Some New Approaches to Measuring Willingness to Pay:

A Case Study of Flood Risk Reduction in Roanoke, Virginia

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(ABSTRACT)

Benefits from a flood control project that accrue to a landowner are defined as the amount the landowner is willing to pay for the reduction in flood risk. The primary method utilized by the U.S. Army Corps of Engineers to estimate a residential landowner's benefits is the property damages avoided method. Only under a set of restrictive assumptions will this method accurately estimate landowner willingness to pay. Therefore, several alternative techniques, such as the hedonic price method, are approved for use by the Corps but it is not known how they compare.

The purpose of this study is to examine the benefit measures from the property damages avoided and hedonic price methods and two new measures, restricted willingness to pay (RWTP) and restricted willingness to accept (RWTA). The measures RWTP and RWTA are biased estimates of willingness to pay (WTP) and willingness to accept (WTA) where the direction of the bias is known. In addition, the methods that calculate these measures, the RWTP and RWTA methods, do not require data on income or an aggregator for the prices of all goods not in the

analysis. Benefit estimates from the hedonic price and RWTP methods provide upper and lower bounds on WTP for non-marginal reductions in flood risk and converge for marginal reductions.

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TABLE OF CONTENTS

LIST OF FIGURES. ix

LIST OF TABLES x

CHAPTER I INTRODUCTION. 1

1.1 Willingness to Pay Methods. 2

1.1.1 The Property Damages Avoided Method. 3

1.1.2 The Hedonic Price Method 4

1.1.3 Compensating and Equivalent Variation Methods. 5

1.2 Comparing the Methods: A Case Study of Roanoke, Virginia . 6

1.3 Objectives. 8

1.4 Procedures. 9

CHAPTER II WILLINGNESS TO PAY AND BENEFITS. 10

2.1 The Property Damages-Avoided Method 12

2.1.1 Expected Utility 13

2.1.2 PVERD Formulae 14

2.1.3 Assumptions. 15

2.2 Willingness to Pay and Accept 18

2.3 Hedonic Price Models. 19

2.3.1 The Property Price Model 20

2.3.2 Forecasting Property Prices. 24

2.3.3 Obtaining Willingness to Pay 29

2.4 Willingness to Pay and Accept Methods 30

2.4.1 The Hausman Approach 31

2.4.2 The RWTP and RWTA Methods. 32

2.5 Summary. 40

CHAPTER III HEDONIC MODEL AND BENEFIT ESTIMATION RESULTS 43

3.1 The Roanoke Case Study Area 44

3.2 The Hedonic Property Price Model. 46

3.2.1 Data Sources 49

3.2.2 Property Prices. 49

3.2.3 Accessibility to Non-residential Activity. 50

3.2.4 Neighborhood Characteristics 52

3.2.5 Property Characteristics 52

3.2.6 Market Conditions. 54

3.2.7 The Hedonic Model. 55

3.3 Functional Form Specification 56

3.3.1 Linear Hedonic Price Models. 56

3.3.2 Box-Cox Hedonic Price Models 57

3.3.3 The Hedonic Property Price Function. 58

3.4 Distributional Assumptions. 59

3.4.1 Independence 61

3.4.2 Identically Distributed. 61

3.4.3 Normality. 62

3.4.4 Testing the Assumptions. 63

3.4.5 Respecified Model. 72

3.5 Calculating New Flood Zones 72

3.6 Estimating Willingness to Pay from the Hedonic Model. . . . 73

3.7 Results 76

3.8 Summary 78

CHAPTER IV ESTIMATING WILLINGNESS TO PAY AND ACCEPT 79

4.1 Estimating Willingness to Pay and Accept for Changes in Property Characteristics. 80

4.2 Estimating Willingness to Pay and Accept from a Direct Translog Utility Function 82

4.2.1 Estimating Willingness to Pay from the RWTP Method . . 84

4.2.2 Estimating Willingness to Accept from the RWTA Method. 86

4.3 Results 88

4.4 Summary 88

CHAPTER V CONCLUSIONS AND RECOMMENDATIONS 91

5.1 Review of the Corps' Benefit Estimation Procedures. 92

5.2 Methodology 92

5.2.1 The Hedonic Price Method 93

5.2.2 The RWTP and RWTA Methods. 93

5.3 Results 94

5.4 Recommendations 96

5.4.1 The Property Damages Avoided Method. 97

5.4.2 The Hedonic Price Method 98

5.4.3 The RWTP and RWTA Methods. 99

5.4.4 Closing Remarks. 99

REFERENCES 101

VITA 105

LIST OF FIGURES

Figure 2.1 One Dimension of the Composite Good Market Equilibrium. 23

Figure 2.2 Marginal Shift in Hedonic Price Function 26

Figure 2.3 Non-Marginal Shift in Hedonic Price Function 27

Figure 3.1 City of Roanoke and the Case Study Area. 45

Figure 3.2 The Case Study Area. 47

Figure 3.3 Stage-Frequency Curve for Properties Below Walnut Street. 75

LIST OF TABLES

Table 3.1 Regression Results with BCFLOOD 60

Table 3.2 Regression Results with post-1985 flood observations. 65

Table 3.3 Regression Results with pre-1985 flood observations. 66

Table 3.4 Regression Results of new hedonic model 68

Table 3.5 Regression Results of new hedonic model with pre-1985 flood observations. 69

Table 3.6 Regression Results of new hedonic model with post-1985 flood observations 70

Table 3.7 Flood Zones 74

Table 3.8 Benefit Estimates from the Property Damages Avoided Hedonic Price Methods 77

Table 4.1 Benefit Estimates from the RWTP and RWTA Methods. . . 89

CHAPTER I

INTRODUCTION

Before 1936, federal flood control spending was limited and all but restricted to the lower Mississippi River Valley. Flood control efforts throughout the rest of the nation were generally funded by state and local governments. The Great Depression, which coincided with a series of floods, prompted Congress to pass the Flood Control Acts of 1936 and 1938. These Acts made flood control a national concern and placed the responsibility for flood control project construction in the hands of the federal government and the U.S. Army Corps of Engineers, commonly referred to as the Corps. Changes in the economic evaluation procedures employed to justify individual projects came in the decades that followed (Shabman, 1989). The most recent changes came in 1983 from the U.S. Water Council's Economic and Environmental Principles and Guidelines For Water and Related Land Resource Implementation Studies, called the P&G, which provides the overall framework the Corps follows when estimating flood control benefits for residential, commercial and industrial properties (U.S. Water Council, 1983).

The P&G requires that benefits conceptually measure a project beneficiary's willingness to pay as the area under a demand curve for reduced flood risk (U.S. Water Council, 1983). However, the P&G

recognizes that the absence of markets for services such as flood control makes the direct estimation of demand curves from market data prices impossible. Therefore, several alternative methods are approved to approximate residential flood control benefits. The most recent regulations for the Corps, the National Economic Development Procedures Manual-Urban Flood Damage, referred to as the NED, were published in 1988 by the Corps' Water Resource Support Center. The NED gives specific guidelines on using approved methods such as the property damages avoided and the restoration of land market values methods (U.S. Army Corps of Engineers' Water Resource Support Center, 1988). Although all of these methods are expected to measure willingness to pay, it is not known how the approved methods compare.

One aim of this study is to compare the various benefit estimation methods which estimate landowner willingness to pay for a flood control project. In order to compare these methods, it is necessary to (i) understand the extent to which the methods accurately measure landowner's willingness to pay for a change in flood risk and (ii) how the results from each benefit estimation method compare with each other.

1.1 WILLINGNESS TO PAY METHODS

Willingness to pay methods theoretically measure the amount the consumer is willing to pay for a change in the level of an amenity. Of the methods to be discussed, the property damages avoided method is unique in that the estimated benefits are based on engineering techniques, whereas benefits estimated from the other methods use market transactions to reveal consumer preferences and estimate willingness to pay. In the property damages avoided method, the present value of expected reduced damages from the flood control project is examined and equated to consumer willingness to pay. Benefit estimates from the other methods are subjective values of the land buyers based on factors such as clean up and repair costs, the trauma and anxiety from the flood, and flood insurance costs. Differences between the methods are expected to occur.

1.1.1 The Property Damages Avoided Method

The P&G states that the general benefit method for estimating willingness to pay is "the reduction in actual or potential damages associated with land use" (U.S. Water Council, 1983, p. 32). For a particular residential property, the property damages avoided method estimates expected dollar damages inflicted by different floods where each flood has a different probability of occurrence. Future costs in terms of property damages are avoided as a result of the flood control project and the present value of avoided costs are used to measure landowner willingness to pay for the project.

Total expected damages are measured by summing the probability weighted damages where damages are calculated as the costs of replacing or repairing flood damage to the property. Flood damage reduction for a given year from a flood control project is estimated as the difference between total expected damages with the project and total expected damages without the project. This analysis is repeated for each year in which benefits and costs occur, called the planning horizon. The total benefit estimate from the project is measured by the present value of the annual benefits in the planning horizon computed at the project discount rate.

This method is an accurate measure of willingness to pay when a set of rather restrictive assumptions hold. Shabman (1987) examines the effects of many of the assumptions and the conditions under which the property damages avoided method will accurately measure landowner willingness to pay.

1.1.2 The Hedonic Price Method

The hedonic price method employs a hedonic property price function, which relates the property price to the levels of its characteristics, to separate the property price effects of non-flood risk characteristics from flood risk. Benefits derived from a flood control project are estimated as the increases in property prices associated with the change in flood risk. The difference in the prices of properties with identical characteristics but differing degrees of flood risk represents the present value of the difference in flood risk.

Some studies using this method have related the effects of flood control projects on property values (Struyk, 1971; Soule and Vaughan, 1973; Shabman and Damianos, 1976; Babcock and Mitchell, 1980; Park and

Miller, 1982; and Donnely, 1989) but did not estimate benefits from reduced flood risk. In other studies (Maxwell and North, 1974; Senjem and Freshwater, 1981; and Thompson and Stoevener, 1983), benefits from a reduction in flood risk were estimated using this simple hedonic application.

1.1.3 Compensating and Equivalent Variation Methods

Freeman (1971, 1974), Anderson and Crocker (1972), Polinsky and Shavell (1974, 1976) and Small (1975) argue that the hedonic price method can properly estimate willingness to pay only under certain restrictive assumptions about market conditions and consumer preferences. Rosen (1974) suggests that methods that measure areas under compensated or ordinary demand curves would produce better estimates of willingness to pay than the hedonic price method. In addition, Scotchmer (1985) and Kanemoto (1988) conclude that in order to obtain appropriate willingness to pay benefit estimates of public projects that change amenity levels, measures derived from compensated demands must be calculated.

One measure of willingness to pay is compensating variation. Another measure of interest which is analogous to compensating variation is equivalent variation which measures willingness to accept. Using Maler's (1974) concepts of compensating and equivalent variation for a change in an amenity level, the two measures are defined in commodity space as:

Compensating Variation: the amount the consumer is willing to pay for a change in an amenity level.

Equivalent Variation: the amount the consumer is willing to accept in compensation in place of the change.

Benefits from a change in flood risk are calculated as the change in expenditures required to keep the landowners indifferent between the new and old levels of flood risk. However, computing exact compensating and equivalent variation requires, at a minimum, observations on consumer income and a price aggregator on the goods not in the analysis, which are often unavailable.

Therefore, methods that analyze the consumer's problem over a reduced set of available data are needed. The results from these methods provide bounds on compensating and equivalent variation. Such methods, called the RWTP and RWTA methods, produce biased estimates where the direction of the bias is always known.

1.2 COMPARING THE METHODS: A CASE STUDY OF ROANOKE, VIRGINIA

Theoretically, estimates from the various benefit estimation methods can be expected to differ. Therefore it is important to examine both the methods and the source of their differences. However few studies have compared the empirical estimates from the willingness to pay approaches cited above. A flood control project planned for the city of Roanoke, Virginia, provides this opportunity.

The Corps recently completed a study on the economic feasibility of a flood control project in Roanoke. In their study, benefits using the property damages avoided method were estimated for all individual flood prone properties in the city. As a result, information on the flood risk, in particular the flood zone of individual properties, is available. In addition, data required to apply the hedonic price, RWTP, and RWTA methods can be easily obtained; the city of Roanoke has data on property prices and characteristics dating back to 1980, the beginning of the data set.

The city of Roanoke has been severely flooded by the Roanoke River twice during the last 20 years, in 1972 and 1985, offering the possibility that property prices have been affected by flood risk. In late June of 1972, Hurricane Agnes hit the Roanoke Valley causing the second worst flood of the Roanoke River in the city. It rained 6.3 inches in four days and the Roanoke River crested around nine feet (U.S. Army Corps of Engineers Interim Feasibility Report, 1984). The worst flood suffered by the city of Roanoke occurred on November 4, 1985. It rained 6.6 inches in one day after raining four inches during the previous four days. The Roanoke River crested around 23 feet on the evening of the fourth, about two and a half times the crest height of the 1972 flood. The city of Roanoke suffered an estimated $225 million in damages (Roanoke Times and World News, November 11, 1985).

The flood of 1972 prompted governments in and around the Roanoke Valley to request a study by the Corps on alternative projects that would reduce flood risk. These alternatives included dams and local protection projects requiring the computation of flood control benefits for each project. After several years, the Corps proposed a 10-mile channelization of the Roanoke River within the city of Roanoke. In its final design this project would widen the river channel, construct protective walls and dikes at several locations along the river and install a flood warning system. It was for this project that the Corps reported its final benefit estimates. Because the estimates using the property damages avoided approach are available for individual properties, it is possible to use this case study area to compare the benefits estimated from the property damages avoided approach with those from the hedonic price, RWTP, and RWTA methods.

1.3 OBJECTIVES

The main purpose of this study is to analyze measures of willingness to pay that are potential alternatives to the property damages avoided method. Specifically, the three main objectives are to:

1) develop a theoretical basis for interpreting the hedonic price and RWTP methods as measures of willingness to pay and the RWTA method as a measure of willingness to accept,
2) estimate flood risk reduction benefits using the hedonic price, RWTP, and RWTA methods, and
3) compare the benefits estimated from the hedonic price, RWTP, and RWTA methods with those from the property damages avoided method, explaining any differences between the results of the methods.

1.4 PROCEDURES

The remainder of this study is organized as follows. In the second chapter, the property damages avoided, hedonic price, RWTP, and RWTA methods are examined in terms of their ability to provide an accurate measure of willingness to pay or accept. The case study area, a small, low-income neighborhood in the city of Roanoke along the Roanoke River, is described in Chapter III. In addition, a general overview of hedonic property price models is reviewed along with the characteristics that affect price differentials of the properties in the case study area. The implications of certain functional forms of the hedonic model are addressed and a hedonic property price function is estimated and tested to determine whether the function is well defined over the data set. Benefit estimates using the hedonic price method are then calculated. In Chapter IV, the RWTP and RWTA methods are applied to the Roanoke case study area, benefits are estimated using these methods, and the estimates are compared. Finally, the estimates from the property damages avoided, hedonic price, and RWTP methods are compared in Chapter V and the various results from the study are evaluated.

CHAPTER II

WILLINGNESS TO PAY AND BENEFITS

When evaluating the feasibility of a project, the expected monetary value of benefits associated with the project are calculated and compared with the expected cost of the project. The benefits from a flood control project range from the creation of new jobs to the creation of improved or additional recreational amenities at the site. The focus of this study, however, is measuring the benefits that accrue to landowners from reduced flood risk. The monetary equivalent of ex ante benefits is the amount consumers are willing to pay for the project.

Ordinarily, consumer willingness to pay, a term that encompasses many methods, is estimated using market transaction data. Because there are no markets for flood risk and many other property characteristics, such a direct approach is infeasible. Therefore methods that directly or indirectly employ a hedonic price model are typically employed to determine consumer willingness to pay.

Three methods available for assessing consumer willingness to pay for a change in the level of a property characteristic are the hedonic price, RWTP, and contingent valuation methods. The first two methods require the estimation of the hedonic property price function. Under restrictive assumptions, the hedonic property price function may be used directly to obtain a willingness to pay measure for a change in the level of a characteristic of a composite good. When estimating willingness to pay for a change in the level of a characteristic of a composite good, the RWTP method makes use of implicit prices derived from the hedonic property price function and observed consumer data. Analogous to the RWTP method, the RWTA method makes use of implicit prices and observed consumer data to estimate willingness to accept compensation to forego a change in the level of a characteristic of a composite good. In the contingent valuation method, willingness to pay is obtained by asking consumers how much they would be willing to pay for changes in the level of the characteristic in question. The assessment of changes in flood risk permits the use of a fifth method: property damages avoided. In this method, landowner willingness to pay for a flood control project is measured as the present value of expected reduced damages from the project. The contingent valuation method was employed in a study performed by Thunberg (1988) on the same study area. Therefore only the hedonic price, RWTP, RWTA, and property damages avoided methods will be examined and compared.[1]

In this chapter, the property damages avoided, hedonic price, RWTP, and RWTA methods are reviewed. Expected utility theory and its relation to the property damages avoided method are examined and the set

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[1] For a comparison of the contingent valuation and property damages avoided method, see Thunberg or Thunberg and Shabman (1991).

of conditions under which the property damages avoided method provides an accurate willingness to pay measure is shown to be restrictive. In the second section, compensating and equivalent variation are defined in terms of willingness to pay and willingness to accept respectively. Next, the conditions under which the hedonic property price function can be used to forecast property prices and to directly measure willingness to pay are established, along with the consequences that arise when the conditions do not hold. In the final section, the RWTP and RWTA methods which use an implicit price procedure suggested by Rosen, are developed.

2.1 THE PROPERTY DAMAGES AVOIDED METHOD

The standard method of benefit estimation for residential properties used by the U.S. Army Corps of Engineers is the property damages avoided method described in the introduction. In this method, benefits are measured as the maximum a landowner is willing to pay for reduced flood damages derived from a flood control project. Using expected utility theory, landowner willingness to pay is equated with the present value of expected reduced damages (PVERD) from the flood control project. Next, a description of the Corps' formulae for calculating PVERD is presented. Finally, the assumptions under which this method generates an accurate measure of willingness to pay are listed and examined.

2.1.1 Expected Utility

A method of calculating willingness to pay from expected utility can be generated from the von Neumann-Morganstern (1953) axioms of utility. Assume a landowner faces the risk of suffering a loss from flooding of D dollars over time with probability P and that he or she is willing to pay W dollars to reduce damages over time by RD. Thus the landowner will be assured a wealth of H-W where H is the landowner's initial wealth. The amount the landowner would be willing to pay for the reduced damages can be calculated by solving for W in equation (2.1).

$$U(H-W)=P*U(H-RD)+(1-P)*U(H) \tag{2.1}$$

If the landowner is risk neutral, then

$$P*U(H-RD)+(1-P)*U(H)=U[P*(H-RD)+(1-P)*H] \tag{2.2}$$

so

$$\begin{aligned} U(H-W) &= U[P*(H-RD)+(1-P)*H] \\ &= U(P*H-P*RD+H-P*H) \\ &= U(H-P*RD) \end{aligned} \tag{2.3}$$

Therefore, W=P*RD, or the maximum the landowner is willing to pay to reduce damages over time is the expected value of the reduced damages over time, i.e. the present value of expected reduced damages.

2.1.2 PVERD Formulae

For all flood control projects, the Corps uses engineering procedures described in the NED to calculate PVERD for every property affected by the project. For each property, a probability density and damage function, f(x) and d(x) respectively, governing a flood of severity x are obtained from the engineering procedures. Then PVERD is defined in terms of expected and present value equations and calculated from the damage and probability density functions using an appropriate project discount rate r.

The expected value of damages for a particular property occurring in one year is

$$ED=\sum_{i=1}^{N} f(x_i)\, d(x_i) \qquad (2.4)$$

where X_i represents flood i.[2]

Expected reduced damages from a flood control project are estimated as the difference between expected damages with the project and expected damages without the project. Because the project alters the probability of a flood occurring, the probability function and

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[2] The X_i are ordered such that X_1 is the smallest flood possible that incurs nonzero property damage and X_n is the largest flood possible that has a nonzero probability of occurring.

damage functions change to $f^0(x_i)$ and $d^0(x_i)$ respectively for conditions with the project. The expected value of reduced damages occurring in one year is

$$(2.5)\qquad ERD=\sum_{i=1}^{N}[f(x_i)d(x_i)-f^0(x_i)d^0(x_i)]$$

The present value of expected reduced damages from a flood control project is calculated as the expected value of reduced damages from the project occurring over the planning horizon. The formula for PVERD, the maximum the landowner is willing to pay for reduced damages, is

$$(2.6)\qquad PVERD=\sum_{t=1}^{T}\left(\sum_{i=1}^{N}\frac{[f(x_{it})d(x_{it})-f^0(x_{it})d^0(x_{it})]}{(1+r)^t}\right)$$

where the subscript t represents the tth year of the planning horizon which consists of T years.

2.1.3 Assumptions

Given expected utility theory and the PVERD formulae, the property damages avoided method is an appropriate measure of willingness to pay when the following assumptions hold:

1) landowners have the project planner's knowledge about the probability and effects of certain flood events,
2) willingness to pay consists solely of reduced damages to the property owned solely by the landowner,

3) landowners are risk neutral,

4) landowners would fully replace or restore all damaged property, and

5) landowners possess the same discount rate as used by the project planner.

It is likely that one or more of the assumptions will not hold. Therefore, it is important to review the implications of relaxing any of these assumptions.

The first assumption requires that all landowners have the same perception of the likelihood and consequences of various flood events as the project planner. In terms of equation (2.6), this assumption implies that f(x) and d(x) are known. Such an assumption is unlikely to hold and the benefits estimated are likely to misstate landowner willingness to pay. However, the bias and the direction of the bias cannot be calculated without information on the perceived values of f(x) and d(x) (Shabman, 1987).

The second assumption suggests that only the property of the landowner will be damaged. The landowner, however, may consider the project as a way to reduce human impairment or secure a future for his neighborhood. Removal of these nonproperty or community effects of flood risk reduction will result in benefit estimates that understate landowner willingness to pay (Shabman, 1987).

The third assumption states that all landowners are risk neutral. A risk averse landowner would be willing to pay more and a risk taking landowner would be willing to pay less for a reduction in flood risk than a landowner who was risk neutral. From equation (2.2), the expected utility of a risk taking landowner would be

$$(2.7) \qquad P*U(H-RD)+(1-P)*U(H)>U[P*(H-RD)+(1-P)*H]$$

Then

$$(2.8) \qquad U(H-W)<U[P*(H-RD)+(1-P)*H]$$

and subsequently, W<P*RD. Thus the PVERD would overstate landowner willingness to pay. If the landowner is risk averse, similar arguments can be derived to show that PVERD will understate landowner willingness to pay. In addition, the assumption of risk neutrality implies a linear utility function and thus constant marginal utility of income (von Neumann and Morganstern, 1953).

The fourth assumption states that the landowner will replace or restore all structures damaged by the flood to their pre-flood conditions. However, the factors that determine the landowner's investment choices will change over time. This change could result in a change in the investment patterns resulting in a future land use different from the current use. Thus, the benefits estimated will misstate landowner willingness to pay, but the extent and direction are uncertain (Shabman, 1987).

The last assumption maintains that each landowner possesses the same discount rate as the project. If the discount rates differ, the present value of expected benefits, equation (2.6), will differ from the potential wealth change of the landowner. The estimated benefits will misstate landowner willingness to pay, but the extent and direction depend on the difference between the project and landowner's discount rates (Shabman, 1987).

2.2 WILLINGNESS TO PAY AND ACCEPT

Compensating variation (CV) and equivalent variation (EV), each related to the area under a compensated demand curve, are theoretical welfare measures. From Hanneman (1991), compensating and equivalent variation are defined as

$$V(\mathbf{p}, q^1, Y-CV) = V(\mathbf{p}, q^0, Y) \quad (2.9)$$

$$V(\mathbf{p}, q^1, Y) = V(\mathbf{p}, q^0, Y+EV) \quad (2.10)$$

where Y is consumer income, **p** is the price level, and q^0 and q^1 are the initial and new levels of the good in question respectively. In terms of the expenditure function E(p,q,U), CV and EV are defined as

$$CV = E(\mathbf{p}, q^0, U^o) - E(\mathbf{p}, q^1, U^0) \quad (2.11)$$

$$EV = E(\mathbf{p}, q^0, U^1) - E(\mathbf{p}, q^1, U^1) \quad (2.12)$$

where U^0 and U^1 are the initial and new levels of consumer utility respectively. Therefore, compensating variation is defined as the amount of compensation the consumer is willing to pay for the change in the level of q, holding utility constant, given the initial price level and the level of q and is called willingness to pay. Similarly, equivalent variation is defined as the amount the consumer is willing to accept in compensation to forego the change in the level of q, holding utility constant, given the initial price level and the new level of q and is called willingness to accept. Negative measures of willingness to pay and accept can occur as a result from decreases in the level of q.

In welfare analysis, changes in welfare are generally measured as the maximum payment required to keep the consumer indifferent between before and after conditions. So compensating and equivalent variation are more appealing than ordinary consumer surplus, although under certain circumstances, ordinary consumer surplus approximates them reasonably well. The conditions under which ordinary consumer surplus can be used to approximate compensating and equivalent variation are reviewed in Randall and Stoll (1980) for changes in commodity space and Willig (1976) for changes in price space.[3]

2.3 HEDONIC PRICE MODELS

To estimate willingness to pay for a change in the level of good X_1 from X_1^0 to X_1^1, the consumer's inverse demand must be estimated. When examining willingness to pay for a change in a characteristic of a

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[3] In Randall and Stoll, compensating and equivalent variation are referred to as willingness to accept (WTA^C) and willingness to pay (WTP^E) respectively.

composite good, however, direct prices are often unavailable because the individual characteristics are not traded in open markets. In this case, analysts resort to an approach pioneered by Rosen. This approach makes use of hedonic price functions which measure the effects of various characteristics on the price of the composite good.

Under appropriate circumstances, these models can be used to both accurately forecast prices and directly estimate consumer willingness to pay for the change in the characteristic. The relative supply of a composite good affected by a characteristic change is a significant factor in determining whether the hedonic model can accurately forecast prices. In addition, the hedonic model can directly estimate willingness to pay only for <u>marginal</u> characteristic changes. When nonmarginal changes are considered, the hedonic model can no longer be used to estimate consumer willingness to pay. Compensating and equivalent variation are used instead to calculate consumer willingness to pay using implicit marginal prices for attributes obtained from the hedonic model.

<u>2.3.1</u> <u>The Property Price Model</u>

Property, which can be defined as a plot of land and any structures on the plot, can be characterized by many attributes, from the lot size to the number of bathrooms in the structure, where the individual attributes are not generally traded in markets. The market clearing price of property i is defined by the hedonic property price function as

$$p_i = P(X_{1i}, \ldots, X_{mi}) \tag{2.13}$$

where $X_{1i}, \ldots, X_{mi}$ are the property characteristics associated with property i and the price p_i is a market clearing price based on supply and demand conditions.

In the analysis that follows, the following are assumed:

1) the supply of properties is fixed and the land buyers bid against each other for the properties,
2) the housing market is in equilibrium and land buyers are price takers and
3) for any particular set of remaining characteristics, there is a supply which is continuously differentiable with respect to the X_j.

Consider the conventional representation of the land buyer's problem presented by Scotchmer (1985). Let all land buyers have identical preferences described by $U(\mathbf{X}_i)$, different incomes Y_i and let the vector $\mathbf{X}_i$ consist of both property characteristics and nonproperty goods. The utility maximization problem becomes

$$\begin{aligned} &\max \ U(X_{1i}, \ldots, X_{mi}, X_{(m+1)i}, \ldots, X_{ni}) \\ &st \ \ P(X_{1i}, \ldots, X_{mi}) + \textstyle\sum_{j=k+1}^{n} p_k X_{ki} = Y_i \end{aligned} \tag{2.14}$$

Let the expenditure function $e(\mathbf{p_x}, X_{1i}, \ldots, X_{mi}; U_i^0)$ be the minimum expenditure required to keep utility constant. Total expenditures can be defined as

(2.15) $$Y_i = e(\mathbf{p_x}, X_{1i}, \ldots, X_{mi}; U_i^0) + p(X_{1i}, \ldots, X_{mi})$$

or similarly,

(2.16)

$$p(X_{1i}, \ldots, X_{mi}) = Y_i - e(\mathbf{p_x}, X_{1i}, \ldots, X_{mi}; U_i^0) = \theta_i(\mathbf{p_x}, X_{1i}, \ldots, X_{mi}; U_i^0)$$

where $\mathbf{p_x}$ is a vector of prices of all other goods and U_i^0 is the initial level of utility obtained from $U(X_{1i}^0, \ldots, X_{ni}^0)$.

Given the market conditions and the land buyers problem, figure 2.1 depicts one dimension of the market equilibrium. The function $\Theta_i(\mathbf{p_x}, X_{ij}, \mathbf{X_{ij}^c}; U_i^0)$ is land buyer i's bid function for the jth property characteristic, where $\mathbf{X_{ij}^c}$ is the vector of other property characteristics optimally chosen to attain the highest utility possible, U_i^0 given the budget constraint Y_i. The bid function represents the locus of points where the land buyer is indifferent between different amounts of X_{ij} and indicates the price the consumer is willing to pay for the composite good.

The hedonic property price function $P(X_{1i}, \ldots, X_{mi})$, the upper envelope of the land buyers' bid functions, is an equilibrium achieved under a particular set of supply and demand conditions. Changes in any of these conditions will result in a new equilibrium hedonic function. The focus of the remainder of this section is to determine when it is appropriate to use the estimated hedonic function $p(X_{1i}, \ldots, X_{mi})$ to

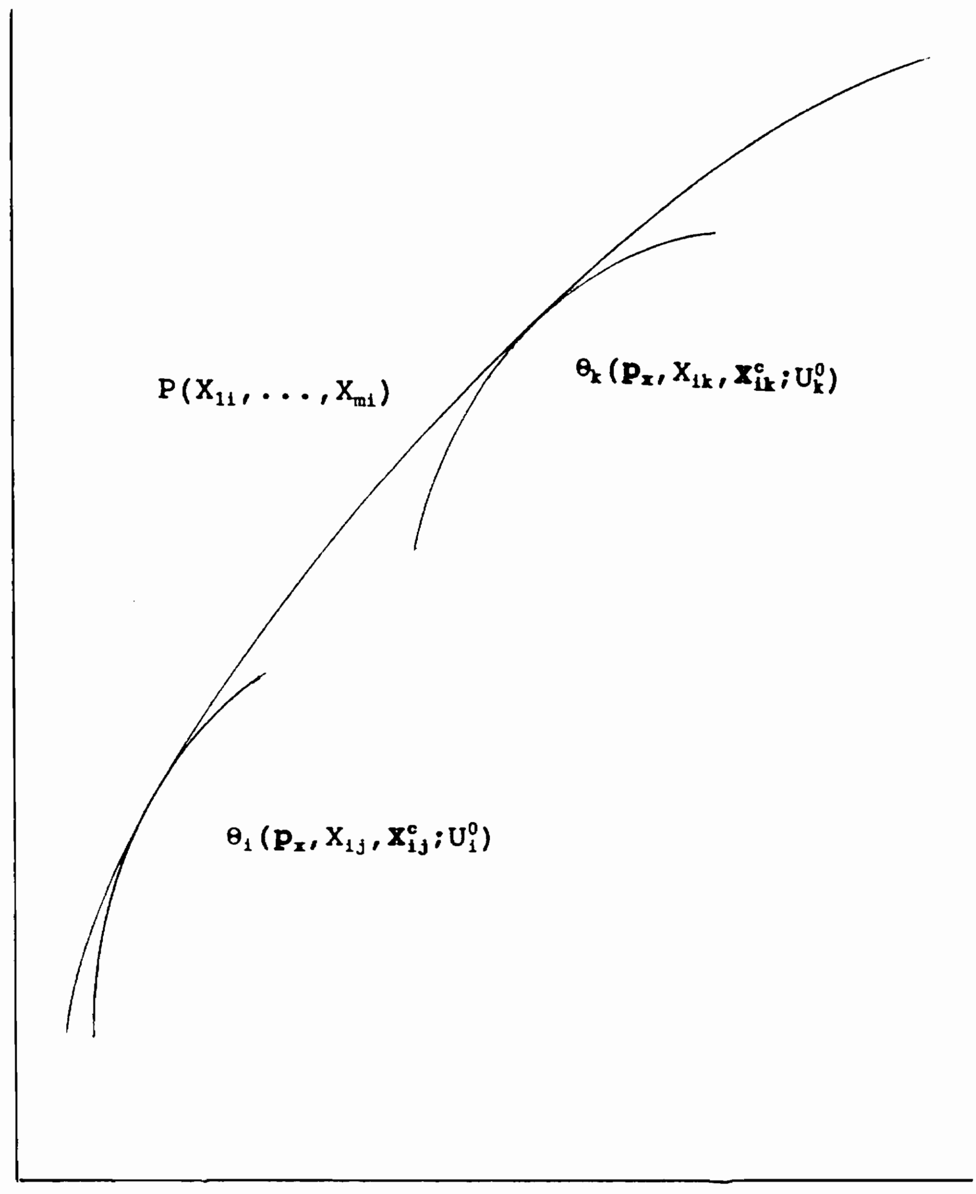

Figure 2.1: One Dimension of the Composite Good Market Equilibrium

(1) forecast the land prices from a change in the level of a housing attribute or amenity and (2) to calculate willingness to pay for a change in the level of a housing attribute or amenity.

2.3.2 Forecasting Property Prices

Often it is important to determine the effects of a change in amenity levels on property prices. Ridker and Henning (1967) attempted to determine the effect on property values in St. Louis of a change in sulfation levels in the air. Using cross-sectional data, Ridker and Henning estimated a hedonic property price function and concluded that if sulfation levels drop by .25 mg/100 cm^2/day, individual property values could increase by $245 and property values for the entire St. Louis metropolitan area could increase by as much as $82 million. Freeman (1971) argued that Ridker and Henning's results were incorrect because the estimated hedonic property price function could only be used to forecast the difference in values of two properties within a system under conditions which include no significant change in the air quality over all other properties in the city.

The fundamental flaw with the Ridker-Henning conclusions is that changes in air quality affect the entire city and this change causes the hedonic property price function to shift. The supply shift due to the lower pollution levels results in a new equilibrium hedonic property price function. In order to accurately measure the change in property values, the hedonic property price function must be able to account for the shifts in supply conditions. Such a shift cannot be identified using cross-sectional data based upon supply conditions at only one point in time.

Ridker and Henning's study prompted economists to isolate a set of conditions that permit the calculation of land price effects based on a hedonic model estimated using cross-sectional data. Polinsky and Shavell determined that when the affected urban area is small relative to other nearby urban areas and open, where household mobility between the urban areas is costless, property prices at any location depend only on the amenity levels at that location and the hedonic property price function generated by cross-sectional data can accurately predict the price effects of the amenity change in the affected urban area. An amenity change of this sort produces a marginal change in supply conditions which only negligibly shifts the hedonic property price function (figure 2.2). However, when the affected urban area is large relative to other urban areas or closed, where household mobility is restricted to the affected urban area, property prices at any location depend on the amenity levels throughout the urban area and the hedonic property price function generated by cross-sectional data cannot be used in a direct way to predict the overall pattern of changes in property values from an amenity shift that affects the entire urban area. This amenity change affects all urban areas and produces a nonmarginal shift in the hedonic property price function (figure 2.3).

In order to account for the shifting hedonic property price function when nonmarginal changes in property characteristics are

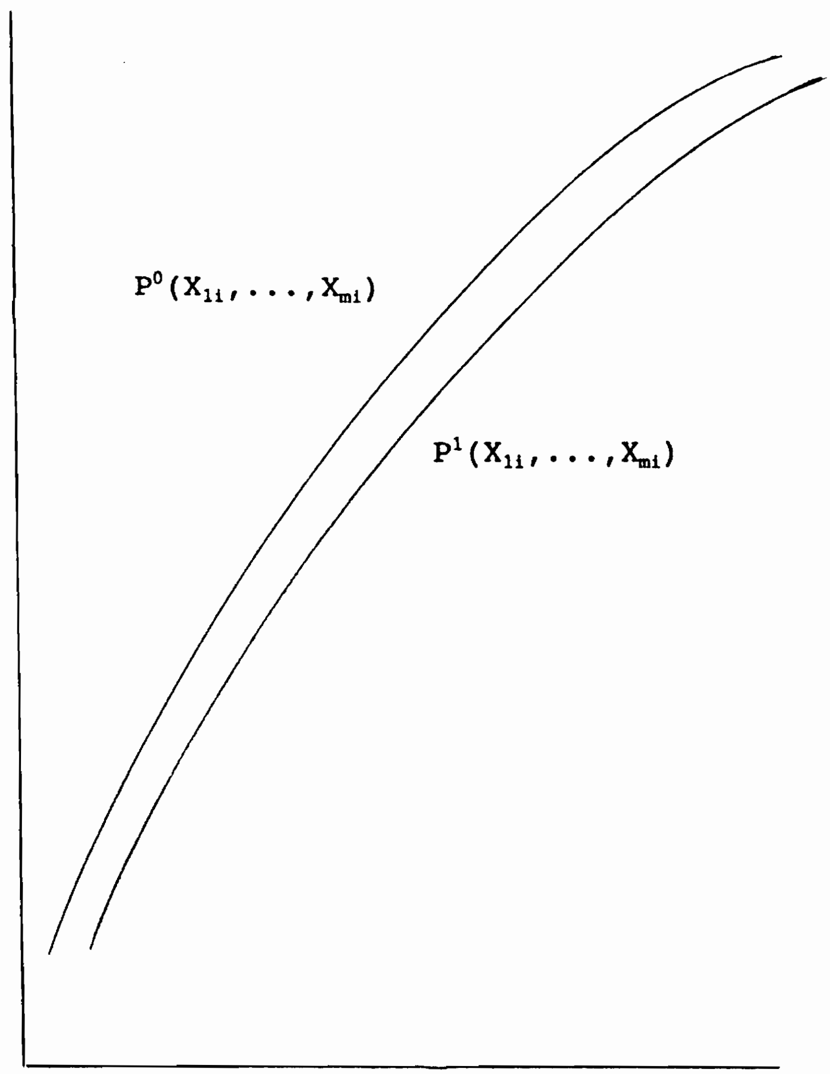

Figure 2.2: Marginal Shift in the Hedonic Price Function

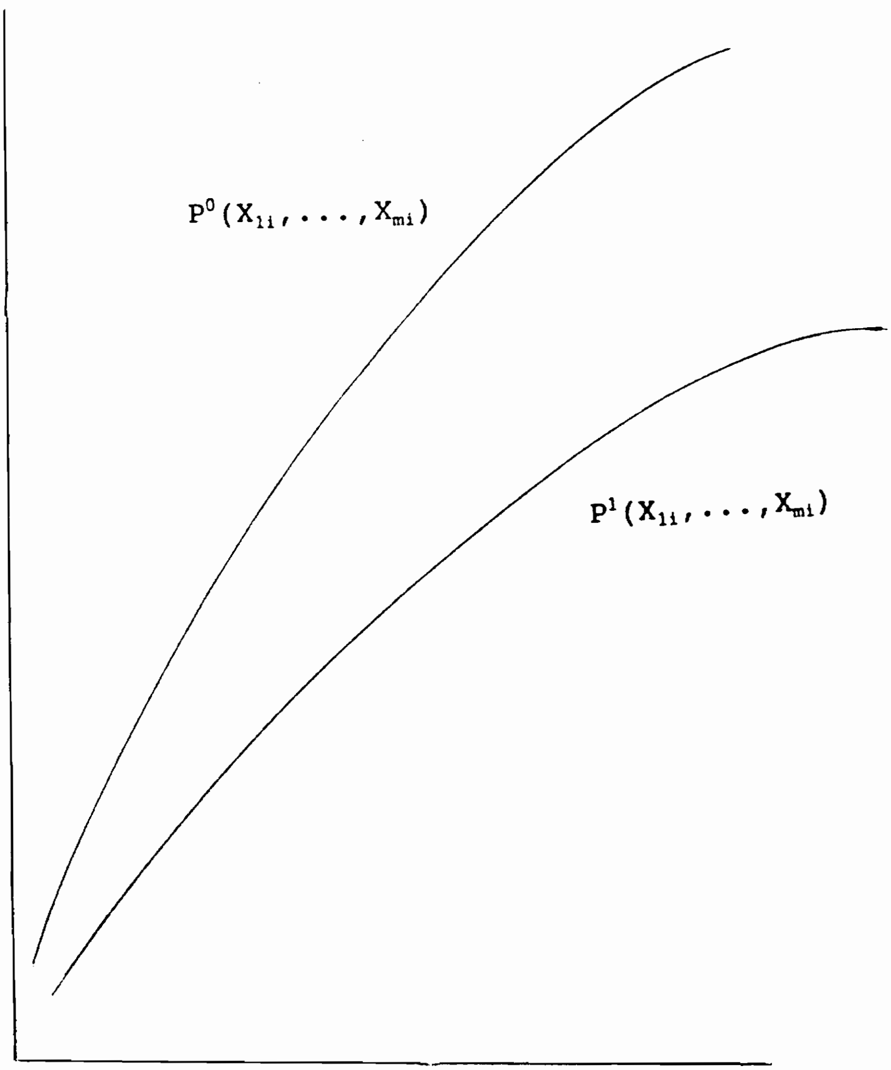

Figure 2.3: Nonmarginal Shift in the Hedonic Price Function

considered, Polinsky and Shavell, Scotchmer (1986) and Bartik (1988) have suggested a general equilibrium approach that permits shifts in the hedonic function to be predicted. Suppose the focus of a study centers on the kth property characteristic X_k and assume that the supply of X_k is exogenous, i.e., independent of its implicit marginal price. The hedonic property price function for the ith property can be expressed as

$$p_{it}=p(\mathbf{p_{xt}},\mathbf{X_{1t}},\mathbf{X_{jkt}},Y_t,N_t) \tag{2.17}$$

where the vector $\mathbf{X_{jkt}}$ contains information at time t on the level of characteristic X_k at all other j properties in the closed area, Y_t contains information on individual consumer incomes at time t, and N_t reflects population densities. The variables Y_t and N_t are added to the model to reflect changing aggregate demand over time. In order to estimate a single equation model of the form in equation (2.17), the following conditions must be met:

1) the variables $\mathbf{p_{xt}}$, $\mathbf{X_{jkt}}$ and Y_t must be aggregable in order to identify the model,
2) a time series dimension must be added to the data set that reflects the varying levels of the amenity at individual sites over time, and
3) all of the explanatory variables must be exogenous.

If the data do not meet either the first or second of these criteria, the shifts in the hedonic are unpredictable. A general equilibrium model is required when the third criterion is invalid (Driscoll, 1992).

2.3.3 Estimating Willingness to Pay Directly from the Hedonic Model

In some circumstances, hedonic price functions may be used to directly evaluate willingness to pay for changes in the characteristic levels of a composite good. A distinction must be made between changes that are marginal and nonmarginal. Willingness to pay for a marginal change in the characteristic of interest X_k may be obtained from the hedonic model. To see this, differentiation of equation (2.16) with respect X_k yields the following shadow price relation.

$$\frac{\partial P(X_{1i},\ldots,X_{mi})}{\partial X_{ki}} = -\frac{\partial e(\mathbf{p_x},X_{1i},\ldots,X_{mi};U_i^0)}{\partial X_{ki}} \tag{2.18}$$

Thus the willingness to pay for a marginal change in X_k is the derivative of $-e(\mathbf{p_x},X_{1i},\ldots,X_{mi};U_i^0)$ with respect to the X_k and can be determined by differentiating the hedonic property price function with respect to X_k and evaluating this derivative at the characteristic level. Since this is true for all consumers, the welfare change for a change in the level of a property characteristic, say flood risk, will be the sum of property value differences predicted by the hedonic model.

Suppose now that a nonmarginal change in X_k is considered. As can be seen from figure 2.1, the hedonic price function is not identical to any consumer bid function over a nonmarginal change in the characteristic unless consumers have identical preferences and income.

In this case, the hedonic price function in figure 2.1 would be the envelope of a single consumer bid function and the hedonic model could be used to compute compensating variation for nonmarginal changes. If consumers do not have identical preferences and income, results from the hedonic price method will overestimate compensating variation.

The limitations of using the hedonic property price function to directly obtain measures of willingness to pay for nonmarginal changes was recognized by Freeman (1971) and more theoretically appealing approaches were suggested by Freeman (1974), Rosen, and Harrison and Rubinfeld (1978). The common theme of these latter approaches is that consumer compensated demand curves for the characteristics in question must be estimated in order to measure willingness to pay.

2.4 WILLINGNESS TO PAY AND ACCEPT METHODS

When estimating the willingness to pay or accept for a nonmarginal change in an amenity level, methods that calculate the area under a compensated demand curve should be utilized. A method utilized by Hausman (1981) estimates compensating variation for a single price change from the indirect utility function derived from observed ordinary demand functions. For several functional forms of the ordinary demand function utilized by Hausman, rather restrictive assumptions on consumer preferences are imposed. In addition, data on consumer income is required. In the second approach, biased estimates of compensating and equivalent variation are calculated from a direct utility function whose parameters are estimated from an expenditure share system derived from the first-order conditions of utility maximization. By specifying a flexible form of the direct utility function, consumer preferences are not restricted a priori. In addition, income information is not required.

Optimally, estimates of willingness to pay should permit consumers to adjust consumption of all goods. Computing exact compensating and equivalent variation requires, at a minimum, data on the subset of consumer goods of interest, an aggregator for the prices of all goods not included in the subset, and consumer income. LaFrance (1985) argues that when such data are available, a quasi-utility function of the available data may be used in the analysis without placing any a priori structure on the utility function. In many situations, however, consumer income is difficult to obtain. Therefore, determining compensating or equivalent variation from the consumer's problem over a reduced choice set may be the only feasible method of computing either measure.

2.4.1 The Hausman Approach

In Hausman's approach, a functional form of the ordinary demand function is specified and these demand functions are estimated using implicit prices obtained from the hedonic model or market prices. An indirect utility function is obtained by integrating the ordinary demand functions using Roy's identity. Given the price change, or commodity change in commodity space, compensating variation is calculated from the indirect utility function. Hausman computes this measure using the method described above with various linear and nonlinear demand functions.

In the two good case, the indirect utility function is directly estimated from the market demand curve using duality theory. However, in the many good case, Hausman generates a "quasi" indirect utility and expenditure function that do not correspond to the individual's indirect utility and expenditure function. To derive these, one would require the estimates of a complete system of demand equations.

Although the linear demand functions are simple to estimate, LaFrance has shown that linear ordinary demand functions imply restrictive consumer preferences. In addition, the indirect utility functions recovered from the nonlinear ordinary demands suggested by Hausman will not always contain enough parameters to avoid restricting the consumer preferences. One way to ensure that the form of the ordinary demand does not restrict consumer preferences is to measure compensating variation using a flexible form utility function.

2.4.2 The RWTP and RWTA Methods

The RWTP and RWTA methods calculate biased estimates of compensating and equivalent variation using the direct utility function. Although the direct utility function is seldom used, it is convenient for determining welfare changes in amenity levels because the direct utility function is a function of goods consumed. By assuming a flexible form direct utility function, compensating and equivalent variation can be estimated where no a priori restrictions are placed on consumer preferences. The direct utility function cannot be directly estimated from market data, however all parameters (except the intercept) of the direct utility function may be obtained by estimating a system derived from the first order conditions of utility maximization.

A similar approach by Horowitz (1984) assumes that consumers reallocate only among goods other than the composite good. This method requires additional data on all goods consumed which are often unavailable. The methods proposed here differ from Horowitz' in that data on all goods consumed are not needed and the consumer is assumed to make all reallocations among the characteristics of the composite good. This implies that the consumer only adjusts consumption of the other characteristics of the composite good when faced with changes in one or more characteristics of that good. This assumption is reasonably appropriate for many consumer products with small transaction costs associated with changes in demand, where at least two characteristics of the composite good are easily modified and available over a continuous range, and substitution possibilities outside the composite good are limited (Driscoll, Dietz, and Alwang, 1992). Since estimates from the hedonic price and compensating variation methods should converge for marginal changes in characteristic levels, a check on the validity of the results is possible.

In commodity space, compensating variation from a change in the level of a good can be defined as

(2.19)
$$CV = \mathbf{p_c X_c^0} - \mathbf{p_c X_c^1}$$

such that $U(\mathbf{X^0})=U(\mathbf{X^1})$ where $\mathbf{X_c}$ and $\mathbf{p_c}$ denotes all goods and prices other than the one under consideration. Because the change is mandatory, the consumer is not expected to pay for the change in good under consideration.

Under certain assumptions, the reduced choice set model can be analyzed resulting in measures that strictly underestimate compensating variation. Consider a static equilibrium case where the direct utility function is weakly separable in terms of goods $X_1,\ldots X_m$ as

(2.20)
$$U(X_1,\ldots,X_n)=U[U_1(X_1,\ldots,X_m),X_{m+1},\ldots,X_n]$$

At t=0, the consumer's choice set is assumed to be in equilibrium and given by

(2.21)
$$\max\ U[U_1(X_1^0,\ldots,X_m^0),X_{m+1}^0,\ldots,X_n^0]$$
$$st\ \ \Sigma_{i=1}^{n} p_i^0 X_i^0 = Y$$

Assume that at time t=1, an improvement in X_1 from X_1^0 to X_1^1 occurs. An accurate measure of compensating variation can be obtained by solving for X_i^1, i=2,...,n, in equation (2.22) and using these values in equation (2.19) to compute CV.

(2.22)
$$\min \ \Sigma_{1=2}^{n} p_i^0 X_i^1$$
$$st \quad U^0 = U[U_1(X_1^1, \ldots, X_m^1), X_{m+1}^1, \ldots, X_n^1]$$

where X_1^1 is fixed. If consumers are not permitted to change their consumption levels of goods X_{m+1} to X_n from the initial to the first time periods, a new restricted measure of compensating variation can be obtained by solving for X_i^1, i=2,...,m in equation (2.23) and using these values in equation (2.24) to compute for RWTP.

(2.23)
$$\min \ \Sigma_{i=2}^{m} \ p_i^0 X_i^0$$
$$st \quad U_1^0 = U_1^1(X_1^1, \ldots, X_m^1)$$

where $U_1^0 = U_1(X_1^0, \ldots, X_m^0)$. Given the weak separability condition, $U_1^0 = U_1^1$ implies $U^0 = U^1$.

The restricted compensating variation measure RWTP is calculated as

(2.24)
$$RWTP = \Sigma_{i=2}^{m} p_i^0 X_i^1 - \Sigma_{i=2}^{m} p_i^0 X_i^0$$

where RWTP will always underestimate compensating variation by the le Chatelier principle since consumers are constrained to make adjustments only in the goods subset of $(X_1, \ldots, X_m)$.[4]

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[4] In the method by Horowitz, the measure of compensating variation will underestimate actual compensating variation as well because consumers are not allowed to make any adjustments among the goods in $(X_1, \ldots, X_m)$.

When goods in the sub-utility aggregator U_1 represent characteristics of a composite good, the budget constraint must be slightly altered. In particular, the consumer's problem in equation (2.21) becomes

$$\max \; U[U_1(X_1^0,\ldots,X_m^0),X_{m+1}^0,\ldots,X_n^0] \tag{2.25}$$

$$st \;\; P(X_1^0,\ldots,X_m^0) + \textstyle\sum_{i=m+1}^{n} p_i^0 X_i^0 = Y$$

If consumer are not permitted to adjust initial levels of $X_2,\ldots,X_m$ at t=1, then the problem analogous to equation (2.23) is

$$\min \; P(X_1^1,\ldots,X_m^1) \tag{2.26}$$

$$st \;\; U_1^0 = U_1^1(X_1^1,\ldots,X_m^1)$$

with X_1^1 fixed. The measure RWTP becomes

$$RWTP = P(X_1^0,X_2^0,\ldots,X_m^0) - P(X_1^0,X_2^1,\ldots,X_m^1) \tag{2.27}$$

Consumers are not expected to pay for the change in X_1, so when calculating RWTP, the price of a hypothetical composite good $P(X_1^0,X_2^1,\ldots,X_m^1)$ is calculated such that the consumer derives the same utility from the new set of characteristics as is derived from the old set. Given positive marginal utilities of $X_1,\ldots,X_m$, the measure RWTP defined in this manner will result in negative values when the level of X_1 is decreased.

Similarly, a restricted measure of equivalent variation, RWTA, from a change in the level of X_1 can be determined in an analogous fashion given by

$$RWTA=P(X_1^0,X_2^*,\ldots,X_m^*)-P(X_1^0,X_2^0,\ldots,X_m^0) \tag{2.28}$$

where $P(X_1^0,X_2^*,\ldots,X_m^*)$ is the solution to

$$\begin{gathered} \min\ P(X_1^0,X_2^*\ldots,X_m^*) \\ st\ \ U_1^0(X_1^1,X_2^0,\ldots,X_m^0)=U_1^*(X_1^0,X_2^*\ldots,X_m^*) \end{gathered} \tag{2.29}$$

where X_1^0 is fixed and $(X_1^0,X_2^*,\ldots,X_m^*)$ is the minimum cost set of characteristics given X_1^0 that gives the same utility as the original composite good given X_1^1. Given positive marginal utilities of $X_1,\ldots,X_m$, this measure will be negative as well when the level of X_1 is decreased.

Before applying these methods, it is important to choose a flexible form utility function so preferences are not restricted a priori. Although the direct utility function cannot be estimated from market data, its parameters (except the intercept) may be estimated from a system of expenditure share equations resulting from the first-order conditions of utility maximization.

Christensen, Jorgensen, and Lau (1975) derived a system of expenditure share equations resulting from the first-order conditions of utility maximization from which the parameter estimates of the direct utility function are calculated. Given the translog direct sub-utility function,

$$(2.30) \qquad \ln U_1 = \alpha_0 + \Sigma_{i=1}^{m} \alpha_i \ln X_i + \frac{1}{2} \Sigma_{i=1}^{m} \Sigma_{j=1}^{m} \beta_{ij} \ln X_i \ln X_j$$

the system of expenditure share equations resulting from the first-order conditions of utility maximization

$$(2.31) \qquad \frac{p_i X_i}{M} = \frac{\partial \ln U_1 / \partial \ln X_i}{\Sigma_{j=1}^{m} (\partial \ln U_1 / \partial \ln X_j)} \quad for \quad j=2,\ldots,m-1$$

where $\Sigma_{i=1}^{m} p_i X_i = M$.

The estimated parameters of the direct utility function are calculated by estimating the system of nonlinear equations in equation (2.31) for j=1,...,m-1 using an ITSUR procedure. The estimates of the α's and ß's from the estimated system of expenditure share equations are then substituted in the direct utility function and the initial levels of utility for the RWTP and RWTA methods are calculated.

To determine RWTP from a change in X_1 from X_1^0 to X_1^1, the new levels of $X_2,\ldots,X_m$ associated with the change in X_1 need to be calculated. Using the expenditure share equations in equation (2.31) and a constant utility equation, the new levels of $X_2,\ldots,X_m$, $X_2^1,\ldots,X_m^1$, can be calculated by solving the m-1 simultaneous equations for $X_2^1,\ldots,X_m^1$.

$$(2.32) \qquad 0 = U_1(X_1^0, X_2^0, \ldots, X_m^0) - U_1(X_1^1, X_2^1, \ldots, X_m^1)$$

(2.33) $$0=\left(\frac{COST}{P_i}\right)\left(\frac{M_i}{SUM}\right)-X_i^1$$

for $i=2,\ldots,k-1,k+1,\ldots,m$ where X_k is the characteristic with the smallest expenditure share. The variables in equation (2.33) are

(2.34) $$COST=\sum_{i=2}^{m} MP_i^1 X_i^1$$

(2.35) $$M_i=\hat{\alpha}_i+\sum_{j=1}^{m}\hat{\beta}_{ij}\ln(X_j^1)$$

(2.36) $$SUM=\sum_{i=2}^{m} M_i$$

(2.37) $$P_i=MP_i^1/SUM$$

and MP_i^1 is a function of the new levels $X_2^1,\ldots,X_m^1$ holding X_1 at X_1^0.

The resulting values $X_2^1,\ldots,X_m^1$ along with the initial values $X_1^0,X_2^0,\ldots,X_m^0$ are used in equation (2.25) and the restricted compensating variation measure is calculated where $RWTP \geq CV$ for a decrease in X_1 and $RWTP \leq CV$ for an increase in X_1.

To determine RWTA from the change in X_1 from X_1^0 to X_1^1, the new levels of $X_2,\ldots,X_m$ associated with the change in X_1 need to be calculated. Using the expenditure share equations in equation (2.31) and a constant utility equation, the new levels of $X_2,\ldots,X_m$, $X_2^*,\ldots,X_m^*$, can be calculated by solving the m-1 simultaneous equations for $X_2^*,\ldots,X_m^*$.

(2.38) $$0=U_1(X_1^1,X_2^0,\ldots,X_m^0)-U_1(X_1^0,X_2^*,\ldots,X_m^*)$$

(2.39) $$0=\left(\frac{COST^*}{P_i^*}\right)\left(\frac{M_i^*}{SUM^*}\right)-X_i^*$$

for $i=2,\ldots,k-1,k+1,\ldots,m$ where X_k is the characteristic with the smallest expenditure share. The variables in equation (2.39) are

(2.40) $$COST^*=\Sigma_{i=2}^m MP_i^* X_i^*$$

(2.41) $$M_i^*=\hat{\alpha}_i+\Sigma_{j=1}^m \hat{\beta}_{ij}\ln(X_j^*)$$

(2.42) $$SUM^*=\Sigma_{i=2}^m M_i^*$$

(2.43) $$P_i^*=MP_i^*/SUM^*$$

and MP_1^* is a function of the new levels $X_2^*,\ldots,X_m^*$.

The resulting values $X_2^*,\ldots,X_m^*$ in addition to X_1^1 and the initial values $X_1^0,X_2^0,\ldots,X_m^0$ are used in equation (2.28) to calculate the restricted equivalent variation measure where RWTA≥EV for a decrease in X_1 and RWTA≤EV for an increase in X_1..

2.5 SUMMARY

The property damages avoided, hedonic price, RWTP, and RWTA methods were reviewed and the conditions under which the property damages avoided, hedonic price, and RWTP methods generate an accurate measure of willingness to pay were analyzed in this chapter. The most constraining method was found to be the property damages avoided method. Several assumptions, some of which are unreasonable for the conditions under which the method is used, are required for this method to provide an accurate measure of willingness to pay. The hedonic price method has been used by many researchers in numerous situations to estimate willingness to pay. However, this method can accurately estimate willingness to pay only when marginal changes in characteristic levels occur and a proper hedonic model has been specified. The most general methods examined were the RWTP and RWTA methods. In these methods, which use an implicit price procedure suggested by Rosen, the parameters of the utility function are estimated from a series of nonlinear equations generated from the first order conditions of utility maximization. The estimated utility function along with first-order conditions of utility maximization is then used to generate a new set of characteristic levels from which a new expenditure level is generated. The differences between the new and old levels of expenditures for the RWTP and RWTA methods are estimates of compensating and equivalent variation respectively.

Since the benefit estimates from the property damages avoided have already been calculated by the Corps, those from the hedonic price, RWTP, and RWTA methods need to be calculated. Therefore a properly specified hedonic model must be formulated. In the third chapter, the general theory of the variables used in the hedonic model is discussed along with the effects of the study area on the choice of variables used in the hedonic model resulting in a well specified hedonic model. In addition, benefit estimates from the hedonic price method are calculated.

In the fourth chapter, the RWTP and RWTA methods are applied to the Roanoke case study area using the hedonic property price function generated in Chapter III. Additional assumptions about consumer preferences are made due to the nature of the variables used in the hedonic model. Finally, benefit estimates from the RWTP and RWTA methods are computed.

CHAPTER III

HEDONIC MODEL AND BENEFIT ESTIMATION RESULTS

Most methods employed by researchers to estimate willingness to pay for and price effects from a change in an amenity level of a property use a hedonic property price function. However, assumptions about the conditional distribution of prices given characteristic levels and the conditional means (functional form) may not hold and are often not tested. Invalid assumptions may result in biased parameter estimates, incorrect size and power of tests, and possibly incorrect benefit estimates. Before assessing the effects of flood risk reduction on property prices and consumer willingness to pay, it is important to ensure that the hedonic model is correctly specified and that the benefit estimation methods yield measures of willingness to pay.

In the first section, the study area, a small area beside the Roanoke River in the city of Roanoke, is described in terms of its physical and socioeconomic conditions. Then an overview of the hedonic model, including the general characteristics that affect property prices, is presented along with the data sources used and the specific characteristics that explain price differentials in the study area. Several functional forms of the hedonic model are then examined and a hedonic property price function is specified and estimated using the specific regressors from the previous section. In the following section, misspecification tests are reviewed and conducted on the model to determine whether the hedonic property price function is well defined over the data set. The model is then respecified given the results from the misspecification tests. In the next section, the method used by the Corps to calculate the new flood zones induced by the flood control project is inspected and the new flood zones are calculated. Then, benefits from the hedonic price method are estimated and the ability of the hedonic property price function to accurately forecast prices in the study area is demonstrated. Finally, the results from the hedonic price and property damages avoided method are compared.

3.1 THE ROANOKE CASE STUDY AREA

The first stage in specifying a hedonic model is to determine the characteristics that affect property prices. To do so, the study area, which comprises a small strip along the Roanoke river between the hospital and the 9th Street bridge in southeast Roanoke to be affected by the Roanoke channelization project (figure 3.1) must be described.

As stated earlier, the U.S. Army Corps of Engineers performed a property damages avoided analysis on all flood prone properties in the city of Roanoke. The study area was chosen from all flood prone areas because 1) it was one of two residential areas on the flood plain that exhibited a relatively dense clustering of homes and 2) there were no multiple unit dwellings which were considered commercial property.

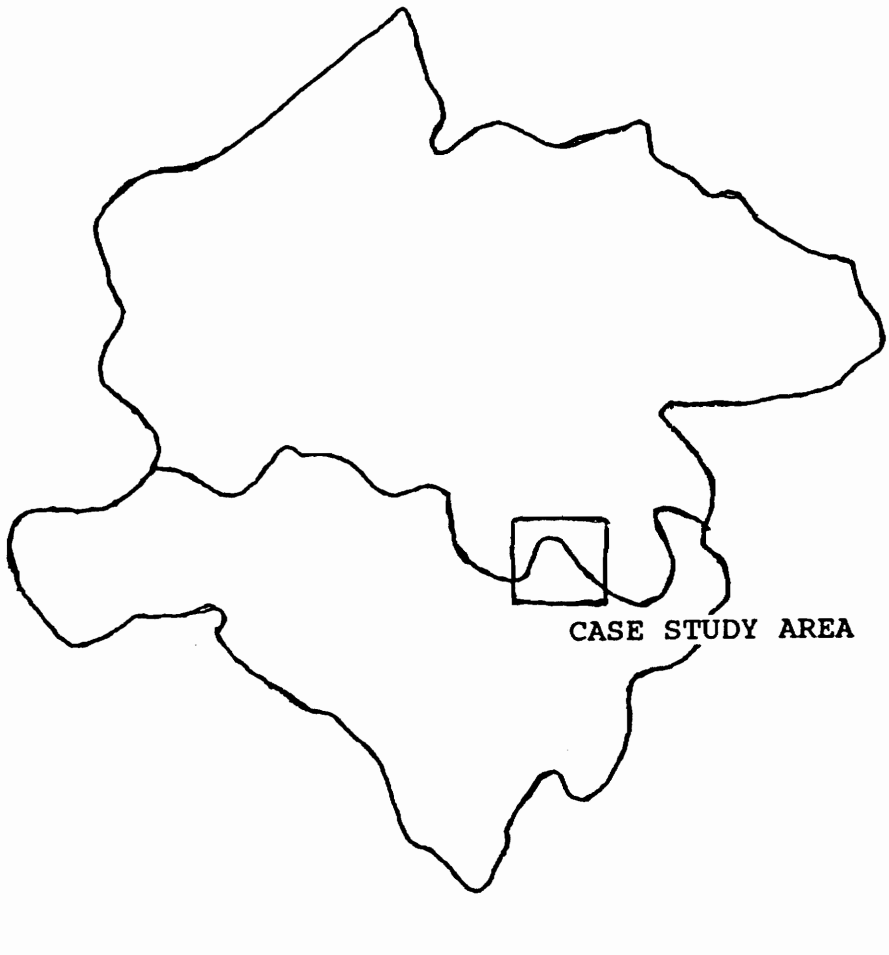

Figure 3.1: The city of Roanoke and the Case Study Area

Therefore, no considerable future land use changes are expected (Thunberg, 1988). This study area can be divided into two separate neighborhoods, one to the east and the other to the west of Walnut Street (figure 3.2). The properties affected by flooding represent only a small portion of the total number of properties in the city.

In the west neighborhood, the city owns all the property adjacent to the river. In addition, the river cannot be seen from the properties due to overgrown vegetation on the city property. As a result, no visual flood threats exist. The properties in this neighborhood are similar, in particular in terms of the size of the lots and the structures on the lots. In the east neighborhood, the city owns all the land adjacent to the river except for a few properties. The river can be seen clearly only from those properties and the park in the northeast corner of the neighborhood so again no visual flood threat exists. In general, properties in this neighborhood closer to the river have smaller lots and smaller structures on the lots than properties further away from the river. This neighborhood consists solely of residential properties except for the park mentioned earlier.

3.2 THE HEDONIC PROPERTY PRICE MODEL

Numerous studies have attempted to determine the effect of varying levels of amenities, such as the level of air pollution or flood risk and proximity to parks, sewage treatment plants or nuclear power plants, on property prices. Brigham (1965) was one of the first researchers to

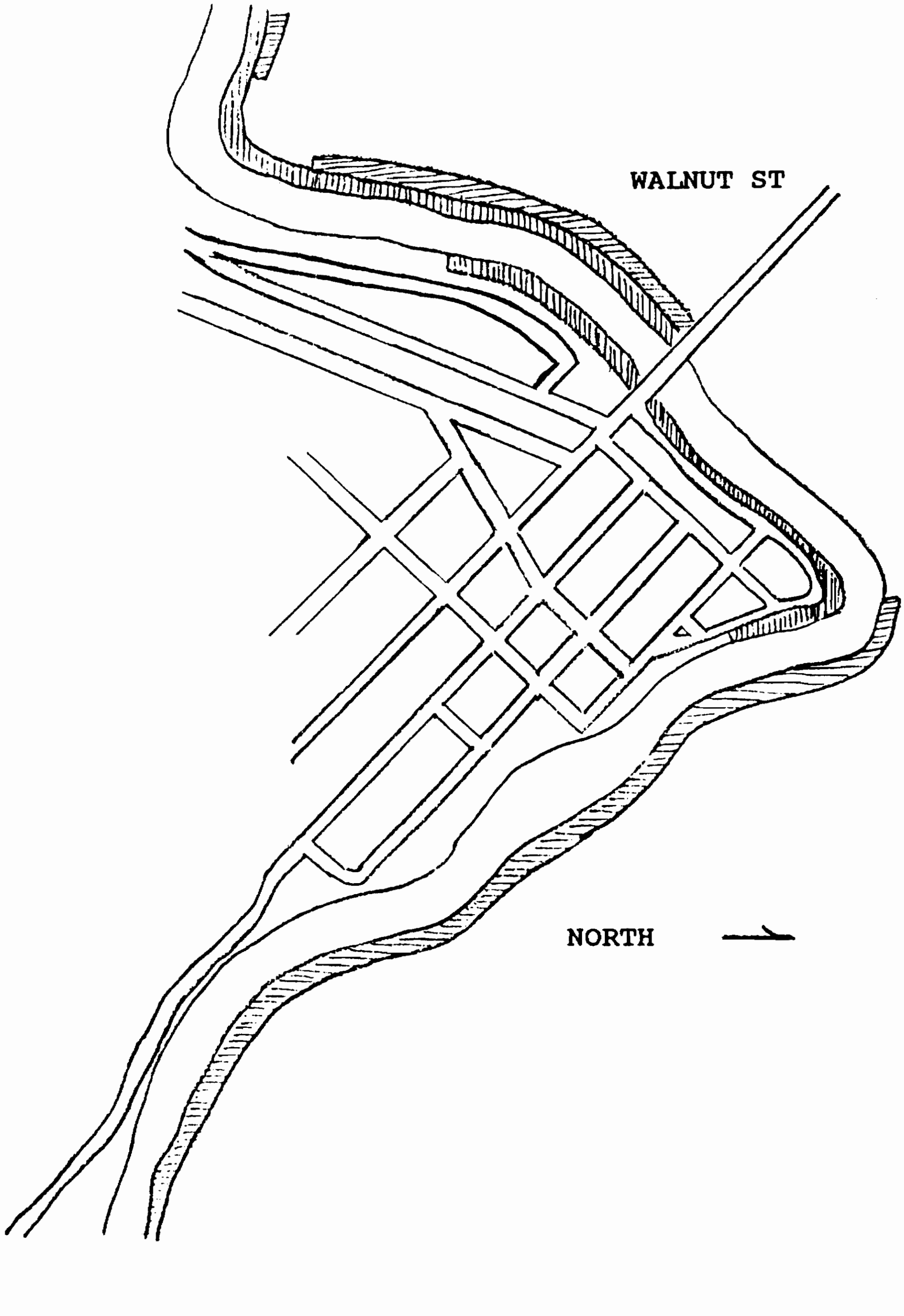

Figure 3.2: The Study Area

use regression methods to determine how different property characteristics affect prices. For residential properties in the Los Angeles area, Brigham assumed that the value of residential property is "functionally related to its accessibility to economic activities, to its amenities, to its topography, to its present and future use, and to certain historical factors that affect its utilization" (p. 325). Studies that followed, like Ridker and Henning, Struyk, Soule and Vaughn, Maxwell and North, Shabman and Demetrios, Babcock and Mitchell, Diamond (1980), Li and Brown (1980), Senjem and Freshwater, Park and Miller, Thompson and Stoevener, Palmquist (1984) and Donnely, regressed similar explanatory variables on property prices to determine the effect of an amenity of interest.

The variables, or characteristics, that affect property prices will be categorized in this study under headings similar to Brigham's: (1) accessibility to nonresidential activities, (2) neighborhood characteristics, (3) property characteristics, and (4) market conditions. The focus of this study, flood hazard, is considered a property characteristic. In this study, the accessibility, neighborhood and property characteristics may vary across both time and properties; however, market conditions are assumed to vary only across time.

3.2.1 Data Sources

Each property in the city of Roanoke has been assigned a tax map number for a variety of uses. From the set of tax map numbers of the properties in the study area, computer printouts describing the properties were obtained from the Office of Real Estate Valuation for the City of Roanoke. These printouts revealed the age and other physical conditions of the structure and the last few sale dates and sales prices of each property. When the transaction data was omitted or illegible, the missing data was obtained from the original deeds from the Grantor and Grantee Indexes available in the vault of the Office of the Clerk of the Circuit Court.

To supplement and verify the transactions data obtained from the printouts, photocopies of the tax map records provided by the Office of the Commissioner of the Revenue were examined. These copies showed the transaction history of each property dating back to at least 1980 or the year in which the structure was built. In addition, a parcel-by-parcel examination of the permanent card file of the Office of Real Estate Valuation was undertaken to provide information concerning improvements or additions made to each parcel over the years.

3.2.2 Property Prices

In this study, the observations are the prices of properties sold between 1980 and 1990. Several observations occurred shortly after the flood of 1985; some reflect damages caused by the flood and others were transactions significantly less than the true value of the property, possibly due to an inheritance or a divorce settlement. In these cases, the observations were removed because the property prices did not represent the present value of the benefit stream generated from owning the property.

Because this study utilizes time-series data, the property prices are deflated to make the observations comparable over time. The property prices in this study are deflated into 1990 dollars using the monthly consumer price index for shelter expenditures. This index is a weighted average of current and new residential property mortgages and rent. The resulting variable, MPRICE, is the dependent variable used in the hedonic model.

3.2.3 Accessibility to Nonresidential Activity

Theoretically, property with easier access to nonresidential activity is of higher value than property without similar ease. Two indicators of accessibility suggested by Li and Brown and Diamond are: (1) proximity to nonresidential activities and (2) accessibility to major roads.

The further the landowner must travel to a nonresidential activity, such as a shopping mall, place of work, or a park, the more he or she expends in time and money. Thus a landowner who owns property closer to places of nonresidential activity saves both time and money and hence the value of the property should be greater than those without similar proximity, holding all other characteristics constant. Brigham, Li and Brown, and Diamond, among others, have measured a property's accessibility to nonresidential activity by measuring the distance along major roads to specific centers of nonresidential activities. However, if the property is too close to a place of nonresidential activity, the value of the land may decrease due to the disamenities produced by traffic and noise. Li and Brown, one of the first researchers to measure both the positive and negative effects of proximity to centers of nonresidential activity, measured this disamenity in terms of the noise pollution (dba) at the property and quality of the view from the property.

Similarly, if a landowner can quickly get to a major road, his or her travel time and costs decrease. Therefore the value of the property should be greater than those without similar access, holding all other characteristics constant. Li and Brown measured the positive effects of living close to major roads as the distance to expressway interchanges. In addition, they measured the negative effects as the distance away from the nearest major thruway and the level of noise pollution (dba) at the property.

Because the study area is compact relative to the city, every property in the study area is approximately the same distance from any major nonresidential activity. The value generated from the property's accessibility to the major nonresidential activities and roads will be identical for each property. Therefore no accessibility characteristic will be used in the hedonic model.

3.2.4 Neighborhood Characteristics

The "perceived" quality of a neighborhood is a theoretical determinant of the value of the properties in that neighborhood. The overall quality of a neighborhood can be determined by examining the socioeconomic characteristics of the neighborhood's residents and the neighborhood's physical characteristics. Researchers like Li and Brown, Diamond, and Palmquist have used characteristics like the racial composition, housing density, median neighborhood income, vandalism, and crime rates of the neighborhood and the quality of schools and other public services affecting the neighborhood to determine the quality level of a neighborhood. Li and Brown, however, argue that higher quality neighborhoods correspond to higher median neighborhood incomes, but a high median neighborhood income may not correspond to a higher quality neighborhood, possibly due to the scarcity of quality neighborhoods. Neighborhood characteristics, however, have no effect on property price differentials of properties in the same neighborhood. Therefore, no neighborhood characteristics will be used in the hedonic model in this study.

3.2.5 Property Characteristics

In many situations, differences between property prices lie in the different characteristics of the respective properties. If the existence of a property characteristic has a positive effect on the landowner's utility, the characteristic is considered desirable, whereas a property characteristic that has a negative effect on the landowner's utility is considered undesirable. Therefore, a property with more desirable characteristics than another property, holding all other characteristics constant, is valued more than the other property.

Due to the homogeneity of the accessibility and neighborhood characteristics of the study area, only the property characteristics of each property will explain the cross-sectional variations in the property price of the properties. At any point in time, the following desirable property characteristics are expected to have significant effects on property price differentials:

ACREAGE:	the acreage of the lot,
LIVEAREA:	the square footage of the structure,
BATHFIX:	the total number of bathroom fixtures,
USE:	whether the property is zoned for single or multi-family use,
CONST:	whether the exterior is of brick/stone construction or not, and
PARK:	whether the property is adjacent to the park in the neighborhood.

The property characteristic of interest in this study though is flood risk. Theoretically, flooding decreases the utility gained from owning a property due to factors such as the anxiety from flooding, clean up and repair costs and flood insurance and thus decreases property values. Many researchers have estimated the extent to which flood risk affects property prices (Struyk, Soule and Vaughn, Maxwell and North, Shabman and Demetrios, Babcock and Mitchell, Senjem and Freshwater, Park and Miller, Thompson and Stoevener, and Donnely). Some characteristics used to represent flood risk include the elevation from the river, the proximity to the river, and the flood zone, a function of both elevation and proximity, of the property in question.

Because the flood zones of the properties in the data set are available from the Corps, flood risk is measured in terms of the flood zone of the property, the minimum flood flow that will damage the property. The higher the flood zone, the lower the risk of the property flooding. A property in the 100-year flood zone will be flooded only by a 100-year flood or greater, i.e. a flood flow that occurs only once every 100 years. The flood zone (FZ) is converted into the variable flood freeness (FZONE100) which is defined as the percent chance of not being flooded in a given year and calculated as

(3.1) $$FZONE100 = 1 - \frac{1}{FZ}$$

3.2.6 Market Conditions

When time-series data is used, it becomes important to measure changes that may affect supply and demand conditions of and for properties from year to year. These changes affect the utility gained from the property and thus cause changes in property prices. These characteristics, which include unemployment rates, mortgage rates, and population, may play an important role in measuring these changes. Other factors that may affect market conditions are changes over time in the centers of nonresidential activity and the attributes that determine neighborhood quality.

By deflating, the sales observations were made comparable over time. However, various regional market conditions are still needed to control for changes in the supply and demand conditions. But observations for most of these characteristics are unrecorded. In this instance, annual dummy variables, DUM80, DUM81, . . . , DUM89, are used to control for and proxy annual market conditions. These variables take on a value of one if the property was sold in the appropriate year and a value of zero otherwise.

3.2.7 The General Hedonic Model

The hedonic model can be used to define property prices as a function of the variables defined in this section as

$$MPRICE=f(ACREAGE, LIVEAREA, BATHFIX, FZONE100, CONST, USE, PARK, \mathbf{DUM}) \tag{3.2}$$

where **DUM**=(DUM80,DUM81,...,DUM89).

3.3 FUNCTIONAL FORM SPECIFICATION

Property price studies have specified the relationship between the property price and the characteristics of the property as a linear function. Many of these studies, though, used models with constant marginal prices. In general, the more a good is consumed, the less it is valued. Therefore marginal utility, and subsequently marginal price, is expected to decrease as more of the good in question is consumed. The constant marginal price model used in many studies is modified to get a decreasing marginal price model.

3.3.1 Linear Hedonic Price Models

A general representation of equation 3.2 is

(3.3) $$P_j=\alpha_0+\sum_{i=1}^{N}\alpha_i X_{ij}$$

where P_j is the price of property j and X_{ij} is the ith characteristic of the jth property. The marginal price of characteristic i at property j is defined as

(3.4) $$MP_{ij}=\alpha_i$$

and is constant.

When the marginal price of a characteristic is constant, it is assumed that the landowner is willing to pay the same price for each additional unit of that characteristic regardless of the amount of the characteristic already present. However, it is more reasonable to expect marginal prices to decrease unless the characteristics are Giffen goods, which is unlikely. More importantly, a linear model indicates linear isoquants which imply that the characteristics are perfect substitutes for each other. Perfect substitutibility, however, is an invalid assumption for property characteristics. So a model that does not impose linear isoquants and perfect substitutibility between characteristics should better describe consumer preferences.

3.3.2 Box-Cox Hedonic Price Models

A commonly used model that does not imply that attributes are perfect substitutes for one another is the Box-Cox model defined in equation (3.5)

(3.5) $$BC(P_j) = \alpha_0 + \sum_{i=1}^{N} BC(X_{ij})$$

where the Box-Cox transformation for any variable X is defined as,

(3.6) $$BC(X) = \frac{X^{\lambda}-1}{\lambda}$$

where lambda is unknown. The marginal price of characteristic i at property j, defined as

(3.7) $$MP_{ij} = \alpha_i P_j^{(1-\lambda)} X_{ij}^{(\lambda-1)}$$

is decreasing in X_{ij} for lambda less than one. When the X_{ij} are discrete or dummy variables, the Box-Cox transformations will only result in a rescaling of the parameter estimate.

It is important to determine an appropriate level for lambda. A value close to zero will result in a log-log model with constant expenditure shares. Subsequently, a value too high, like 1.0, will result in a linear model that exhibits constant marginal prices. Various models were analyzed and a model with a value for lambda of 0.05 had a good R^2 and the expected sign and magnitude for each parameter estimate. This is the model that will be examined throughout the chapter.

3.3.3 The Hedonic Property Price Function

The hedonic property price function resulting from equation (3.2) where the variables ACREAGE, LIVEAREA, BATHFIX, and FZONE100 have been changed to BCACRE, BCLIVE, BCFIX, and BCFLOOD using the Box-Cox transformation with lambda equal to 0.05 is estimated as

$$BCPRICE_t=\hat{\beta}_0+\hat{\beta}_1*BCACRE_t+\hat{\beta}_2*BCLIVE_t+\hat{\beta}_3*BCFIX_t+\hat{\beta}_4*BCFLOOD_t+ \hat{\beta}_5*CONST_t+\hat{\beta}_6*USE_t+\hat{\beta}_7*PARK_t+\hat{\boldsymbol{\theta}}*\boldsymbol{DUM}_t \quad (3.8)$$

The parameter estimates for this hedonic property price function are found in table 3.1.

3.4 DISTRIBUTIONAL ASSUMPTIONS

Given the specified model, it is important to determine whether the model is well defined over the data set. Spanos (1986) suggests that the assumptions of the linear regression model are properties of the probability model called the Haavelmo distribution. Let $Z_t=(y_t, X_t)$ where y_t is the price of the tth observation and $\mathbf{X}_t$ is the vector of characteristics at the tth observation and let $P_Z(Z_t)$, the distribution of Z_t, be normal. The joint distribution $P(Z_1,...,Z_T;\Phi)$ can be reduced into the following by assuming (A) independence of the Z_t's and (B) identical distribution of the Z_t's and by applying (C) Bayes Theorem:

(A) independence

$$P(\mathbf{Z}_1, ..., \mathbf{Z}_T; \mathbf{\Phi}) = \Pi_{t=1}^{T} P_t(\mathbf{Z}_t; \boldsymbol{\phi}_t)$$

(B) identically distributed

$$= \Pi_{t=1}^{T} P_{\mathbf{Z}}(\mathbf{Z}_t; \mathbf{\Gamma})$$

(C) Bayes' Theorem

$$= \Pi_{t=1}^{T} P_{y/\mathbf{X}}(y_t/\mathbf{X}_t; \boldsymbol{\theta})\, P_X(\mathbf{X}_t; \boldsymbol{\pi})$$

The assumption of normality of $P_Z(Z_t;\Gamma)$ implies that the conditional and marginal distributions in (C), $P_{y/X}(y_t/X_t;\theta)$ and $P_X(X_t;\pi)$ respectively, are also normal. In addition, joint normality implies X_t is weakly exogenous and therefore the marginal distribution $P_X(X_t;\pi)$ is not relevant as far as the statistical inference on the

Table 3.1: Regression results

Variable	Parameter Estimate	Standard Error	T-value	Prob > |T|
INTERCEPT	12.300766	1.697572	7.246	0.0001
BCACRE	1.357509	0.452949	3.019	0.0034
BCLIVE	0.385120	0.165771	3.323	0.0227
BCFIX	0.399476	0.240652	1.660	0.1008
BCFLOOD	5.959255	2.600908	2.291	0.0245
CONST	0.211325	0.120377	1.756	0.0830
USE	0.520062	0.198918	2.614	0.0107
PARK	0.284324	0.221170	1.286	0.2023
DUM80	0.361928	0.231002	1.567	0.1211
DUM81	-0.070357	0.251977	-0.279	0.7808
DUM82	-0.123736	0.254498	-0.486	0.6281
DUM83	0.237153	0.232115	1.023	0.3092
DUM84	0.379775	0.266814	1.423	0.1585
DUM85	-0.193653	0.281948	-0.687	0.4941
DUM86	-0.215612	0.232233	-0.928	0.3559
DUM87	0.219136	0.237435	0.923	0.3588
DUM88	-0.247945	0.268662	0.923	0.3588
DUM89	0.083471	0.248348	0.336	0.7377

R^2=0.4706

Adjusted R^2=0.3595

parameters of interest $\boldsymbol{\theta}$ is concerned. Therefore, the distribution of interest is

$$P_{y/\boldsymbol{x}}(y_t/\boldsymbol{X}_t;\boldsymbol{\theta}) \tag{3.9}$$

which has a normal distribution with mean $\mathbf{X}_t\boldsymbol{\beta}$ and variance σ^2.

3.4.1 Independence

The first distributional assumption is independence. Because the data has no natural ordering, temporal or otherwise, and modelling dependence would be impractical, independence is presumed.

3.4.2 Identically Distributed

The next distributional assumption is that the Z_t's are identically distributed. A common method used to determine whether the $\mathbf{Z}_t$'s are identically distributed is to examine for structural changes between two particular partitions of the data set. A test for structural change between two partitions of a data set is

$$F_{obs}=\frac{RSS_5/(k_1+k_2-k)}{RSS_4/(N_1+N_2-k_1-k_2)} \tag{3.10}$$

where

$RSS_4 = RSS_2 + RSS_3$,

$RSS_5 = RSS_1 - RSS_4$,

RSS_1 = residual sum of squares from the full model,

RSS_2 = residual sum of squares from the first partitioned model, model 1,

RSS_3 = residual sum of squares from the second partitioned model, model 2,

N_1 = the number of observations from model 1,

N_2 = the number of observations from model 2,

k = the number of parameters estimated in the full model,

k_1 = the number of parameters estimated in model 1, and

k_2 = the number of parameters estimated in model 2.

which is distributed $F[(k_1+k_2-k),(N_1+N_2-k_1-k_2)]$.

If $F_{obs} > F[\alpha,(k_1+k_2-k),(N_1+N_2-k_1-k_2)]$ then structural differences exist between the two time periods and must be modelled.

3.4.3 Normality

The assumption of normality is important because the distribution of test statistics will be t, F, and χ^2 only if $P_{y/\mathbf{X}}(y_t/\mathbf{X}_t;\boldsymbol{\Theta})$ is normal. If normality of the conditional distribution does not hold, the results from the tests are likely to be invalid. Normality of the conditional distribution $P_{y/\mathbf{X}}(y_t|\mathbf{X}_t=\mathbf{x}_t)$ can be tested using the skewness-kurtosis test by examining the scaled third and fourth conditional moments, α_3 and α_4, which are functions of the third and fourth conditional moments,

μ_3 and μ_4 respectively.

(3.11) $$\alpha_3 = \frac{\mu_3}{\sigma^3} \quad \textit{and} \quad \alpha_4 = \frac{\mu_4}{\sigma^4}$$

The estimates for α_3 and α_4 are calculated using the estimated residuals from the model in the following manner:

(3.12) $$\hat{\alpha}_3 = \frac{(1/T)\sum_{t=1}^{T} \hat{u}_t^3)}{[(1/T)\sum_{t=1}^{T} \hat{u}_t^2]^{3/2}}$$

(3.13) $$\hat{\alpha}_4 = \frac{(1/T)\sum_{t=1}^{T} \hat{u}_t^4)}{[(1/T)\sum_{t=1}^{T} \hat{u}_t^2]^{2}}$$

where the $\hat{u}_t$'s are the residuals of the hedonic property price function. Under normality, the test statistic, calculated as

(3.14) $$\mathbf{T}(\boldsymbol{y}) = [(T/6)\hat{\alpha}_3^2 + (T/24)(\hat{\alpha}_4 - 3)^2]$$

has a chi-square distribution with two degrees of freedom.

3.4.4 Testing the Assumptions

Because structural change tests are based on F-distributions, the assumption of normality for the model in equation (3.11) must first be tested. From the SAS procedure IML, an algorithm for computing the estimates for α_3 and α_4 was generated and the results for the skewness-kurtosis test follow:

$\hat{\alpha}_3$ =−0.006538

$\hat{\alpha}_4$ = 3.217223

T(y) = 0.195347

The critical value for a chi-square variable with 2 degrees of freedom at the 5% significance level is roughly 5.99. The test statistic T(y) is significantly less than the critical value, so under the null hypothesis of normality, we fail to reject that $P_{y/\mathbf{X}}(y_t|\mathbf{X_t}=\mathbf{x_t})$ is normally distributed.

The structural change of interest is the difference between pre- and post-flood sales observations for the flood of 1985. No sales observations occurred after the flood in 1985 so the two partitioned models are

Model 1: Sales observations from 1980 to 1985
Model 2: Sales observations from 1986 to 1990

Results from the regressions on models 1 and 2 are found in tables 3.2 and 3.3 respectively.

From the regressions of models 1 and 2 and the full model, the following values are given:

RSS_1 = 19.16419,

RSS_2 = 6.04300,

RSS_3 = 9.54958,

RSS_4 = 15.59258,

RSS_5 = 3.57161,

N_1 = 53,

Table 3.2: Regression results of pre-1985 flood observations

Variable	Parameter Estimate	Standard Error	T-value	Prob > |T|
INTERCEPT	14.962124	1.874017	7.984	0.0001
BCACRE	2.521774	0.559951	4.504	0.0001
BCLIVE	0.304332	0.181775	1.674	0.1019
BCFIX	0.422886	0.272215	1.553	0.1282
BCFLOOD	−0.796180	3.071153	−0.259	0.7968
CONST	0.156793	0.131642	1.191	0.2406
USE	0.438155	0.214599	2.042	0.0478
PARK	0.131962	0.236880	0.557	0.5806
DUM80	0.451098	0.228125	1.977	0.0549
DUM81	−0.060896	0.233825	−0.260	0.7959
DUM82	0.056818	0.232421	0.244	0.8081
DUM83	0.320538	0.223253	1.436	0.1588
DUM84	0.336384	0.245657	1.369	0.1785

R^2 = 0.5821

Adjusted R^2 = 0.4568

Table 3.3: Regression results of post-85 flood observations

Variable	Parameter Estimate	Standard Error	T-value	Prob > |T|
INTERCEPT	8.461992	2.753771	3.073	0.0042
BCACRE	0.704393	0.656955	1.070	0.2920
BCLIVE	0.686127	0.279046	2.459	0.0192
BCFIX	0.414341	0.374796	1.106	0.2767
BCFLOOD	10.795997	3.940495	2.740	0.0097
CONST	0.189089	0.200010	0.945	0.3513
USE	0.614300	0.330429	1.859	0.0717
PARK	0.780210	0.380050	2.053	0.0478
DUM86	-0.107415	0.260066	-0.413	0.6822
DUM87	0.165843	0.279728	0.593	0.5572
DUM88	0.002727	0.306080	0.009	0.9929
DUM89	0.152168	0.282599	0.538	0.5938

$R^2 = 0.5519$

Adjusted $R^2 = 0.4070$

$N_2 = 46$,

$k = 18$,

$k_1 = 13$, and

$k_2 = 12$.

So, $F_{obs} = 2.42$ and $F[\alpha{=}0.05,7,74] = 2.23$. Because $F_{obs} >$ $F[\alpha{=}0.05,7,74]$, some structural difference exists. From the regression results in tables 3.2 and 3.3, it can be hypothesized that the difference in the parameter estimates of the flood risk variable BCFLOOD are causing the problem.

To model this structural change, two new flood risk variables are created from BCFLOOD, FLOOD1 and FLOOD2 where

FLOOD1 = BCFLOOD for all observations between 1980 and 1985 and
= 0 otherwise.

FLOOD2 = 0 for all observations between 1980 and 1985 and
= BCFLOOD otherwise.

The parameter estimates of the new hedonic model, defined in equation (3.15), using the full data set and the subsets from 1980–1985 and 1986–1990, are found in tables 3.4, 3.5 and 3.6 respectively.

$$BCPRICE_t=\beta_0+\beta_1*BCACRE_t+\beta_2*BCLIVE_t+\beta_3*BCFIX_t+\beta_4*FLOOD1_t+ \beta_5*FLOOD2_t+\beta_6*CONST_t+\beta_7*USE_t+\beta_8*PARK_t+\boldsymbol{\theta}*\boldsymbol{DUM_t} \quad (3.15)$$

Before the model in equation (3.21) can be tested to ensure that the structural change has been removed, normality of the new model must be tested. The results of the skewness–kurtosis test on the respecified model follow:

Table 3.4: Regression results of the new hedonic model

Variable	Parameter Estimate	Standard Error	T-value	Prob > |T|
INTERCEPT	12.189883	1.640991	7.428	0.0001
BCACRE	1.487910	0.440153	3.380	0.0011
BCLIVE	0.429764	0.161112	2.667	0.0092
BCFIX	0.388484	0.232590	1.670	0.0988
FLOOD1	0.807315	3.202284	0.252	0.8016
FLOOD2	10.832229	3.136836	3.453	0.0009
CONST	0.224287	0.116433	1.926	0.0576
USE	0.510800	0.192256	2.657	0.0095
PARK	0.338547	0.214745	1.577	0.1189
DUM80	0.174529	0.234606	0.744	0.4591
DUM81	−0.278232	0.256322	−1.085	0.2810
DUM82	−0.207421	0.248036	−0.836	0.4055
DUM83	0.076498	0.232718	0.329	0.7432
DUM84	0.133732	0.274698	0.487	0.6277
DUM85	−0.298422	0.275431	−1.083	0.2819
DUM86	−0.154735	0.225638	−0.686	0.4948
DUM87	0.213547	0.229454	0.931	0.3548
DUM88	−0.189144	0.260609	−0.726	0.4701
DUM89	0.178877	0.242787	0.737	0.4634

R^2 = 0.5118

Adjusted R^2 = 0.4019

Table 3.5: Regression results of pre-1985 flood observations using the new hedonic model.

Variable	Parameter Estimate	Standard Error	T-value	Prob > |T|
INTERCEPT	14.962124	1.874017	7.984	0.0001
BCACRE	2.521774	0.559951	4.504	0.0001
BCLIVE	0.304332	0.181775	1.674	0.1019
BCFIX	0.422886	0.272215	1.553	0.1282
FLOOD1	-0.796180	3.071153	-0.259	0.7968
CONST	0.156793	0.131642	1.191	0.2406
USE	0.438155	0.214599	2.042	0.0478
PARK	0.131962	0.236880	0.557	0.5806
DUM80	0.451098	0.228125	1.977	0.0549
DUM81	-0.060896	0.233825	-0.260	0.7959
DUM82	0.056818	0.232421	0.244	0.8081
DUM83	0.320538	0.223253	1.436	0.1588
DUM84	0.336384	0.245657	1.369	0.1785

$R^2 = 0.5821$

Adjusted $R^2 = 0.4568$

Table 3.6: Regression results of post-85 flood observations using the new hedonic model.

Variable	Parameter Estimate	Standard Error	T-value	Prob > |T|
INTERCEPT	8.461992	2.753771	3.073	0.0042
BCACRE	0.704393	0.656955	1.070	0.2920
BCLIVE	0.686127	0.279046	2.459	0.0192
BCFIX	0.414341	0.374796	1.106	0.2767
FLOOD2	10.795997	3.940495	2.740	0.0097
CONST	0.189089	0.200010	0.945	0.3513
USE	0.614300	0.330429	1.859	0.0717
PARK	0.780210	0.380050	2.053	0.0478
DUM86	-0.107415	0.260066	-0.413	0.6822
DUM87	0.165843	0.279728	0.593	0.5572
DUM88	0.002727	0.306080	0.009	0.9929
DUM89	0.152168	0.282599	0.538	0.5938

R^2=0.5519

Adjusted R^2=0.4070

$\hat{\alpha}_3$ = 0.1259346,

$\hat{\alpha}_4$ = 3.3714825, and

T(y) = 0.8309293.

The critical value for a chi-square variable with 2 degrees of freedom at the 5% significance level is roughly 5.99. The test statistic T(y) is significantly less than the critical value, so under the null hypothesis of normality, we fail to reject that $P_{y/\mathbf{X}}(y_t|\mathbf{X}_t=\mathbf{x}_t)$ is normally distributed.

An F-test can now be performed to determine whether the structural change has been removed. From the regressions of models 1 and 2 and the full model with the new flood risk variables, the following values are given:

RSS_1 = 17.67491,

RSS_2 = 6.04300,

RSS_3 = 9.54958,

RSS_4 = 15.59258,

RSS_5 = 2.08233,

N_1 = 53,

N_2 = 46,

k = 19,

k_1 = 13, and

k_2 = 12.

So, F_{obs} = 1.647 and $F[\alpha=0.05,6,74]$ = 2.15. Because $F_{obs} <$ $F[\alpha=0.05,6,74]$, the structural difference no longer exists. The change in flood risk perceptions due to the flood of 1985 has been modelled.

3.4.5 Respecified Hedonic Model

The hedonic model used in the computations throughout the remainder of the study is equation (3.15). However, when determining marginal prices and changes in the predicted prices of properties, the observations are computed as if they sold in 1990. Therefore, the estimated price becomes

$$PR\hat{I}CE_t = [\lambda * BCMP\hat{R}ICE_t + 1]^{1/\lambda} \tag{3.16}$$

where

$$\begin{aligned} BCMP\hat{R}ICE_t = {} & \hat{\beta}_1 + \hat{\beta}_1 * BCACRE_t + \hat{\beta}_2 * BCLIVE_t + \hat{\beta}_3 * BCFIX_t + \hat{\beta}_4 * BCFLOOD_t + \\ & \hat{\beta}_5 * CONST_t + \hat{\beta}_6 * USE_t + \hat{\beta}_7 * PARK_t \end{aligned} \tag{3.17}$$

3.5 CALCULATING NEW FLOOD ZONES

From plate A-53 (figure 3.3) from the U.S. Army Corps of Engineers' Feasibility Report, the Corps computes new levels of flood zones using a stage-frequency curve for the improved channel near the study area. This stage-frequency curve describes the relationship between the elevation of the property and the frequency of a flood occurring per 100 years. The initial level of frequency per 100 years, 100 divided by the flood zone, is plotted against the stage-frequency curve to determine the elevation in feet above mean sea level. Using this elevation, the with project frequency per 100 years is calculated using the reverse procedure but using the stage frequency curve for the improved channel. The resulting values, including flood frequency and flood zones, are called with project conditions. Based on figure 3.3, the with project flood zones generated by the without project flood zones are found in table 3.5.1.

3.6 ESTIMATING WILLINGNESS TO PAY FROM THE HEDONIC MODEL

When the area by a flood control project is small relative to other nearby areas and where household mobility between areas is relatively costless, the hedonic property price function can accurately forecast the price effects of a change in flood risk. In the city of Roanoke, the areas affected by the change in flood risk represents only a small portion of the properties in the city. Therefore the hedonic model should be able to accurately forecast property prices.

To determine the amount a consumer would be willing to pay for an increase in flood risk reduction given a marginal change in flood risk, the estimated value of the property from the hedonic model is calculated given the old and new flood zones. From the estimated hedonic property price model, the difference between estimated property prices with the old and new flood zones is defined as the benefit derived from the

Table 3.7: Flood Zones

Old Flood Zones	New Flood Zones[1]
10	33
15	45
20	63
25	77
30	100
50	167
100	333
500	*
1000	*

[1] Given the Corps' proposed flood control project, the properties in the 500 and 1000 year flood zones are removed from the standard project flood area and therefore have no corresponding flood zones.

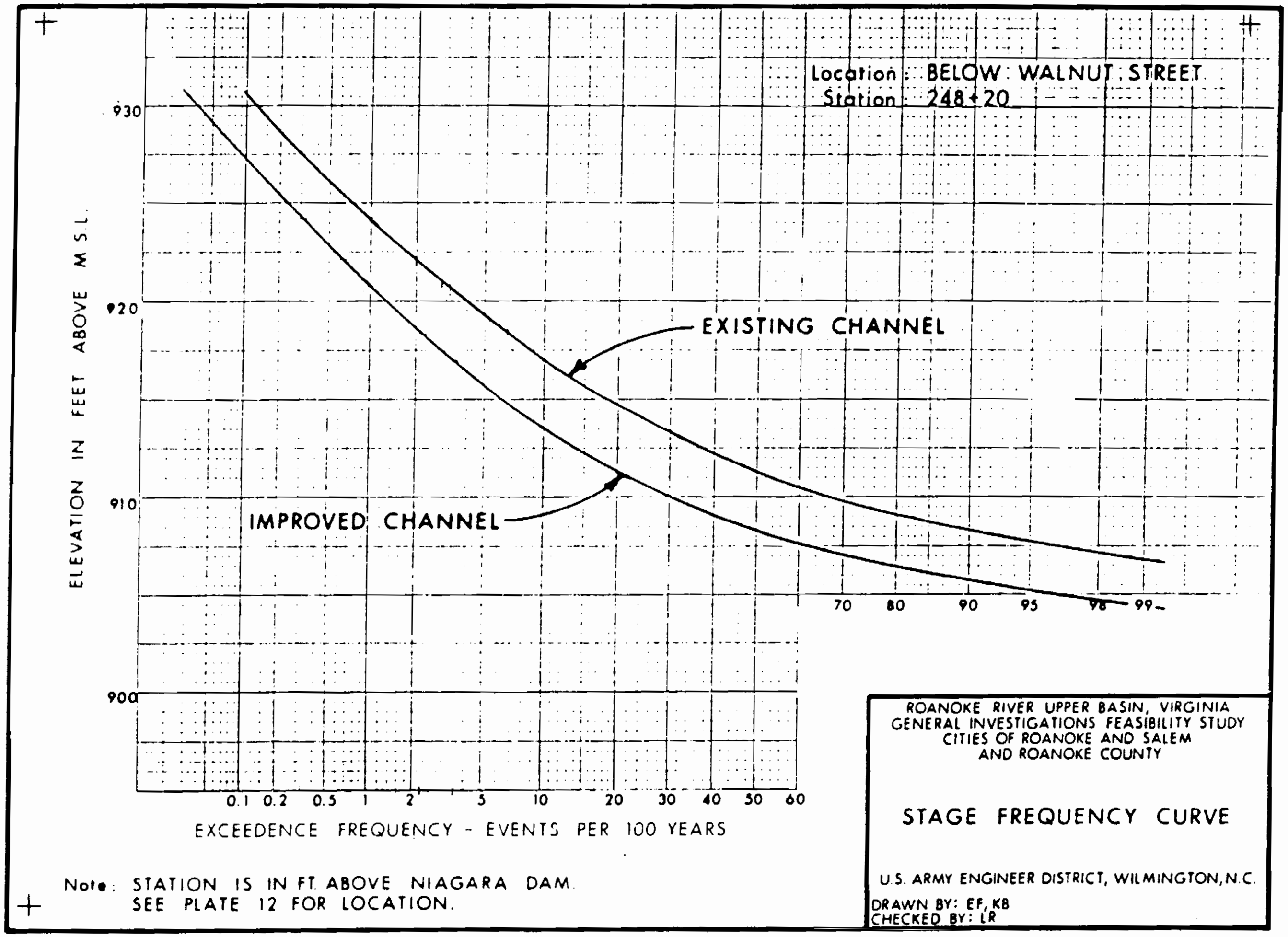

PLATE A-53

Figure 3.3: Stage Frequency Curve for Properties below Walnut Street (Source: U.S. Army Corps of Engineers Feasibility Report)

amount of flood risk reduction associated with the flood control project.

3.7 RESULTS

The results for the property damages avoided and the hedonic price methods are tabulated in Table 3.8. For all flood zones, the benefit estimates from the hedonic price method are significantly greater than those from the property damages avoided method. For nonmarginal changes in flood risk it is impractical to make comparisons about willingness to pay between the results from the property damages avoided and hedonic methods. However, for marginal changes in flood risk, the hedonic price method provides an accurate measure of willingness to pay so conclusions for specific observations can be drawn.

Conclusions about the relationship between the property damages avoided method and willingness to pay can be drawn from the estimates for the properties in the 500 and 1000 year flood zones. Examining the assumptions from section 2.1.3, it appears that either 1) landowners in flood prone areas are risk averse, 2) landowners are willing to pay for nonproperty effects of flood risk reduction not included in the property damages avoided method, or 3) a combination of both. If landowners are willing to pay for nonproperty effects of flood risk reduction and landowners are risk neutral, then the methods that estimate nonproperty benefits from a reduction in flood risk can be utilized in conjunction with the property damages avoided method in order to obtain a better

Table 3.8: Benefit Estimates from the Property Damages Avoided and Hedonic Price Methods

		Benefit Estimates (in dollars)			
		Property Damages Avoided Method		Hedonic Price Method	
Original flood zones	Number of properties in flood zone	Mean	Total	Mean	Total
10	1	1540.00	1540.00	7362.36	7362.36
15	9	2260.00	20340.00	7092.85	63835.65
20	8	1442.50	11540.00	5341.14	42729.12
25	2	1240.00	2480.00	4836.55	9673.10
30	5	1022.00	5110.00	4780.24	23901.20
50	11	770.00	8470.00	2783.54	30618.94
100	13	343.08	4460.00	1542.82	20056.66
500	16	80.00	1280.00	480.11	7681.76
1000	38	11.05[1]	420.00	270.68	10285.84
Total	103	540.19	51932.00	2098.49	216144.47

[1] 29 out of 38 properties had a value of 0.

estimate of benefits that accrue to landowners from a reduction in flood risk. However, if landowners are risk averse, the property damages avoided method will not be able to measure landowner willingness to pay for a reduction in flood risk regardless of any nonproperty method used unless the level of risk aversion can be estimated and made comparable for all landowners.

3.8 SUMMARY

The purpose of this chapter was to examine the study area, identify a hedonic model that could accurately forecast property prices and that satisfied distributional and functional form assumptions, and derive an estimate of willingness to pay for a change in the level of flood risk using the hedonic price method. Both the linear and log-log hedonic models restricted consumer preferences. Therefore, a hedonic model whose variables exhibit a Box-Cox transformation was used so no restrictions on consumer preferences were placed a priori. Given the Box-Cox model, distributional assumptions of the linear regression model were examined and tested resulting in a well-specified model. While testing for structural change, it became evident that the flood of 1985 had a significant effect on changing land buyers' perception of flood risk. Using the respecified hedonic model that took into account the change in flood risk perceptions, benefits were estimated for the hedonic price method and the difference between the results from the property damages avoided and hedonic price method were examined.

CHAPTER IV

ESTIMATING WILLINGNESS TO PAY AND ACCEPT

For the neighborhood of interest, willingness to pay for and accept compensation in place of nonmarginal changes in flood risk can be calculated from the RWTP and RWTA methods described in Chapter II. Given high property transactions costs, determining willingness to pay may not be appropriate since it is assumed that residents must alter characteristics of the current property or trade properties following flood risk reduction in such a way that utility remains constant. However, when determining willingness to accept, zero transaction costs can be assumed because the property is assumed to be modified only with regard to flood risk, for which there is no transaction cost (Driscoll, Dietz, and Alwang, 1992). Therefore, the RWTA method is well suited to estimate a lower bound on equivalent variation and can be considered appropriate when estimating benefits from changes in a property's amenity level due to a public project although estimates from both methods are calculated.

4.1 ESTIMATING WILLINGNESS TO PAY AND ACCEPT FOR CHANGES IN PROPERTY CHARACTERISTICS

The static equilibrium case discussed in the analysis of the RWTP and RWTA methods in Chapter II may not be appropriate because consumers may be maximizing their utility over multiple periods subject to equating the present value of expenditures to the present value of expected income. In order to conduct the analysis, this intertemporal equilibrium case must be reduced to a static equilibrium case. The multi-period utility maximization problem is defined as

$$\max \; U(X_{10},\ldots,X_{m0},\ldots,X_{1T},\ldots,X_{mT},\; X_{(m+1)0},\ldots,X_{n0},\ldots,X_{(m+1)T},\ldots,X_{nT}) \tag{4.1}$$

$$st \quad Q(\mathbf{X}^1) + \sum_{t=0}^{T} \frac{\mathbf{p}_t^2 \mathbf{X}_t^2}{(1+r)^t} = \sum_{t=0}^{T} \frac{E[Y_t]}{(1+r)^t}$$

where $\mathbf{X}^1=(X_{10},\ldots,X_{mT})$ are the characteristics of the property, $Q(\mathbf{X}^1)$ represents the purchase of the property plus the cost of future renovations, $\mathbf{X}_t^2$ and $\mathbf{p}_t^2$ are vectors consisting of the nonproperty goods and their respective prices in time period t, and $E[Y_t]$ denotes expected income in time period t.

Assuming that property characteristics are separable from all other goods in the utility function, the utility function may be written as

$$\max \quad U[U_1(X_{10},\ldots,X_{m0},\ldots,X_{1T},\ldots,X_{mT}), \tag{4.2}$$
$$X_{(m+1)0},\ldots,X_{n0},\ldots,X_{(m+1)T},\ldots,X_{nT}]$$

which permits the analysis of the following problem

$$\max \quad U_1(X_{10},\ldots,X_{m0},\ldots,X_{1T},\ldots,X_{mT}) \tag{4.3}$$
$$st \quad Q(\mathbf{X^1}) = \Sigma_{t=0}^{T}\frac{y_{1t}}{(1+r)^t}$$

where y_{1t} is the expenditure on housing in year t.

If it is assumed that no renovations are undertaken or that characteristics of the house when purchased are separable from future renovations, the consumer's problem may be further simplified to

$$\max \quad U_1(X_1,\ldots,X_m) \tag{4.4}$$
$$st \quad P(X_1,\ldots,X_m) = \Sigma_{t=0}^{T}\frac{M_t}{(1+r)^t}$$

where $P(X_1,\ldots,X_m)$ is the hedonic property price function and M_t are mortgage payments in time t. The original property characteristics in the utility function no longer require a time subscript as they either do not change over time or are assumed separable from future renovations.

The seven variables from the hedonic model to be used in the RWTP and RWTA methods are defined as

X_1 = ACREAGE,

X_2 = LIVEAREA,

X_3 = FZONE100,

X_4 = BATHFIX,

X_5 = CONST,

X_6 = USE, and

X_7 = PARK.

The variables X_1, X_2, and X_3 are continuous variables whereas X_4, X_5, X_6, and X_7 are discrete variables. Therefore, the sub-utility function must be partitioned as

$$U_1 = U_1[U1(X_1, X_2, X_3), U2(X_4, \ldots, X_7)] \tag{4.5}$$

because marginal prices may be obtained only for characteristics classified as continuous. Assuming the separability in equation (4.5) holds, the consumer's problem becomes

$$\max \quad U1(X_1, X_2, X_3) \quad st \quad \Sigma_{i=1}^{3} MP_i X_i = E \tag{4.6}$$

where E is total expenditures on continuous property characteristics.

4.2 ESTIMATING WILLINGNESS TO PAY AND ACCEPT FROM A DIRECT TRANSLOG UTILITY FUNCTION

Equation (2.31) is used to generate the system of expenditure share equations from which the parameters of the direct utility function are estimated given the three choice variables in the model. Only two expenditure share equations are used in the SAS procedure SYSNLIN where the equation with the smallest expenditure share is dropped. Given the translog direct utility function relating to the consumer's problem in equation (4.6) where the intercept is arbitrarily set to zero,

$$U_1=[\alpha_1 LN(X_1)+\alpha_2 LN(X_2)+\alpha_3 LN(X_3)]-\frac{1}{2}[\beta_{11}LN(X_1)^2+$$

(4.7) $$\beta_{22}LN(X_2)^2+\beta_{33}LN(X_3)^2]-[\beta_{12}[LN(X_1)*LN(X_2)]$$

$$\beta_{13}[LN(X_1)*LN(X_3)]+\beta_{23}[LN(X_2)*LN(X_3)]$$

the system of expenditure share equations is

(4.8) $$SX_1=\frac{\alpha_1+\beta_{11}LN(X_1)+\beta_{12}LN(X_2)+\beta_{13}LN(X_3)}{TOT}$$

(4.9) $$SX_3=\frac{\alpha_3+\beta_{13}LN(X_1)+\beta_{23}LN(X_2)+\beta_{33}LN(X_3)}{TOT}$$

where

$$TOT=[\Sigma_{i=1}^{3}\alpha_i]+(\beta_{11}+\beta_{12}+\beta_{13})*LN(X_1)+(\beta_{12}+\beta_{22}+\beta_{23})*LN(X_2)+$$

(4.10)

$$(\beta_{13}+\beta_{23}+\beta_{33})*LN(X_3)$$

and $SX_1 = MP_1^0X_1^0/M$, $SX_3 = MP_3^0X_3^0/M$, and $M = MP_1^0X_1^0 + MP_2^0X_2^0 + MP_3^0X_3^0$.

Given the normalization $\alpha_1+\alpha_2+\alpha_3=1$ from Christensen, Jorgensen, and Lau, the initial level of utility is calculated using the estimated direct utility function in equation (4.11). Although α_0 is set equal to 0, the direct utility function and resulting initial levels of utility are only rescaled by a constant.

(4.11)

$$LN(U) = \alpha_0 + 0.116395 LN(X_1) + 0.031443 LN(X_2) + 0.852162 LN(X_3) + 0.001649 [LN(X_1)]^2 - 0.000575 [LN(X_1) LN(X_2)] - 0.015433 [LN(X_1) LN(X$$

$$0.000984 [LN(X_2)]^2 - 0.006977 [LN(X_2) LN(X_3)] - 0.040589 [LN(X_3)]^2$$

4.2.1 Estimating Willingness to Pay from the RWTP Method

To estimate willingness to pay, the new values of X_1 and X_2, X_1^1 and X_2^1, need to be estimated. Equations (4.12) and (4.13) are used in the nonlinear equation solver MINPACK to determine the new levels of X_1 and X_2 given the with project level of X_3 such that utility is held at the initial level U^0 given X_1^0, X_2^0 and X_3^0. The following nonlinear equations, constant utility and the first-order utility maximization condition corresponding to X_1, are used in solving for X_1^1 and X_2^1 using the MINPACK subroutine HYBRD1.

$$0 = U^0 - [\hat{\alpha}_1 LN(X_1^1) + \hat{\alpha}_2 LN(X_2^1) + \hat{\alpha}_3 LN(X_3^1)] - \frac{1}{2} [\hat{\beta}_{11} LN(X_1^1)^2 + \hat{\beta}_{22} LN(X_2^1)^2 + \hat{\beta}_{33} LN(X_3^1)^2] - [\hat{\beta}_{12} [LN(X_1^1) * LN(X_2^1)] \quad (4.12)$$

$$\hat{\beta}_{13} [LN(X_1^1) * LN(X_3^1)] + \hat{\beta}_{23} [LN(X_2^1) * LN(X_3^1)]$$

$$0 = \left(\frac{COST^1}{P_1^1}\right)\left(\frac{M_1^1}{SUM}\right) - X_1^1 \quad (4.13)$$

where

(4.14) $$COST^1 = MP_1^1 * X_1^1 + MP_2^1 * X_2^1$$

(4.15) $$M_i^1 = \hat{\alpha}_i + \hat{\beta}_{i1} LN(X_1^1) + \hat{\beta}_{i2} LN(X_2^1) + \hat{\beta}_{i3} LN(X_3^1)$$

(4.16) $$SUM = M_1^1 + M_2^1$$

(4.17) $$P_1^1 = \frac{MP_1^1}{SUM}$$

and where MP_1^1 is a function of both X_1^1 and X_2^1.

The resulting values are different for each property resulting in new levels of expenditures. The amount the landowner is willing to pay for the change in flood risk found in table 3.7 given the initial level of utility U^0 can be calculated using equation (2.27). Specifically,

(4.18) $$RWTP = PR\hat{I}CE^0 - PR\hat{I}CE^1$$

where

(4.19) $$PR\hat{I}CE^0 = [\lambda * BCMP\hat{R}ICE^0 + 1]^{1/\lambda}$$

(4.20) $$PR\hat{I}CE^1 = [\lambda * BCMP\hat{R}ICE^1 + 1]^{1/\lambda}$$

and

$$BCMP\hat{R}ICE^0=\hat{\beta}_1+\hat{\beta}_1*BCACRE^0+\hat{\beta}_2*BCLIVE^0+\hat{\beta}_3*BCFIX+\hat{\beta}_4*BCFLOOD+\hat{\beta}_5*CONST+\hat{\beta}_6*USE+\hat{\beta}_7*PARK \quad (4.21)$$

$$BCMP\hat{R}ICE^1=\hat{\beta}_1+\hat{\beta}_1*BCACRE^1+\hat{\beta}_2*BCLIVE^1+\hat{\beta}_3*BCFIX+\hat{\beta}_4*BCFLOOD+\hat{\beta}_5*CONST+\hat{\beta}_6*USE+\hat{\beta}_7*PARK \quad (4.22)$$

4.2.2 Estimating Willingness to Accept from the RWTA Method

To estimate willingness to accept, the new values of X_1 and X_2, X_1^* and X_2^*, need to be estimated. Equations (4.23) and (4.24) are used in the nonlinear equation solver MINPACK to determine the new levels of X_1 and X_2 given the with project level of X_3, such that utility is held constant at the new level U^* given X_1^0, X_2^0 and X_3^1. The following nonlinear equations, constant utility, and the first-order utility maximization condition corresponding to X_1 are used in solving for X_1^* and X_2^* using the MINPACK subroutine HYBRD1.

$$0=U^*-[\hat{\alpha}_1 LN(X_1^*)+\hat{\alpha}_2 LN(X_2^*)+\hat{\alpha}_3 LN(X_3^0)]-\frac{1}{2}[\hat{\beta}_{11}LN(X_1^*)^2+\hat{\beta}_{22}LN(X_2^*)^2+\hat{\beta}_{33}LN(X_3^0)^2]-[\hat{\beta}_{12}[LN(X_1^*)*LN(X_2^*)]+\hat{\beta}_{13}[LN(X_1^*)*LN(X_3^0)]+\hat{\beta}_{23}[LN(X_2^*)*LN(X_3^0)] \quad (4.23)$$

(4.24) $$0=\left(\frac{COST^*}{P_1^*}\right)\left(\frac{M_1^*}{SUM^*}\right)-X_1^*$$

where

(4.25) $$COST^*=MP_1^* * X_1^* + MP_2^* * X_2^*$$

(4.26) $$M_i^*=\hat{\alpha}_i+\hat{\beta}_{i1}LN(X_1^*)+\hat{\beta}_{i2}LN(X_2^*)+\hat{\beta}_{i3}LN(X_3^0)$$

(4.27) $$SUM^*=M_1^*+M_2^*$$

(4.28) $$P_1^*=\frac{MP_1^*}{SUM^*}$$

and where MP_1^* is a function of both X_1^* and X_2^*.

The resulting values are different for each property resulting in new levels of expenditures. The amount the landowner is willing to accept to forego the change in flood risk found in table 3.7 given the new level of utility U^*, can be calculated using equation (2.28). Specifically,

(4.29) $$RWTA=PR\hat{I}CE^*-PR\hat{I}CE^0$$

where

(4.30) $$PR\hat{I}CE^*=[\lambda * BCMP\hat{R}ICE^*+1]^{1/\lambda}$$

(4.31) $$PR\hat{I}CE^0=[\lambda * BCMP\hat{R}ICE^0+1]^{1/\lambda}$$

and

$$\widehat{BCMPRICE}^{*}=\hat{\beta}_1+\hat{\beta}_1*BCACRE^{*}+\hat{\beta}_2*BCLIVE^{*}+\hat{\beta}_3*BCFIX+\hat{\beta}_4*BCFLOOD+ \hat{\beta}_5*CONST+\hat{\beta}_6*USE+\hat{\beta}_7*PARK \tag{4.32}$$

$$\widehat{BCMPRICE}^{0}=\hat{\beta}_1+\hat{\beta}_1*BCACRE^{0}+\hat{\beta}_2*BCLIVE^{0}+\hat{\beta}_3*BCFIX+\hat{\beta}_4*BCFLOOD+ \hat{\beta}_5*CONST+\hat{\beta}_6*USE+\hat{\beta}_7*PARK \tag{4.33}$$

4.3 RESULTS

In commodity space, Hanneman analyzed the difference between willingness to pay and willingness to accept and concluded that willingness to pay will be at most equal to willingness to accept for an increase in the level of a charateristic of a composite good. From table 4.1, the benefit estimates from the RWTP method are less than those from the RWTA method which coincides with Hanneman's results.[5]

4.4 SUMMARY

The purpose of this chapter was to present the RWTP and RWTA methods of measuring willingness to pay and accept for changes in property characteristics, to assess benefit estimates in the case study

[5] For a more complete discussion, see Hanneman (1991).

Table 4.1: Benefit Estimates from the RWTP and RWTA Methods

Original flood zones	Number of properties in flood zone	Benefit Estimates (in dollars)			
		RWTP Method		RWTA Method	
		Mean	Total	Mean	Total
10	1	4562.14	4562.14	7362.45	7362.45
15	9	5307.52	47767.68	7099.07	63891.63
20	8	4286.71	34293.68	5340.00	42720.00
25	2	4074.06	8148.12	4836.56	9673.12
30	5	4131.41	20657.05	4793.07	23965.35
50	11	2554.05	28094.55	2781.68	30598.59
100	13	1482.98	19278.74	1540.17	20022.21
500	16	478.86	7661.76	477.01	7632.16
1000	38	274.83	10443.54	267.61	10169.18
Total	103	1756.38	180907.14	2097.42	216034.26

area for a reduction in flood risk using these methods, and to briefly compare the results. The static equilibrium case discussed in Chapter II was deemed inappropriate due to the possibility that consumers maximize their utility over time. The resulting dynamic case was reduced to a static case and then further reduced to a case where only continuous variables were examined by maintaining various separability assumptions about consumer preferences. Benefit estimates derived from the RWTP method were less than those from the RWTA method which is consistent with expected results.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

The goal of this study was to examine alternative techniques to the property damages avoided method that estimate willingness to pay benefits for a reduction in flood risk. In the process, two methods, the RWTP and RWTA methods, were developed that underestimate willingness to pay and accept respectively. The property damages avoided, hedonic price, RWTP, and RWTA methods, measures of willingness to pay and accept, were analyzed and benefit estimates from the hedonic price, RWTP, and RWTA methods were calculated.

By examining the case study area and analyzing studies employing hedonic property price functions, a hedonic model was specified and estimated in Chapter III. In doing so, it was determined that the flood of 1985 had a significant effect on landowners' and land buyers' perceptions of flood risk. In addition, results indicate that the property damages avoided method strictly underestimates willingness to pay. In Chapter IV, the RWTP and RWTA methods described in Chapter II were applied to the Roanoke case study area and benefits were estimated from. The results from the RWTP method were less than those from the RWTA method which corresponds to expected results. In this chapter, an overall review of the benefit estimation methods is presented and recommendations for uses of the property damages avoided, hedonic price, RWTP, and RWTA methods are given.

5.1 REVIEW OF THE CORPS' BENEFIT ESTIMATION PROCEDURES

The U.S. Army Corps of Engineers has been responsible for analyzing the efficiency of flood control projects since the Flood Control Acts of 1936 and 1938. The Corps' program has evolved resulting in changes in the economic evaluation procedures employed to justify individual projects. Currently, the U.S. Water Council's P&G and the Corps' Water Research Support Center's NED provide the overall framework the Corps follows when estimating flood control benefits for residential, commercial and industrial properties.

In the P&G and NED, the property damages avoided method is the primary method recommended for use in estimating residential landowners' benefits from a reduction in flood risk. In this method, the present value of expected reduced damages is equated to willingness to pay benefits. However, a set of restrictive assumptions is required so that the present value of expected reduced damages equals landowner willingness to pay for a reduction in flood risk.

5.2 METHODOLOGY

The three methods used in this study to assess benefits from a flood control project were the hedonic price, RWTP, and RWTA methods which require the estimation of the hedonic property price function in terms of the property's flood risk. The RWTA method, which generates an estimate of equivalent variation or willingness to accept, is included for the following reasons: 1) either compensating or equivalent variation may be the desired benefit estimation method and 2) the RWTP may not be appropriate due to high property transactions costs whereas zero transaction costs are associated with the RWTA method.

5.2.1 The Hedonic Price Method

A prominent method for estimating willingness to pay is hedonic pricing. However, this method accurately estimates willingness to pay only for marginal changes in characteristic levels and only when a proper hedonic model has been specified. Otherwise, results from this method overestimate willingness to pay and provide an upper bound.

5.2.2 The RWTP and RWTA Methods

The RWTP and RWTA methods were used to measure both marginal and nonmarginal changes in flood risk. Given the weak separability assumptions, the results from the RWTP and RWTA methods will at most equal willingness to pay and accept respectively. When used alone, the RWTP method overestimates willingness to pay. In conjunction with the hedonic price method, these two methods provide bounds on willingness to pay. However, the RWTP method may not generate a good lower bound since the assumption that residents must alter current property characteristics weakens the zero property transaction cost assumption. Zero transactions costs can be assumed in the RWTA method because the only modified characteristic is flood risk, for which there is no transaction cost. Therefore, this method is well suited to estimate a lower bound on willingness to accept but no method is available to provide a suitable upper bound.

5.3 RESULTS

The third objective of this study was to compare the benefit estimates from the different benefit estimation procedures. The Corps' benefit estimation procedure is designed to estimate the present value of flood control benefits based on a fifty year project life, whereas the other procedures are based on the present value of the benefit stream over the life of the property. So the resulting benefit estimates from property damages avoided method are comparable with those from the hedonic price and RWTP. From the assumptions of the willingness to pay methods and their respective estimates, conclusions about the property damages avoided, hedonic price, and RWTP methods can be drawn.

For a marginal change in flood risk reduction, theory suggests that the estimates for the hedonic price and RWTP methods should be equal. As the change becomes more substantial, the difference between the benefit estimates from the RWTP method and those from the hedonic price method should increase. The empirical results from the RWTP and hedonic price methods mirror the theoretical results. Therefore the exact compensating variation for the change in flood risk lies somewhere between the results from the hedonic price and RWTP methods. No upper bound on equivalent variation is generated and the actual equivalent variation for the change in flood risk is only known to exceed estimates from the RWTA method.

An important finding was that benefit estimates from the property damages avoided method were significantly less than those from the RWTP method. Since the estimates from the RWTP method are at most equal to willingness to pay, the present value of reduced damages underestimates willingness to pay. Conclusions made in Chapter III can now be generalized for all properties in the study area, so that one of the following statements is true for all flood prone properties in the study area: 1) landowners in flood prone areas are risk averse, 2) landowners are willing to pay for nonproperty effects of flood risk reduction not included in the property damages avoided method, or 3) a combination of both.

5.4 RECOMMENDATIONS

Willingness to pay for a flood control project depends on an individual's perceptions about flood risk and changes in flood risk. For landowners in the study area, the hedonic property price function for the time period 1980-1985 implied that land buyers were indifferent to a property's flood risk as defined by the flood zone. However, after the flood in November of 1985, land buyers became more aware of flood risk as demonstrated by the hedonic property price function for the time period 1986–1990. Although the threat of flooding has always existed, landowners would not have been willing to pay for any flood control project had it been proposed before 1985 regardless of whether benefits were estimated using the hedonic price, RWTP, or RWTA methods.

The important question to be answered is what method should be used to estimate benefits that accrue to landowners from a reduction in flood risk. Presently, the Corps uses the property damages avoided method, which examines flood prone properties alone, to estimate residential landowner benefits from a flood control project. However, a result from two studies on the same study area concluded that non–flood prone landowners are also willing to pay for a flood control project. Specifically, Thunberg determined that "Residential landowners. . .off the flood plain are [willing to pay] for the community effects of a [flood control] project..." (p. 87) and in a telephone survey by Shabman and Stephenson (1992) on whether or not voters supported an increase in utility taxes to fund the proposed flood control project, 56 percent of voting non–flood prone landowners voted for the increase to pay for the project. To obtain benefit estiamtes for all landowners in a community, variables that measure community effects, unavailable in this study, should be used in the hedonic price, RWTP, and RWTA methods. So, the results from the four benefit estimation methods are analyzed in terms of accurately measuring benefits that accrue to <u>flood prone</u> landowners from a reduction in flood risk.

5.4.1 The Property Damages Avoided Method

It has been shown that the property damages avoided method will provide an accurate measure of landowner willingness to pay for a reduction in flood risk if he or she has the same information as the project planner, is risk neutral, and does not benefit from any nonproperty effects of flood risk reduction. Although it is possible for landowners to obtain similar information about flood risk from the media, it is difficult to believe that landowners are risk neutral to flooding or that they do not benefit from nonproperty effects of flood risk reduction. As shown by the hedonic property price function for 1986-1990, landowners appear to be risk averse given the awareness of flood risk provided by the flood of 1985. In addition, from Thunberg's study: "Residential landowners on . . . the flood plain are [willing to pay] for the community effects of a [flood control] project . . ." (p. 87). The property damages avoided method, when used alone, will not provide an accurate measure of benefits that accrue to landowners from a reduction in flood risk and should therefore be used in conjunction with other methods that evaluate a landowner's level of risk aversion and the nonproperty effects of a reduction in flood risk.

5.4.2 The Hedonic Price Method

Although this method overstates willingness to pay for nonmarginal changes in flood risk, it utilizes market transaction data and therefore hypothetically measures the trauma and anxiety due to flooding and future flood insurance costs of the landowners. Because this method is based on the perceived risks of flooding, estimates from this method can be biased by either a lack of information or hysteria about flooding. Since devastating floods were not a recent memory in the city of Roanoke in the years just prior to 1985, landowners may not have been fully informed about flood risks explaining the land buyer's indifference to flood risk modelled in the hedonic property price function for the time period 1980-1985. On the other hand, many residents may have overreacted to the flood of 1985 and believe that floods are more damaging and frequent than they actually are.

When landowners and land buyers are well informed of flood risk, the perceived risks are very close to actual risks and estimates from this method should not be biased. Under these circumstances, the hedonic method generates an upper bound on willingness to pay benefits determining when a project is economically infeasible, the economic feasibility of a project cannot be positively determined.

5.4.3 The RWTP and RWTA Methods

Similar to the hedonic price method, these two methods are based on perceived risks of flooding and their estimates can therefore be biased by either a lack of information or hysteria about flooding.

Unlike the hedonic price method, these methods can provide more accurate measures of willingness to pay and willingness to accept respectively as a better or larger data set is made available to better describe consumer preferences. Although these methods require more complex techniques, lower bounds can be generated to determine if a project is economically feasible, but the economic infeasibility of a project cannot be positively determined.

5.4.4 Closing Remarks

If all landowners and land buyers had perfect information about flood risk, almost any method could be used to calculate willingness to pay benefits for a reduction in flood risk. However, landowners and land buyers do not have perfect information and therefore it is important to determine the best benefit estimation method available to researchers. Regardless of whether or not the RWTP and RWTA methods accurately estimate willingness to pay or accept benefits for a reduction in flood risk, they are extremely useful and adaptable methods. These methods require no a priori assumptions about consumer behavior except utility maximization, but instead of measuring benefits per se, these methods determine the amount consumers would be willing to pay or accept to face different constraints (Silberberg, 1978).

The property damages avoided method assumes certain consumer behavior and derives benefits based on these assumptions. However, these assumptions are rarely if ever accurate and make a weak case for the property damages avoided method. The other three methods, although based on perceived flood risks, provide somewhat accurate benefit estimates when landowners and land buyers have good information about flood risks and the land market is in long run equilibrium. In particular, when used together, the hedonic price and RWTP methods can provide lower and upper bounds on willingness to pay benefits. Therefore many, but not all, alternative projects can be analyzed and classified as economically feasible or infeasible.

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