or amenities. Equations (3 - 3) and (3 - 4) show how the consumer responds to the situation as the price changes from p_o to p′ maintaining his constant level of utility, U(.), where " C" and "E" are the income changes which cause price changes. The marginal willingness to pay curves derived from the utility function (3 - 3) and (3 - 4) can be the inverse Hicksian demand curves, while the inverse demand curve from hedonic implicit price function is the Marshallian demand curve because the income effect of price change is assumed to be small in the hedonic price equation.

In Fig 3-1, the demand curve which is the inverse form of marginal willingness to pay as shown in equation (3 - 2) is defined as $Q1(p,m^o)$. The heavy line $Q1(p, m_o)$ is the observable Marshallian demand curve in which the marginal utility of income is constant at m_o. $Q1(p, \mu(p/p_o, m_o))$ and $Q1(p, \mu(p/p', m_o))$ are the Hicksian demand curves, where μ (.) is the expected function of income regarding the changes in the price. The difference between the two Hicksian demand curves is the level of utility which would compensate for the presence of the diseconomy or externality.

The area under the demand curves provides the measure of consumer's surplus. The concept and estimation of consumer surplus will be discussed further in chapter 4.

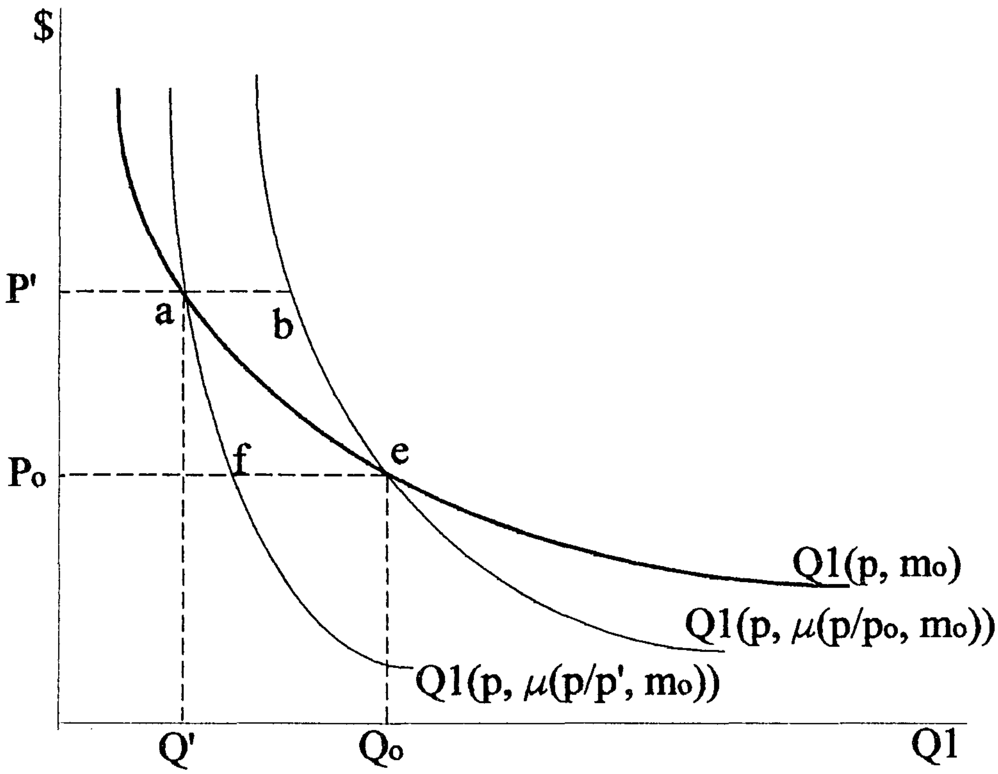


Figure 3 - 1. Marginal Willingness to Pay as a Hicksian Demand Curve.

Section 2. Data and Methodology

Data for this study were collected by direct personal interview using a seven-page questionnaire, including the cover letter and map. In order to avoid, or at least minimize, strategic behavior, the cover letter introducing the interviewer stated that the results of the questionnaire would not be used for specific pricing policies, but for academic research. The map was provided to the respondent to help him (her) locate his(her) location and to refer to hypothetical locations.

The survey was conducted during April 30 - May 10, 1994 on a sample of single- family- house and townhouse residents in Green Valley. Condominium and apartment residents were excluded from the survey so that the sampled population would be generally conformable to that of the hedonic approach. 43 samples were collected. 40 of the respondents completed all questions, while three did not provide answers about their annual income and the price of their current house. Each respondent was selected randomly across Green Valley.

An open-ended contingent valuation format method was used to survey willingness to pay for a house with amenities. This requires the assumptions that all the respondents are rational, familiar with the housing market, and full information is provided. Contingent valuation is one of the methodologies for valuing public goods, such as air quality, drinking water, national park, etc. It has been commonly employed as a preference technique in economic analysis, for modeling complex trade-offs among the multiple attributes of public goods. The respondents are asked to answer the hypothetical questions about how much they are willing to pay to obtain the benefit of the nonmarket resources. There are three versions of contingent valuation:

open-ended, closed, and sequential bids.

In the sequential bids version, respondents are asked whether they would accept an increase or decrease from the starting point bid or would reject the offer, until they reach the maximum or minimum dollar bound. The method to reach the final bid is very similar to that of an auction. The results of sequential-bids contingent valuation can be affected by the starting point and the amount of the specific sum. These give rise to what are termed starting point bias and instrumental bias. Boyle et al. (1985) found statistically significant differences between the mean final bids for different starting bids in previous close-ended contingent valuation studies.

In the closed-ended contingent valuation method, the respondents are asked whether they would accept or reject the specific hypothetical price for the amenity. Knetsch and Kahneman (1985), and Carmeron and James (1987) suggest that the closed ended contingent valuation method can avoid the starting point bias. However, the results of closed ended contingent valuation may depend on the specific sum which is presented by a researcher, which means the structure can be somewhat artificial, and the amount of willingness to pay may be restricted by the researcher or the questionnaire, generating an instrumental bias.

In the open-ended contingent valuation method the respondents are asked to specify what they would be willing to pay for the specific amenity. According to Seller et al. (1985), in their study of recreational boating, the relative accuracy of the

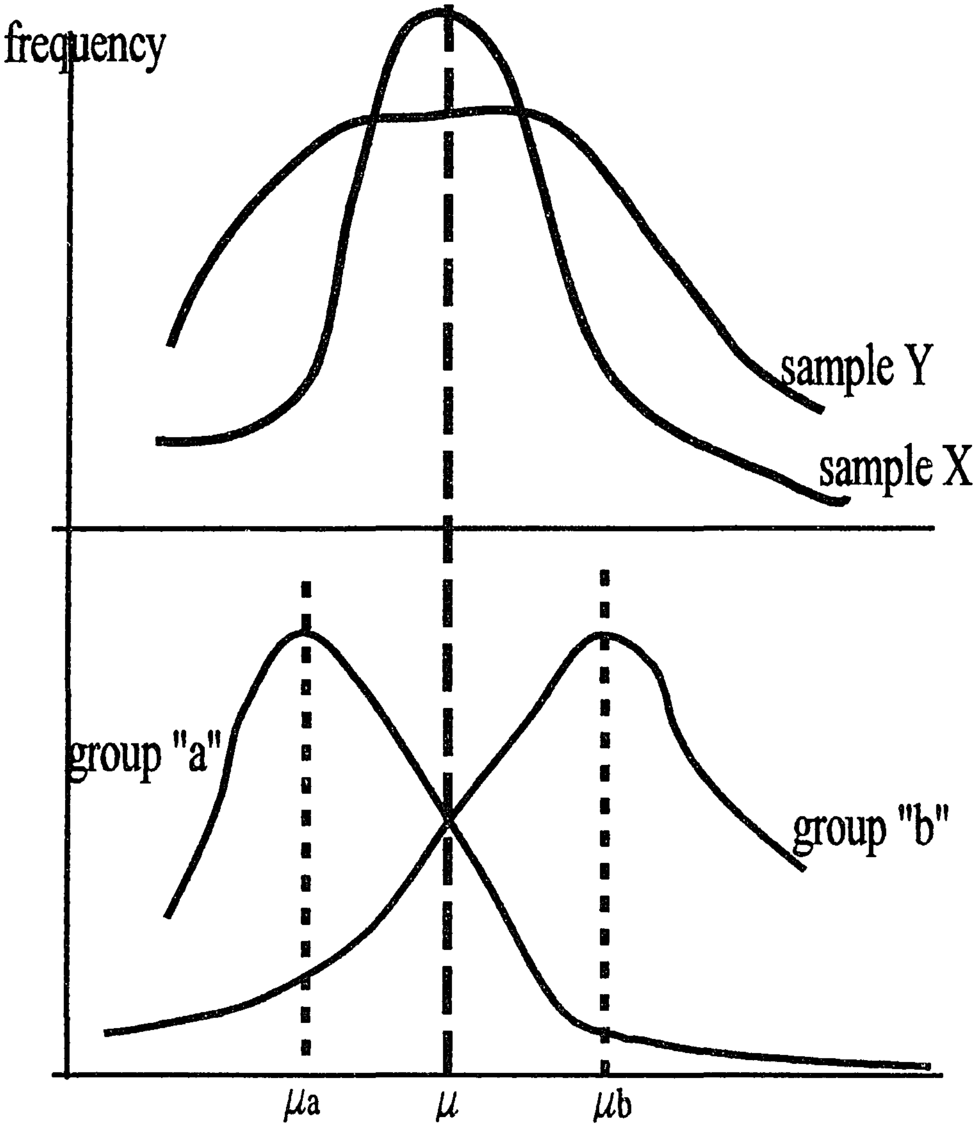


Figure 3-2. The Comparison of the Distributions of the Homogenous Sample of "X" and the Heterogenous Sample of "Y" Which Is Consisted of Two Significant Different Groups "a" and "b".

open-ended contingent valuation was low when compared with results of the travel cost (indirect method) and the closed-ended valuation methods. They tested the accuracy by asking the respondents how sure they were about their bid. The amount of willingness to pay can vary considerably across different kinds of users, especially for a recreational resource. A user who visits the recreational site once in a while may provide a higher sum of willingness to pay than some one who lives near by the recreational sites and often use the recreational facility. Therefore, the average willingness to pay can not represent homogeneously the whole group of respondents, when the respondents in the sample are heterogenous. In other words, the average willingness to pay may represent the average of several means of different sample groups. For example, in Fig 3-2, we can compare the case of homogenous sample "X" with the case of heterogenous sample "Y". The heterogenous sample "Y" consists of two different groups as "a" and " b", and μ_a and μ_b are the means of willingness to pay for group "a" and group "b", respectively, while "μ" is the average willingness to pay over sample "X". The mean willingness to over the heterogenous sample "Y" shows the same value "μ" as with the case of the homogenous sample "X", even though the distribution is quite different from that of sample "X". But, in the case of a community like Green Valley, which is relatively homogenous, the interpersonal effect probably is relatively small. Generally, for Green Valley the open-ended contingent valuation method is expected to provide estimates of willingness to pay that are not strongly affected by instrumental or starting point biases that have occurred in other studies.

Besides starting point and instrumental biases, there could be strategic bias, information bias, and hypothetical bias in survey results. Unlike starting point and instrumental biases, which are caused by the researcher, these biases can be introduced by the respondents. If an individual thinks that the results of the survey may affect his welfare, he may not provide honest answers. Or, if an individual does not have enough information, he can not give a useful answer. And if the hypothetical situation is too far beyond the real world, the answers can be very noisy.

Survey Design

The survey questionnaire followed the structure of an open-ended contingent valuation survey. Specifically, the respondents were asked how much they would be willing to pay for a house in a specific location but with amenities other than those that it currently possesses. However, prior to posing these questions, the respondents were asked for background information, such as their age, annual income and house characteristics. Housing information included the price of the current house, the type of payment, the year when it was purchased, the year when the house was built, the size of the house, and its location and orientation. For convenience, the respondents merely had to indicate which of several specific numerical ranges applied to his/her answer.

Location of house was described by five different ranges of distance, based on the distance from mine to the house in 0.8 mile increments, such as:

location I : if the house is located within 0.8 miles from the mine.

location II : if the house is located between 0.8 and 1.6 miles from the mine.

location III: if the house is located between 1.6 and 2.4 miles from the mine.

location IV: if the house is located between 2.4 and 3.2 miles from the mine.

location V : if the house is located in farther than 3.2 miles from the mine.

The map given each respondent depicted zones for the five location ranges. This map was used to locate the respondent's home and four other hypothetical locations. Of course, besides hypothetical locations, the willingness to pay questions included two different type of house orientations, the current and the hypothetical orientation. Each respondent answered 10 different willingness to pay questions for the exact same house: five different hypothetical locations and two different hypothetical orientations, including the current location and orientation. The questionnaire used in the survey is provided in appendix B.

Willingness to pay in this study will be described as a function of the information collected from the survey, such as income, size of house, age of house, distance from mine, and orientation of house. The marginal willingness to pay function will be derived by differentiating the willingness to pay function with respect to the specific amenity and will be considered to be the inverse demand for the amenity. This inverse demand function for the amenity will be used to estimate the change in welfare due to a change in an amenity.

Section 3. Empirical Results

This section presents the results and interpretation of willingness to pay as estimated by an open-ended contingent valuation. Then, the demand for the environmental quality will be derived from the analysis of willingness to pay.

Willingness to Pay

Response to the open ended contingent valuation survey was relatively high (93.02%) when compared with previous studies, such as Sellar et al. (1985) who shows a response rate of 62.4%. However, several respondents did not answer two of the ten willingness to pay questions, especially the question of willingness to pay for the house hypothesized to be located very close to mine. When the respondents were asked why they left the question blank, they answered that they were not willing to move to that location range, even though it would be free or subsidized. Should we treat this "no response" answer as "$ 0" for willingness to pay for that house? Or, would it be better to eliminate the "no response" from analysis? Treating the no response as "0" willingness to pay requires either that the value of that house is "0", or the "0" dollar is treated as a result of the second best solution of the corner solution of Pareto optimality for the respondent. But, such a case can happen only when the marginal cost is high compared to the marginal benefit at any positive level of "X", as shown in Fig. 3-3, so that the marginal benefit curve and marginal cost curve can not meet at any positive value of "X". However, even though the corner solution is assumed to be the appropriate answer in this case, it is not always

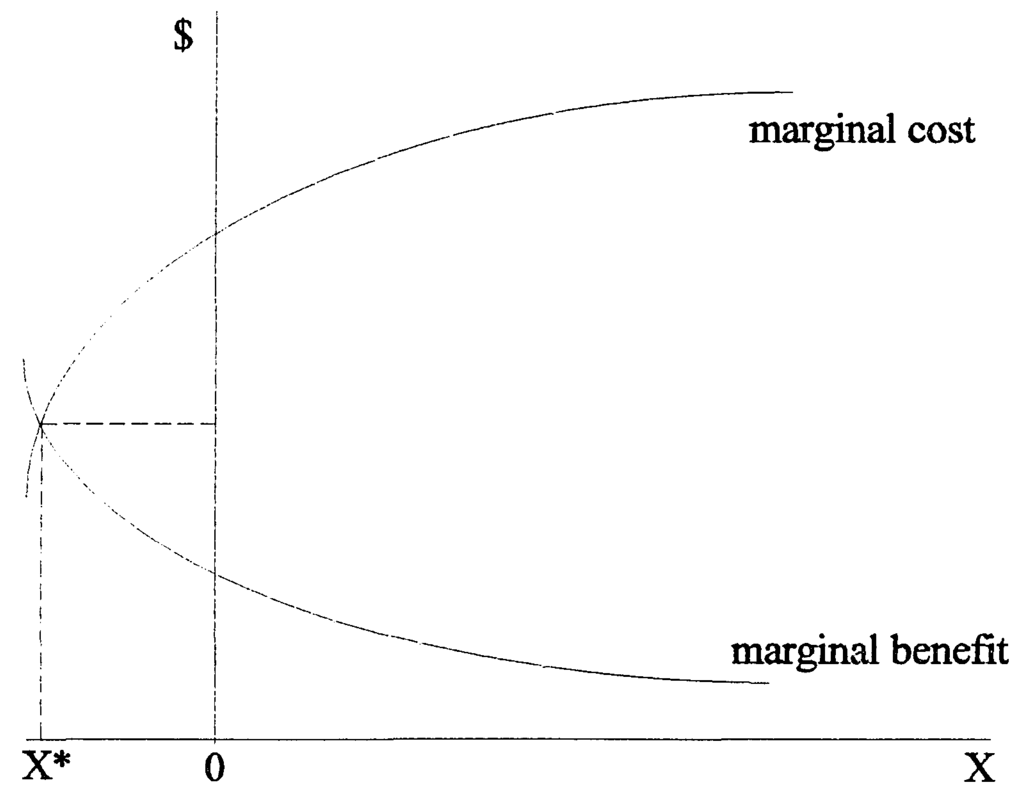


Figure 3-3. Corner Solution for the Optimality

guaranteed that the price of a corner solution is also zero. In other words, the willingness to pay is required to be highly restricted by a special functional form , such as a quadratic functional of the variable "X" with or without a constant term, for example:

$$P = 2X^3$$

In this study, the cases of "non-response" were excluded from statistical analysis. Therefore, the total sample of willingness to pay estimation is 375, not 400 (ten willingness to pay questions by 40 sample residents).

The willingness to pay relationship is likely to be non-linear in the variables of this study. Accordingly, the log-log functional form was selected as the best model for the willingness to pay, based on the statistical results and the general concept of consumer behavior. Compared with the other functional forms, the log-log form has both statistical and conceptual advantages, providing a good fit and an appropriate demand curve. One advantage of the log-log model is that the associated demand model is parameterized on shift variables, which act to shift the demand curve. A linear model for willingness to pay results in an inverse demand curve for a specific amenity that will be constant at any level of the amenity and is independent of the other variables that affect willingness to pay and the derived demand.

Of course, not all nonlinear models result in derived inverse demand functions with shift variables. Consider, for example, the following nonlinear (semilog) model:

$$P = g\ (\ \ln(Q),\ \ln(I),\ldots),$$

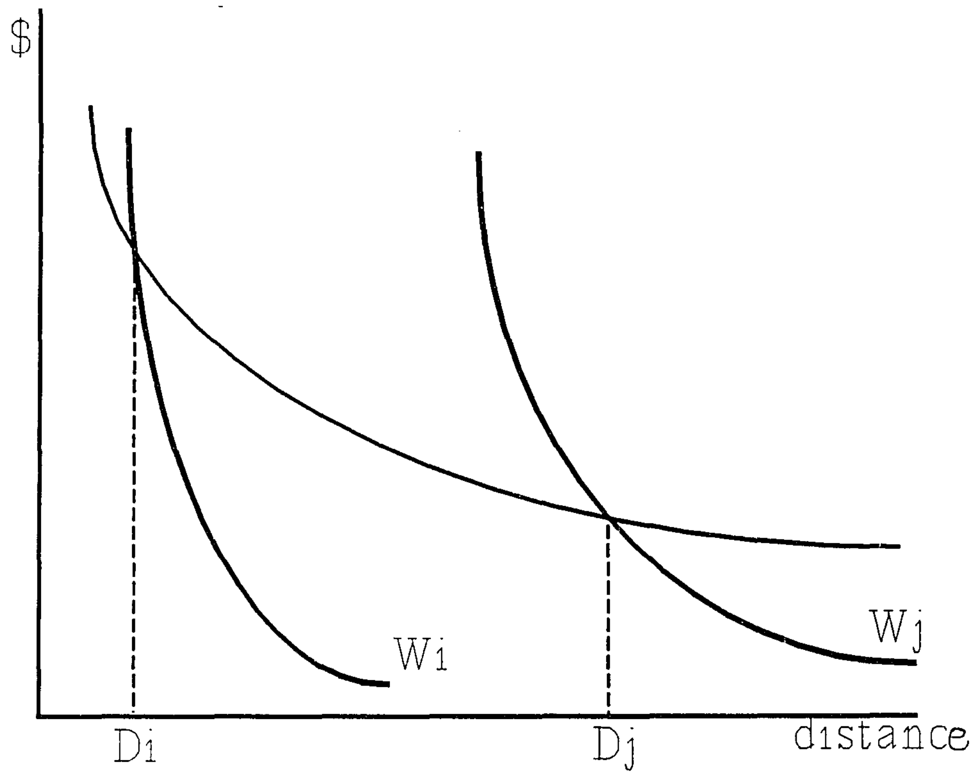


Figure 3 - 4. Income Effects in the Willingness to Pay Curves

then, differentiating willingness to pay with respect to "Q" is

$$\frac{\partial P}{\partial Q} = \frac{1}{Q}$$

That is, the demand curve is a function of "Q" only. Therefore, the demand curve may not be shifted upward or downward by the important shift variables which represent determinants of demand, e.g. income, etc..

The estimated willingness to pay model is the following:

$$\ln(P) = \underset{(-6.4630)}{-199.741} \underset{(6.330226)}{+0.11468 \ln(D)} \underset{(-1.53319)}{-0.0423 \ln(DD)} \underset{.(9.182997)}{+0.21525 \ln(I)} \underset{(11.89545)}{+0.6644 \ln(SQ)}$$

$$+ \underset{(6.572679)}{26.854 \ln(Y)} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3\text{- }5)$$

R Square = 0.615117

F value = 117.9468

where

P= sales price of the house ($)

SQ= the size of living area (sqft)

Y= the year when the house was built

I = annual income ($)

D= the distance from mine (mile)

ln(DD)= the orientation of house

= 1, if the backyard of house faces the mine.

= 0, others.

t-statistics are shown in parentheses.

Inspite of criticisms about the hypothetical nature of questions and the fact that actual behavior is not observable, the results of this survey show that all the variables are statistically significant, as they are in the hedonic implicit price equation. Even though the willingness to pay curve is not identical to the hedonic price equation, it has the same relationship of housing price with respect to the independent variables as the results of hedonic approach. All t-statistics of the variables are increased except that for the orientation of house (DD). Especially, the t-statistics for size of house (SQ) and distance from mine (D) are increased by more than two times. But, the coefficients of all the variables are numerically smaller than those of the hedonic equation, which means that the elasticities of demand for amenities with respect to the amenity prices are higher than those of hedonic approach. For example:

Consider the following hypthetical model

$$p = A\, Q^{0.5} \qquad \text{................(3 - 6)}$$

or $$Q = (1/A)^2\, p^2$$

where

p = the housing price

A = constant

Q = variable of housing amenity

Here, the small coefficient in the price model implies a large price elasticity of demand for Q.

The size of the house (SQ), which along with age of house (Y), represent the physical characteristics of the house, is shown as the most significant variable in the willingness to pay function.

In this willingness to pay equation, income is a highly significant factor. The income elasticity of price is 0.21525.

With its high t-statistic, the positive coefficient of distance from mine (D) provides evidence of the environmental impact of the mine complex on the Green Valley community. On the one hand, most respondents agree that improvements have been made in dust control and reduction. But, on the other hand, some respondents complain that the height of the tailings bank has been increasing continuously, and the appearance (viewscape) of the tailings bank is not improving, still being without enough tree or shrub cover. They suggest that planting trees would help to avoid dust flow as well as helping to improve the scenic view.

Some extreme respondents do not want to trade off with other amenities, or they answered they are not willing to move close to the mine with any incentives. However, some residents responded with non-increasing and non-decreasing willingness to pay as the location of house from mine was increased. There are three cases. First, suppose that the individual lives near the mine and is too poor to move in Fig 3 - 4. Due to the limit of his budget, his actual indifference curve can not be shifted up to Dj. Thus, his marginal willingness to pay curve can not exist in the location which is far from mine. Second, the strategic behavior can cause such a result. Suppose that someone who purchased an expensive house which is located near the mine worries that the survey results might affect the price of his current house. He may answer the same willingness to pay for any location. Third, a person may have no preference with respect to distance from mine, so he answers the same willingness to pay for any location.

Yet, no one answered with decreasing willingness to pay with respect to increasing distance from the mine. Especially significant is the fact that those who had experienced living very close to the mine and recently moved to a more distant location reacted to the questionnaire very sensitively, stating significantly lower willingness to pay for the house located very close to the mine than for the house at its current location. This fact indirectly says that the answers to the questionnaire can be affected by the individual's personal experience as well as by his/her preference and budget constraint.

Unlike distance from mine (D), the orientation of house (DD) has a lower t-statistic in the willingness to pay equation than in the hedonic price equation. But, it is still a significant variable in the willingness to pay equation at the 5 % level. In the willingness to pay function, a combination of distance from mine (D) and the orientation of the house (DD), (D/DD), shows a high t-statistic:

$$\ln(P) = \underset{(-6.42695)}{-199.399} + \underset{(6.223023)}{0.094788} \ln(D/DD) + \underset{(9.15261)}{0.215307} \ln(I) + \underset{(11.91437)}{0.66751} \ln(SQ) + \underset{(6.536692)}{26.80505} \ln(Y) \quad \ldots\ldots\ldots\ldots\ldots\ldots(3-7)$$

R Square = 0.611324

F value = 145.4875

In subsequent analysis, the first equation in which D and DD are separated is employed because of greater flexibility that it provides.

Derived Inverse Demand for Environmental Quality

The marginal willingness to pay for air quality or inverse demand curve is derived from the willingness to pay equation (3 - 5) as below:

$$\frac{\partial P}{\partial D} = 0.11468e^{-199.741}[D^{-0.88532}DD^{-0.0423}I^{0.21525}SQ^{0.6644}Y^{26.854}]$$

..........................(3 - 8)

where

$$P = e^{-199.741}[D^{0.11468}DD^{-0.0423}I^{0.21525}SQ^{0.6644}Y^{26.854}]$$

This Hicksian demand is downward-sloping with respect to distance from mine (D). The marginal willingness to pay for the better scenic view or inverse demand for better view is

$$\frac{\partial P}{\partial DD} = -0.0423e^{-199.741}[D^{0.11468}DD^{-1.0423}I^{0.21525}SQ^{0.6644}Y^{26.854}]$$

..................(3 - 9)

These empirical findings also confirm the hypothesis that the derived demands are influenced by distance from mine and orientation of house. This marginal willingness to pay or inverse demand equation will be used to evaluate the welfare change from the environmental quality change, and Chapter 4 compares the results of contingent valuation with those of the hedonic housing model.

CHAPTER 4.

CONSUMER'S SURPLUS

This chapter evaluates the impacts of mining on the Green Valley Community using the results of the hedonic housing model and contingent valuation survey described in Chapters 2 and 3.

The mining impacts on the housing market can be calculated in terms of consumer's surplus from the changes in the variables representing the presence of mine and environmental characteristics.

In this study, consumer surplus is an approximation to the sum of individual surpluses, with allowances for specific values of and determinants of demand, e.g. income, age, etc.. This contrasts with the average consumer's surplus from " the constant (or identical) changes" in the levels of the specific variables across the individual household. Here, changes in the levels of the specific variables represent the individual households. This attempt is quite different from many of the previous consumer's surplus studies, and the results may be practically useful and easily adapted for benefit-cost analysis where the average welfare change can not represent the welfare change of the whole community because the community is typically heterogenous in race, age, and income.

The results from section 2 (hedonic implicit price estimation) and section 3 (contingent valuation) will be used to estimate measures of the consumers surplus, and the two different measures will be compared. As explained later, these estimates may bound the actual value of consumers surplus.

Section 1. Theoretical Background

Marshall (1930) developed an approximation to consumer's surplus as the area under the Marshallian demand curve, with the assumption that the marginal utility of money is constant. Since then, assuming ordinal utility, Henderson (1941), Samuelson (1938), and Hicks (1943) suggest that the Marshallian measure of consumer's surplus can be a good measure when the income effect is small. Hicks (1943) generalized the theory of consumer's surplus into four types, which are quantity-compensating (Cq), price-compensating (Cp), price-equivalent (Ep), and quantity-equivalent (Eq).

He defined compensating variation as the amount of income the consumer would have to lose in order to offset the gain due to the fall in price or due to the increase in quantity. In Fig 4 - 1, the consumer will purchase the unit of commodity (except for an inferior good) if the actual price OP is less than the marginal valuation ΔV, which is the same thing as Marshall's marginal utility in terms of money. When the price falls from OP to OP′, the consumer looses an amount of income, which equals the price-compensating variation PccP′, where CC′ is the Hicksian compensating demand curve, EE′ is the Hicksian equivalent demand curve, and CE is the Marshallian demand curve. When the quantity increases from Q to Q′, which was used to correspond to P′ in Marshallian observable demand curve, his quantity-compensating variation is price-compensating variation PCcP′ minus the area cEC′. On the other hand, equivalent variations measure the gain in income taking place at the higher price, which would give the same gain in satisfaction as the fall in price

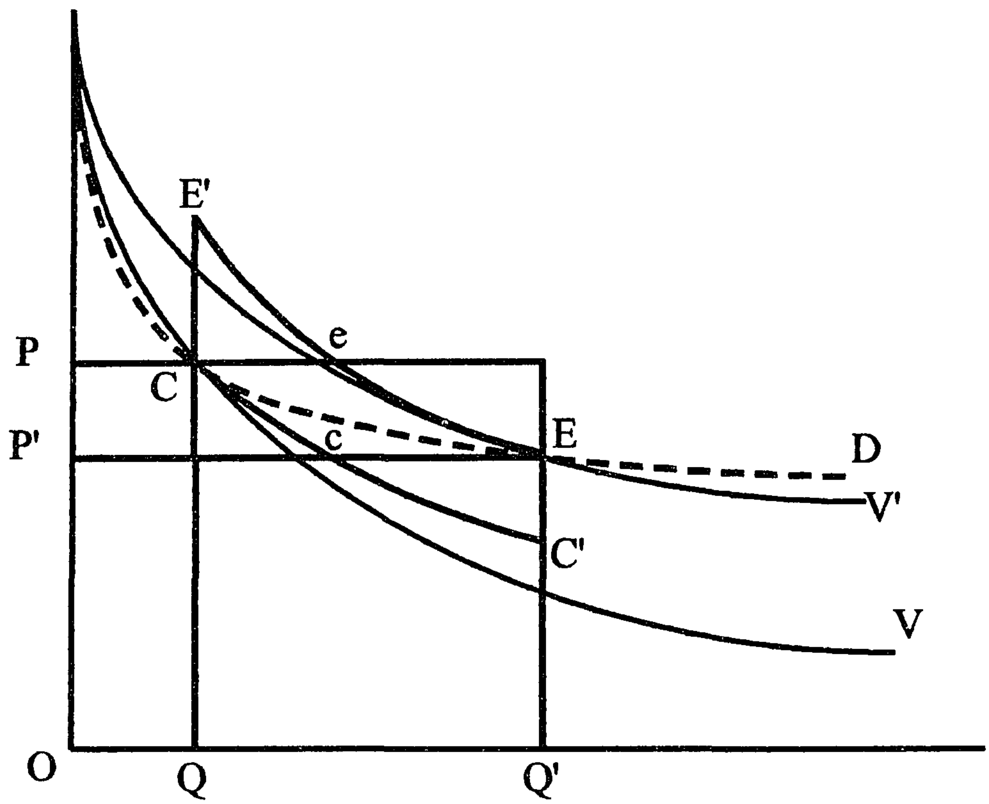


Figure 4-1. The Marshallian and the Hicksian Measures of Consumer's Surplus.

gives. The price-equivalent variation is PeEP′, while the quantity-equivalent variation equals the price-equivalent PeEP′ plus the area E′Ce.

Hicks (1943) and Willig (1976) demonstrate the theory for equivalent and compensating variations from observable Marshallian consumer's surplus when the income elasticity of demand is not zero. According to Willig (1976), the area usually called consumer's surplus, which is defined by the observable Marshallian demand curve, is PCEP′. When there is no income effect, in other words, the income elasticity of demand is close to zero, the observable Marshallian consumer's surplus can represent all of the compensating and equivalent variations.

Following the suggestions of Brookshire et al (1980) and Sellar et al (1985), the equivalent measures use the subsequent welfare level as a reference level of what a consumer would be willing to pay in order to avoid moving to a less preferred situation. And, the compensating measures use the initial welfare level as a reference level when a consumer would be willing to pay in order to obtain a more preferred situation. Therefore, the willingness to pay may be either Hicksian equivalent or compensating measures of welfare change depending on the circumstances facing the consumer.

This chapter will provide two different estimates of consumer's surplus. One of them is calculated as the area under the demand curve by using the derivative of the estimated hedonic implicit price equation, as was demonstrated in chapter 2. This hedonic consumer's surplus will be a Marshallian measure of consumer's surplus, because the estimated hedonic implicit price function was assumed to have no income effect.

$$CS^H = \int_{Qo}^{Q1} mip\ (Q\ ,.....)\ dQ$$

where

CS^H = the measure of consumer's surplus from the changes in quantity of characteristic Q from Qo to Q1.

mip = marginal hedonic implicit price equation.

The second estimate uses the derivative of the willingness to pay bid curve and provides a Hicksian demand curve, as shown in chapter 3. The Hicksian consumer's surplus will be estimated as the area under the Hicksian demand curve.

$$CS^S = \int_{Qo}^{Q1} mwp\ (Q\ ,........)\ dQ$$

where

CS^S = the measure of consumer's surplus from the changes in the quantity of characteristic Q from Q_o to Q1.

mwp = marginal willingness to pay.

Section 2. Data and Methodology

Since the study uses the housing market to estimate the environmental impact of mining on Green Valley, information about total housing units in Green Valley is required. Following COLE(1994), the total number of separate family houses during the year of 1993 to 1994 is 9,394. COLE's data include town homes and condominiums in the category of single family houses. Single family units total 7,514.

Table 4-1. The Housing Units Information of Green Valley, Arizona Based on the COLE Directory (1994).

Type of Family Home	Number of House Units
Single Family Houses (including town houses and condominiums)	7,514
Two Family House	423
Three Family House	455
More than Three Family house	1,002

On the other hand, the Census (1990) separates the town homes and condominiums from the single family house, as shown in Table 4 - 1. Compared with COLE's (1994) data, the Census data are based upon a somewhat different area, one extended to include surrounding areas, such as Sahuarita. However, this Census provides data about single family houses, which is shown as detached single family houses in Table 4 - 2.

Table 4-2. The Housing Information of Green Valley, Arizona Based on the Census (1990)

Type of House	Number of House Units
Single Family house	8,072
Detached Single Family House	3,968
Attached Single Family House (town homes + condominiums)	4,104
Total units of House	10,047

The detached single family house is 49% of total single family houses in Census data.

Since the information about detached single family houses is not available in COLE (1994), we have to estimate the units of detached single family houses in 1994 using the proportion of detached single family homes among the single family houses in the Census (1990) data. Roughly, the estimates of detached single family units for the COLE's basis can be approximated as below

$$
\begin{aligned}
EDN^1_{COLE} &= SN_{COLE} \cdot \frac{DN_{CENSUS}}{SN_{CENSUS}} \\
&= 7{,}514 \cdot \frac{3{,}968}{8{,}968} \\
&= 7{,}514 \cdot 0.49 \quad = \quad 3{,}682
\end{aligned}
$$

where

EDN^1_{COLE} = the estimate of detached single family house units in COLE's basis.

SN_{COLE} = the actual number of single household units in COLE basis.

DN_{CENSUS} = the actual number of detached single family household units in Census basis.

SN_{CENSUS} = the actual number of single family house units in Census basis.

This 3,682 units is close to the estimated units converted from the Census data by multiplying the ratio of total single family in COLE's basis to total single family in Census basis by the detached single family house units in the Census basis. That is,

$$EDN^2_{COLE} = \frac{TN_{COLE}}{TN_{CENSUS}} \cdot DN_{CENSUS}$$

$$= \frac{9{,}394}{10{,}047} \cdot 3{,}968 = 3{,}710$$

where

EDN^2_{COLE} = the estimate of detached single units in COLE's basis.

TN_{COLE} = the actual number of total house units in COLE's basis.

TN_{CENSUS} = the actual number of total house units in Census basis.

DN_{CENSUS} = the actual number of detached single family house units in Census basis.

Therefore, the Range of actual number of detached single family house units (DN_{COLE}) is

$$3{,}682 \text{ or } 3{,}710 \leq DN_{COLE} \leq 7{,}514$$

In order to calculate the average consumer's surplus per living unit, relative frequency functions are required, functions that describe the relative frequency of determinants of demand for environmental amenities which in this study are proxied by distance from mine and orientation of house. Let us refer to these by vector "z" and to all other variables in the marginal willingness to pay inverse demand function by vector x. And, let f (x, z) be the joint relative frequency distribution for "x" and "z", define z* as the most favorable values for the environmental proxies. Then, the average consumer's surplus for the Green Valley community is the difference between maximum consumer surplus, compensated as if "z" were to be equal to z* everywhere, and the consumer surplus computed using the actual values of z.

$$CS = \int_z \int_x mip(x; z = z^*) \cdot f(x,z)\, dx dz - \int_z \int_x mip(x, z) \cdot f(x, z)\, dx\, dz$$

where

CS = average consumer surplus per living unit in Green Valley.

mip (x, z) = marginal implicit price, which is function of x and z.

x = a set of characteristics of the house.

z = an environmental characteristic.

mip (x; z = z*) = marginal hedonic implicit price, given z is fixed at z*.

z*= the maximum level of the characteristic "z".

f(x,z) = the joint relative frequency function of x and z.

Of course, this calculation requires knowledge of or estimates of the relative frequency functions. The best approximation to these relative frequency functions for this study is derived from the survey data , i.e. the contingent valuation survey.

Accordingly, that data was used to calculate the relative frequency functions, and these functions were used for the estimation of consumer's surplus by both the hedonic and contingent valuation approaches. First of all, frequency for each characteristic was calculated. Then the relative frequency for a house with all the characteristics involved in the price equation can be calculated as below, Table 4 - 3, when all variables X and Z are statistically independent.

Table 4-3. The Relative Joint Frequencies When the Variables Are Statistically Independent.

	f (x1)	f (x2)	....	f (z)
f (x1)		f (x1, x2)	....	f (x1, z)
f (x2)	f (x2, x1)		....	f (x2, z)
....	....	....	....	....
f (z)	f (z, x1)	f (z, x2)	....	

where

$f(x1, x2) = f(x1) \cdot f(x2) = f(x2, x1)$

$f(x1, x2, x3) = f(x1) \cdot f(x2) \cdot f(x3)$

......

and eventually, the relative frequency of a house which is associated with the characteristics x1, x2, x3, ... , and z is

$f(x1, x2, x3, ..., z) = f(x1) \cdot f(x2) \cdot f(x3) \cdot .... \cdot f(z)$

But, according to the correlation coefficients for the variables (Table 4 - 4), income (I) appears to have high correlation with two variables: the size of living area (SQ) and the year when the house was built (Y). Thus, we need to use the conditional relative frequencies f(SQ;I), f(Y;I) instead of the marginals f(SQ) and f(Y).

Table 4-4. The Correlation Coefficients of the Variables.

	DD	SQ	Y	I	D	TP
DD	1					
SQ	0.0166	1				
Y	-0.00176	0.235206	1			
I	0.001899	0.552402	0.422946	1		
D	-0.01129	0.054353	0.022797	0.050704	1	
TP	0.0049	-0.081	-0.16797	-0.12559	0.00448	1

Therefore, in this study, the relative joint frequency of a house with the survey variables is:

$$f(SQ, Y, I, D, DD) = f(SQ; I)\, f(Y; I)\, f(I)\, f(D)\, f(DD)$$

where

$$f(SQ;I) = f(SQ, I) / f(I)$$

$$= \text{the marginal relative frequency of SQ.}$$

$$f(Y;I) = f(Y, I) / f(I)$$

$$= \text{the marginal relative frequency of Y.}$$

$f(SQ, I)$ = the joint relative frequency of SQ and I.

$f(Y, I)$ = the joint relative frequency of Y and I.

$f(I)$ = the marginal relative frequency of I.

$f(D)$ = the marginal relative frequency of D.

$f(DD)$ = the marginal relative frequency of DD.

On the other hand, since income is not a variable in the hedonic equation, the joint relative frequency of a house for the hedonic approach is simply the product of the marginal relative frequencies:

$$f(SQ, Y, TP, D, DD) = f(SQ) \cdot f(Y) \cdot f(TP) \cdot f(D) \cdot f(DD) .$$

Total consumer surplus (TCS) can be calculated by multiplying the mean consumer surplus per housing unit, CS, by the number of housing units, N:

$$TCS^H = N \cdot CS^H$$

and

$$TCS^S = N \cdot CS^S .$$

Section 3. Empirical Results

Consumers Surplus by Use of Hedonic Approach

The measure of welfare changes generated from the changes in location of house are calculated from the expression derived from the hedonic equation (2 - 6) in section 2. The mean value of welfare changes or consumer surplus associated with the improvements in location of house, in particular, from the individual household's current location to the best location (set as D= 50 cm = 5 mile) in terms of distance from mine can be calculated as below, using the relative frequency function.

$$CS_D^H = \int_Y\int_{SQ}\int_{TP}\int_{DD}[mip(Y,SQ,CS,DD;D=50)\cdot f(Y,SQ,TP,DD)]\ dY dSQ dTP dDD$$
$$-\int_Y\int_{SQ}\int_{TP}\int_{DD}\int_D[mip(Y,SQ,TP,DD,D)\cdot f(Y,SQ,TP,DD,D)]\ dY dSQ dTP dDD dD$$ [1]

= $ 18,058.73 ....Eq.. 4 - 1

where

CS_D^H = the mean of hedonic consumers surplus from the changes in location D.

D = the location of house in terms of distance from mine (cm in aerial photographic map; 1 cm = 0.09 mile).

Y = the year when the house was built.

[1] This equation and those that follow represent the mathematical concepts involved in the estimation of consumer's surplus. In actual computation, the relative frequency function was discretized and the integrals replaced by summations.

SQ = the size of living area of the house.

TP = the type of payment.

DD = the orientation of house.

mip (Y, SQ, TP, DD; D = 50) = the relative marginal implicit price function when the variable "D" is fixed as D equals to 50 cm, which is consistent with 5 miles from the mine.

f (Y, SQ, TP, DD, D) = the relative frequency of a house with the characteristics Y, SQ, TP, DD, and D.

$f(Y, SQ, TP, DD) = \int_D f(Y, SQ, TP, DD, D)\, dD.$

The maximum value of distance from mine (D) is set as D= 50 cm, which is consistent with D= 5 mile in survey approach. Setting a maximum distance of D= 50 cm = 5 mile is based on the assumption that the areas under marginal implicit price and marginal willingness to pay curves are maximum at this distance. This implies that values of the marginal implicit hedonic price and marginal willingness to pay are both non-negative at this distance, D= 5 mile. In Fig 4 - 2, if the demand curve is XYZ, the maximum area under the demand curve can be obtained at D = d3, which is the maximum level of "D". However, this maximum level of distance does not always give the maximum area under the demand curve. When the demand curve is XYZ′, the area under demand curve reaches the maximum at D = d2, not d3, because the area under the curve YZ′ is negative. In addition, when we assume that the boundary of the research area is not "d2", but "d1", which is smaller than even "d2", the maximum area is "d1", no matter what the demand curve is, XYZ or

XYZ′, even XYZ″.

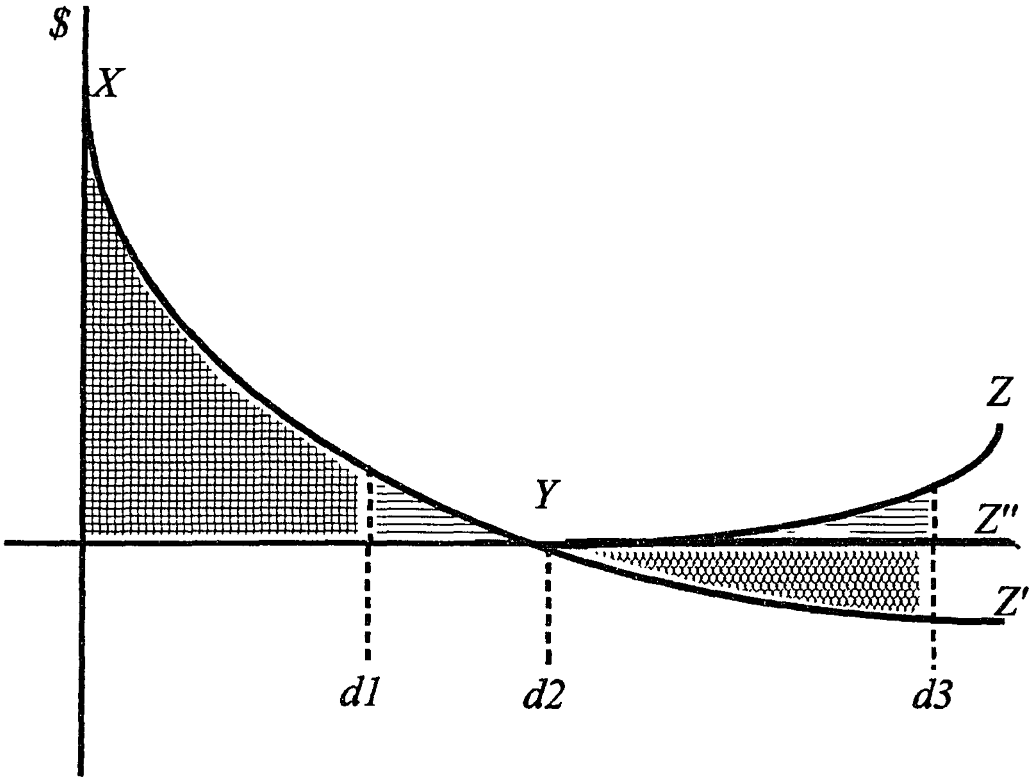


Figure 4 - 2. Possible Measures of the Consumer's Surplus With Respect to Different Types of Demand Curves and Different Optimal Levels of Environmental Variable.

In this dissertation, the demand curve is likely to be of the form XYZ″ or XY. Since the estimated hedonic price function is of the log-log form with respect to the distance, the derivative of the hedonic function is always positive. That means we do not need to worry about negative consumer's surplus.

In Green Valley, 5 miles is the maximum distance from the mine in any location. Therefore, the estimate of CS_D^H provides the maximum mean value of welfare improvements when the location of the house is changed from its current location to a location which is as far as 5 miles from mine.

The mean value of welfare changes resulting from house orientation is calculated as below:

$$CS_{DD}^{H} = \int_Y\int_{SQ}\int_{TP}\int_D [mip(Y,SQ,TP,D;DD=1)\cdot f(Y,SQ,TP,D)]\,dY\,dSQ\,dTP\,dD$$
$$-\int_Y\int_{SQ}\int_{TP}\int_D\int_{DD} [mip(Y,SQ,TP,D,DD)\cdot f(Y,SQ,TP,D,DD)]\,dY\,dSQ\,dTP\,dD\,dDD$$

= \$ 7,747.349 ....Eq.. 4 - 2

where

CS_{DD}^H = the mean of hedonic consumers surplus from change in the orientation of a house.

mip (Y, SQ, TP, D; DD = 1) = the marginal implicit price equation when the orientation is fixed as DD= 1, which means that the backyard of the house faces away from the mine.

f (Y, SQ, TP, D) = $\int_{DD}$ f(Y, SQ, TP, D, DD) dDD.

Since the variable of orientation (DD) is one of the dummy variables in the hedonic equation, in the log-log regression equation, the value of ln (DD) is 1 or 0, meaning that DD = 2.7138 or 1. DD equals to 1, and ln (DD) = 0 when the backyard of the house faces away from mine. Therefore, $CS_{DD}{}^{H}$ provides the mean value of consumer's surplus from scenic view improvement by changing the house orientation from current to facing away from the mine (DD = 2.7139), which is identical to ln (DD) = 0.

In section 2, the distance factor (D) and orientation factor (DD) were described as environmental variables. Based on the results from equation 4-1 and 4-2, we can estimate the environmental impact of mining as the combined effects of D and DD:

$$CS_{D,DD}{}^{H} = \int_Y\int_{SQ}\int_{TP}[mip(Y,SQ,TP;D{=}50cm,DD{=}1)\cdot f(Y,SQ,TP)]\,dY\,dSQ\,dTP$$
$$-\int_Y\int_{SQ}\int_{TP}\int_D\int_{DD}[mip(Y,SQ,TP,D,DD)\cdot f(Y,SQ,TP,D,DD)]\,dY\,dSQ\,dTP\,dD\,dDD$$

= \$ 25,470.56

where

$CS_{D,DD}{}^{H}$ = the mean of total consumers surplus which is generated from the environmental quality improvement by the use of the hedonic approach;

mip (Y, SQ, TP; D = 50 cm, DD = 1) = marginal hedonic implicit price which is function of Y, SQ, and TP, and when D and DD are fixed as 50 cm and 1, respectively.

$f(Y, SQ, TP) = \int_{DD}\int_{D} f(Y, SQ, TP, D, DD)\,dD\,dDD.$

This estimate of $CS_{D,DD}{}^{H}$ provides the mean of welfare changes when the environmental qualities are improved in terms of the distance from mine and orientation across the households in Green Valley. The total consumers surplus can be obtained multiplying this mean of consumer's surplus by the total number of house units in Green Valley. Of course, this requires identifying or estimating the appropriate number of houses.

Environmental impact analysis by housing models, such as the hedonic price model, requires an appropriate definition of the housing unit. For this purpose, apartments and condominiums should be excluded from the total number of units. Accordingly, the number of single family houses is used in this study to calculate total consumer's surplus for the Green Valley community with respect to environmental quality improvements. However, as mentioned in section 2, there are some concerns about what the actual number of detached and attached single family houses is in Green Valley. COLE (1994) does not provide information about detached and attached single family house, but only aggregate single family house, which is the sum of detached and attached single family houses, as shown as 7,514. On the other hand, Census (1990) specified the single family houses into detached single family house, " and" attached single family house (here including town houses and condominiums). Therefore, the estimated number of detached single family house units is used for calculation of consumers surplus in Green Valley.

When EDN^1_{COLE} or EDN^2_{COLE} is taken as the number of detached single family houses, the total consumers surplus is \$ 93,782,602 or \$ 94,495,778.7, respectively. When the number of total single family houses is used, the total consumers surplus reaches \$ 191,385,790.

<u>Consumers Surplus by Contingent Valuation (Survey) Approach</u>

The survey approach uses the results from the willingness to pay equation in order to estimate the mean of consumer's surplus. The mean of welfare changes from location improvements in terms of distance form mine can be calculated by setting D= 5 miles, as in the hedonic approach.

$$CS_D^S = \int_Y\int_{SQ}\int_I\int_{DD}[mwp(Y,SQ,I,DD;D=5)\cdot f(Y,SQ,I,DD)]\,dY\,dSQ\,dI\,dDD$$
$$-\int_Y\int_{SQ}\int_I\int_{DD}\int_D[mwp(Y,SQ,I,DD,D)\cdot f(Y,SQ,I,DD,D)]\,dY\,dSQ\,dI\,dDD\,dD$$

= \$ 7,914.372

where

CS_D^S = the mean Hicksian consumers' surplus from the changes in the location of a house.

mwp (Y, SQ, I, DD, D) = marginal willingness to pay function with respect to the variables, Y, SQ, I, DD, and D.

mwp (Y, SQ, I, DD; D = 5) = marginal willingness to pay when the variable D is fixed as D equals 5 mile representing the location of house in terms of distance from mine.

I = the annual income of household

f (Y, SQ, I, DD) = $\int_D$ f(Y, SQ, I, DD, D) dD.

f (Y, SQ, I, DD, D) = the relative frequency function for the house with characteristics Y, SQ, I, DD, and D.

Similarly, the mean of measure of welfare changes from scenic view improvement can be estimate as below.

$$CS_{DD}^{S} = \int_Y\int_{SQ}\int_I\int_D [mwp(Y,SQ,I,D;DD=1)\cdot f(Y,SQ,I,D)]\, dY\, dSQ\, dI\, dD$$
$$-\int_Y\int_{SQ}\int_I\int_D\int_{DD} [mwp(Y,SQ,I,D,DD)\cdot f(Y,SQ,I,D,DD)]\, dY\, dSQ\, dI\, dD\, dDD$$

= \$ 2,193.256

where

CS_{DD}^{S} = the mean of consumer's surplus from the changes in house orientation.

mwp (Y, SQ, I, D ; DD= 1) = marginal willingness to pay function when the orientation is fixed as DD= 1, which explains the backyard of house faces away from mine.

f (Y, SQ, I, D) = the relative frequency function of the house with the characteristics Y, SQ, I, and D.

The mean of total consumer's surplus generated from the air quality and scenic view improvements, which are shown as variables D and DD in the marginal willingness to pay function is:

$$CS_{D,DD}^{S} = \int_{Y}\int_{SQ}\int_{I}[mwp(Y,SQ,I;D=5mile,DD=1)\cdot f(Y,SQ,I)]\,dY\,dSQ\,dI$$
$$-\int_{Y}\int_{SQ}\int_{I}\int_{D}\int_{DD}[mwp(Y,SQ,I,D,DD)\cdot f(Y,SQ,I,D,DD)]\,dY\,dSQ\,dI\,dD\,dDD$$

= \$ 11,759.27

where

$CS_{D,DD}^{S}$ = the mean of total consumer surplus environmental quality improvements by the use of survey approach.

mwp (Y, SQ, I; D = 5, DD = 1) = marginal willingness to pay function when the variables D and DD are fixed as 5 mile and 1, respectively.

f (Y, SQ, I) = the relative frequency function of the house with the characteristics Y, SQ, and I.

The total amount of consumers surplus with respect to the environmental quality improvements is \$ 43,297,632 or \$ 43,626,892 when the estimated number of detached house units are employed. If we consider the total single family house including town houses and condominiums, the total amount of consumers surplus reaches as much as \$ 88,356,155.

Section 4. Comparison of the Hedonic Approach and Survey Approach

As shown in section 3 of this chapter, all estimates of consumer's surplus by the hedonic approach exceed the estimates of consumer's surplus by use of the open-ended contingent valuation method. The estimates are approximately 2.5 times those of the survey approach.

The real value of total consumers surplus could be between the estimates by hedonic approach and the estimate by open-ended contingent valuation. That is

$$\$\ 88{,}356{,}155 \leq \quad TCS \quad \leq \$\ 191{,}385{,}790.$$

An interesting result of this study is that the estimate of consumer's surplus from the scenic view improvement turns out to be very close to the premium for a good view provided to potential buyers by real estate agencies. According to the respondents, the real estate agents ask \$ 5,000 more for a house with a good view. The real estate premium of \$ 5,000 is close to the average of \$ 7,747 by the hedonic approach and the \$ 2,193 by the contingent valuation (survey) approach. This suggests that the assumption made at the outset of this study that the respondents are well-informed about the housing market is not a strong assumption. There could be many reasons for this result. First, the research area is homogenous in race and age. In addition, most of the residents are retirees, so that the extreme poor or the extreme rich are rare. This could minimize overestimation by the hedonic approach. Second, the housing market is relatively well-defined. This could be a benefit to obtaining practical results, providing buyers with good information about the housing market. At the same time, this makes the respondents better able to answer the questionnaire with more confidence.

According to several respondents, the results from the contingent valuation survey could have been quite different from those of this study if the survey had been conducted before the complaints were made by the GVCCC (Green Valley Community Coordinating Council, home owners association) about the dust from the mine complex. Since their complaints, the mining companies have made significant improvements in dust control. Moreover, the mining companies occasionally provide Green Valley residents with mine tours to show visual information about the mining processing and dust control.

Because the Green Valley community is small and much simpler (a retirement community) than other cities, such as Tucson or Phoenix, it permits the omission of some variables which have been shown to be very significant variables in other previous studies, such as the distance from work place or distance from school.

Finally, although there is no attempt in this study to estimate the economic benefits that derive from the mining activities, it is appropriate to mention that besides the employment and support activities and the tax revenues, benefits must include the buiilding of a local high school and a recreation park. Estimation of the benefits and their comparison to the environmental impacts of mining are left for further research.

CHAPTER 5.

CONCLUSIONS

Section 1. Summary

This dissertation evaluates the impacts of mining on the Green Valley community using the results of an hedonic housing model and contingent valuation analysis described in chapter 2 and chapter 3. In those chapters the hypothesis that the presence of the mine is significant is tested by both the hedonic implicit price function and the willingness to pay function.

Chapter 2 identifies the determinants of property value in Green Valley by estimating $p = f(z)$, which eventually enables the estimation of the shadow price of environmental characteristics (here, these variables are proxied by distance from mine and orientation of house). The hedonic house price is defined as a function of the size of house (SQ), the year that the house was built (Y), the type of payment (TP), the distance from mine (D), and the house orientation (DD), as shown in eqaution 2 - 8. All the variables are significant at the 5% level.

The size of living area (SQ) and the year that the house was built (Y) have signs consistant with a priori expectations from economic theory. The type of payment (TP) turns out to be a useful variable in case of Green Valley. Since type of payment is a dummy variable allowing (1,0), it serves as a shift variable in the hedonic equation.

Especially, with its high t-statistic, the positive coefficient of distance from mine (D) which is used as a proxy for air quality provides evidence of the environmental impact of the mine complex on the Green Valley community. The (-) sign in front of the coefficient of the orientation of house (DD) shows the preference for a better scenic view with respect to orientation of house, meaning away from the mine complex.

Although good statistical results were obtained for the combination of D and DD (equation 2-9), that model was deemed inferior to the one in which D and DD are not combined (2-8). This means that people who buy a house far from the mine still prefer a better scenic view. That both forms of the equation provide good statistical results and similar coefficients builds confidence for the hypothesis that the presence of the mine is significant in the Green Valley housing market, assuming homogeneity in neighborhood characteristics.

Chapter 3 is based on a contingent valuation study using an open-ended willingness to pay response mode. A sample of Green Valley residents were asked directly to answer questions designed to elicit their willingness to pay for their house with amenities assuming that all the respondents are rational and familiar with housing market and full information is provided. For contingent valuation, income, I, is added to the determinants of willingness to pay and type of payment is deleted. With its high t-statistic, the positive coefficient of distance from mine provides evidence of the environmental impact of the complex on the Green Valley community. Unlike distance from mine, the orientation of house (DD) has a lower t-statistic in the willingness to pay equation than in the hedonic price equation. But, it is still a significant variable in the willingness to pay equation at the 5% level. Thus, the survey results suggest that the hypothesis that the presence of mine is significant in the Green Valley housing market can not be rejected.

The demand curves from the estimated hedonic and willingness to pay equations are shown as Marshallian and Hicksian demand curves, repectively, with negative slopes across the environmental amenities. These are used to estimate mean and total consumers surplus as a means of evaluation of environmental impacts of mining on the whole Green Valley community.

The estimates of consumer's surplus from scenic view improvement are very close to the premium for a good view provided to potential buyers by real estate agencies: the real estate premium of $ 5,000 is close to the average of $ 7,747 by the hedonic approach and the $ 2,193 by the contingent valuation approach. Although the hedonic price estimation and the contingent valuation methods have been criticized because of overestimation and bias problems, respectively, these results give confidence in using both methods to evaluate non-market or public goods in a relatively homogeneous community.

Section 2. Concluding Remarks

The central questions posed in this dissertation are the following: First of all, is the presence of mine a significant factor for the Green Valley community? If so, what is the magnitude of the environmental impacts of mining ? The hedonic and survey approaches to answering these questions were compared and contrasted, assuming that each household has an identical utility function. Some of the assumptions necessary for such comparisons may be acceptable for communities which are homogeneous in socioeconomic characteristics, e.g., race, age, and income in the Green Valley retirement community.

Based on empirical results, the conclusion can be made that the presence of the mining complex impacts the Green Valley community. The actual value of the environmental impacts of mining on Green Valley may be bounded by the estimates from the hedonic and contingent valuation (survey) approaches:

This study demonstrates that the mine complex impacts both air and scenic quality, both of which were proxied in the hedonic and contingent valuation approaches by distance of house from mine and orientation of house, respectively. Of the two, the impact of air quality is the greatest on the Green Valley community.

In this dissertation, consumer surplus is an approximation to the sum of individual surpluses, with allowances for specific values of demand from the changes in the levels of environmental variables representing each household. The relative frequency functions computed from the contingent valuation survey are used to infer the environmental impact of mining on both scenic and air quality for the entire

Green Valley community.

Based upon the number of detached single family homes, the environmental impact of mining on the Green Valley community is estimated by the contingent valuation to be approximately $ 44,000,000 and by the hedonic price approach to be approximately $ 94,000,000. When impact is based upon total units (detached and nondetached), the environmental impact is estimated by contingent valuation to be approximately $ 88,000,000.

These attempts at estimation of consumer's surplus differ in some ways from many of the previous consumer's surplus studies. The results may be practically useful and easily adopted for benefit-cost analysis where the average welfare change can not represent the welfare change of the whole community because the community is typically heterogenous in race, age, and income.

Section 3. Further Research

One of the important directions for future research is the consideration of the benefits of mining, e.g., the employment, supporting activites, and tax revenues that impact the Green Valley community, relative to the results found in this dissertation. Another interesting area of research is the phycological effects in the willingness to pay bid curves. A third relevant area of research is capturing uncertainties in respondents estimates. Of course, this would be a signficant extension, as it would require a probabilistic survey and appropriate analyses.

APPENDIX A: HEDONIC DATA

#	Y	SQ	TP	D	X	DD	P
77	1977	1112	0	2.65	0.285378	0	44900
78	1979	1112	0	2.78	0.293306	0	49900
81	1978	1115	0	7.01	0.513432	0	54250
67	1978	1617	1	4.95	0.41489	0	108900
57	1977	1583	0	7.45	0.532585	0	87000
96	1978	1390	0	11.4	0.67905	1	83000
76	1978	851	1	1.25	0.19493	1	43000
60	1971	1766	1	26.62	0.968889	1	88500
112	1989	2315	1	28.3	0.985034	0	249500
111	1991	1847	0	6.24	0.478361	0	179900
125	1993	1605	0	8.51	0.576223	0	140290
108	1993	1605	0	8.23	0.56503	0	135000
110	1993	1808	0	7.9	0.551534	0	169000
109	1993	1605	0	7.23	0.523087	0	149900
73	1987	2056	0	16.5	0.814241	0	146000
28	1983	3228	0	17.62	0.837641	0	199500
86	1975	1881	0	3.32	0.325428	1	63500
29	1983	2900	0	14.6	0.769782	0	199900
17	1985	2020	0	5.55	0.445173	1	64900
85	1972	1320	0	27.3	0.975669	0	63000

APPENDIX B. SURVEY QUESTIONNAIRE

THE UNIVERSITY OF ARIZONA
TUCSON, ARIZONA 85721

COLLEGE OF ENGINEERING AND MINES
DEPARTMENT OF MINING AND GEOLOGICAL ENGINEERING

BUILDING #12
TELEPHONE (602) 621-6212

28 April 1994

Dear Resident of Green Valley,

I am pleased to introduce you to Hyo-Sun Kim, who is a Ph.D student in Mineral Economics, University of Arizona. Since the topic of her dissertation research has to do with environmental issues as they affect the housing market in Green Valley, I believe her research is of interest to you, a house owner. Accordingly, I invite you to take a few minutes and complete the questionnaire.

For your participation, we promise to send you an advance summary interpretation of the questionnaire responses.

As Hyo-Sun Kim's dissertation advisor, I thank you on behalf of Hyo-Sun and myself for your generous cooperation.

Sincerely,

DeVerle Harris

DeVerle Harris, Director
Mineral Economics

TIME ENDED:________________________

TIME STARTED:______________________

INTERVIEW LENGTH:__________________

DATE: _____________________________

Section A.

1. Please tell me whether you feel the amount of money we are spending as a nation is too much, just about the right amount, or too little.

	Too much	About the Right Amount	Too Little	Don't Know	Refuse to Answer
a) Reducing air pollution					
b) Fighting crime					
c) Reducing water pollution in fresh water lakes, streams, and rivers					

Section B: BACKGROUND INFORMATION

This section will ask a few questions about you.

1. Please indicate your age.

( ) 55 years and older

( ) 40 to 54

( ) 30 to 39

( ) under 30

2. Are you or one of your family members working at mine?

( ) yes

( ) no

3. Please indicate your annual income level.

( ) under $ 10,000

( ) $ 10,000 - $ 19,999

( ) $ 20,000 - $ 29,999

( ) $ 30,000 - $ 39,999

( ) $ 40,000 - $ 49,999

( ) $ 50,000 - $ 59,999

( ) $ 60,000 - $ 69,999

( ) $ 70,000 - $ 100,000

( ) $ 100,000 or higher

Section C: HOUSE INFORMATION

This section is asking for information about your current residence. This information is very important to the analysis.

1. How far is your house located from mine?

( ) within 0.8 mile

( ) 0.8 - 1.6 mile

( ) 1.7 - 2.4 mile

( ) 2.5 - 3.2 mile

( ) 3.3 mile or farther

If you are uncertain about the distance, please refer the map attached in the last page or please state the street intersection nearest to your residence.

( )

2. Does your house (front door) face toward mine?

( ) yes

( ) no

3. Please indicate the living size of your house.

( ) less than 1,000 sq. ft.
( ) 1,000 - 1,500 sq. ft.
( ) 1,500 - 2,000 sq. ft.
( ) 2,000 - 3,000 sq. ft.
( ) 3,000 sq. ft. or larger

4. When was your house built?

( ) before 1970
( ) 1971 - 1980
( ) 1981 - 1990
( ) after 1990

5. Which type of payment did you choose?

( ) cash
( ) mortgage
( ) other

6. When did you buy your current house? ( )

7. How much did you pay for your current house?

( ) less than $ 40,000
( ) $ 40,000 - $ 59,999
( ) $ 60,000 - $ 79,999
( ) $ 80,000 - $ 99,999
( ) $ 100,000 - $ 129,999
( ) $ 130,000 - $ 159,999
( ) $ 160,000 - $ 189,999
( ) $ 190,000 - $ 219,999
( ) $ 220,000 and more

<u>**Section D:**</u>

The two questions that follow permit you to show your preference regarding location of house with respect to the mine.

Before answering a) and b) of section D, please examine the fictious example below.

Mr. Jones has $ 40,000 as an income. His current house is located 1.7 miles away from mine and the front door of his house faces away from mine. (i.e., the backyard of house faces toward mine) His current house is valued as much as $ 88,000 and he would pay $ 5,260 more for the same house that he now lives in if it were located 2.4 miles from the mine, which is 1.1 miles further away than his present location.

	within 0.8 mile	0.8 - 1.6 mile	1.7 - 2.4 mile	2.5 - 3.2 mile	3.3 mile and farther
How much would you be willing to pay?	$ 79,100	$ 88,000 (current location)	$ 93,260	$ 95,940	$ 97,860

a) Suppose that your income were to increase by **25 %** and you are able to move to a house like the one that you now live in except that the house is farther away (or nearer to) the mine. Please indicate in the table **how much you would be willing to pay** for the house at different locations within Green Valley **when the house (the front door) faces the mine.**

	within 0.8 mile	0.8 - 1.6 mile	1.7 - 2.4 mile	2.5 - 3.2 mile	3.3 mile and farther
How much would you be willing to pay?					

b) The same conditions as part a) except that **the house (front door) faces away from the mine.** Please indicate willingness to pay, as you did in part a).

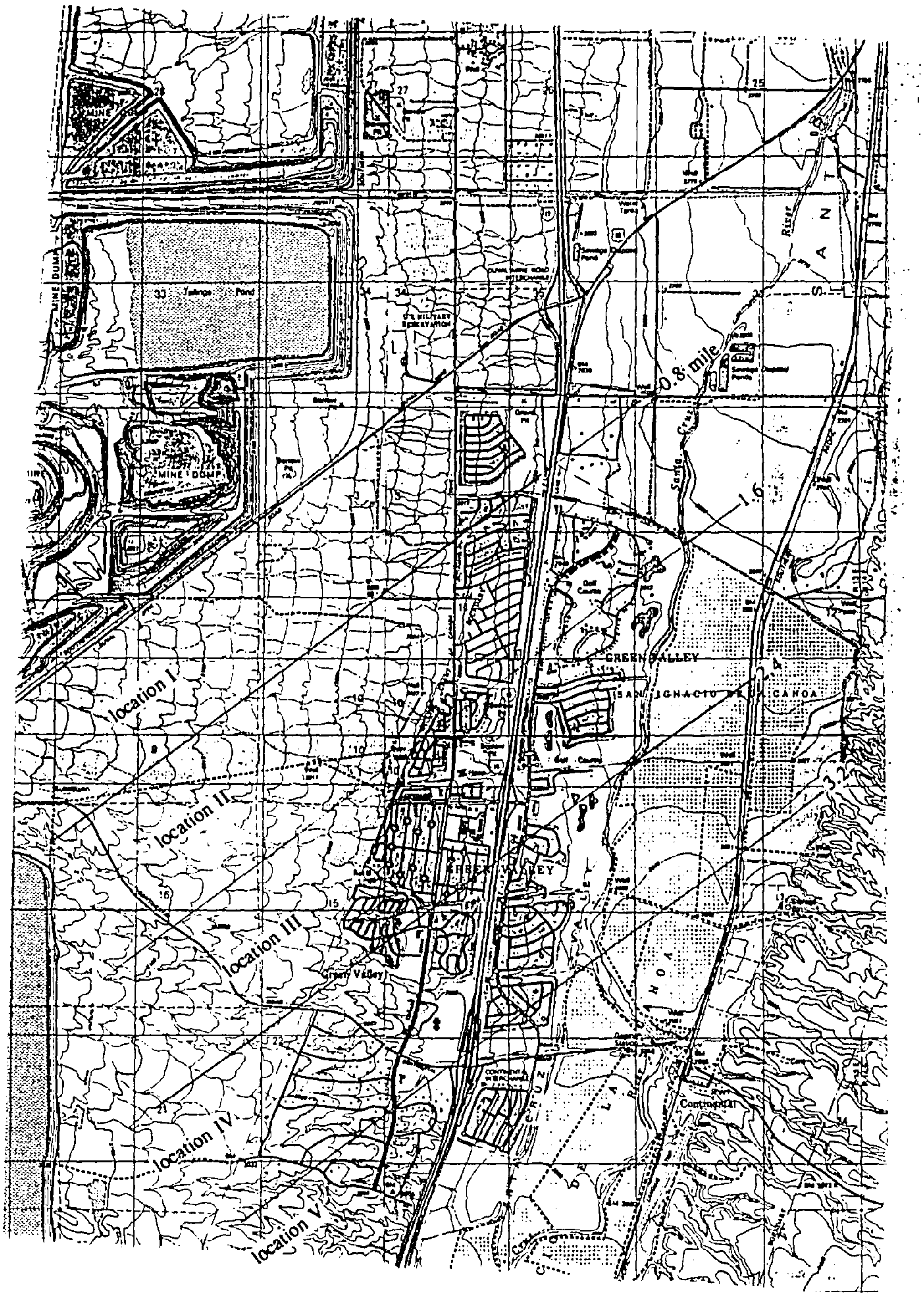
	within 0.8 mile	0.8 - 1.6 mile	1.7 - 2.4 mile	2.5 - 3.2 mile	3.3 mile and farther
How much would you be willing to pay?					

c) Any suggestions regarding to the mine?

( )

<u>Thank you for your time and cooperation.</u>

Map of Green Valley



APPENDIX C: HUMAN/ANIMAL SUBJECTS APPROVAL

Human Subjects Committee

THE UNIVERSITY OF
ARIZONA
HEALTH SCIENCES CENTER

1690 N. Warren (Bldg. 526B)
Tucson, Arizona 85724
(602) 626-6721 or 626-7575

May 9, 1994

Hyo-Sun Kim, M.S.
c/o DeVerle Harris
Director, Mineral Economics
Department of Mining and Geological Engineering
Harvil, Room 320E
Main Campus

RE: IMPACT OF MINING ON HOME VALUES IN GREEN VALLEY

Dear Ms. Kim:

We have received documents concerning your above cited project. Regulations published by the U.S. Department of Health and Human Services [45 CFR Part 46.101(b) (2)] exempt this type of research from review by our Committee.

Thank you for informing us of your work. If you have any questions concerning the above, please contact this office.

Sincerely yours,

WFDenny

William F. Denny, M.D.
Chairman
Human Subjects Committee

WFD:js

cc: Departmental/College Review Committee

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