UNIVERSITY OF CALIFORNIA,
IRVINE

Water Woes in the West:
A Spatial Hedonic Approach

DISSERTATION

Submitted in partial satisfaction of the requirements
For the degree of

DOCTOR OF PHILOSOPHY

in Planning, Policy, and Design

by

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2015

DEDICATION

To

My Mom

A tower of strength, whose commitment to my PhD is only surpassed by her love and devotion to her gorgeous grandsons, Cubby and Heshi

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In addition, I sincerely thank Professor Victoria Basolo, who recommended me for the Salton Sea Project and ultimately directed me to water and environmental research. Despite, not being her student, she has routinely provided me with great career and academic advice, which ultimately made me a viable candidate for the academic job market. I also want to thank Professor Basolo for maintaining a steady stream of chocolates outside her office door, which has provided me with much needed sugar during many stressful work days.

Finally, I want to thank Professor Tim Bradly and the Salton Sea Initiative for first exposing me to the problems associated with the Salton Sea and waterbodies in general, and for providing the financial support that made my research possible.

Curriculum Vitae

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EDUCATION

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J2. Hipp, J. R., & **Singh, A**. (2014). Changing Neighborhood Determinants of Housing Price Trends in Southern California, 1960–2009. City & Community, 13(3), 254-274.

J3. Bruckner TA. Cheng Y, **Singh A**, Caughey AB. Economic downturns and male cesarean deliveries: a time-series test of the economic stress hypothesis. BMC Pregnancy and Childbirth 2014 (doi:10.1186/1471-2393-14-198)..

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Abstract of Dissertation

Declining Water Levels in the West:
A Spatial Hedonic Approach

By

Amrita Singh

Doctor of Philosophy in Planning, Policy, and Design

University of California, Irvine, 2015

Professor Jean-Daniel Saphores, Chair

In addition to irrigation and consumption, water provides recreational, aesthetic, and ecosystem services. These services are not traded in traditional markets and thus do not have an observable market price. Assigning monetary values to environmental goods and services allows policy makers to compare the costs and benefits of waterbodies to the economic value of alternative uses. This monetization is especially important given the precarious state of waterbodies all over the world, which are subject to drastic declines in water levels and persistent pollution from urban and agricultural runoff. Given these conditions, waterbodies will require costly remediation efforts in the near future.

The goal of this dissertation is to evaluate the monetary values of two such waterbodies in the Southwestern United States (US): the Salton Sea in southeast California, and Lake Mead in Clark County, Nevada, which is also the primary water source for Las Vegas and for other large urban centers in the Southwest. Typically economic valuation methods include hedonic pricing, travel costs, and contingent valuation techniques. After examining all three methods and reviewing preexisting economic valuation studies on waterbodies, I use the hedonic price method and recent

residential sales near both waterbodies to determine the economic costs of environmental degradation at both waterbodies.

In general, hedonic studies find that both proximity and environmental quality of waterbody sites are positively capitalized within the housing market. Although this is a consistent result in much of the economic valuation literature, even among travel costs and contingent valuation studies, these case studies suggest that this effect is vulnerable to worsening climate conditions and unstable economic conditions. With regards to the Salton Sea, I find that the severe environmental degradation of the Sea has transformed this one-time amenity to a disamenity. Homes located farther from the Sea sell at higher values than those located closer. With regards to Lake Mead, the economic dynamics of the Las Vegas Metro Area dominate the housing market such that proximity to the Lake Mead National Recreation Area, in spite of its size and millions of visitors, does not seem to have an impact on the local real estate market. Taken together, results indicate that declining waterbodies have heterogeneous effects on adjacent real estate values. Results from the Salton Sea analysis, however, indicate that other declining waterbodies worldwide may adversely affect the regional economy.

Chapter 1: Introduction

Climate change is manifesting itself in a variety of ways. One of its most debilitating consequences is its impact on water resources. Given the ubiquitous importance of water – it is consumed by households, used for irrigation, and is critical to industry - drastic declines in water supply around the world and especially in relatively dry regions like the Southwest are disconcerting and worrisome. Arid conditions coupled with growing populations have recently caused the complete desiccation of several large lakes in Asia, Middle East, Europe, Africa, and North America. In light of waterbodies' vulnerability, their preservation will need to rank higher on political agendas and compete with other economic priorities. To quantify trade-offs, it is necessary to assign values to waterbodies so they can be managed more efficiently (and fairly).

This dissertation makes a step in that direction. It is comprised of three essays. In Chapter 2, I discuss economic valuation techniques and literature pertaining to site quality of waterbodies. The second and third essays rely on hedonic pricing models, which link housing prices to site environmental quality, to assess some of the costs associated with two failing lakes in Southwestern United States (US): the Salton Sea in Southern California, and Lake Mead in Clark County, Nevada. Both studies span the recent Great Recession, which was characterized by a drastic increase in foreclosure rates.

Since waterbodies are not traded in a traditional economic market, their material values are inferred from the goods and services they provide. In Chapter 2, I describe the three most common economic valuation techniques: hedonic, travel cost, and contingent valuation models. Hedonic models infer value for a waterbody from estimating how much consumers are willing to pay for a home with a view of or recreation access to water. Travel costs studies infer value from the costs incurred by visitors, which primarily come in the form of travel time and other costs incurred while traveling such as gas, entry fees, and forgone wages. In both instances, models link variation of either sales price of a home or travel costs to proximity and site quality. More often than not they find that people pay premiums for proximity to and for the quality of a waterbody.

Nonuse services typically refer to existence value. In other words, even those who do not use a lake themselves receive some satisfaction from knowing that the lake is there and that it will continue to exist for future generations. Another common nonuse value refers to the ecosystem services that water provides to plant and animal species. Nonuse values are inferred from surveys that ask people their willingness to pay for the preservation of waterbodies by paying a fee or accepting an increase in taxes. In Chapter 2 I describe each method, summarize key results from studies published since 2000, and suggest future avenues of research.

Chapter 3 presents the Salton Sea Case study. The Sea, like other terminal lakes around the world, is beleaguered by a variety of problems including falling water levels and polluted agricultural runoff that threaten fish and bird populations, but also impacts air quality as dusty shores become exposed to the wind. It is an example of a waterbody that, due to unrelenting neglect and pollution, has become a major disamenity.

Chapter 4 analyzes the impact of Lake Mead National Recreation Area on the Las Vegas Metropolitan Area (LVMA) housing market. Lake Mead has received national attention due to the drastic falls in water levels and its importance to water supplies in the Southwest. Both studies suggest that capitalization of water and site quality depends upon the degree of environmental degradation as well as housing market conditions.

Finally, Chapter 5 summarizes my main findings and presents suggestions for future analyses of the Salton Sea and Lake Mead.

Chapter 2: Economic Valuation of Water Quality: 2000-2015

INTRODUCTION

In this review, I discuss three of the most common economic valuation methods—the Hedonic price model (HP), the travel cost (TC) model, and contingent valuation (CV)—used to estimate the value of water quality in waterbodies. All three methods estimate the economic value of a number of environmental goods and characteristics. This valuation is especially important since environmental goods are not traded on a traditional market. Furthermore, current climate conditions as well as human activities have led to the precarious conditions for waterbodies. Evaluating the economic implications associated with these ever-growing threats will inform policy makers during times of rapidly changing environmental conditions.

Overall, the economic valuation literature indicates that individuals are willing to pay considerable amounts to view, use, and preserve water quality of lakes, rivers, and beaches. However, each specific method is unique in its valuation approach. Both HP and TC are often referred to as revealed preference methods. These methods estimate a value for environmental goods by examining how environmental quality is associated with demand for goods. HP studies exploit the relationship between water quality and purchasing of nearby properties. Alternatively, TC studies examine the cost people incur to visit recreation sites. CV is a *stated* preference method, whereby individuals clearly state via survey or interview methods the amount they are willing to pay for water quality.

Water quality is the measure of the suitability of water for a particular use (USGS). As a result, changes within a body of water's physical, chemical, or biological characteristics can impact the suitability of the water for particular uses. I select recent economic valuation studies that examine how the physical, chemical, and biological characteristics of water influence demand for housing and recreation. I also examine stated preference studies evaluating visitors' willingness to pay (WTP) for non-use values concerning ecosystem services. For each valuation method, I give a brief overview of the statistical model, discuss trends in the literature that have emerged within the last 15 years, and suggest avenues for future research. Although I do mention and briefly discuss articles published prior to 2000, I focus on studies published after 2000since I know of no synthesis of water quality studies since 2000. Overall, across the three methods examined, a number of studies estimate values pertaining to objective measures of water quality and sea level rise. CV, by contrast, primarily focuses on valuating the ecosystem services associated with water quality conditions. Very few of the economic valuation studies estimate the value of declining water levels of fresh waterbodies, a critical consequence of climate change.

METHOD

I retrieved articles using several databases that could potentially refer me to articles of interest, including EconLit, JSTOR, and Water Resources Abstracts. I also relied on the references cited within each paper. Keywords and phrases used in the search included various combinations of travel cost, hedonic price, contingent valuation, water quality, waterbodies, economic value, revealed preference, non-market valuation, catch rates, and recreation. I primarily describe peer-reviewed HP, TC, and CV studies published within the last 15 years. Furthermore, I only present results from studies pertaining to waterbodies within the United States.

Water quality refers to the biological (e.g. catch rates), chemical (e.g. pollutants) and physical (e.g. water levels) quality of estuaries, lakes, rivers, and beaches within the U.S. I also review articles that use indirect measures of water quality, such as beach erosion and degradation of riparian buffers. In the contexts of CV studies, I reflect the themes within the literature by focusing less on direct water quality measures and present studies estimating individuals' willingness to pay for ecological services, such as fish and bird habitats.

HEDONIC PRICE MODEL

The hedonic literature dealing with the impacts of waterbodies on housing markets dates back several decades. Several distinct strands of research has emerged (David, 1968; Epp & Al-Ani, 1979; H. J. Michael, Boyle, & Bouchard, 1996; Poor, Pessagno, & Paul, 2007). The majority of hedonic housing studies evaluating water quality—an indicator of aesthetic appeal and recreational use—find that both water quality and proximity to a waterbody are positively capitalized in single family residential homes. These findings are consistent throughout the literature, despite the diversity of water quality indicators, locations, types of waterbodies, and modeling specifications (see Table 2.I). However, many waterbodies all over the world are subject to severe environmental degradation. This degradation could jeopardize the well-established premium associated with water quality and hence proximity to water. Thus far, there has been little examination of the economic consequences associated with these types of waterbodies. The literature would also benefit from further analysis of the geographic reach of water quality on surrounding residential sales. Finally, there are a number of methodological advances within the hedonic framework that should be applied to future water quality valuation studies.

MODEL

The standard hedonic framework (Rosen, 1974), a hedonic price model applied to an environmental problem via the housing market, can typically be written:

$$\mathbf{P} = f(\mathbf{S}, \mathbf{N}, \mathbf{E}, \boldsymbol{\varepsilon}) \tag{2.1}$$

where **P** is a vector of housing prices; **S**, **N**, and **E** respectively are matrices of structural, neighborhood, and environmental variables; and $\boldsymbol{\varepsilon}$ is a vector of error terms. The partial derivative of f with respect to explanatory variable j is an implicit price that represents the marginal willingness to pay for the characteristic it represents.

The classical hedonic framework analyzed by Rosen (1974) requires stringent idealized conditions to hold, including market equilibrium with perfect competition, perfect information for buyers and sellers, and a continuum of products. However, Benkard and Bajari (2005) proved that the hedonic pricing method is still valid when competition is imperfect, there is no continuity of products, and not all product characteristics are observable, which is often the case in housing markets.

In linear regression models, omitting an explanatory variable that is correlated with one or more explanatory variables results in biased and inconsistent estimates (Kennedy, 2003). Omitted variables in hedonic studies are often location-specific factors, such as school quality or crime rate. Furthermore, housing values are influenced by nearby properties and hence susceptible to spatial interactions. Ignoring this spatial dependence may lead to biased and inconsistent estimators (Anselin & Arribas-Bel, 2013). As a result, much of the recent hedonic literature does account for space. However, other sources of omitted variable bias include time dependency. Just as surrounding properties influence sales price, sales that took place within a proximal time frame will likely influence future sales prices. Another source of bias is the number of nearby distressed sales. Below I discuss how the literature has accounted for both phenomena.

MEASURING WATER QUALITY

One of the primary debates within the hedonic framework concerns the proper measurement of water quality. A number of studies use objective measures of water quality that typically indicate chemical imbalance in water quality. However, how these measures are perceived by those who visit waterbodies is up for debate. A review of the literature reveals that many studies have demonstrated that both subjective and objective water quality measures are capitalized in surrounding property values.

Epp & Al-Ani (Epp & Al-Ani, 1979) utilize pH levels to assess its economic impact on lake front property in rural Pennsylvania. In David's analysis (1968), water quality for sixty Wisconsin lakes is obtained via opinions of government officials from water governing boards (poor, fair, and good). Similarly Young (1984) also related lakefront property values of St. Albans Bay in Vermont to subjective measures of water quality obtained from local officials as well. Both models concluded that subjective measures of water quality were capitalized in the waterfront real estate market.

A more recent study to collect and examine subjective measures is Poor and colleagues. (Poor, Boyle, Taylor, & Bouchard, 2001) . They compare objective scientific measures of water quality (e.g. secchi disk readings) to subjective measures. The subjective measures were of people's perceptions of water quality obtained from waterfront property owners via a survey. The purpose of the paper was to evaluate if the different measures of clarity were statistically similar in equivalent hedonic models. The hedonic models were estimated using sales price of waterfront property from 1990-1995 in 4 markets in Maine. Each market had approximately 4-13 fresh waterbodies. The results from the models indicate that both water clarity measures were statistically significant and positively associated with property values in two out of the four markets. In one of the significant markets subjective and objective measures were not statistically different. However, in the second market the implicit price associated with subjective water clarity was 43 percent larger than the objective measure. This result is due to the systematic underestimation of water clarity using subjective measures. Their results indicate that objective measures of clarity better predicted variation in sales price.

Many later studies use secchi disk readings to evaluate water clarity's effect property values. Water clarity, typically summarized by a single index, is a widely-used measure because it is believed to be readily observable. Many studies demonstrate that water clarity is positively capitalized in property values (Michael, Boyle, & Bouchard, 2000; Poor, et al., 2001; Patrick J. Walsh, Milon, & Scrogin, 2011). Gibbs Halstead, Boyle, and Huang (2002) estimate effects of water clarity of an average lake in four real estate market areas. They find that water clarity is positively capitalized within all markets. However, the magnitude of the effect varies by region, such that a one-meter decrease in water clarity can lead to decreases in property value ranging from 0.9% to over 6%. The Authors do not explain the variation in capitalization rates across these four markets.

Leggett and Bockstael (2000) evaluate waterfront sales prices for the Chesapeake Bay in Maryland. The data used in the analysis consist of sales of waterfront property between July 1993 and August 1997. In this study, water quality is measured by objective measures of water pollutants such as fecal coliform counts. When levels of this pollutant are high, the water can be unsightly and may give off an unpleasant odor. Even moderate levels of fecal coliform pose a hazard to human health. The dependent variable of the models is the actual sales price adjusted to constant dollars using the CPI. This studies hedonic model however, was an improvement over previous models since it tried to account for omitted variable bias by accounting for spatial autocorrelation and including additional pollutant sources such as distance from a local sewage plant. Their main finding is that a change of 100 fecal coliform counts per 100 mL is estimated to produce about a 1.5% change in property prices.

Similarily, Poor, Pessagno, Paul (2007) account for water quality and additional pollutants. However, they do not address spatial affects. This analysis included properties proximity to a naval air station and county landfill. The model utilizes 1377 real estate transactions located in St Mary's river watershed in Maryland. The property sales occurred between June1, 1999-May 31, 2003. Water quality data was retrieved from 22 monitoring stations located throughout the watershed. The water quality variables, total suspended solids and dissolved inorganic nitrogen, are pollutants associated with urban runoff from roadways, parking lots, and large commercial structures. The results from the cross sectional analyses indicate that both pollutants had negative impacts on average sales price.

Another indicator, that has yet to be addressed within the HP literature, is the economic benefit associated with biological indicators such as birds and fish. While a number of TC studies examine the value of fish abundance in lakes and rivers, Tuttle and Heintzelman (2014) provide the only study, to my knowledge, that estimates the value of wildlife for property values. They specifically estimate the value of loons on lakes in the Adirondacks, and find that presence of loons in nearby lakes increases property values. However, biological indicators such as algal blooms and fish kills can also severely impair property values, particularly through the emission of odors. However, I know of no HP study that estimates the cost associated with this indicator of severe environmental degradation.

THE VALUE OF PROXIMITY TO A WATERBODY

Most published hedonic studies dealing with the impact of waterbodies on housing markets, from older papers that do not account for structural characteristics (David, 1968; Epp & Al-Ani, 1979; H. J. Michael, et al., 1996; Poor, et al., 2007; Prospero, Ginoux, Torres, Nicholson, & Gill, 2002) to more recent papers that model spatial dependence (Cho, Bowker, & Park, 2006; Leggett & Bockstael, 2000), report that proximity to a waterbody boosts the value of residential properties. Because of the strong relationship among property values and waterbodies many hedonic studies on water quality limit their analyses to waterfront properties (Artell, 2014; Bin & Czajkowski, 2013; David, 1968; Epp & Al-Ani, 1979; Gibbs, Halstead, Boyle, & Huang, 2002; Horsch & Lewis, 2009; Leggett & Bockstael, 2000; H. J. Michael, et al., 1996; Poor, et al., 2001; Poor, et al., 2007; Steinnes, 1992; Vesterinen, Pouta, Huhtala, & Neuvonen, 2010). However, waterbodies provide recreational opportunities to households beyond the waterfront. Therefore water quality may impact sales price beyond the waterfront. A number of studies find that waterbodies are capitalized in homes located several thousands of feet from the waterfront (Lansford Jr & Jones, 1995; Netusil, Kincaid, & Chang, 2014; Tuttle & Heintzelman, 2015; Patrick J. Walsh, et al., 2011).Furthermore, this assumption rests on the amenity status of waterbodies, In instances where the water quality of lakes and rivers are seriously impaired a premium associated with proximity may no longer exist. However, the literature in general has not examined such cases. One notable exception is Lewis & Acharya’s (2006) study of the Quinnipiac River watershed. Located in New Haven County, Connecticut, it counts eleven landfills, eight sewage treatment plants, and three raw sewage holding areas. Their results show that proximity to the river lowers property values, making the heavily polluted Quinnipiac River a clear disamenity.

VALUATION OF WATER LEVELS

Lansford and Jones (1995) estimate the marginal value of lake level deviations within Lake Travis in Texas on surrounding property values. They examine the effect associated with lake-level deviation from the long-term average at the time of sale (LLDEV) for all homes within 2,000 feet of the waterbody. They find that buyers are willing to pay for higher lake levels. The authors argue that buyers of waterfront and non-waterfront homes are responding to the aesthetic appeal of properties and recreational facilities (marina, boat ramps) associated with higher vs. lower water levels.

Loomis and Feldman (2003) use 14 years (1987 to 2001) of single family home residential sales within Plumas County, California, to estimate the price effects associated with exposed shoreline along Lake Almanor. They find that increases in exposed shoreline, a direct consequence of falling water levels, are negatively capitalized in surrounding real estate. Because the Authors do not indicate the geographic extent of the transactions with respect to the lake, I cannot further define the distance implied by “surrounding”. Nevertheless, the distance variable in the regression suggest that the authors analyzed more than just waterfront properties. In order to account for temporal influences, Loomis and Feldman (2003) include a number of economic trend measures such as inflation and unemployment rates as well as mortgage interest rates. More recent hedonic studies suggest sophisticated econometric modeling techniques that will reduce temporal autocorrelation associated with allocating 14 years of data (I include a brief discussion on these techniques in section 2.1.6).

Although few articles explore lake level decrease, a number of studies estimate the effects of sea level rise on coastal properties. Climate change threatens to raise sea level over the next century. Sea level rise is associated with coastal erosion, and hence damage to shoreline development (Landry & Hindsley, 2011). Parsons and Powell (2001) and Landry and Hindsley (2011), Michael (2007), and Bin, Poulter, Dumas, & Whitehead (2011) all find a premium associated with beach width. All studies are concerned with estimating future economic loss due to sea level rise. They all use hedonic framework to first estimate the implicit prices of measures of proximity. Next, all studies use future scenarios of sea level rise and subsequent effects on property damage and estimated coefficients from the model to predict loss of value for at-risk properties. Parsons and Powell (2001) examine erosion rates along the Delaware coast. They find that if erosion remains at its current pace, property loss value is about $291 million in 2000 dollars. Michael (2007) estimates residential property value loss associated with future inundation in the Chesapeake Bay, and also uses local non-inundated property to estimate economic loss associated with episodic flood events due to sea level rise. The estimated damage from flooding using a 3-foot sea-level rise over 100 years scenario is 9 times greater than the damage from complete inundation. Both Bin, Poulter, Dumas et al. (2011) and Landry and Hindsley (2011) use spatial hedonic models to estimate property loss values in, respectively, North Carolina coastal communities, and Tybee Island, located roughly 19 miles east of Savannah, Georgia.

Bin et al. (2011) estimate inundation loss of coastal residential properties using high-resolution topographic data to predict sea level rise scenarios for 2030 and 2080. Using a spatial hedonic model, they examine residential loss in 4 coastal communities in North Carolina and find that the estimated loss in property value in 2030 (2080) ranges from $179 ($526) million for the mid-range sea-level rise scenarios.

Unlike the previous researchers, Landry and Hindsley (2011) do not estimate future loss associated with sea rise and reductions in beach width. Instead, they examine how valuation of beach width varies with distance to the shoreline among recent homebuyers. They find that beach width is statistically insignificant for properties located more than 300 meters from the shoreline. They also note current arguments that beach width varies seasonally and is prone to fluctuation; however, previous work does not account for coastal dynamics, thereby resulting in biased estimators. They acknowledge that this is problematic, since homebuyers aware of seasonal fluctuations will value beach width differently from homebuyers expecting beach width to stay stagnant. However, without information on individual expectations, they focus on the relationship between sales price and observed beach width.

Gopalakrishnan, Smith, Slott, & Murray (2011) improve upon the previous studies' model specification by first linking property values to the average beach width, instead of the beach width at the time of sale. The authors also use instrumental variables to correct for the beach width endogeneity. Previous studies suggest that beach width is positively capitalized in sales price. However, beach width is not an exogenous variable, since beach nourishment decisions, which influence beaches, are also influenced by property prices. As a result, Gopalakrishnan et al. (2011) use beach characteristics that indicate beach width, but do not vary with sales prices. An additional improvement is the use of a two-stage least squares (2SLS) spatial autoregressive model with autoregressive disturbances (SARAR) which accounts for spatial autocorrelation and heteroskedastic error terms. They find that the beach width coefficient in the instrumental variable model is five times the ordinary least squares (OLS) estimate. Furthermore, they conclude that predicted results using this model are closer to observed data than OLS results.

In preparation for sea level rise and subsequent beach erosion, coastal communities have three primary amelioration options: beach nourishment, installation of hard structures, and removal of at-risk development. However, decisions depend on the cost of each option, as well as the value of additional beach width. The above studies on beach width estimate property value loss that would occur if properties were removed, as well as the gain in property values associated with increases in beach width due to beach nourishment programs. However, this work has not examined the value of hard structures that provide erosion benefits and (in some cases) aesthetic appeal.

Additional water quality variables the literature could further examine include increases in sedimentation loads and biological episodic events. Flooding in estuaries and rivers will increase sediment loads transferred to lakes and impact freshwater habitats. Likewise, reduced velocities associated with frequent droughts will result in further concentration of nutrients, resulting in greater potential for toxic algal blooms and reducing dissolved oxygen levels, which can cause fish kills. All of the above changes to water quality are highly visible and are likely associated with considerable economic losses.

ACCOUNTING FOR FORECLOSURE AND TEMPORAL EFFECTS

In light of the recent Great Recession and mortgage crisis, a number of recent studies have examined the relation between neighborhood foreclosure rates and sales price of non distressed properties (Daneshvary and Clauretie, 2012; Harding, Rosenblatt, and Yao, 2009;Gerardi *et al.*, 2012, Immergluck and Smith, 2005, 2006). Furthermore, one study finds that structural and environmental characteristics of distressed homes are capitalized differently than non-foreclosed homes. For example, an additional bedroom in a distressed home may be associated with less of a premium than a non-distressed home. Likewise, environmental amenities among distressed properties may be capitalized differently among distressed and non-distressed homes. However, most hedonic studies evaluating environmental amenities, particularly water quality studies, have avoided major real estate crises. Two recent exceptions include Netusil *et al.* (2014) and Tuttle and Heintzelman (2014), who both analyze housing transactions that took place during the Great

Recession. While Netusil *et al.* (2014) included in their models binary variables for different time periods, Tuttle and Heintzelman (2014) added a variable that indicates whether a transaction took place before or after 2006. However, neither study examines the effects of neighboring properties, nor do they account for effects that may be stratified by foreclosure status.

With regards to space, it is well-accepted that both geographic and temporal factors play an important role in the real estate market. The bias estimates associated with failure to account for spatial autocorrelation are acknowledged and addressed in more recent hedonic water quality studies with the use of spatial hedonic models. Such models that control for spatial autocorrelation have become commonplace across all strands of the literature from 2008 onwards. The spatial hedonic models estimate a global water quality effect that remains constant over space. However, the relationship between housing price and water quality can also be estimated using a geographically weighted regression model (GWR). GWR is a local regression model that also accounts for spatial dependency bias (Brunsdon, Fotheringham, & Charlton, 2008; Fotheringham, Brunsdon, & Charlton, 2003; Stewart Fotheringham, Charlton, & Brunsdon, 1996). GWR is especially amenable to studies covering a very large geographic region. Although this framework has been applied to economic valuation of other environmental amenities such as urban green space (Saphores & Li, 2012), it has not been used in hedonic water quality studies.

Hedonic studies concerned with water quality, as well as other environmental features, have not adequately accounted for price dependencies associated with temporal autocorrelation. In cases where housing data spans several years, as in Loomis and Feldman (2003), housing prices can vary over time due to a number of macroeconomic conditions, such as inflationary factors, unemployment rates, depreciation rates and mortgage interest rates. Furthermore, prices also depend on lagged price values, as is the case with spatial heterogeneity, temporal heterogeneity will lead to biased estimators.

In light of this, Huang, Wu, & Barry (2010) propose the use of a geographically and temporally weighted regression (GTWR). They point out that global regressions assume that determinants of housing prices are constant over space and time. However, this assumption is unrealistic within the real estate market. GTWR allows for processes to vary over space and time. They use 2002 to 2014 real estate values from Calgary, Canada to estimate standard hedonic, GWR, temporally weighted regression (TWR), and GTWR models. They find that TWR, GWR, and GTWR models' absolute errors were 3.5%, 31.5%, and 46.4% less than those associated with the standard hedonic model, and the GTWR model had the best goodness-of-fit out of the four models. Applying the GTWR model to hedonic water quality studies could result in more accurate estimates and better information for water recreation policy decisions.

IMPLICATIONS

The review of the literature above suggests that the hedonic water quality literature could benefit from further exploration of the geographic scope of water quality effects on housing values, as well as further examination of additional water quality trends. Initially, water quality studies relied on the standard hedonic framework to examine how water quality varies with sales prices among waterfront homes. These studies primarily focus both theoretically and empirically on determining the most appropriate water quality measures, most of which are indicators of chemical conditions or clarity. However, limiting analysis to waterfront properties alone is likely to result in an underestimation of welfare effects associated with improvements in chemical composition and clarity alone. Few studies examine the role of water level and sedimentation on sales price, and no study I know of examines biological incidents pertaining to water quality, even though all of these are likely to be associated with great economic losses.

Furthermore, the overwhelming majority of the literature focuses on estimating the value of healthy waterbodies during periods of relatively stable market conditions. Thus, additional studies could provide more information regarding the value of waterbodies during times of recession, and in cases where waterbodies have suffered severe environmental deterioration. The latter condition is especially relevant, given the precarious state of current and future water quality due to climate change. Finally, the literature should rely on recent methodological advances pertaining to temporal and geographic heterogeneity and the use of instrumental variables, since these estimation methods will address resulting bias and provide decision makers with better information.

TRAVEL COST

According to the travel cost (TC) framework, the cost an individual bears when visiting recreation facilities reveals their willingness to pay, or the price incurred, for a visit to the recreation site. This price for recreation can then be used to estimate demand for the site and provide estimates regarding the economic values of the site. The price can also reveal whether travel costs vary over time with environmental degradation of the site. One of the most common applications of the TC method is the valuation of water quality for lakes, rivers, and beaches. The majority of non-market valuation studies on water quality are travel cost studies. TC studies evaluate how variations in water quality impact recreation demand. There are several types of recreation that can occur at water sites, such as fishing, swimming, boating, sightseeing, etc.

Travel cost recreation demand models stem from Hotelling's (1947) early insights. However, Burt and Brewer (1971), McFadden (1974) and Moncur (1975) were the first to apply the TC framework to data pertaining to recreation choice and travel cost. However, these studies evaluated a single site. The primary shift in the literature occurred when Hanemann (1978, 1984 and 1985) introduced the RUM model, which was later used by Bockstael, Hanemann and Strand (1987). The treatment of substitute s is an important issue in any recreation valuation study, and it is discussed at length in the literature.

Although the TC method has been used for decades to evaluate water quality, the literature is surprisingly lacking with regard to the number of recreation types and geographic locations of waterbodies used in analyses. In addition, the literature examines effects associated with numerous chemical and physical characteristics, yet changes associated with climate changes and current sources of pollutants have yet to be well-examined. I specifically present results from studies that examine how changes in water quality—in the form of fluctuations in catch rates, pollutants, water level, and closures due to oil spills—affect willingness to pay for water recreation sites.

MODEL

TC models estimate demand for a recreation site. Demand refers to the number of trips taken to a site within a season, and it is a function of travel cost, site quality, and other factors that may influence demand. Travel cost represents the price consumers are willing to pay to visit the site, and hence the economic value of the site. Price varies with the time spent and monetary cost incurred for travel to (e.g. gas, entrance fee). Therefore, visitors who live farther from a site have a higher travel cost than those who live closer (Parsons, 2003). Once data on visitors' TC and site selection are gathered, the economic value of a recreation site is then derived from estimated demand functions.

TC estimate methods differ between single and multiple site valuation. In the single site model, the outcome variable is the number of trips taken to the site per season, and trip number is a function of travel cost and site quality. In the Random Utility Model (RUM), which is the most common multiple site model, the outcome variable is site choice, and this is also a function of travel cost and site quality. Because nearly all recent studies use the RUM framework, I describe this model below. Nevertheless, in both cases, the economic or monetary value of a trip to a single site or a choice of site is determined by consumer surplus. Consumer surplus is the difference between what the consumer is willing to pay and the market price or cost of the product; it is essentially a measure of individual welfare. Consumer surplus is also called net willingness to pay, since it represents willingness to pay net of the costs. Below, I discuss the theory and estimation methods associated with single site and multiple site evaluation as presented in Parsons G.R (2013) and Parsons (2003).

Single Site Model

Demand for the site is expressed in terms of number of visits to the site, and travel cost represents the price to visit the site. In the general demand function, r, is demand for recreation site:

$$r = f(t_c, t_s, s) \tag{2.2}$$

Equation (2.2) gives the total number of visits to the site per season and t_c is the cost incurred to travel to the site. The demand for trips also depends on t_s , the cost or price associated with substitute sites and the characteristics of the site s.

Consumer surplus cs_r associated with recreation demand, r, is the difference between consumers' total willingness and ability to pay for a recreation site. The willingness to pay is expressed by t_{cr}^0 and their ability to pay is t_{cr}^*, this is the price where consumer demand is zero.

$$cs_r = \int_{t_c r^0}^{t_c r^*} f(t_c, t_(s,)s_{(n)})dtc_r \tag{2.3}$$

The consumer surplus is a measure of welfare that comes from the site. Likewise it also represents the loss in welfare if the site was no longer accessible. Improvements or changes to the site or travel cost will ultimately influence consumer welfare.

To extract the economic value associated with a site, the demand function in Equation (2.2) must be estimated using individual data on number of trips, travel cost, site characteristics, and anything else that might impact the demand for the site. Economic theory does not give us a functional form for demand, but in practice the demand for a site is usually expressed using count data models such as the negative binomial and the Poisson model below, due to the non-negative and discrete nature of trips. Equation (2.4) describes the probability of visiting a recreation site r times, and Equation (2.5) is the estimated version of the general demand function in equation (2.2).

$$\Pr(r) = \frac{\exp(-\lambda)\lambda^r}{r!} \tag{2.4}$$

$$\lambda = \beta_{tc} t_c + \beta_{ts} t_s \tag{2.5}$$

The estimated consumer surplus for r trips to the site is expressed below, the hats indicate that the estimated parameter are used in the expression:

$$cs_r = \hat{r} / -(\hat{\beta}_{tc})$$

Similarly the following expression provides the estimated consumer surplus per trip:

$$cs_r / \hat{r} = 1 / -(\hat{\beta}_{tc})$$

Multiple Site Model Random Utility Maximization

In the RUM, individuals choose from a set of possible site choices S within a single season, where i is a single site from the set i=1, 2,.S. Demand for sites varies with the utility gained from each site. U_i, utility per site i, depends on travel cost, site characteristics, and an error term ε_i that accounts for unobserved factors.

$$U_i = \beta_{tc} tc_i + \beta_s S_i + \varepsilon_i \tag{2.6}$$

In RUM, consumers pick the site that maximizes their utility, subject to their budget constraints. The maximum utility per site choice is expressed in Equation (2.6); this can also be referred to as the baseline utility. Note that consumers' trip utility depends upon all possible sites within a single choice set.

$$v = max(U_{i,} U_2 \ldots..U_s) \tag{2.7}$$

In the case where site i is closed, then consumers' utility, v_{close}, represents the utility associated with the closure.

$$V_{close} = max(U_{i,} U_2 \ldots ..U_s) \tag{2.8}$$

Likewise, if site 2 is improved, then v^*represents the utility associated with the improvement.

$$v^* = max(U_i^*, U_{(2,)} U_3 .... U_s) \tag{2.9}$$

In each scenario, the consumer surplus, or willingness to pay, per trip is the difference in utility over the marginal utility of income β_{tc}. Because utility is expected to decrease in the case of closure, the marginal utility is expected to decrease. The monetary cost per site choice is expressed in Equation (2.10). In the case of a site improvement, the monetary benefit per site choice is expressed in Equation (2.11):

$$cs_{close} = v - v_{close} / -\beta_{tc} tc \tag{2.10}$$

$$CS^* = v^* - v / \beta_{tc} tc \tag{2.11}$$

Since $\varepsilon_i$is unknown, the utility function is stochastic and ε_i is assumed to be distributed independently and identically (iid) as a Type-1 extreme value. This assumption allows one to estimate the utility function per site choice, which can be expressed with a simple logit model as in Equation (2.12):

$$E(V) = ln(\sum_{(i=1)}^{S} exp(\beta_{tc} tc + \beta_s S_i)_{(i=1)}^{S}) - ln(\sum_{(i=1)}^{S} exp(\beta_{tc} tc)_{(i=1)}^{S})$$

$$E(V) = ln(\sum_{(i=1)}^{S} exp(\beta_{tc} tc + \beta_s S_i)_{(i=1)}^{S}) \tag{2.12}$$

The change in welfare due to a site closure or an improvement in site quality can be written respectively as:

$$E(V) = ln(\sum_{(i=1)}^{S} exp(\beta_{tc}tc + \beta_s S_i)_{(i=1)}^{S}) - ln(\sum_{(i=1)}^{S} exp(\beta_{tc}tc)) \tag{2.13}$$

$$E(V) = ln(\sum_{(i=1)}^{S} exp(\beta_{tc}^{*}tc + \beta_s S_i)_{(i=1)}^{S}) - ln(\sum_{(i=1)}^{S} exp(\beta_{tc}tc + \beta_s S_i)_{(i=1)}^{S}) \tag{2.14}$$

The last two equations give the average change in utility for each scenario. Finally, dividing by β_{tc} as in Equation (2.9) and (2.10) will yield the change in consumer surplus per site occasion. After obtaining consumer surplus estimates per site choice occasion, multiplying it by number of trips taken per season will yield the aggregate measure of consumer surplus.

Variations in RUM

Recall that the standard multinomial logit model used to estimate site choice demand in equation (2.11) is criticized for its independence of irrelevant alternatives (iia). The restriction suggests that the probability of choosing site k over site h depends only on the utility of k and h, and as a result the utility of the remaining sites in the choice set is not considered. This is unrealistic, since the individual could gain more utility from another site in the choice set. The iia restriction does not account for the quality of the additional sites in the choice set. Both the mixed and nested logit models relax the iia assumption and recognize the quality of multiple substitution sites. Within the nested logit framework, all sites that are theoretically close are grouped together, and each group makes up a nest. For example, in a TC study valuing beach use in beaches in two separate counties, if visitors primarily choose sites within their county of residence, then it may be appropriate to create a nest for each county. Furthermore, the incorporation of a pattern of substitution makes the nested model an improvement of the multinomial model (Morey, Rowe, &

Watson, 1993). The mixed logit model, also known as the random parameters model, facilitates a more general pattern of substitution. Simulated probability techniques are used to estimate parameters in the mixed logit models. The variation in each parameter suggests correlation between utilities across the site choice set, thereby facilitating greater site substitution than the nested logit model. Allowing site substitution reduces the impact of changes and closures on utility, and is more representative of household decision making, thereby yielding more accurate welfare estimates (Parsons, 2003; Train, McFadden, & Johnson, 2000). Once again, total willingness to pay or aggregate consumer surplus is equal to the product of the per-trip willingness to pay and the average number of recreation trips.

ANGLER TRAVEL BEHAVIOR AND CATCH RATES

As noted earlier, most of this literature relies on angler travel behavior to determine the economic values of water sites. This focus is in sharp contrast to HP and CV valuation studies that rarely examine biological indicators of water quality. Over half of the fifteen articles in Table 2.2 rely solely on angler behavior to determine economic values of these waterbodies.

Lipton and Hicks (2003) argue that higher water quality yields higher population of fish and ultimately higher catch rates. They use monthly and biweekly dissolved oxygen (DO) measures to estimate the catch rate of striped bass in the Chesapeake Bay's Patuxent River. DO measures come from the monitoring station closest to the place each angler was intercepted and interviewed. As a result, the level of reported DO would only represent water quality for anglers who fished where they were intercepted. However, if anglers fished in a location different from their interception site, water quality conditions could differ from conditions faced while fishing.

Using RUM, the Authors link estimated catch rates to site choice. They find that reductions in catch rates due to low DO levels result in $0.012 loss per trip. They argue that the effect is small because there are a number of substitution sites outside the river and along the Chesapeake Bay. Massey and Gentner (2006) note that modeling catch rates as a function of water quality ignores the chain of events that explicitly link water quality to angler demand, since water quality affects site choice, trip demand, and ultimately the welfare of anglers through several pathways. Furthermore, the use of temporally and spatially aggregated measures of water quality conditions, which occurs frequently in TC studies using catch rates, does not capture intra-annual variations in water quality conditions.

Massey et al. (2006) use structural equation modeling to first link quarter-hour DO levels to fish movements in and out of the study area. Fish abundance is simultaneously linked to catch rates, and finally catch rates are included in a recreation demand model to estimate the value of water quality changes to number of fishing trips. They conclude that water quality improvements in all bays and estuaries are predicted to increase catch rates by approximately 20%, or an increase of one fish. Anglers are willing to pay $4.22 for the additional fish per choice occasion.

Although Massey et al. (2006) take additional steps to link water quality to catch rates, catch rates also depend upon angler ability. As a result, catch rates are an imperfect measure of water quality. Furthermore, little is known about how catch rates relate to other forms of recreation such as swimming, viewing, and boating. Nevertheless, catch rates are an important biological indicator of water quality that is actively assessed and perceived by waterbody visitors, even if anglers represent only a portion of them.

In the next section I will present results from papers exclusively evaluating objective measures of water. A number of these papers also use angler visiting data. As a result, the literature has successfully addressed how both catch rates and objective measures impact angler behavior. However, less is known about how various measures of water quality affect other types of recreation (Parsons, Helm, & Bondelid, 2003; Pendleton, Atiyah, & Moorthy, 2007; Von Haefen & Phaneuf, 2003).

Use of Objective Measures of Water Quality

The majority of TC as well as HP studies evaluating water quality are primarily concerned with how variations in objective measures of the water quality impact recreation, and ultimately with visitors' willingness to pay for site visits. The results column in Table 2.I consistently shows that in studies that do include an objective measure of water characteristics, willingness to pay for visits is related to it. However, Phaneuf (2002) finds that the size and significance of these measures can vary with the recreation type. He uses RUM models to link conventional nutrient pollutants to site choice using the travel behavior of anglers, swimmers, boaters, and viewers. Phaneuf notes that the primary water quality issue in North Carolina is nonpoint sources of conventional pollutants, including DO, acidity, phosphorus, and ammonia. Phaneuf (2002) finds that DO and phosphorus are negatively related to angler choice recreation, though ammonia is insignificant. Further model specification investigations suggest that neither ammonia nor phosphorus may be appropriate when estimating demand among watershed viewers, but all four indicators explain variation in swimming and boating.

Many objective measures, including DO, acidity, and ammonia, may not be perceived by visitors, and therefore do not drive recreation behavior. This disconnect is problematic for TC studies that assume chemical measures are proxies for visitors' perceptions of water quality and are related to site choice. According to Phaneuf (2002), one strategy in response to this is to identify and include water quality measures that are publicly available, in the hope that these measures will accurately describe subjective and objective measures of water quality. One example is the Index of watershed indicators, or IWI website. This index uses a scale from one to six and is an aggregate measure of each watershed's condition and future vulnerability. The IWI measure is subjective since it is easy to interpret, available to the public, and is likely to be correlated with populations' perceptions of waterbodies. Phaneuf also find that the IWI index does not explain trip demand for viewers. However, the IWI index does explain variation among the remaining recreation types. He concluded that subjective and objective measures are closely aligned, and water quality significantly impacts recreation decisions. Phaneuf (2002) estimates that the mean WTP per trip, for IWI index value of one, thereby indicating some improvement across all watersheds A IWI is $5.90 and the aggregate benefit associated with such improvement is $86.73 million.

Parsons, Helm, and Bondelid (2003) estimate the value of water quality using day trip data to 20,925 rivers, 2,975 lakes, and 1,231 coasts located within the northeastern U.S. They estimate separate RUMs for fishing, swimming, boating, and viewing. Water quality is based on an index that characterizes each waterbody's water quality as low, medium, or high. The index is based on measures of biological oxygen, total suspended solids (TSS), dissolved oxygen (DO), and Fecal Coliform. In general, fecal coliform indicates contamination via wastewater treatment plants, on-site septic systems, domestic and wild animal manure, and storm runoff (USEPA, 2012) and it can lead to health risks. However, levels of fecal coliform are not directly perceived by consumers. Parsons, Helm and Bondelid first construct welfare estimates associated with attaining a medium level of water quality, then those associated with high water quality. The results from the models suggest that medium water quality (relative to low water quality) is positive for all recreation activities except for viewing, where the improvement was not significant. Achieving medium water quality across all waterbodies is associated with a $3.00 benefit for fishing visitors and a $5.00 benefit for swimmers, and only a $.04 increase for boaters. High water quality is positive and significant across all four recreational activities. Furthermore, the economic benefit for high water quality is valued substantially more that medium quality. Benefits associated with high water quality improvements are $31 for viewers, $8 for boaters and fishers, and $71 for swimmers. The aggregate benefits for medium water quality and high water quality at all sites are $77 million and $1.295 billion, respectively.

Egan *et al.* (2009) use an extensive number of water quality measures to explain recreation demand among lakes in Iowa. They include measures of physical (e.g. water clarity), chemical (nutrients), and biological (bacteria) characteristics of water quality. Their primary purpose is to delineate which water quality characteristics are significant determinants of recreation demand, and determine the most appropriate functional form and distribution for water quality measures. They choose the mixed logit model for the analysis. Results indicate that water clarity and nutrients are associated with the largest marginal effects, but all five variables are significant. They conclude that the preferred model is one that has linear water clarity (secchi) and suspended solids measures, and they log transformation of nutrients (phosphorus and nitrogen), chlorophyll, and bacteria (blue green algae and microalgae), all three of which are related. Human activity has led to large increases in nutrient loading of water. Ultimately, bacteria such as blue green and micro algae grow rapidly in nutrient-rich water, which can then reduce oxygen levels and cause toxic blooms that make the water unfit for drinking, agriculture and recreation (NOAA, 2014). Although the relationship between the chemical and biological measures indicates multicollinearity, the authors suggest that there was no major issue with it and conclude that models could contain one or all five indicators.

They find that improvement of all lakes to a high standard of water quality yields an average benefit of $153.04. An improvement of 9 lakes to a high standard is associated with a benefit increase of $19.56 per households, and an improvement across 65 lakes to meet acceptable EPA standards is associated with an $11.52 increase in benefits per household. They conclude that improving water clarity of nine lakes, thus achieving a high level of water quality, yields the largest benefit relative to cost—an annual compensating variation of $19 for each Iowa household.

The results above suggest that a number of papers examine measures of nutrients and bacteria, as well as biological indicators such as abundance of fish and bacteria. However, the effect of dirt or sediments associated with erosion is less frequently examined, particularly in the TC literature, despite the fact that the EPA cites dirt as one of the greatest sources of pollution in impaired waterbodies in the U.S. Therefore, estimating the costs associated with rising dirt levels is a future area of research in TC studies.

WATER LEVELS AND CLIMATE CHANGE

While climate change is associated with a number of environmental consequences, in this review climate change refers to changes in water due to global warming, such changes manifest in a variety of ways, including desiccating freshwater ecosystems and sea level rise. These changes have the potential to significantly alter water quality. The TC method can uncover the economic effect of climate change on individual demand for recreation activities and ultimately reveal the aggregate welfare costs or benefits associated with these changes. Within the travel cost literature, a number of studies have examined temperature and precipitation on beach, reservoir, and stream recreation, as well as angler welfare (Shaw & Loomis, 2008). With regard to water quality, a number of TC studies determine the welfare loss associated with sea level rise for beach visitors. Consequences of climate change such as sea level rise and severe storms can reshape beaches altogether, dramatically changing their width and size. Several studies have found that beach erosion reduces willingness to pay for beach sites and results in substantial losses.

Von Haefen, Phaneuf, and Parsons (2004) and Parsons, Massey, & Tomasi (2000) estimate welfare losses associated with beach erosion and beach closures at 62 mid-Atlantic beaches. Parsons and Powell (2001) find that narrow beaches with a shore less than 75 feet wide, as well as wide beaches greater than 200 feet wide, are associated with welfare losses. They find that loss in beach width reducing all Delaware beaches to less than 75 feet would be associated with a mean per-trip, per-person welfare loss ranging from $5.78 to $10.94. Von Haefen et al. (2004) use a Kuhn-Tucker framework, whichI will discuss later, to find the individual and aggregate welfare losses associated with lost beach width at all Delaware, Maryland, and Virginia beaches. The individual mean welfare loss per season ranges from $54 to $35. The aggregate welfare losses associated with 75 foot reduction in beach width is $20.1 million per season.

Bin *et al.* (2007) acknowledge the grave consequence of sea level rise on beach recreation in North Carolina, and estimate a nested logit RUM model to link angler utility to beach width, which is an indicator of sea level rise (Haab & McConnell, 2002). They find that narrow beaches stifle beach access and hinder anglers' ability to transport gear to fishing sites; anglers therefore prefer sites with additional beach width. The authors use the existing relationship between variation in beach width and site selection to simulate the impact of current erosion rates as well as projected erosion rates for the years 2030 and 2080. The change in WTP per trip attributed to an increase in beach width of 10 meters is $2.97.The mean change in WTP per trip with reduced beach width in 2030 is $8.54. The mean change in WTP per trip with reduced beach width in 2080 is $9.39 Assuming that the shore fishing participation rate is constant between 2006 and 2080, aggregate annual WTP loss due to the decrease in quality associated with sea level rise is $33 million in 2030 and $36 million in 2080.

Pendleton *et al.* (2012) estimate the welfare benefits of increased beach width due to beach nourishment programs in Southern California. They also use a nested logit utility function to link beach width to recreation behavior. However, their study specifically uses panel data collected every two months over the course of the year to examine how beach width affects water (e.g. swimming, boating), sand (e.g. volleyball), and pavement-based activities (e.g. restaurants and development) at local beaches. They find that wider beaches are preferred for water, sand, and pavement-based activities. They find that there are diminishing returns associated with beach width greater than 60 meters. Similar to Parsons et al. (2000), this study finds that very wide beaches impair the process of hauling boats. According to Pendelton et al. (2012) the value of a beach trip in California is just over $100. The aggregated value of increase in beach width is about $3.1 million in consumer surplus per year.

Although sea rise is a well-documented consequence of climate conditions, less is known about the cost associated with severe decreases in water levels due to arid conditions. Falling water levels can affect the aesthetic appeal of a waterbody, hence the potential link to property values. However,I know of no travel cost study that examines the loss in consumer surplus due to climate-induced decreases in water levels. Similar to the HP literature, only one study that I am aware of estimates costs associated with falling water levels, in spite of the fact severe decreases that can impair boating, viewing and fishing. Jakus and colleagues (Jakus, Dowell, & Murray, 2000), for example, examine how routine drawdowns in the Tennessee River impact angler behavior from 1994 to 1997.

The Tennessee Valley Authority initiated routine drawdowns to help produce electricity and control flooding in the upper regions of the watershed. The reduced water levels, however, resulted in landlocked boat ramps and exposed mud flats. Jakus et al. (2000) find that in this situation anglers still participate at the same rate, but their trips primarily occur when water levels are highest in the season. They also find that water levels influence site choice, and that anglers' willingness to pay for full pool, or normal water conditions is $1.82 per angler per season. This estimate shows an aggregate benefit of $476,500 per season.

The TC literature has determined the economic cost associated with beach erosion due to sea rise. The results indicate that decreases in beach width as a consequence of sea rise reduce willingness to pay for various types of recreation among anglers, swimmers, and those engaging in sand- and pavement-based recreation. Given the high levels of participation in beach recreation and the high cost of beach protection, additional TC studies can contribute to my understanding of water quality and beach recreation (Freeman, 1995; Shivlani, Letson, & Theis, 2003). Another area of important research that the TC literature has yet to address is recreation demand in reaction to shrinking water levels. Like sea level rise, falling water levels in rivers and lakes constitute an important consequence of climate change. Future research should focus on decreasing water levels, given their enormous impact on recreation.

Beach Closures as an Indicator of Water quality

In addition to sea rise, excessive pollution in the form of bacteria and oil spills can further impair water quality for beaches and result in a beach closure. Given the wide range of visitor participation at beaches, a closure can have severe economic consequences. Studies by Parsons, Von Haefen et al. (2004) and Parsons et al. (2000) both estimate the welfare loss due to beach closures. Parsons et al. (2000) find that the average estimated welfare loss per trip, per person for the closure of

Rehoboth Beach, DE ranged from $8.00 to $17. Likewise, Von Haefen et al. (2004) find that welfare losses associated with the closure of Rehoboth Beach, DE range from $57 to $83 per season, per person. The aggregate welfare loss associated with closure of Rehoboth Beach is $33.1 million for all Delaware residents for one season.

Murray, Sohngen, and Pendleton (2001) use RUM to examine how reduction in beach advisories impacts Lake Erie beach goers' willingness to pay. They note that high levels of bacteria such as fecal coliform can cause adverse health effects, motivating beach closures. Examining survey results from the summer of 1998, they find that a single reduction in beach advisories per season at a single beach is associated with a $28 increase in the welfare per person, per year. The aggregate seasonal benefit of reducing an advisory at each beach in Ohio is in the range of $3.2 to 3.4 million.

Hicks and Strand (2000) estimate welfare effects pertaining to beach closures and improvements in water quality. They examine fecal coliform levels and closures at Chesapeake Bay beaches, and find that the closure of Close Bay Ridge and Sandy Point beaches are associated with a welfare loss of $27.49 and $116.30 respectively. Additionally, they find that the average consumer surplus associated with a 40% reduction in fecal coliform is $27.33.

TREATMENT OF SUBSTITUTES AND REPEAT ANALYSIS IN TC LITERATURE

Treatment of substitutes within the TC framework has been an important topic of debate within the literature. A number of TC studies have pointed out that failing to account for substitution sites results in biased welfare estimates (Bin, Landry, & Ellis, et al., 2005; Hicks & Strand, 2000; McConnell & Tseng, 1999). Since consumers can substitute for a deteriorating site, in such cases there may not be a significant welfare loss. A great deal of the literature either focuses on economic models that can account for substitution patterns consistent with realistic demand patterns, or emphasize the importance of specifying an appropriate site choice set that will include all relevant substitutes. Variations in model and site choice specification have led to repeat analysis of two data sets in particular: recreation behavior across 62 mid-Atlantic beaches, or at 12 beaches along the western shore Chesapeake Bay. Furthermore, a review of Table 2. I reveals that a large proportion of TC studies are concentrated within the Northeast, Mid-Atlantic, and North Carolina if the Southeast. As a result, the geographical scope of TC studies is limited.

Bockstael, Strand, and McConnell (1987) are the first to use the Chesapeake Bay beach data to estimate willingness to pay for improvements in water quality. Both Hicks and Strand (2000), and McConnel and Teng (2000) also use this dataset. Lipton and Hicks (2003) do not use this dataset however they also estimate angler WTP for the Patuxent River within the Chesapeake Bay.

Hick and Strand (2000) also use this dataset to determine the sensitivity of RUM estimates to various choice sets, including those that contain all alternatives, only familiar alternatives and alternatives based on distance. The Authors conclude that welfare estimates associated with choice sets including all possible sites and those based on distance overstate welfare effects relative to the familiarity-based choice set. Similarly, McConnell & Tseng (2000) specifically estimate welfare loss, among Chesapeake Bay beach goers, associated with fecal coliform levels. They find no evidence that suggest that parameter estimates are sensitive to sampling bias. Conclusions indicate that doubling fecal coliform yields a $1.12 loss per individual, per trip for one site, and $8.79 per individual, per trip for all sites in the Chesapeake Bay.

As noted earlier, Parsons et al. (2000) and Von Haefen et al. (2004) use beach visitation data from 62 beaches within the Mid-Atlantic region to estimate recreation demand for beach access and beach width. This includes beaches on the coast of several northeastern states, including New Jersey, Delaware, Maryland, and Virginia, while Massey and Getner (2006) estimate welfare losses associated with bay areas also located in Maryland.

Both Phaneuf and Sinderlis (2003) and Phaneuf (2000) examine welfare losses among North Carolina waters. Phaneuf and Siderlis (2003) also use the Kuhn-Tucker models to estimate multi-site demand for water quality water trails in eastern North Carolina. They use paddling recreation data and the EPA's IWI index, which is extensively described in Phaneuf (2002), to measure water quality, and find that better water quality is positively associated with visitation rates. They conclude that visitors are willing to pay an average of $24.44 per season for an increase in water quality in the paddling areas.

Repeat analysis has led to more sophisticated econometric modeling and a thoughtful strategy regarding site choice. However, given current climate conditions, waterbodies all over the country are subject to a number of further water quality threats, including drought, smell associated with biological degradation and pollution, as well and rise in sediment levels. Yet few economic valuation studies have examined these additional threats. Like the hedonic literature, the TC literature does not address smells associated with biological indicators such as fish kills. Finally, entire regions of the country, particularly the Midwest and Southwest, could benefit from valuation studies.

LIMITATIONS AND FUTURE IMPLICATIONS

The results from the TC studies suggest that water quality measures of all types—biological, physical, and chemical—influence recreation decision behavior. Given the consistent effect of water quality on recreation demand, the literature needs to expand its geographic scope and the types of recreation analyzed. Furthermore, additional water quality measures that are emblematic of current environmental threats should also be included in future studies.

For example, a large portion of the literature relies on angler travel behavior to assign economic value to a waterbody. This is problematic, since anglers make up only a small fraction of the visitor population for the majority of these sites. As a result, welfare estimates associated with these studies will understate the effects associated with changes in water quality.

There is also a lack of variety with respect to the location and types of waterbodies. A review of the literature reveals that many studies reuse data sets from previous studies. For instance, several studies examine the Chesapeake Bay Mid-Atlantic Beaches, and waterbodies in North Carolina. Each of these contributions is important, because each iteration of analysis yielded advancement of econometric modeling techniques and site choice definitions, and repeat analysis demonstrated the consistency of results over time. However, current climate conditions have impaired waterbodies all over the country. Future studies should examine how the relationship between recreation demand and climate-induced changes in water quality vary between different regions of the country.

Despite a lack of diversity within the literature over the last 15 years, the current rate of environmental change yields a number of interesting case studies that should further economic valuation literature and provide much-needed welfare estimates that will better inform environmental management of recreation sites.

CONTINGENT VALUATION

INTRODUCTION

In cases where there is a considerable amount of residential development near a waterbody, a hedonic price (HP) model can estimate a value for water quality. Likewise, in instances where a waterbody is primarily used for recreation, a travel cost model will reveal how travel cost to a site varies with water quality. In cases where improvement in water quality will yield a non-use value, only stated preference methods are capable of measuring these passive use values of ecosystem services (Loomis, Kent, Strange, Fausch, & Covich, 2000). Examples of non-use values include increases in a population of rare or endangered fish, or future preservation for generations to come.

The most common stated preference valuation technique is contingent valuation (CV). This method, unlike the revealed preference methods, relies on asking survey respondents their willingness to pay (WTP) for specified changes in water quality for certain sites. The questionnaire first presents the respondent with a hypothetical situation facing a waterbody, and suggests ranges of values that the respondent and the proposed outcome associated with respondents' financial contribution, The method also requires that the survey to outline how such funds would be collected to achieve this change (e.g., taxes, bills, access fee) and the schedule of such payments.

CV has been used to estimate the value of a number of environmental amenities. Ciriacy-Wantrup (1947) introduced the CV method. He believed that prevention of soil erosion provides a market benefit and that the market could be uncovered by asking individuals about their WTP for these benefits through a survey (Portney, 1994; Hanemann, 1994). Davis (1964) was the first to apply the CV method to estimate benefits associated with good hunting among good hunters (Venkatachalam, 2004) Over the last two decades, the CV method has been widely accepted as one of the only valuation techniques suitable for the estimation of non-use values (Desvousges, et al., 1993; Smith, 1993) As a result, it has been used to determine cost and benefits associated with the deterioration or restoration of a number of environmental amenities. Additionally, environmental agencies around the world, including the U.S. Environmental Protection Agency (EPA), reference such studies, or employ CV methods to determine non-use values for a wide array of environmental goods (Holmes, Bergstrom, Huszar, Kask, & Orr, 2004; Raeburn, Carson, & Randall, 1999). Despite its widespread application, it has also received a great deal of criticism.

The primary criticism is that the method is unreliable since the restoration choices presented to respondents are hypothetical, meaning that the stated WTP could in fact be greater than their WTP in reality (Diamond & Hausman, 1994). For a comprehensive discussion on the various errors/biases associated with the CV, as well as a synthesis of empirical studies that address concerns over its validity and reliability, see Venkatachalam (2004) or Carson, Flores and Meade (2000). Nevertheless, there have been important uses of CV applied to hydrological bodies. . Because both phenomena are easily observed, there is little debate in the literature regarding people's perception of water quality.

More recent stated preference studies embrace other valuation techniques including contingent behavior (CB) or choice experiments (CE). Additionally, there are a number of studies that combine stated and revealed preference data. A reoccurring theme throughout the literature is the justification for, and credibility of CV, and the validity of CV estimates.

MODEL

The CV method begins with a survey instrument that conveys possible future scenarios. CV studies are referred to as stated preference valuation techniques—as opposed to a revealed preference technique—since respondents state their preferred course of action given the possible scenarios. Thus, respondents state their preferences concerning those actions. Similar to the TC, an individual's utility U_0 depends on G a vector of services provided by the site, as well as the level of environmental quality g_0 of the site, and *P* a vector of prices for private consumption of goods. *W*, the individual's maximum WTP for improved environmental quality g_1, is the difference in utility gained from the improvement. This is expressed below as:

$$W = U_1\left(G(g_1), P\right) - U_0\left(G(g_0), P\right) \tag{2.15}$$

Typically, to obtain WTP in CV studies, the respondent is offered a binary choice between the status quo and the improved condition, which requires the respondent to pay a fee of some kind, either in the form of a tax or an increase in prices. Given this choice structure, most studies utilize a discrete choice model such as the negative binomial or a Poisson model, such as the one specified in count data models such as the negative binomial or the Poisson model specified in Equation (3), however in the case of CV the respondent's stated WTP takes place of travel cost.

Likewise, in CV studies where the analysis estimates value of improvement (cost) among multiple sites are evaluated using RUM Equation (2.5). In such cases, the dependent variable is the probability of choosing one range of value over other possible ranges. This estimate is aggregated for all individuals within a certain designated jurisdiction in order to obtain a total WTP. Finally, the benefit associated with an environmental policy is the difference between this total and the cost of the program or policy intended to yield improvement (Cooper, Poe, & Bateman, 2004). For steps to estimation of both single site and multiple models please refer to the TC section above.

STATED VALUE OF WATER QUALITY AND DEBATE OVER RELIABILITY

A considerable number of revealed preference studies evaluate water quality; however there are few examples of CV studies that focus on specific water quality measures. Carson, Michell and Haneman (2003) is a well-cited example of a CV study that estimates the value of water quality.

They specifically estimate households' WTP to prevent future Exxon Valdez-type oil spills in the ocean. The spill involved the rupture of oil compartments and the release of 11 million gallons of oil shortly after the Exxon Valdez tanker left the port of Valdez, Alaska. Prior to the Exxon Valdez oil spill, the estimation of non-use values was not a widely recognized valuation method (Carson, Flores and Mitchell, 1999). However, at the time of the oil spill, the federal government intended to seek damage claims based on the loss of non-use values associated with the spill. The application of CV to Alaska yielded a debate among economists about the validity of the method. Ultimately, a panel of economists sanctioned appropriate conditions and parameters that supported reliable CV estimates of preservation of waterbodies, and they were incorporated into a survey tool used soon after the spill in 1990 to obtain local residents' WTP for the prevention of future oil spills (Carson *et al.*, 1992).

The Exxon Valdez represented a quintessential case where non-use values prevented Exxon from effectively claiming that public resources that were not developed had very little value, and thus degradation of the resource was of little consequence and monetary value. Because of the huge implications associated with the Exxon Valdez oil spill, individuals other than local residents will likely place some value on prevention of future incidents. To uncover U.S. households' WTP for prevention, Carson *et al.* (2003) administered this survey nationally in 1998, ultimately finding, just as the previous study did, that as the cost to prevent future oil spills goes up, the percentage responding with a "for" vote declines, from 67 percent in favor at $10 to 34 percent at $120. They estimated a $2.8 billion loss in non-use value among locals in 1990, and a $7.19 billion WTP among Americans in 1998.

Strumborg, Barenklau, and Bishop (2001) estimate the aggregate WTP of Dane County residents for achieving a 50 percent reduction in phosphorus levels in Lake Mendota, Wisconsin.

Lake Mendota, due to high phosphorus from agricultural runoff, experiences blue-green algal blooms near 50% of the time during summer months despite a state water abatement program, riparian buffer zones, livestock fencing, wetland restoration, etc. These efforts have led to a drop in pollution levels, increases in water clarity and fish stock, and the return of aquatic species that disappeared. The Authors also try to determine if the scheduling of payments influenced respondents' WTP. They ask the first group their maximum annual WTP for the next three years, and they ask the second group their WTP for the next 10 years. The average amount for those in the 10 year plan group was $57 versus $87 for the 3 year plan group. This contradicts economic theory that suggests that present value should be the same for both groups since the final product is the same. The Authors do not have an explanation for this discrepancy. They determine that the sum of the annual payments yields a $354 mean WTP. This would yield over $43.9 million aggregate WTP among country residents, which far exceeds the $17.8 million costs of the program. This paper is a rare example of a study that estimates values associated with algal blooms—a common biological consequence associated with agricultural and urban runoff.

CONSIDERATION OF ECOSYSTEM SERVICES AND CHOICE EXPERIMENTS

Water quality is not a final ecosystem service; instead, it contributes to a number of other services. As a result, a number of studies estimate the CV of final ecosystem services, since improvement in water quality yields improvement among a number of ecosystem services(Keeler, et al., 2012) Ecological services can include biodiversity, support for terrestrial and estuarine ecosystems, or habitats for plants and animals (Wilson & Carpenter, 1999).Simply valuing a single service will underestimate the value associated with improvement of hydrological environmental conditions (Bockstael, Freeman, & Kopp, et al., 2000; Turner & Daily, 2008). Loomis *et al.* (2002) and Holms *et al.* (2004) use CV surveys to determine WTP associated with riparian repair and subsequent improvements in several ecosystem services. Loomis et al. (2000) specifically look at WTP for water and acres of conservation easement on a 45 mile-stretch near the South Platte River, in Denver and Fort Collins, Colorado. They find that on average, respondents would accept a $21 increase in their monthly water bill, $252 annually, for additional ecosystem services.

Holmes *et al.* (2004) conducted a similar study estimating average willingness to pay for riparian restoration along the Little Tennessee River in western North Carolina. However, instead of a monthly increase in water bill for a single scenario, this study assesses household willingness to pay increased county sales taxes for differing amounts of riparian restoration. The Authors also take a holistic approach, evaluating benefits associated with several ecosystem services and finding that a unit change in restoration conflates a number of different ecosystem services. They therefore conclude that changes in restoration scenarios do not yield linear improvements among ecosystem services. Instead, restoration seems to be associated with an additive improvement in services, such that full restoration yields exceedingly greater benefits that lower levels of restoration. Thus, the primary purpose of the study is to determine value for restoration of a bundle of ecosystem services and to compare additive benefits to restoration costs. They find that ratios for riparian restoration range from 4.03 (for 2 miles of restoration) to 15.65 (for 6 miles of restoration), whereas the ratio of benefit to cost in Loomis et al. (2000) was 5.22. Holmes et al. argue that not accounting for conflated effects results in underestimation of value associated with ecological benefits.

Bell, Huppert, and Johnson (2003) estimate the value of a rehabilitation of Coho salmon population among residents in coastal communities in Oregon and Washington. In this study, they examine residents' willingness to pay for a high and low enhancement program using two separate surveys. One version promotes the more expensive high enhancement program, which yields a quadrupling of run and catch rates, versus a low enhancement program that doubles these rates.

Furthermore, the low enhancement program severely precludes fishing sport activity, whereas the high enhancement program has relatively relaxed restrictions on fishing activity. The study pools all responses and indicates those that were given the high enhancement surveys. The mean WTP estimate for high enhancement was $116 versus $119 dollars for low enhancement. This difference is not statistically significant; thus, price tag and reduction in the catch numbers permitted do not explain variation in price. They ultimately find that variation in WTP varies with independent variables accounting for the merit of the program as well as the causes of salmon decline, such as overfishing. However, they did not find that WTP differed with participation in sport fishing. They acknowledge the need for further research devoted to understanding preferences to improve the assessment of WTP for enhancement Programs

Like Bell, Huppert, and Johnson (2003), Lew and Larson (2014) use stated preference data from anglers to estimate the economic impact of the 'bag limit' program that limits the amount of fish caught and kept per trip. Meaning all fish caught beyond the bag limit must be released. This study, estimates WTP for trips with or without the bag limit provision, using the choice experiment (CE) method. There have been a number of studies that use the CE method to value fishing trip characteristics (Anderson & Lee, 2013; Lew & Larson, 2012; Mahasuweerachai, et. al., 2010). In the CE framework respondents are asked to rank their preference for several choices. In this study the authors estimate a RUM model where utility from each alternative is a function of travel costs, and alternative characteristics. In this situation, alternative characteristics refer to amount of catch, and bag limit. They conclude with estimates of local residents' mean value for a fishing trip.

COMBINING STATED AND REVEALED PREFERENCES

An increasing number of economic valuation studies combine stated and revealed preferences in order to achieve a more comprehensive estimate associated with environmental amenities. There are several motivations for this approach. 1) It allows researchers to determine whether both types of preferences suggest similar demand behavior, thereby providing additional validity to resulting estimates. 2) Each respondent yields more than one observation, since they are sources of information on both exhibited and stated behavior. 3) It allows researchers to ground controversial stated behavior with actual behavior (Hanley, Bell, & Alvarez-Farizo, 2003). Examples of recent studies combining stated and revealed preferences are Eiswerth, Englin, Fadli, et al. (Eiswerth, Englin, & Fadali, et al., 2000) and Loomis (2000).

As with the HP and TC literature, few studies examine the effects of water level. Eiswerth, et al. (2000) is a rare example. In this paper the authors use a Poisson model to estimate the cost of declining water levels in terms of impact on the frequency of trips taken to Lake Walker, Nevada. Although this is a TC study, the authors use both TC and contingent behavior data. Contingent Behavior is based on respondents' stated visitation behavior under hypothetical environmental conditions. The authors obtained the contingent behavior by surveying local residents about the number of trips they would take to the lake at times of varying water levels. In their final model specification, the authors include an indicator variable for stated preference respondents. However, they conclude that the indicator is not significant, suggesting that the stated behavior is similar to the revealed behavior. Their result provides additional support for the contingent valuation method. They estimate that a one-foot decline in water levels is associated with a $12 to $18 loss per person per season, with the aggregate estimate ranging from $4.8 million to 10.8 million. Fadali and Shaw (1998) used this same data and found that non-visitors' per-person value of lake levels was approximately five percent that of Walker Lake visitors. Using the value obtained from users, Eiswerth *et al.* (2000) estimate the WTP for preservation of water levels ranges from $1.98 million to $2.79 million.

Loomis (2000) also estimates the number of trips taken to a hydrological site using contingent behavior data. However, he attempts to value the potential removal of dams and the restoration of the lower Snake River in Washington State. Since the removal of the dam is merely a prospective project, all data is based on contingent behavior. Respondents from local cities, as well as California, Idaho, and Montana, can only reveal their intended number of trips given the dam removal. Loomis estimates that the removal will yield an annualized benefit of $310 million. This is $60 million less than the cost of dam removal. Furthermore, the geographic scope of the study is considerably larger than most studies within the CV literature.

A number of CV studies estimate the values associated with beach nourishment (Kriesel & Landry, 2004; Shivlani, et al., 2003). However, (Whitehead, Dumas, Herstine, Hill, & Buerger (2008), combine stated and revealed preference data to estimate the value of beach nourishment programs along beaches in North Carolina. They collect stated and revealed preference data from 639 completed surveys. The revealed preference data was based on beach trips actually taken and the stated preference data is based on future trips. More specifically, they ask respondents about their trip behavior if beach nourishment programs added about 100ft of beach width. They use a pooled poison regression model to estimate WTP for beach width; they include a stated preference indicator variable. They find that the SP dummy is positive and statistically significant, when estimating number of trips; however this is not the case when estimating consumer surplus or elasticity per trip. They argue that there is no empirical difference between SP and RP among nonlinear functions. However, when estimating consumer surplus per season, there appears to be a significant difference between the two preferences, thus they conclude that when SP is a suitable substitute when estimating consumer surplus per trip. They find that consumer surplus per trip among beaches under the hypothetical nourishment program is $94. The estimated aggregate benefit among beach trips is $791 million annually. Their estimates are larger than previous work on beach nourishment due to the fact that they aggregate a large number of beaches into a single recreation site.

IMPLICATIONS

Stated preference methods allow for the valuation of non-use values of waterbodies, however more recent literature suggest that stated preference methods can delineate demand for use values associated with waterbodies in hypothetical situations As a result, there has been a shift in the literature from primarily assigning value to non- use values (e.g. ecosystem services), to studies that combine both revealed and stated preference data to determine the value of current water quality characteristics, such as beach nourishment and water level, as well as future characteristics. Thus this method can provide significant insight on potential programs. Because the stated preference data implies value for hypothetical situations, beyond the range of experience, it has faced a great deal of criticism. However, the studies combining both types of data suggest that stated behavior does not statistically differ from revealed behavior, suggesting validity of estimates.

CONCLUSIONS

Overall, the economic valuation literature, irrespective of method type, indicates that individuals are willing to pay for water quality. This finding is evident in studies estimating the value of water quality among beaches, lakes, and rivers throughout the US.As stated earlier, water quality specifically refers to how the physical, chemical, and biological characteristics of water influence demand for housing, recreation, and non-use services. Within the hedonic framework, most studies value measures of chemical properties of water. It is often the case that these measures serve as a proxy for clarity; however in some cases it is unclear how consumers perceive chemical properties. The values of chemical measures were also estimated among travel cost and contingent valuation studies. However, these studies primarily focus on biological indicators such as catch rates and fish abundance. A number of studies within all three bodies of literature examine the cost of beach erosion due to sea level rise. However, there are a number of indicators that are not well studied within the literature.

Climate change is severely impairing a number of waterbodies, in a variety of ways. One way is through drastic drops in water levels among a number of fresh waterbodies. Drops in water level do not only impair aesthetic and recreation value of waterbodies, they also have detrimental biological consequences and can severely impair ecosystem services.

Another salient problem facing waterbodies is nutrient overloading, which can lead to algal blooms and subsequently impair bird and fish species, and in some instances this can lead to fish kills and subsequent odors. Additional drops in water level will result in a higher concentration of pollutants, which will exacerbate these biological consequences. However, there are limited examples of studies that examine these consequences. Economic valuation literature has delineated cost and benefits for a number of waterbodies, facing various water quality issues, thereby offering important information to policy makers. Thus this framework would also provide much needed information regarding environmental degradation via desiccation and increased nutrient load of inland waterbodies. I will focus on economic valuation of these declining waterbodies in the next empirical sections.

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2.1 Summary of Results for Hedonic Evaluation of Water Quality

Authors	Location	Method	Data	Environmental Measures	Main Results
Landsford and Jones (1995)	2.5 miles from Travis Lake, Texas	standard hedonic model	609 SFH transactions 1988- 1990 within 2.5 miles of the lake. Lower Colorado River Authority.	water level at time of sale: lake levels: mean, +/- 1std dev, +/- 2 std. dev. distance from lake to prop in feet; LDIST distance from lake to prop in feet up to 4,000 feet	At the waterfront 1 foot decline in water level is associated with $56 decrease in sales price. At 1500 feet from water front 1 foot decline in water level is associated with $12 decrease in sales price. At 3000 feet from water front 1 foot decline in water level is associated with a $5.41 decrease in sales price.
Gibbs, Halstead, Boyle, and Huang (2002)	69 lakes in New Hampshire	standard hedonic model	Lakefront housing sales data ,1990 - 1995 New Hampshire Department of Environmental Services (DES).	secchi disk readings	1 meter decrease in water clarity is associated with 0.9% to over 6% decreases in sales price
Parsons and Powell (2001)	Delaware's Ocean Beaches	standard hedonic model	266 transactions from 1991-1992	Sea level rise scenarios and projected property damage	Projected property losses over 2000-2050 are $291 million in 2000 dollars.
Loomis, Feldman (2003)	Lake Almanor, California.	standard hedonic model	1964 transactions from Plumas County Assessor's office from 1987 to 2001	feet of exposed shoreline at the time of sale 90 to 120 days prior to closing sale date	10 foot increase in exposed shoreline would reduce the average house price in Lake Almanor by 1%.

Michael (2007)	three communities along Chesapeake Bay, MD	standard hedonic model	SFR transactions from 1995 -2001 Elevation data was LIDAR sensor	sea level rise scenarios	Total inundation loss from two-foot sea level increase scenario ranges from $20,000 to $626,000 Total flood loss from two-foot sea level increase scenario ranges from just under $2 million to about $19 million
Phaneuf, Smith, Palmquist et al. (2008)	80 lakes within Wake Forest County, North Carolina	fixed effects hedonic model that combined stated and revealed preferences	26,000 SFH transactions from 1998 and 1999 household behavior: mail survey sent to 1,187 Wake water quality: from 12 separate sources	total suspended solids, total phosphorous, and dissolved oxygen recreation access index characterizes neighborhood according to driving time and water quality of lakes	30% increase in total phosphorus in the largest hydrologic unit is associated with an annual estimated loss of $16 and $19 per year.
Walsh, Milon, Scrogin, (2011)	1 km around 146 lakes in Orange County, Florida.	fixed effect spatial lag hedonic model	54,000 SFH sales 1996-2004 Orange County Environmental Protection-water quality division	secchi depth water clarity distance from property to lake (<=1km) waterfront indicator water area	1 unit increase in secchi depth is associated with 1.24% and .36% increase in average waterfront and non-waterfront sales prices respectively. A 10-fold increase in lake size is associated with an increase of about 20% in the water quality premium in waterfront properties.
Bin Poulter Dumas Whitehead (2011)	four counties New Hanover in North Carolina	spatial hedonic model	Assessed value of Oceanfront and estuarine-front sales 2004 Elevation data was LIDAR sensor	estimated sea level rise	residential property value losses 2030 and 2080 sea level rise is range from .07 percent -10 percent

Walsh, Milon, Scrogin, (2011)	1 km around 146 lakes in Orange County, Florida.	fixed effect spatial lag hedonic model	54,000 SFH sales 1996-2004 Orange County Environmental Protection-water quality division	secchi depth water clarity distance from property to lake (<=1km) waterfront indicator water area	1 unit increase in secchi depth is associated with 1.24% and .36% increase in average waterfront and non-waterfront sales prices respectively. A 10-fold increase in lake size is associated with an increase of about 20% in the water quality premium in waterfront properties.
Bin Poulter Dumas Whitehead (2011)	four counties New Hanover in North Carolina	spatial hedonic model	Assessd value of Oceanfront and estuarine-front sales 2004 High-resolution topographic light detection and ranging (LIDAR) data	estimated sea level rise	residential property value losses 2030 and 2080 sea level rise is: Dare County: 1.24 -9.45 % of the total assessed value New Hanover County: 0.07 -.44 % of the total Carteret County: 0.20-2.41 % of the total assessed value

Gopalkrishan, Smith, Slott, Murray (2011)	four counties—Bertie, Dare, Carteret, and New Hanover in North Carolina	2sls SARAR model corrects for beach width endogneity.	RSFR transactions 2004 - 2007 Beach width data NOAA National Geophysical Data Center	beach width	1 foot increase in beach width is associated with $8,800 increase in sales price among water front homes. This effect is more than five times the effect when beach width is assumed exogenous, as in most other studies.
(Landry and Hindsley, 2011)	Tybee Island Georgia	spatial hedonic model	373 transaction 1990-1999 USGS archival data on beach erosion	beach width distance to beach	Beach width significant for homes within 300m of beach edge. 1 meter of beach width high tide beach, sales price increases by $421-$487 and $272 to $465 on a low tide beach.
Neutsil Kincaid and Chang (2013)	Johnson Creek, Oregon, and Burnt Bridge Creek, Washington	hedonic model with district-level fixed effects	**Johnson Creek:** 10,479 SFH transaction from 2005-2008 Portland Bureau of Environmental Services **Brunt Bridge**: 5093 SFH transaction from 2005-2008	dissolved oxygen (DO), bacteria, pH, temperature, total suspended solids (TSS) distance dummies; 1/4mile (only Johnson);1/2mile;1 mile; >1mile	**Johnson Creek:** 1 mg/L increase in DO associated with 13.7% average increase in sales prices within ¼ mile of creek; a 3.12% increase in sales price for homes more than 1 mile from the creek. **Brunt Bridge:** 1 mg/L increase in DO associated with an 4.49% increase in sales price within ¼ mile of creek; a 3.17% increase in sales price for homes > 1 mile from the creek.
Bin and Czajkowski (2013)	Water front homes in Martin County, Florida	spatial error hedonic models with district-level fixed effect	510 SFH transactions from 2000-2004 Florida Oceanographic Society	Objective: temperature, pH, water clarity, salinity, and (DO) Composite: Florida Oceanographic Society's grade index	A 1% increase in water clarity, evaluated at the mean value, associated with $36,070 increase in mean property value. A .10-point increase in pH is associated with a $7,531 increase in mean property value A 1% increase in salinity is associated with a $31,938 increase in mean property values.

Yoo Simonit, Connors, Kinzig, Perrings (2012)	40 min driving time to 5 lakes within Prescott, AZ	spatial error hedonic model	8301 SFH transactions 2002-2005	sediment per lake acre driving time	1 unit increase in sedimentation is associated with .0023 % ($215) decrease in mean property values.
Tuttle and Heintzelman (2014)	52 lakes within Adirondack Park, NY	spatial lag model with waterbody-level fixed effects	12,001 SFH transactions from 2001-2009 Adirondack Lakes Survey National Lake Assessment Program	Eurasian water milfoil, pH, birds distance to the nearest lake waterfront indicator variable	A pH level below 6.5 associated with a 20% decrease in sales values A pH level below 6.5 associated with 23% decrease for waterfront parcels relative to lakes with known good pH.
Walsh, Milon, Scrogin, (2015)	1 km around 76 lakes in Orange County, Florida.	spatial error hedonic models	54,000 SFH sales 1996-2004 EPA: Storet database USGS	Total phosphorus (TP), Total nitrogen (TN Chlorophyll (CHLA) Florida's Trophic State Index (TSI)	A 1-unit increase in CHLA is associated with a 0.207 % decrease in property values and a 0.063 % decrease among waterfront homes only. TSI is associated with a .33 % increase in property values.

2.2 Summary of Results for Travel Cost Evaluation of Water Quality

Authors	Recreation type	Water quality measures	Location/ Water type/Trip behavior data	Method	Results
Hicks and Strand (2000)	Single-day beach trip during the season.	fecal coliform beach closure	***Chesapeake:*** 12 beaches along the western shore Chesapeake Bay beach Survey Maryland residents in 1984	Discrete Choice RUM with multinomial logit utility	*Unit Estimate:* Willingness to pay per trip for a 40 % reduction in 1 unit fecal coliform is $27.33 The welfare loss due to closure of Bay Ridge is $27.49.
Jakus, Dowell, & Murray (2000)	Single-day fishing trips per season	water levels	***Southeast:*** Tennessee River Recreational fishing data 1994- 1997	multinomial logit model with a double-hurdle count-data model	*Unit Estimate:* Willingness to Pay for full pool, or normal water conditions is $1.82 per angler per season. *Aggregate Welfare Estimate:* Aggregate benefit per season is $476,500.
McConnell and Tseng (2000)	single-day beach trip during the season.	fecal coliform	***Chesapeake:*** 12 beaches along the western shore Chesapeake Bay beach Survey Maryland residents in 1984	Random Parameters Logit (Mixed Logit) Model use full and sampled site alternatives.	*Unit Estimate:* Doubling fecal coliform yields a $1.12 loss per individual per trip for one site and $8.79 per individual per trip for all sites in the Chesapeake Bay.

Murray, Sohngen, Pendleton (2001)	single-day beach trips per season	EPA's The Index of	***Midwest:*** 15 Beaches Lake Erie, Ohio Onsite surveys summer of 1998.	RUM Poisson model	*Unit Estimate:* A one-unit reduction in beach advisories per year at all beaches is associated with a $28 gain in welfare per person per season. *Aggregate Welfare Estimate* This yields an aggregate welfare benefit of $227,598 per beach per year.
Phaneuf (2002)	single-day visits per season	EPA's Index of Watershed Indicators ammonia, acidity (pH), phosphorous, and dissolved oxygen	***Southeast:*** 58 watersheds in North Carolina (California Department of Health Services) National Demand for Water-Based Recreation Survey 1994	RUM model multinomial logistic utility function	*Unit Estimate:* The welfare effects of individual watershed-level quality improvements produced a mean willingness to pay across all watersheds of $0.17 per trip. *Aggregate Welfare Estimate:* A 10% reduction in IWI across all watersheds resulted in a $100.84–342.95 million benefit.
Lipton and Hicks (2003)	single-day fishing trips per season	dissolved oxygen (DO)	***Chesapeake:*** Patuxent River in Chesapeake Bay Recreational Fisheries Statistics Survey (MRFSS) 1999	Poisson model linking catch rate to DO levels RUM model, multinomial logistic utility function.	*Unit Estimate:* DO levels <= 3 mg l_1, $0.012 loss per trip *Aggregate Welfare Estimate*: $9,775 annual loss

Phaneuf and Siderlis (2003)	single day visits per season	EPA's Index of Watershed Indicators	***Southeast:*** Water trails in eastern North Carolina Survey of visiting behavior of paddlers in year 2000	Multi-site Kuhn Tucker Model nested log-likelihood demand function	*Unit Estimate:* The willingness to pay for improved water quality such that IWI index value is at least 2 at all paddling sites is \$24.44 per visitor per season.
Von Haefen, Phaneuf, and Parsons (2004)	Single-day beach trip during the season.	Beach erosion due to sea level rise Beach closures	***Mid-Atlantic:*** 62 Beaches NJ, DE, MD, VA Survey of recreation trips from Delaware residents in 1997	Random parameter (mixed) logit log-likelihood demand function Single and double hurdle repeated discrete choice models	*Unit Estimate:* Individual welfare loss with erosion at all developed beaches in DE and MD ranges from \$35 to \$54 per season per person. *Aggregate Welfare Estimate*:Losses associated with erosion at all developed beaches in DE and MD are \$20.1 million per season. *Unit Estimate:* Welfare loss from closure of Rehoboth Beach,DE \$83-\$57 per season per person. *Aggregate Welfare Estimate:* Aggregate loss of \$33.1 million per season.

Massey, Newbold, and Gentner (2006)	single-day fishing trips per season	DO, water temp, salinity, secchi	***Mid-Atlantic:*** 4 coastal bays in Maryland MD DNR Angler Survey2002	Use Structural equation model to evaluate fish abundance, flounder catch rates, and demand as a function of long run effects of changes in water quality repeated choice mixed logit model	Unit Estimate: Increase in catch rate by approximately one fish increases the value of a choice occasion by $4.22. *Aggregate Welfare Estimate:* Predicted aggregate welfare change of $1.9 million per year from increasing the average catch per trip in the study area by 50%.
Egan, Herringes, Kling, & Downing (2009)	single day visits per season	Secchi, chlorophyll, nutrients (total nitrogen and total phosphorus), suspended solids (inorganic and organic), and bacteria (cyanobacteria and total phytoplankton).	***Midwest:*** Iowa's 129 principal lakes 2002 Iowa Lakes Survey of trip visits in year 2002	Repeated Mixed logit Model	*Unit Estimate:* The benefit of improvement of all lakes to meet high water quality standards is $153 per household. *Unit Estimate:* The benefit of improvement in 9 lakes with high quality standards is $19 per household *Unit Estimate:* The benefit of improvement in 65 lakes to min quality $11 per household.

Whitehead, Poulter, Dumas, Bin (2009)	Marine recreational shore fishing day trips per season	Beach erosion due to rea level rise Beach closure	***Southeast:*** 2005 and 2006 National Marine Fisheries Service (NMFS) recreational fishing data for North Carolina	RUM model nested multinomial logit utility function.	*Unit Estimate:* WTP per trip from an increase in beach width of 10 meters is $2.97. *Unit Estimate:* The mean change in WTP per trip with reduced beach width in 2030-2080 is $8.54 -$9.39 *Aggregate Estimate:* WTP to prevent loss is $33 million in 2030 and $36 million in 2080.
Pendleton, Mohn, Vaughn, King, Zoulas, 2012	single-day beach trip beach activities: 1)activities in water, sand, paved trails and restaurant	Beach erosion due to sea level rise	***Pacific West:*** 51 beaches on the Southern CA coastline Survey of panelists beach visitation behavior every 2 months from Dec99-Dec00	RUM model with nested logit multinomial utility function	*Unit Estimate:* The value of a beach trip in California is just over $100. *Aggregate Welfare Estimate:* Increase in beach width is about $3.1 million in consumer surplus per year.

2.3 Summary of Results for Contingent Valuation of Water Quality

Authors	Location	Method	Data	Good Being Measured	Main Results
Loomis, Kent Strange Fausch Covich, 2000	Platte river, Denver Fort Collins, CO	Qualitative choice logit model	Survey of household in the South Platte river basin, 1998 41% response rate 96 accepted interviews	Increase in household monthly water bill to purchase water and 300, 000 acres of conservation easements along the river.	*Unit estimate:* Mean monthly WTP per household was $21 per month; $252 annually Individual benefit/cost ratio: 5.22 *Aggregate estimate:* $19 million annually
Loomis (2000)	Lower Snake River, Washington	Negative binomial count data model Dependent variable: Number of trips to sight	Survey of 18 counties within 150 miles of River, and 6 nearest states. 43.5% response rate 4350 completed surveys	Number of Trips Taken to River if Damns removed 225km of River restored	*Aggregate estimate:* $310 Million benefit gain per season among potential visitors (J. B. Loomis, 2000)
Eiswerth, Englin, Fadali, and Shaw (2000)	Lake Walker, Nevanda	Pooled Poisson with stated and revealed preference data	USGS 1996 survey of local residents USGS	Number of Trips Taken to Lake under varying water levels	*Unit estimate:* $12 to $18 loss per person per season among visitors *Aggregate* WTP to maintain water: $1.98 million to $2.79 million
(Stumborg, 2001)	Lake Mendota, Wisconsin	Censored dependent variable (tobit) model	Survey of Dane County 1998 193 resident survey 44% response rate	Annual WTP for obtaining 50% reduction in nutrients.	*Unit estimate:* mean monthly WTP $354 *Aggregate estimate:* $43.9 million

Carson, Mitchell, Hanemann, Kopp, Presser, Rudd (2003)	Exxon Valdez Oil Spill Prince William Sound Alaska	Dichotomous choice model	1200 household surveys in US, 1998 75% response rate	WTP one time federal tax increase for Prince William Sound Protection Fund.	*Unit estimate:* Mean payment of $53.60 Aggregate estimate: $7.19 billion
Bell, Huppert, and Johnson (2003)	Oregon and Washington 5 rural coastal communities	RUM model program	1 ,771 completed survey Mean response rate of 50%	WTP for expensive high enhancement program that allows fishing WTP for inexpensive low enhancement program precludes fishing	*Unit estimate:* WTP estimate for high enhancement was $116 versus $119 dollars for low enhancement
Holmes,Bergstrom, Huszar, Kask, Orr (2004)	Little Tennessee River (LTR) , North Carolina	Random utility model	96 surveys from focus group of local civic service groups,2003 0.7% of the households in the Macon County	Increase in sales tax for 6,4,2 miles of riparian restoration	*Unit estimate:* Benefit/cost ratio: 4.03 (for 2 miles of restoration) 15.65 (for 6 miles of restoration) Household benefits per mile $4.54 for full restoration of the LTR
Lew and Lewis (2014)	Southeast and Southcentral Alaska	Choice Experiment RUM model	Survey of people purchased sport fishing license in 2006 1115 nonresident surveys 435 Southeast Alaska residents 547 Southcentral Alaska residents	WTP for trips and without bag limits	*Unit estimate:* WTP for trips with bag limit range from $248 to $284 WTP for trips with/out bag limit range from $313-$385

Chapter 3: A Spatial Hedonic Analysis of the Salton Sea in California

INTRODUCTION

A number of waterbodies in arid and semi-arid regions around the world are threatened by persistent drought, water diversion projects, and polluted inflows. The Aral and Caspian Seas in Central Asia, which are among the largest inland waterbodies in the world, have drastically declined in recent decades (Gill, 1996). Similarly, Ebinur and Lop Nur in Northwest China are quickly shrinking (Abuduwaili, Liu, & Wu, 2010; Mu *et al.*, 2002; Prospero *et al.*, 2002), while Poyang Lake, which was China's largest fresh water lake, is completely desiccated. In the Middle East, Lake Urmia (Hoseinpour, Fakheri Fard, & Naghili, 2010), the Tigris-Euphrates River Basin, and the Dead Sea, are a fraction of their former size (Prospero *et al.*, 2002).

Dropping lake levels in arid or semi-arid regions are also often associated with increases in regional air pollution, as exposed lake beds often consist of salt-rich sediments that are vulnerable to wind erosion and, ultimately, the production of hazardous salt-dust (Abuduwaili *et al.*, 2010; Mu *et al.*, 2002; Yang *et al.*, 2008).Moreover, in many cases scarce water resources are impaired by agricultural runoff. Although a number of papers in ecology (e.g, see Grimm *et al.*, 2013; Indoitu *et al.*, 2015; Velasco & Millan, 1998) analyze the implications of deteriorating water quality and quantity on living organisms and the environment, much less is known about the economic implications of these deteriorations.

Relatively few studies in the hedonic literature have examined the influence of water quality on home values (Bin & Czajkowski, 2013), and few consider severely impaired waterbodies. By contrast, many hedonic papers have analyzed mildly impaired rivers, lakes, and coastal areas, where proximity to water confers a positive premium to residential properties and different levels of water quality simply affect the magnitude of that premium. The dearth of hedonic studies analyzing waterbodies that are a *disamenity* is noteworthy given that environmental deterioration due to urban or agricultural runoff is a leading cause of impairment in freshwater and coastal marine ecosystems around the world. Such deterioration often results in ecological and health hazards (Novotny, 1999).

In this study, I estimate spatial hedonic models to jointly examine how deteriorating water quality, falling water levels, and the associated decline in air quality are capitalized in the residential real estate market around the Salton Sea, which is California's largest inland lake. Unlike some of the desert waterbodies mentioned above, irrigation contributes to increasing the water level of the Salton Sea via runoff. However, this runoff contains high levels of salt, which over time has caused algal blooms followed by massive fish kills and noxious smells. Increases in salt concentration have accelerated after a decrease in irrigation due to decreasing water levels, which due to transfers of water from local farmers, and subsequently the Sea, to thirsty coastal California cities. My starting hypothesis is that the Salton Sea is negatively capitalized in residential real estate values because it has become a major environmental liability.

This paper makes several contributions. First, although the identification of sources of dust storms, such as shrinking lakes, has been an important area of research (e.g., see Furman, 2003; Goudie, 2009; Sokolik & Toon, 1996),I know of no published hedonic study that jointly examines drying lakes of deteriorating water quality combined with and their associated air quality impacts. Second, my analyses are not restricted to waterfront properties since severely degraded water quality affects regional recreational opportunities and thereby the regional housing market, not just the value of waterfront homes. Furthermore, in cases of disamentiy, distance effect extends to homes located away from the site, since it is anticipated that these properties will have a higher sales value than those located adjacent to the site. Third, since during the period I analyze (2009-2013) the housing market around the Salton Sea was deeply affected by the Great Recession, I pay special attention to distressed properties whereas previous water quality studies mostly avoid such markets. Finally, I use state-of-the-art spatial econometric techniques to capture spatial dependence in the presence of heteroskedasticity.

BACKGROUND

LITERATURE REVIEW

The hedonic literature dealing with the impacts of waterbodies on housing markets dates back several decades (e.g., see David, 1968; Epp & Al-Ani, 1979; Michael, Boyle, & Bouchard, 1996). Different strands of that literature are particularly germane here.

Measuring Water Quality

The first strand involves the proper measurement of water quality. Poor *et al.* (2001) formally test the performance of different water quality indicators by comparing objective scientific measures (e.g., Secchi disk readings) with subjective measures obtained from surveys of local homeowners. Their results indicate that improved water quality is positively capitalized in property values for both types of measures, but objective indicators of clarity are better predictors of sale prices. Both Bin and Czajkowski (2013) and Walsh and Milon (2015) evaluate the performance of water quality measures by comparing singular and composite indicators of objective measures of water quality but they obtain different results: Bin and Czajkowski (2013) find that singular measures outperform more user friendly composite indexes whereas Walsh and Milon's (2015) models with composite measures yield more consistent and interpretable results.

Water clarity (typically summarized by a single index) is another widely used measure because it is believed to be readily observable and many studies demonstrate that water clarity is positively capitalized in property values (Michael *et al.*, 1996; Michael, Boyle, & Bouchard, 2000; Poor *et al.*, 2001; Walsh, Milon, & Scrogin, 2011). However, Artell (2014) notes that water clarity varies with the type of waterbody and does not adequately reflect ecological benefits as clearer water does not necessarily improve recreational activities, nor is it consistently beneficial to wildlife (Artell, 2014; Walsh and Milon; 2015, Leggett and Bockstael, 2000).

The Spatial Extent of the Impact of Water Quality

Another strand of the literature questions the spatial extent of the impact of water quality changes on property values. Until recently, many hedonic studies on water quality limited their analyses to waterfront properties (Artell, 2014; Bin & Czajkowski, 2013; David, 1968; Epp & Al-Ani, 1979; Gibbs *et al.*, 2002; Horsch & Lewis, 2009; Leggett & Bockstael, 2000; Michael *et al.*, 1996; Poor *et al.*, 2001, 2007; Steinnes, 1992; Vesterinen *et al.*, 2010). However, several papers demonstrate that proximity to a waterbody can boost property values beyond a few thousand feet (Lansford Jr & Jones, 1995; Netusil, Kincaid, & Chang, 2014; Phaneuf *et al.* (2008; Tuttle & Heintzelman, 2015; Walsh *et al.*, 2011).

The Value of Proximity to a Waterbody

Most published hedonic studies dealing with the impact of waterbodies on housing markets, from older papers that do not account for structural characteristics (e.g., see David, 1968; Epp & Al-

Ani, 1979; or Michael *et al.*, 1996) to more recent papers that model spatial dependence (Cho, Bowker, & Park, 2006; Leggett & Bockstael, 2000), report that proximity to a waterbody boosts the value of residential properties.

The generality of this finding is questionable, however, given that the water quality of many lakes and rivers around the world has been seriously impaired. One explanation is that the hedonic literature mostly focuses on healthy waterbodies in reasonably affluent communities, thereby neglecting severely polluted lakes and rivers that are often bordered by distressed housing markets.

One notable exception is Lewis & Acharya's (2006) study of the Quinnipiac River watershed (located in New Haven County, Connecticut), which counts eleven landfills, eight sewage treatment plants, and three raw sewage holding areas. Unsurprisingly, their results show that proximity to the river lowers property values, making the heavily polluted Quinnipiac River a clear disamenity.

Hedonic Studies with Foreclosed Properties

Most hedonic water quality studies have avoided major real estate crises. Two recent exceptions include Netusil *et al.* (2014) and Tuttle and Heintzelman (2014), who both analyze housing transactions that took place during the Great Recession. While Netusil *et al.* (2014) included in their models binary variables for different time periods, Tuttle and Heintzelman (2014) added a variable that indicates whether a transaction took place before or after 2006. However, Coulson and Zabel (2013) argue that during a boom and bust period, a housing market may not be in long term equilibrium. Moreover, if the percentage of foreclosures is high, the housing market is likely composed of two distinct submarkets, one for distressed properties and the other for non-distressed properties. A property is deemed “distressed” if its sale occurred under foreclosure order or if it was advertised for sale by a mortgage lender.

Since distressed properties typically sell at a discount (e.g., see Harding, Rosenblatt, and Yao, 2012), a number of earlier hedonic studies simply allowed for a different intercept for distressed properties (e.g., see Forgey, Rutherford, & VanBuskirk, 1994; Shilling, Benjamin, & Sirmans, 1990; or William & Marvin, 1996). This approach, however, assumes that attribute prices are the same for distressed and non-distressed properties, which is unlikely since foreclosed properties are generally not well maintained (e.g., see Harding, Rosenblatt, and Yao, 2012).

Several papers also show that the price of foreclosed properties impacts the price of nearby properties (Daneshvary and Clauretie, 2012; Harding, Rosenblatt, and Yao, 2009; Gerardi *et al.*, 2012, Immergluck and Smith, 2005, 2006). Daneshvary and Clauretie’s analysis (2012) is of particular interest because it examines transactions of single family properties that took place from January 2008 to June 2009 in Las Vegas, Nevada, which had among the highest rate of foreclosures in the country during the recession. Using a Spatial Autoregressive Model with Autoregressive Disturbances (SARAR) model estimated via Generalized Spatial Two Stage Least Squares (GS2SLS), they find that no-default homes that sell up to 6 months after the sale of a foreclosed neighbor suffer a cumulative spillover loss of approximately 10%.

Water Levels and Air Quality

This chapter also departs from the rest of the hedonic literature on water quality in that I account for air quality impacts (i.e., increased particulate matter concentration) of exposed, dusty shores resulting from falling water levels. Reviews of air quality studies suggest that reductions in air pollution are consistently and positively associated with real estate values (Smith & Huang, 1993, 1995). Recent air quality hedonic studies that account for spatial effects find that reductions in particulate matter concentrations are factored positively in property values (Anselin & Lozano-Gracia, 2008; Carriazo, Ready, & Shortle, 2013; Fernandez-Aviles, Minguez, & Montero, 2012; Graves, 2014; Kim, Phipps, & Anselin, 2003).

Some Implications

Based on the papers I reviewed and on my knowledge of the Salton Sea area (discussed below),I analyze properties located within 10 miles from the Sea shore. I consider a broad range of water quality measures but also particulate matter (PM) concentration because the exposed shores of the Salton Sea are likely an important source of regional PM. More specifically, I model PM_{10}, which is a mixture of extremely small particles and liquid droplets less than 10 micrometers in diameter. I estimate spatial hedonic models because a number of recent hedonic water quality papers report spatial autocorrelation (e.g., see Walsh *et al.*, 2011; Yoo *et al.*, 2012; Bin and Czajkowski, 2013; Neutsil *et al*., 2013; Tuttle and Heintzelman, 2014; Walsh and Milon, 2015).

BACKGROUND ON THE SALTON SEA

The Salton Sea is located approximately 150 miles southeast from downtown Los Angeles, between Imperial Valley and Coachella Valley (Figure 2.1), which are among California's most productive agricultural regions (Palerm, 2003). Geological history indicates that the Salton Sea Basin has alternated between dry lake bed and fresh water lake (ancient Lake Cahuilla), depending upon the ebbs and flows of the Colorado River (McClurg, 1994). The most recent incarnation of the Salton Sea was created in 1905 when flows from the Colorado River broke through diversion canals and discharged for 16 months into the then dry Salton Sink (Gill, 1996), creating what is now California's largest lake. Soon after its reappearance, the Sea quickly attracted desert dwellers seeking a water playground in the middle of the desert.

During the 1950s and 1960s, the Sea's reputation attracted developers who turned the area into a major touristic destination. However, debilitating floods in the 1970s wiped out crucial infrastructure and ultimately devastated the local economy (Gill, 1996; Nakata, Wilshire, & Barnes, 1976). In recent decades the population around the Salton Sea has grown rapidly with the arrival of migrant agricultural workers, primarily from Mexico, and their families. Many of these families purchased and refurbished dilapidated single family homes and permanently settled in the region (Palerm, 2003).I note that several towns near the Sea (Salton Sea Beach, Bombay Beach, Niland, and Brawley) are federally designated Colonias - rural communities within the US-Mexico border region that lack adequate water, sewer, or decent housing, or a combination of all three (Collins, 2010; Donelson & Esparza, 2010).

Despite its economic woes, the Sea has remained biologically important. Over 400 bird species visit the area during migration (California Department of Fish and Wildlife, 2015), as it is one of the last wetlands along the pacific flyway. However, falling water levels and rising salinity threaten its ecological vitality. Currently the Sea is 50 percent saltier than the ocean due to years of inflows from surrounding farmland and wastewater discharges (Gill, 1996; McClurg, 1994). High nutrient levels have led to growth in aquatic plant life and subsequent depletion of dissolved oxygen that led to seasonal fish and bird die-offs, and sulfur smells.

Salt concentration will further increase after 2018 because of the 2003 Colorado River Quantification Settlement Agreement, which mandates water transfers from Imperial Valley's agricultural land to coastal cities and reduces agricultural irrigation flows that have been feeding the Sea. Dropping water levels will also exacerbate the already high levels of wind-borne dust within the Salton Sea air basin, which have been linked to high rates of childhood asthma in

California (Quintero-Nufiez & Sweedler, 2004). Similar health conditions exist near other drying saline lakes such as the Aral Sea (Wiggs *et al.*, 2003). If the Sea dries up, the high levels of arsenic, selenium, and pesticides within its bed are likely to further impair respiratory health in the region (LeBlanc & Schroeder, 2008).

Although California has agreed to mitigate increasing dust concentrations, there has been no serious effort to control dust in the region or to improve the Sea's deteriorating water quality. Over the last three decades, at least 23 restoration plans have been proposed (Chebium, 2014), but none has been implemented due to their high costs. As a result, the environmental and socio-economic conditions of the region are worsening. The State of California acknowledges the environmental degradation of the Sea but persistent drought in the Southwest impair the scope of restoration plans (Barringernov, 2014; Ralston, 2015) and limit the probability that restorative efforts will be undertaken in the near future.

DATA

As shown on Figure 2.1, the Salton Sea is split over two counties: Imperial and Riverside. For my study area,I selected a 10 mile buffer around the Sea. This buffer, which corresponds to the area analyzed by the Salton Sea Authority (a joint powers coalition of government officials from Imperial and Riverside counties) in its 2005 economics and recreation opportunities assessment report, encompasses facilities such as campgrounds, off-road vehicle trails, hiking trails, hunting grounds, marinas, and wildlife refuges. As homes in this region have easy access to the Salton Sea and related recreational facilities, I hypothesized that the Salton Sea impacts the value of these properties not only by the recreational opportunities it provides but also via the strong smells it occasionally generates and the dust from its exposed shores (Buck, King, & Etyemezian, 2011;

King *et al.,* 2011).We analyzed single family detached houses because it is the main segment of the regional housing market.

Housing prices and structural characteristic data for Riverside County were purchased from DataQuick, a real estate data firm. Most of the information on single family residences (SFR) for Imperial County came from the Imperial County Assessor Office because Dataquick only had limited housing information for Imperial County. There are 4,597 (Riverside 1,141, Imperial 3,456) single family residences within 10 miles of the Salton Sea. I was able to recover full structural information for only percent (53 percent) of Imperial county observations for two reasons: first, the Imperial County Assessor's office did not maintain electronic records before 2005, so structural information is not available for most SFR that were not transacted after 2005; and second, the Imperial County Assessor's office does not require field assessors to record the number of bathrooms or bedrooms.

An exploration of the incomplete observations shows that, on average, they sold for $7,000 less their complete transactions; 23 percent of these incomplete transactions were located in Calipatria, versus only 4 percent of complete observations. Note that the majority of homes located in and around Calipatria are in within Riverside County, so they were not affected by problems in the Imperial County Assessor's office. Moreover, 64 percent of incomplete observations (like the complete ones) clustered near the Salton Sea.

The situation is better in Riverside County, where 85 percent (977) of observations had full information. Overall, my dataset has 2,225 SFR observations with structural characteristics. Extracting observations with plausible structural characteristics that were sold after 2008 gave 860 observations. Figure 1 shows the geographical locations of these transactions and Table I presents summary statistics for the variables used in my analyses.

We were able to recover full structural information for only 36 percent (1,248) of Imperial county observations for two reasons: first, the Imperial County Assessor's office did not maintain electronic records before 2005, so structural information is not available for most SFR that were not transacted after 2005; and second, the Imperial County Assessor's office does not require field assessors to record the number of bathrooms or bedrooms. The situation is better in Riverside County, where 85 percent (977) of observations had full information. Overall, my dataset has 2,225 SFR observations with structural characteristics. Extracting observations with plausible structural characteristics that were sold after 2008 gave 860 observations. Only 31 percent of home sales data for Imperial County were usable because the Imperial County Assessor's office does not require field assessors to record the number of bathrooms or bedrooms. Data quality was better in Riverside County, where 80 percent of observations came with full information. Extracting observations with plausible structural characteristics that were sold between 2008 and 2013 reduced my dataset from 2,225 to 860 observations. Figure 2.1 shows the geographical locations of these transactions.

To represent water clarity, I used secchi disk readings because they are the most widely used water quality measures in the literature as they are often construed as gauges of a lake's aesthetic appeal (Boyle & Kiel, 2001; Phaneuf *et al.*, 2008; Poor *et al.*, 2001; Walsh *et al.*, 2011). Seechi disk readings, which are collected every three months, were obtained from the US Bureau of Reclamation (Holdren, 2013). In my models, I assigned the average quarterly secchi disk reading corresponding to the quarter of sale of each property in my sample.

Although salinity is among the most publicized environmental problem facing the Sea as one of the factors responsible for fish kills, I could not use this metric because the USGS only had very incomplete salinity data for my study period.

We also included in my models measures of average quarterly water level of the Salton Sea, which are publicly available from the Westmoreland station operated by the United States Geological Services (USGS).

To represent airborne dust in the region, I obtained PM_{10} readings for the Salton Sea Basin from the California Air Resource Board (ARB). Only four air monitoring stations (see Figure 2.1) are reasonably close to the Salton Sea. ARB gave us measures of PM_{10} concentrations approximately every sixth day from 2009 to 2013, for a total of approximately 300 observations per station. I averaged them over each quarter and assigned each observation in my sample a value calculated using inverse distance weighting for the quarter of its sale (Lu & Wong, 2008; Zimmerman *et al.*, 1999).I preferred this method to alternatives such as Kriging or Thiessen polygons because of the small number of air monitoring stations in my study area.

Odors from fish kills and from the daily decay of various marine organisms are another nuisance associated with the Salton Sea. Unfortunately, neither hydrogen sulfide (one of the most noticeable gases resulting from organism decay) nor fish kill data were available for my study period.

Finally, I used ArcGIS, a well-known geographic information system (GIS) to calculate the straight line distance from each property to the Sea. I created distance bands to explore the potential impact of proximity to the Sea on property values.

Summary statistics for the variables considered are presented in Table 3.1. They show reasonable variations for the variables considered.

METHODS

Overview

In the standard hedonic framework (Rosen, 1974), a hedonic price model applied to an environmental problem via the housing market can typically be written:

$$\mathbf{P} = f(\mathbf{S}, \mathbf{N}, \mathbf{E}, \boldsymbol{\varepsilon}), \tag{3.1}$$

where **P** is a vector of housing prices; **S**, **N**, and **E** are respectively matrices of structural, neighborhood, and environmental variables; and **ε** is a vector of error terms. The partial derivative of f with respect to explanatory variable j is an implicit price that represents the marginal willingness to pay for the characteristic it represents.

The classical hedonic framework analyzed by Rosen (1974) requires stringent idealized conditions to hold, including market equilibrium with perfect competition, perfect information for buyers and sellers, and a continuum of products. However, Benkard and Bajari (2005) proved that the hedonic pricing method is still valid when competition is imperfect, there is no continuity of products, and not all product characteristics are observable, which is often the case in housing markets. Moreover, Bajari and Benkard (2005, p. 1241) showed that if demand is given by the hedonic model then there exists a hedonic price function.

Another potential problem is the high percentage (60%) of distressed properties in my sample. Coulson and Zabel (2013) argue that a real estate market with a high percentage of foreclosed properties may not be in long-term equilibrium. Moreover, such a market is likely to be composed of two submarkets - one with and the other without foreclosed properties – with different buyers operating in each submarket, which suggests a different hedonic price function across these two submarkets. Indeed, because of their owners' precarious finances, distressed properties are often in poorer physical condition than non-distressed properties, so implicit prices for the structural characteristics of the latter likely differ from those of the former (Harding, Rosenblatt, & Yao, 2012). In this context, Coulson and Zabel (2013) recommend adding a separate intercept and interaction terms to allow for different hedonic prices for distressed properties, and to model spatial price interactions, which is the strategy adopted here.

Structural characteristics in my models include the square footage of the lot and of the structure it supports, the number of bedrooms and bathrooms, and the age of a property. Since the inclusion of a number of interaction terms may lead to multicollinearity among explanatory variables, I calculated variance inflation factors (VIF) to detect that problem. Several remedies can be adopted to deal with multicollinearity (Kennedy, 2008): 1) if mild (which is not the case here), multicollinearity can simply be ignored; 2) more data can be collected (which is not possible here); 3) a different estimator (such as a Ridge regression instead of OLS for linear regression) could be used (no easy solution appears available here); or 4) variables with high VIF values (here, above 10) can be removed from the model, which is the approach adopted here.

My neighborhood variables include a binary variable that indicates if a home is in Riverside or in Imperial County. Other standard neighborhood variables (e.g. school quality, crime rates) are not included because the impact of locally constant neighborhood variables is captured by spatial interaction terms (see below). To control for temporal variations, my models include year and season indicator variables.

My environmental variables include proximity to the Sea, Secchi disk readings, and water and PM_{10} levels. Environmental variables assigned to a property characterize the quarter-year in which the property was sold.

To select an appropriate functional form, I conducted a graphical exploration and selected a functional form where the dependent variable and most explanatory variables are log-transformed.

SPATIAL DEPENDENCE AND MODEL

In linear regression models, omitting an explanatory variable that is correlated with one or more explanatory variables results in biased and inconsistent estimates (Kennedy, 2008). Omitted variables in hedonic studies are often location-specific factors, such as school quality or crime rate. Furthermore, it is well known that housing values are influenced by nearby properties and hence susceptible to spatial interactions; ignoring this spatial dependence may lead to biased and inconsistent estimators (Anselin & Arribas-Bel, 2013). In my models, I accounted for spatial dependence but I did not include location specific variables such as the ones mentioned above because they are captured by spatial interactions.

To detect the presence of spatial autocorrelation, I used Moran's I statistic (Cliff & Ord, 1981), which confirmed ($p<0.01$) the presence of spatial autocorrelation in the logarithm of sale prices for the different weight matrices considered and for distance bands ranging from 1.62 km to 3.0 km. Empirical results from a Moran's I correlogram, suggest that spatial dependence of sales price suggested that spatial effects were statistically significant within this range. Results for a single weight matrix are presented in Table 3.2 for brevity. Following Anselin & Le Gallo (2006), I then performed Lagrange multiplier (LM) tests for spatial lags and for spatial errors. Both tests yielded highly significant results ($p<0.01$) suggesting that both spatial error and spatial lag may be useful for explaining price variations, which was further confirmed by results from Robust Lagrange Multiplier tests.

Let n designate sample size and q the number of explanatory variables including a constant term. In matrix form, the Spatial Autoregressive Model with Autoregressive Disturbances (SARAR model) I considered can be written:

$$\begin{cases} \log(\mathbf{P}) = \lambda \mathbf{W} \log(\mathbf{P}) + \mathbf{X\beta} + \mathbf{u}, \\ \mathbf{u} = \rho \mathbf{W u} + \boldsymbol{\varepsilon}, \end{cases} \tag{3.2}$$

where:

- **P** is an $n \times 1$ vector of single family residential property prices;
- λ and ρ ($|\rho|<1$, $|\lambda|<1$) are respectively unknown spatial lag and spatial error parameters;
- **W** is an $n \times n$ spatial weight matrix, which reflects spatial interactions;
- **X** is an $n \times q$ matrix of exogenous explanatory variables;
- $\boldsymbol{\beta}$ is a $q \times 1$ vector of unknown coefficients;
- **u** is an $n \times 1$ vector of correlated residuals; and
- $\boldsymbol{\varepsilon}$ is an $n \times 1$ vector of independently distributed errors with zero mean.

When ρ=0, Equation (3.2) reduces to a spatial lag model and when λ=0, it becomes a spatial error model; setting both λ and ρ to 0 yields a simple linear regression model. In Equation (3.2), the term $\lambda \mathbf{W} \log(\mathbf{P})$ reflects the impact of prices of neighboring properties and accounts for locally constant omitted variables, while **u** captures residual spatial autocorrelation.

We estimated my SARAR model using both Maximum Likelihood (ML) and generalized spatial two-stage least squares (GS2SLS) because ML estimation can lead to inconsistent estimators when errors are heteroskedastic (Arraiz *et al.*, 2010a-b). In contrast, the GS2SLS estimator proposed by Arraiz *et al.* (2010), which uses the generalized-method-of-moments and instrumental variables, yields consistent parameter estimates (λ, $\boldsymbol{\beta}$, and ρ in Equation (3.2)) even in the presence of heteroskedastic errors. I compare estimates from both methods in the Results.

WEIGHT MATRIX

Since spatial hedonic results depend on the spatial weights matrix **W**, I considered several common weight matrices. My starting weight matrix was obtained by calculating off diagonals terms from $w_{ij} = (d_{ij} / b)^{-2}$ for $d_{ij} \le b$ and 0 otherwise, where d_{ij} is the straight line distance between properties *i* and *j*; and *d*=2.25 km is the bandwidth parameter that corresponds to the peak value from Moran's I correlogram for property prices in my sample. Since the weight matrix **W** captures spatial interactions with nearby properties and a property does not spatially interact with its own selling price, the diagonal terms of **W**are 0.I normalized the rows of **W** to sum to 1 to facilitate the interpretation of results. In my dataset, no two distinct observations were in the same location, so $d_{ij}>0$ for $i \neq j$.

To assess the robustness of my results, I repeated my analyses with four other weight matrices where, before row standardization, off-diagonal weights are given by $w_{ij} = (d_{ij} / b)^{-3}$ $w_{ij} = \exp((d_{ij} / b)^{-2})$, $\mathrm{w}_{ij} = (1 + (d_{ij} / b)^{2})^{-1}$, and $\mathrm{w}_{ij} = (1 + (d_{ij} / b)^{3})^{-1}$ for $d_{ij} \le b$ and 0 otherwise.

INTERPRETING RESULTS

Interpreting the results from a SARAR model is more involved than interpreting results from a simple linear regression because of the spatial lag term $\lambda \mathbf{W} \log(\mathbf{P})$. To better understand this term, let us expand $\mathbf{V} \equiv (\mathbf{I} - \lambda \mathbf{W})^{-1}$, which occurs from isolating $\log(\mathbf{P})$ on the left side of Equation (3.2) (**I** is the N×N identity matrix), as follows:

$$\mathbf{V} \equiv (\mathbf{I} - \lambda \mathbf{W})^{-1} = \mathbf{I} + \lambda \mathbf{W} + \lambda^2 \mathbf{W}^2 + \ldots \tag{3.3}$$

This expression is well defined when $|\lambda| < 1$ because **W** is a row-normalized matrix and the product of row-normalized matrices is row normalized. Hence, Equation (3.2) becomes:

$$\begin{cases} \log(\mathbf{P}) = \mathbf{X\beta} + \lambda\mathbf{WX\beta} + \lambda^2\mathbf{W}^2\mathbf{X\beta} + \lambda^3\mathbf{W}^3\mathbf{X\beta} + ... + \boldsymbol{\omega}, \\ \boldsymbol{\omega} \equiv (\mathbf{I} - \lambda\mathbf{W})^{-1}(\mathbf{I} - \rho\mathbf{W})^{-1}\boldsymbol{\varepsilon}. \end{cases} \tag{3.4}$$

Recalling that E($\boldsymbol{\omega}$)=0, the first equation of (3.4) shows that the expected value of the log of the rent of a property equals a mean value $\mathbf{X\beta}$ plus a linear combination of mean values taken by neighboring properties (the terms $[\lambda\mathbf{W} + \lambda^2\mathbf{W}^2 + \lambda^3\mathbf{W}^3 + ...]\mathbf{X\beta}$.) To better understand these impacts, let us expand $\log(\mathbf{P}) = \mathbf{V}(\mathbf{X\beta} + \mathbf{u}) = \mathbf{VX\beta} + \boldsymbol{\omega}$ as follows (LeSage and Pace, 2009):

$$\begin{pmatrix} \log(P_1) \\ \log(P_2) \\ \vdots \\ \log(P_N) \end{pmatrix} = \mathbf{V}\begin{pmatrix} \beta_0 \\ \beta_0 \\ \vdots \\ \beta_0 \end{pmatrix} + \sum_{q=1}^{Q-1} \beta_q \begin{pmatrix} \mathbf{V}_{11} & \mathbf{V}_{12} & \cdots & \mathbf{V}_{1N} \\ \mathbf{V}_{21} & \mathbf{V}_{22} & \cdots & \mathbf{V}_{2N} \\ \vdots & \vdots & \vdots & \vdots \\ \mathbf{V}_{N1} & \mathbf{V}_{N2} & \cdots & \mathbf{V}_{NN} \end{pmatrix}\begin{pmatrix} \mathbf{X}_{1q} \\ \mathbf{X}_{2q} \\ \vdots \\ \mathbf{X}_{Nq} \end{pmatrix} + \boldsymbol{\omega}, \tag{3.5}$$

where for $(i,j)\in\{1,\ldots,\text{N}\}^2$ and for $q\in\{1,\ldots,Q\text{-}1\}$, $\log(P_j)$ is the logarithm of the price of the j^{th} property; $\mathbf{V}_{\text{ij}}$ is the i^{th} line and j^{th} column element of $\mathbf{V} \equiv (\mathbf{I} - \lambda\mathbf{W})^{-1}$; $\mathbf{X}_{\text{jq}}$ is the j^{th} line and q^{th} column element of **X;** and $\boldsymbol{\omega} \equiv (\mathbf{I} - \lambda\mathbf{W})^{-1}(\mathbf{I} - \rho\mathbf{W})^{-1}\boldsymbol{\varepsilon}$.

If $\mathbf{X}_{jq}$ is a continuous variable, taking the derivative of $\log(P_i)$ with respect to $\mathbf{X}_{jq}$ using Equation (3.5) gives

$$\frac{\partial \log(P_i)}{\partial \mathbf{X}_{jq}} = \beta_q \mathbf{V}_{ij}, \tag{3.6}$$

which represents the semi elasticity of price for property *i* with respect to a change in characteristic *q* ($\mathbf{X}_{jq}$) of property *j*, and the elasticity of price for property *i* with respect to a change in characteristic x_{jq} of property *j* if $\mathbf{X}_{jq}$ is the logarithm of x_{jq}. It differs from 0 when $\lambda\neq0$ if observations *i* and *j* are spatial "neighbors" and if $\beta_q\neq0$. Compared to a linear regression model where $\mathbf{V}_{ii}$=1 and $\mathbf{V}_{ij}$=0 for i≠j, $\mathbf{V}_{ij}$ thus plays the role of a spatial correction factor. Equation **Error! Reference source not found.** also shows that the β_q coefficients do not have the same meaning as in a linear regression model.

Since a large number of such partial derivatives could be non-zero, I follow LeSage and Pace (2009, pp. 36-37) and report for each explanatory variable $q \in \{1,\ldots,Q\text{-}1\}$ the following scalar summary measures:

- Average Direct Impact (ADI_q), obtained by averaging the main diagonal terms of $\beta_q\mathbf{V}$:

$$ADI_q = \beta_q N^{-1} \sum_{i=1}^{N} \mathbf{V}_{ii}. \tag{3.7}$$

  It captures feedback passing through neighbors and back to each observation. Inserting Equation (3.6) into Equation (3.7) for a (non) log transformed continuous variable $\mathbf{X}_{jq}$ shows that ADI_q is the average (semi) elasticity of price with respect to variable q across all properties in my sample.

- Average Indirect Impact (AII_q), calculated by averaging only off-diagonal terms of $\beta_q\mathbf{V}$:

$$AII_q = \beta_q N^{-1} \sum_{(i,j)\in\{1,\ldots,N\}^2}^{i\neq j} \mathbf{V}_{ij} = N^{-1} \sum_{j=1}^{N} \left(\sum_{i\in\{1,\ldots,N\}}^{i\neq j} \beta_q \mathbf{V}_{ij} \right). \tag{3.8}$$

  It represents spatial spillovers (i.e., impacts to/from other observations only). Keeping in mind Equation (3.6), the last term in Equation (3.8) shows that AII_q is the average of the impact of a marginal change in $\mathbf{X}_{jq}$ in the price of all properties except for property j.

- Average Total Impact (ATI_q), obtained by averaging all row sums of the $\beta_q\mathbf{V}$ matrix; it is the sum of direct and indirect impacts. Simplifying the sum of ADI_q and AII_q gives

$$ATI_q = \frac{\beta_q}{1-\lambda}. \tag{3.9}$$

If instead $\mathbf{X}_{jq}$ is a binary or a count variable, changing its value by one unit affects the logarithm of the price of property *i* as follows:

$$\Delta \log(P_i) = \beta_q \mathbf{V}_{ij}, \tag{3.10}$$

but the expressions of ADI_q, AII_q, and ATI_q are still given by Equations (3.7)-(3.9).

To assess the statistical significance of ADI_q, AII_q, and ATI_q, I followed LeSage and Pace (2009): after assuming that $\boldsymbol{\beta}$, λ, ρ and σ^2 are normally distributed with mean values and covariance matrix obtained from estimating Equation (3.2), I performed 10,000 draws and estimated their statistical significance based on the resulting empirical distributions.

Building on this distributional assumption, the average expected percentage change in the price of property *i* from incrementing by one unit the binary/count variable $\mathbf{X}_{iq}$ is given by (using the expression of the expected value of a lognormal distribution; see Casella and Berger, 1990):

$$\left(\frac{\Delta P}{P}\right)_q = N^{-1}\sum_{i=1}^{N}\left[\exp(\beta_q \mathbf{V}_{ii} + 0.5\mathbf{V}_{ii}^2\sigma_q^2) - 1\right], \tag{3.11}$$

where σ_q^2 is the variance of the distribution of $\log(\beta_q)$.

RESULTS

Results were estimated using Stata 12 and are presented in Tables 3.3 and 3.4.

MULTICOLLINEARITY, HETEROSKEDASTICITY, AND SPATIAL EFFECTS

We examined a number of models with and without interaction terms between the distress indicator and both structural and environmental variables. While multicollinearity was not an issue without these interactions (see SARAR Model 1 in Table 3.3), it became severe for models that include interactions with structural variables, so I removed variables associated with VIFs above 10, which lead to SARAR Model 2 in Table 3.3. I note that the magnitude and significance of price effects associated with the environmental variables in SARAR Models 1 and 2 (distance from the Salton Sea, air and water quality variables, as well as water levels) do not differ much, which suggests that these estimates are robust to the way I modeled distressed properties. Unfortunately, my dataset did not allow us to estimate SARAR models with interactions between the distress indicator and environmental variables because of multicollinearity. I surmise that distressed and non-distressed properties are affected similarly by environmental degradation around the Salton Sea.

Table 3.3 shows substantial differences between SARAR parameters estimated via maximum likelihood (ML) and Generalized Spatial Two Stage Least Squares (GS2SLS).I attribute these differences to the presence of heteroscedasticity and do not further consider ML estimates, which are presented here simply to contrast them with GS2SLS results.

With GS2SLS estimation, both λ and ρ (respectively the spatial lag and spatial error parameters) are statistically significant and have similar, acceptable values (absolute values under one), which confirms the presence of spatial effects and suggests that my results are robust to the way I specified my weight matrix. For brevity, I present and discuss only SARAR results with weights based on $\mathrm{w}_{ij} = (1 + (d_{ij} / b)^2)^{-1}$.

My preferred model is SARAR Model 2 estimated via GS2SLS (last column of Table 3.3 and first column of Table 3.4); these results are discussed below.

INTERPRETATION AND DISCUSSION

As explained in sub-section 4.4 above, the model coefficients of a SARAR model (column I) do not have the same interpretation as in linear regression. Instead, ADI values (column II) can be interpreted for continuous variables in the same manner as OLS variables are typically interpreted. In this case ADI's are interpreted as elasticities or semi elasticities since the outcome variable is log of price. Therefore, I first interpret the ADI results.

ADI estimates of structural variables have expected signs and magnitudes. The elasticity of price with respect to lot size (0.1707***) implies that a 1% increase in lot size would increase the price of the average single family residence in my sample ($63,085) by $108. The building size elasticity of price is also positive and highly significant (0.7936***) and its value suggests that a 1% increase in building size would lead to a $501 increase in price. Moreover, everything else being the same results show that older building are worth less, with an age elasticity of price of -0.2825***, so a 1% increase in the age of a structure is associated with a $178 price drop.

Neither the number of bedrooms nor the numbers of bathrooms are statistically significant, but an additional bathroom in a distressed property is associated with a $9,179 price decrease (using Equation **Error! Reference source not found.** with a price of $63,085), possibly because bathrooms in distressed properties are not well-maintained. Although an additional bathroom often commands a positive premium, some hedonic studies (e.g., see Anderson, 1985, or Raymond, 2002) report negative premiums associated with additional bathrooms possibly because they reduce the size of the remaining living space. The other distress interaction (with age) is not statistically significant.

With regards to environmental variables, as hypothesized at the outset of this study, the coefficients associated with distance from the Salton Sea are negative, relatively large, and statistically significant (p-value<0.01), which supports my starting hypothesis that the Salton Sea is a disamenity and provides additional evidence that the value of waterbodies can be capitalized in homes located more than 4,000 feet away. Properties closest to the Salton Sea are most affected: from Equation (6) applied to a $63,085 property, single family residences within one mile of the Sea are priced on average $7,200 less (-11.4 percent) than otherwise similar residences located more than 3 miles away from the Sea. Moreover, the average price of a single family residence within 1 to 3 miles of the Salton Sea is $6,872 (-10.9 percent) less than if it were more than 3 miles away from the Salton Sea. These results starkly contrast most of the hedonic literature on water where proximity to a waterbody is associated with a positive premium, even when water quality and levels fluctuate.

Although the average water level in the Salton Sea has fallen by over 1 foot over the last few years (see Figure 2.3), the coefficient of water level is not statistically significant. The coefficient of water clarity based on Secchi disk readings is also not statistically significant. These findings suggest that these characteristics may be eclipsed by the strong smell that often emanates from the Sea and the desiccated fish that litter some of its beaches.

The coefficient of the concentration of particulate matter in the air (PM_{10}) is, however, statistically significant (p-value=0.03). In this case, correctly assessing the impact on the housing market of increasing the concentration of PM_{10} is given by a total impacts measure because air pollution does not change merely in the vicinity of a house. Here I calculate it by averaging semi-elasticities for all houses weighted by the PM_{10} concentration during the quarter of their sale, which yields an average elasticity of -0.2388. Hence increasing by 1% the PM_{10} concentration around the

Salton Sea results in a $151 loss for the average-priced ($63,085) single family residence in the area, this is in line with results from the air quality hedonic literature.

Only three of the control variables are statistically significant. Using Equation**Error! Reference source not found.**, a home in Imperial County sells for an average $15,873 (-11.4 percent) less than a similar home in Riverside County. Moreover, homes sold in the summer command a premium of approximately $8,396 (13.3 percent) more than home sold in spring but there is no difference for the other two seasons compared to spring. Finally, properties sold in 2011 fetched lower prices than homes sold in 2009 (my baseline) with no difference for the other sale years, which suggests that the housing crisis may have peaked in 2011.

The difference between The SARAR coefficient and the corresponding ADI value is due to feedback effect. The feedback effect is a dynamic process that includes effects associated with changes in a single property, neighboring properties on the single property, and the single property on neighboring properties. In this case the difference is quite small (under 1%), which reflects that the feedback from a variable change reflected back by neighbors is small. Due to the complexity of the SARAR coefficient, interpreting ADI, as done above as well as AII is more informative. The AII explicitly indicates the effect of a change among all surrounding properties within 2.25 km of a single property.

We note that a number of average indirect impacts (column III of Table 3.4) are significant, including structural characteristics lot size, building size, and building age, as well as for the number of bathrooms in distressed properties. This suggests that changes in structural characteristics of surrounding properties are in turn statistically significant. Indirect impacts are also sizeable and statistically significant for proximity to the Salton Sea and for the concentration of PM_{10}, although their statistical significance is not as strong (p-values are between 0.05 and

0.10). The ATI, is essentially the ADI and the AII, and differs from the SARAR because the sum does not included feedback effects.

Finally, as indicated above, my SARAR models were estimated with different weight matrices and I found that my results are robust to their specification.

CONCLUSIONS

In this study, I estimated spatial autoregressive models with spatial autoregressive disturbances (SARAR) using generalized spatial two-stage least squares (GS2SLS) to analyze the joint impact on single family detached houses located within 10 miles of the Salton Sea of its falling water levels, deteriorating water quality, and of the resulting regional concentration of particulate matter (PM_{10}). Another feature of my study is the large number of distressed properties (over half) in the transactions I analyzed, which is a product of the Great Recession compounded by the environmental degradation of the Salton Sea. This is noteworthy because most of the hedonic literature has avoided such markets, instead hedonic studies have concentrated on properties adjacent to relatively healthy waterbodies. To my knowledge I also provide the first hedonic study that analyzes the nexus between water and air pollution.

As expected, housing prices exhibit strong spatial dependence, which justifies my spatial hedonic approach. A comparison of maximum likelihood and GS2SLS estimates shows that ignoring heteroskedasticity in model errors may lead to biased and inconsistent estimates of model coefficients. Results pertaining to environmental attributes (water quality, water level, and air quality) are consistent across model specifications that attempt to account for differences in hedonic prices between distressed and non-distressed properties.

My findings indicate that the Salton Sea is a costly disamenity to the local housing market. Single family residences located within one mile of the Salton Sea are worth an average of $7,200 less than identical properties more than three miles away, and this negative premium drops to $6,872 for properties within one and three miles from the Sea. Moreover, a 1% increase in PM_{10} concentration decreases the value of the average priced single family detached house by $151. These results show that severely impaired waterbodies can be negatively capitalized even in distressed housing markets, thereby adding further strain to poor communities.

One limitation of this study is the small number of air quality monitoring stations in the Salton Sea region, which means that the spatial and temporal concentrations of PM_{10} are only known approximately. A second limitation is the imperfect state of the real estate records in the Imperial County Assessor's office, which may have been partly caused by the economic crisis experienced in this region. In addition, it would have been useful to have a more complete set of physical measures characterizing water quality in the Salton Sea. Future work could analyze other failing waterbodies, especially if better real estate and environmental data are available, and consider other tools (such as general equilibrium analysis and contingent valuation) to assess the economic benefits of restoring failing waterbodies to healthy states.

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Table 3 1: Summary Statistics for Salton Sea

Variable	Meaning	Mean	Std. Dev.	Min	1st quartile	3rd quartile	Max
price	sales price	63084.	28949.2	4500	15,000	120,000	280,000
lnprice	log of sales price	10.94	0.485	8.41183	10.71	11.26	12.54
distress	distress indicator	.6442	.4790	0	0	1	1
lnlot	log of lot size	9.194	0.316	6.95654	9.13	9.28	12.00
bldsizesq	log of building size	7.284	0.206	6.39693	7.138	7.432	8.350
Nbaths	number of bathrooms	2.105	0.482	1	1	2	4
d_Nbath	distress interaction	1.350	1.072	0	0	2	4
Nbeds	number of bedrooms	3.340	0.655	1	3	4	6
d_Nbed	distress interaction	2.141	1.68	0	0	5	6
lnage	log of age	2.296	0.673	0.693	1.609	4.21	4.477
d_lnage	distress interactions	1.497	1.237	0	0	1.9	4.431
one_mile	less than 1 mile from the Salton Sea	0.367	0.482	0	0	1	1
two_three	1-3 miles from the Salton Sea	0.379	0.485	0	0	1	1
secchi	water clarity score	0.393	0.307	-0.22314	0.209	0.624	0.862
waterlevel	water level (inches)	-231.3	0.642	-232.308	-231.9	-230.9	-230.14
PM_{10}	(ug/m3)	34.19	10.37	20.77	25.88	39.73	59.26
Imperial	Imperial County	.8291	.3767	0	0	1	1
fall	sold in fall	.1942	.3958	0	0	0	1
summer	sold in summer	.2453	.4305	0	0	1	1
winter	sold in winter	.2372	.4256	0	0	0	1
2010	sold in 2010	.2198	.4143	0	0	1	1
2011	sold in 2011	.1663	.3725	0	0	0	1
2012	sold in 2012	.1791	.3836	0	0	0	1
2013	sold in 2013	.1314	.3380	0	0	0	1

Table 3.2 Spatial Diagnostics of Autocorrelation of Single Family Home Sales Prices

Bandwidth (kilometers)	Moran's I statistic (p-value)	Spatial-Error LM stat (p-value)	Spatial-Error Robust LM stat (p-value)	Spatial-Lag LM stat (p-value)	Spatial-Lag Robust LM stat (p-value)
1.62 km	8.628	47.036	39.717	10.418	0.310
	(<0.001)	(<0.001)	(<0.001)	(0.001)	(0.078)
2.00 km	8.954	52.03	36.352	16.17	0.493
	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(0.483)
2.25 km	9.144	54.293	39.376	15.858	0.942
	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(0.332)
2.50 km	8.336	43.647	38.071	8.95	3.377
	(<0.001)	(<0.001)	(0.050)	(<0.003)	(0.066)
3.00 km	8.402	43.968	39.3777	8.129	3.538
	(<0.001)	(<0.001)	(0.050)	(0.004)	(0.060)

Table 3.3: SARAR Estimation Results

Column	I	II	III	IV	V
	OLS	SARAR Model 1		SARAR Model 2	
Variable Name		ML	GS2SLS	ML	GS2SLS
Structural Characteristics					
Distress indicator	-0.255***	-0.256***	-0.255***	- -	- -
Log of lot size	0.157***	0.192***	0.165***	0.196***	0.170***
Log of building size	0.757***	0.806***	0.778***	0.815***	0.790***
Number of bathrooms	-0.118***	-0.0950***	-0.105**	-0.00601	-0.0121
Distress * number of baths	- -	- -	- -	-0.152***	-0.157***
Number of bedrooms	0.0485*	0.0285	0.0366	0.0254	0.0349
Log of building age	-0.272***	-0.288***	-0.264***	-0.304***	-0.281***
Distress* log of building age	- -	- -	- -	0.0298	0.0343
Environmental Characteristics					
<1 mi from the Salton Sea	-0.203***	-0.087	-0.123**	-0.0938	-0.122**
1-3 mi from the Salton Sea	-0.181***	-0.0646	-0.115**	-0.0713	-0.116**
Water level	-0.00218	0.0235**	0.0119	0.0221**	0.0094
Water clarity score (Secchi)	-0.112	-0.0811	-0.104	-0.083	-0.105
PM_{10} concentration	-0.00412**	-0.00400**	-0.00405**	-0.00433**	-0.00441**
Control Variables					
Imperial County	-0.349***	-0.427***	-0.311***	-0.405***	-0.292***
Sold in fall	-0.00191	0.0228	0.0217	0.0162	0.0146
Sold in summer	0.116***	0.119***	0.124***	0.119***	0.124***
Sold in winter	-0.00548	0.00352	0.00657	-0.0149	-0.0115
Sold in 2010	-0.0324	-0.0267	-0.0264	-0.0355	-0.0355
Sold in 2011	-0.0995*	-0.0913**	-0.0902	-0.0983**	-0.0987*
Sold in 2012	-0.11	-0.0800*	-0.0917	-0.0929**	-0.106
Sold in 2013	-0.0327	-0.003	-0.0127	-0.00565	-0.0172
Constant	5.006	12.03	3.805	11.13	3.0163
λ	- -	-0.161	0.375**	-0.13	0.3690**
ρ	- -	0.673***	0.377***	0.652***	0.3770***
σ^2	- -	0.138***	- -	0.136***	- -
AIC	826.0	793.0	- -	786.7	- -
BIC	921.1	897.6	- -	896.1	- -

Notes:
1. The dependent variable for all 5 models above is the logarithm of price.
2. *, **, and *** designate p-values that are respectively less than or equal to 0.10, 0.05, and 0.01

Table 3.4: Average Direct, Indirect, and Total Impact

Column Variable Name	I SARAR Model 2 coefficient	II Average Direct Impact (ADI)	III Average Indirect Impact (AII)	IV Average Total Impact (ATI)
Structural Characteristics				
Log of lot size	0.1700***	0.1707***	0.0987**	0.2694***
Log of building size	0.7903***	0.7936***	0.4590**	1.2526***
Number of bathrooms	-0.0121	-0.0122	-0.0070	-0.0192
Distress * number of baths	-0.1566***	-0.1572***	-0.0909**	-0.2481***
Number of bedrooms	0.0349	0.0350	0.0203	0.0553
Log of building age	-0.2814***	-0.2825***	-0.1634**	-0.4460***
Distress* log of building age	0.0343	0.0344	0.0199	0.0544
Environmental Characteristics				
Less than 1 mile from Sea	-0.1222**	-0.1227**	-0.0710*	-0.1936**
1 to 3 miles from Sea	-0.1161**	-0.1165**	-0.0674*	-0.1839**
Water level	0.0094	0.0094	0.0055	0.0149
Water clarity score (Secchi)	-0.1052	-0.1057	-0.0611	-0.1668
PM_{10} concentration	-0.0044**	-0.0044**	-0.0026*	-0.0070**
Control Variables				
Imperial County	-0.2919***	-0.2931***	-0.1695**	-0.4626***
Sold in fall	0.0146	0.0146	0.0085	0.0231
Sold in summer	0.1236***	0.1241***	0.0718**	0.1958***
Sold in winter	-0.0115	-0.0116	-0.0067	-0.0183
Sold in 2010	-0.0355	-0.0357	-0.0206	-0.0563
Sold in 2011	-0.0987*	-0.0991*	-0.0573	-0.1564*
Sold in 2012	-0.1060	-0.1064	-0.0616	-0.1680
Sold in 2013	-0.0172	-0.0172	-0.0100	-0.0272

Note:
1. *, **, and *** designate p-values that are respectively less than or equal to 0.10, 0.05, and 0.01.
2. As for Table 3, the sample size is *n*=860 observation

Figure 3.1: Map locating the Salton Sea, Residential Sales and Air Stations

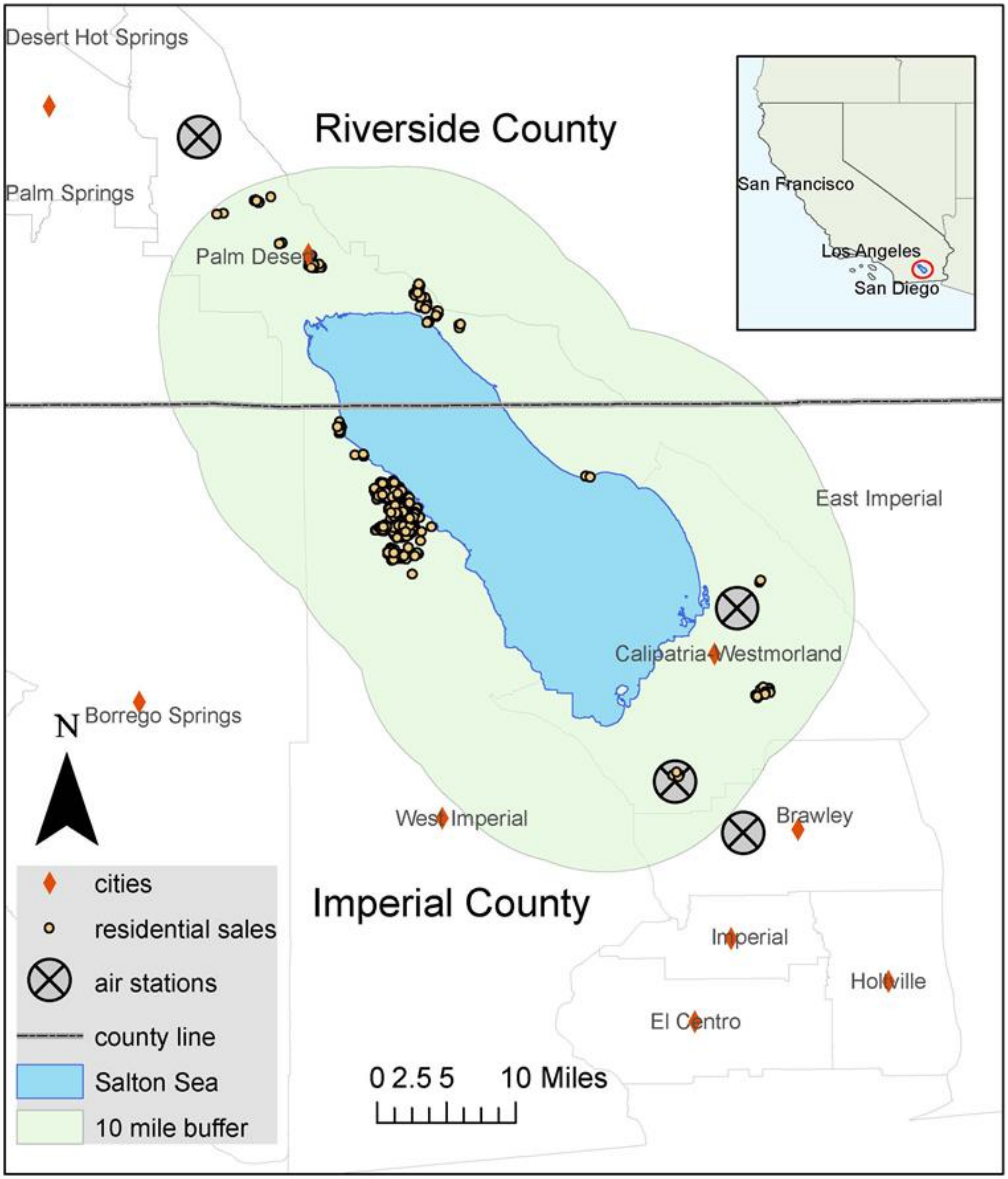


Figure 3.2: Location of Water Quality Data Collection Points

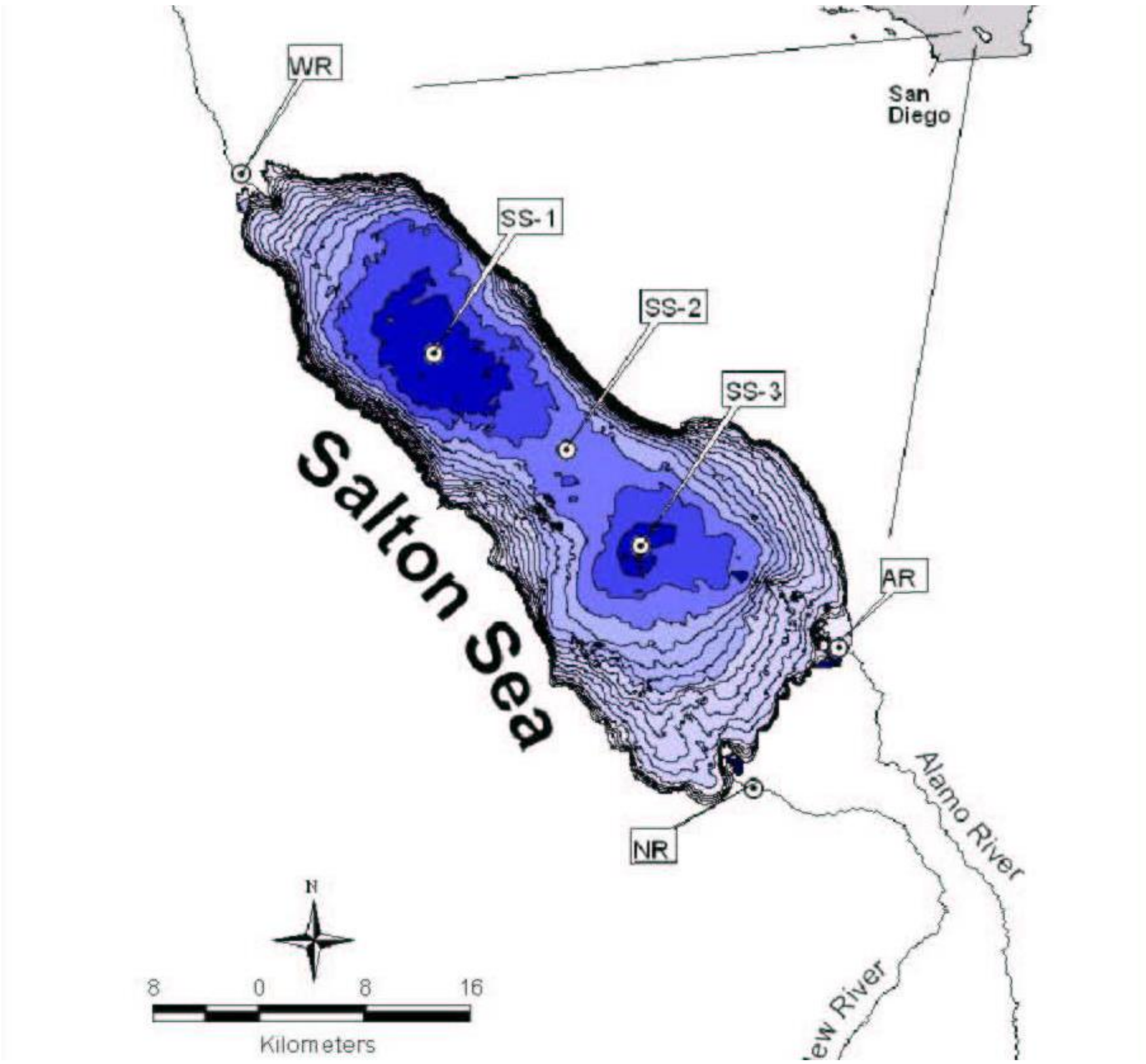


Figure 3.3: Quarterly Distribution of the Average Water Level: Salton Sea

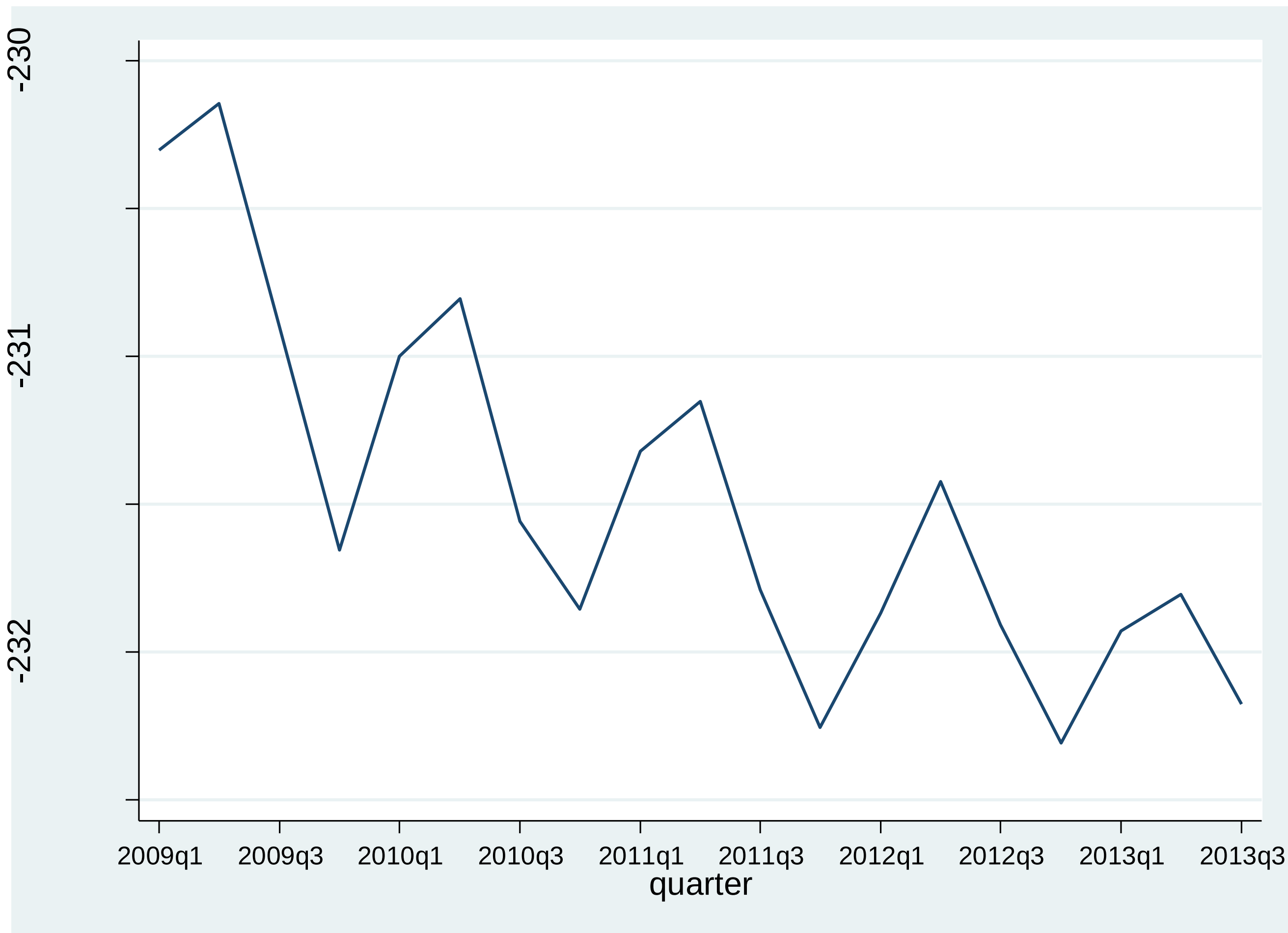
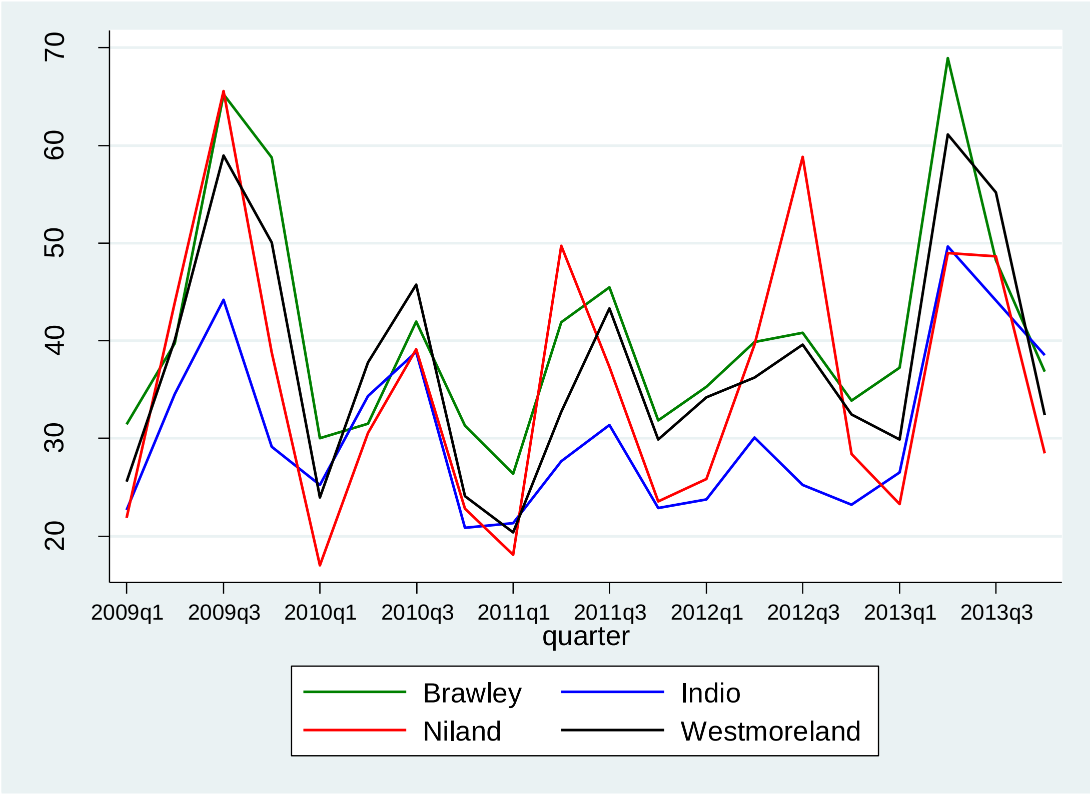


Figure 3.4: Average Quarterly Level of PM10 by Station (2009-2013)



Chapter 4: A Spatial Hedonic Analysis of Falling Water Levels in Lake Mead

INTRODUCTION

Lake Mead, the Colorado River reservoir behind Hoover Dam located within 30 miles of the Las Vegas strip, provides more than 90 percent of Las Vegas' drinking water supply, Due to persistent arid conditions in the Southwest, the water levels within the reservoir have been declining since 2000 (Hobson, 2014;NPS, 2015). In addition to being of vital source of water for the Las Vegas Metro Area (LVMA), the Lake Mead National Recreation Area (NRA) receives more than 6.2 million visitors a year, making it among the most frequented national parks in the US (NPS, 2015). Lake Mead was the first National Recreation Area, which is a federally declared protected space that is reserved for recreations and prohibits development. Since 2010 the deterioration of the Lake has received attention from countless media outlets (Hobson, 2014 McGlade, 2015; NPR, 2011 Quilan, 2010), who discussed what should be done if the largest water basin in the US runs dry.

Typically waterbodies are an amenity that is positively capitalized within the surrounding real estate due to both its recreation and aesthetic values. Likewise, the deterioration of a site's water quality, such as drops in water levels, impairs the aesthetic and recreational values of that site, and thus reduces the premium associated with views and recreational access (Lansford Jr & Jones, 1995; Netusil, Kincaid, & Chang, 2014; Tuttle & Heintzelman, 2015; Walsh, Milon, & Scrogin, 2011). Given Lake Mead's importance and recreation status, the hedonic literature suggests that drops in water level may be negatively capitalized in surrounding properties. However, published studies have not estimate the value Lake Mead within the LVMA, which is best known for its casinos. The recent recession, which hit Las Vegas very hard and resulted in the highest foreclosure rates in the county Daneshvary & Clauretie, 2012)complicates slightly estimating a model that delineates the effects of environmental amenities on real estate, although a number of recent studies have examined the impact of foreclosures on the housing market (Coulton *et al.*, 2008; Forgey, Rutherford, & VanBuskirk, 1994; Immergluck & Smith,2006 Leonard & Murdoch,2009; Pennington-Cross, 2006; Schuetz, Been, & Ellen, 2008; Shilling, Benjamin, & Sirmans, 1990; William & Marvin, 1996).

In this context, the purpose of this study is to investigate whether changes in Lake Mead water levels have been reflected in the LVMA housing market for single family detached houses sold between 2000 and 2013. I estimate quarterly spatial hedonic regression models to control for potential temporal variation over the 58 quarters within the analysis. My models account for foreclosure spillover effects via a couple of variables that count the number of foreclosed properties in the past 12 months within a non-distress sale, as suggested in Harding, Rosenblatt, and Yao (2009)

This study makes several contributions. First, few hedonic studies estimate the value associated with drops in water levels (Eiswerth, Englin, Fadali, et al.,2000; Jakus, Dowell, & Murray, 2000; Lansford and Jones, 1995; Loomis and Feldman, 2003; McConnell,1990) and even fewer studies have estimate a hedonic model for waterbodies located within a national recreation area where development is restricted. Second, whereas most published hedonic studies focus on waterfront properties, even though homes beyond located further away have been shown to also reflect changes in water levels and quality (McConnell,1990; Phaneuf *et al.*, 2008), my analyses consider the LVMA housing market because changes in water levels/quality affects regional recreational opportunities. Finally, I examine a dynamic housing market, during a very precarious economic period, thus shedding light on the importance of environmental amenities in urban markets during a recession.

LITERATURE REVIEW

The hedonic literature is vast; however the focus on this essay is to estimate the value of proximity to water and to examine if this effect, like water levels, varies over time. Prior to discussing previous studies pertaining to water levels, I first review studies that estimate the premium of homes located near waterbodies within the confines of a national park, which typically has development restrictions that inhibit waterfront development and residential density. Finally, due to the drastic foreclosure rate in the study time frame I review hedonic studies that have estimated the effects associated with neighboring foreclosures. I especially highlight the findings of two studies that examine the foreclosure effect for the Las Vegas Area.

PROXIMITY TO RECREATION AREAS

Several hedonic studies have documented that the premium associated with proximity to a waterbody can boost property values beyond a few thousand feet (Lansford Jr & Jones, 1995; Netusil, Kincaid, & Chang, 2014; Tuttle & Heintzelman, 2015; Walsh, Milon, & Scrogin, 2011). However, there are very few published hedonic papers that estimate the value associated with waterbodies within a recreational park, which usually has a number of development restrictions including residential density and proximity to a waterbody.

Tuttle & Heintzelman (2015) examine single family sales and water quality within the Adirondack Park. The Park has over 3,000 lakes and is the largest protected area in the mainland

United States. As in previous studies they find that distance to the lake is associated with a premium although these properties are located within the park and most are within 2 miles of Lake Front. Pearson, Tisdell, and Lisle (2002) use land price transactions to estimate the value of proximity to Noosa National Park in Queensland, Australia. The park is surrounded by rugged coastline on two sides and the other two sides of the park abut residential homes, however there is no development within the park. They find that distance from the NNP is negatively capitalized among land values, albeit all 641 land transactions are located within blocks of the park's perimeter. Pearson *et al.* (2002) note that most economic valuation studies on national parks focus on tourist and use either travel cost or contingent valuation to quantify economic value (e.g. see Chapter 2), and disregard any possible capitalization rates among properties with recreational access to waterbodies. McConnell (1990) was among the first to recognize that a lake used for recreation is an amenity enjoyed by local homeowners that has the potential to be capitalized within home prices. He estimates a hedonic model that directly links sales price to distance from the lake, and points out that a hedonic framework estimates capitalization of water within residential values, so travel costs can be inferred from the distance variable. He thereby concluding that a hedonic framework provides a more comprehensive estimate of economic benefits (costs) associated with waterbodies than travel or contingent valuation studies. McConnell (1990) specifically estimates economic loss associated with water reductions, and finds that site quality is capitalized within the local housing market. These results suggest that recreation and residential location decisions are often intertwined.

Phaneuf *et al.* (2008) relate housing sales price to a recreation index that accounts for a property's distance to all accessible hydrological units, as well as the quality of each site, so this index varies with both site distance and quality. Each of the 39 local watersheds considered are located within Wake County, NC and are within a few hours' drive of a Residential observation. They conclude that proximity to hydrological units and water quality are positively capitalized in homes located within an hour's drive of waterbodies.

ECONOMIC VALUATION OF WATER LEVELS

Although the economic valuation literature pertaining to waterbodies and water quality is vast, there are few examples of studies that estimate the cost associated with drops in water levels among fresh waterbodies. Apart from McConnell (1990), another example is given by Lansford and Jones (1995), who use standard hedonic models to estimate the marginal value of lake level deviations within Lake Travis in Texas on surrounding property values. They examine the effects associated with lake-level deviation from the long-term average at the time of sale (LLDEV) for all homes within 2,000 feet of a waterbody. They find that buyers are willing to pay for higher lake levels. They argue that buyers of waterfront and non-waterfront homes are responding to the aesthetic appeal of properties as well as to the proximity and quality of recreational facilities such as marinas and boat ramps.

Loomis and Feldman analyze 14 years (1987 to 2001) of single family home residential sales within Plumas County, California, to quantify the price effects associated with exposed shoreline along Lake Almanor. They find that increases in exposed shoreline, a direct consequence of falling water levels, are negatively capitalized in surrounding properties. In order to account for temporal effects, Loomis and Feldman (2003) include inflation, unemployment and mortgage interest rates in their model.

Jakus, Dowell, & Murray (2000) is a rare example of a travel cost study that relates the number of trips to the Tennessee River among anglers to routine drawdowns initiated by the

Tennessee Valley Authority (TVA), in order to help produce electricity and control flooding in the upper regions of the watershed. Although, reduced water levels resulted in landlocked boat ramps and exposed mud flats, Jakus *et al.* (2000) find that anglers still participate at the same rate as they did when drawdowns were not routine, but their trips primarily occur when water levels are highest in the season. They also report that water levels do influence site choice, and that anglers' willingness to pay for full pool, or normal water conditions is $1.82 per angler per season, with an aggregate benefit of $476,500 per season.

Likewise, Eiswerth *et al.* (2000) conduct a stated preference study to estimate the costs of falling water levels in Lake Walker, Nevada. By surveying local residents about the number of trips they would take to the lake at times of varying water levels, they estimate that a one-foot decline in water levels is associated with a $12 to $18 loss per person per season, with aggregate losses ranging from $4.8 million to 10.8 million.

From the same data, Fadali & Shaw (1998) found that non-visitors' per-person value of lake levels is approximately five percent of those who actually visit the lakes. Using the value obtained from users, Eiswerth et al. (2000) estimate that the WTP for preserving water levels ranges from $1.98 million to $2.79 million.

DISTRESS PROPERTY SPILLOVER EFFECTS & LAS VEGAS HOUSING MARKET

In light of the recent mortgage crisis, a number of studies have estimated the costs of foreclosures on surrounding non distressed property sales, with the assumption that foreclosed properties sell at a discount capitalized within nearby non distressed sales. Several early studies find a discount associated with foreclosure (Forgey, Rutherford, & VanBuskirk, 1994; Pennington-Cross, 2006; Shilling, Benjamin, & Sirmans, 1990; William & Marvin, 1996), but it is attributable to disrepair and to the lower quality of the housing stock (Frame, 2010). For example, after controlling for differing attribute prices among distressed properties, Harding, Rosenblatt, and Yao (2012) find that the foreclosure discount is less than typical transactions costs.

Although the literature agrees that neglect results in a foreclosure discount, there is no agreement about whether the proximity of foreclosed properties affect non distressed sales. A number of studies find that proximity and the number of foreclosures are negatively capitalized in non-distressed sales (Coulton *et al.*, 2008; Immergluck & Smith, 2006; Leonard & Murdoch, 2009; Schuetz, Been, & Ellen, 2008). These studies' definition of proximate sales ranges from 300 to 1000 feet, and most conclude that the effects of foreclosures are strongest within 300 to 500 ft. However, these earlier studies fail to adequately control for neighborhood characteristics (Frame, 2010). Rogers and Winter (2009), however, use generalized methods of moments (GS2SLS) techniques to estimate spatial models on foreclosure data from 1998-2007 in St. Louis, Missouri. They find that foreclosures physically closer to a sale have negative effects, but the effect decreases as the number of foreclosures increases, although there analysis lacks temporal control variables (Frame, 2010).

In an effort to control for neighborhood characteristics, Harding, Rosenblatt, and Yao (2009) estimate a repeat sales model instead of standard or spatial hedonic regression techniques, which essentially differences out temporally constant characteristics. Their model relates non-distressed sales from 1989 through 2007 to the total number of distressed properties within 0-2000 feet of a non-distressed sale. For them, a distressed property includes all homes anywhere in the foreclosure process, and they consider distressed properties 12 months prior to the foreclosure date and up to 12 months after the real estate owned sale. The foreclosure date indicates when the lender has issued a notice of default, and it is the responsibility of the borrower to sell the property.

In the event that the borrower is unable to make the sale the property is taken back by the mortgage lender or trustee and sold. Estimates for seven metropolitan statistical areas (MSA) suggest that average spillover effects of an additional foreclosure within 300 feet of a non-distressed sale is associated with a 1 percent decline in non-distressed sale's price, and the spillover effect of an additional foreclosure within 1000 feet of a non-distressed home is associated with a .5 percent decline. For the Las Vegas MSA, the spillover effect of an additional foreclosure within 300 ft. is associated with a 0.19 percent decline in non-distresses sales. Additional foreclosures in subsequent rings are not significant.

Claurtie and Daneshvary (2009) estimate foreclosure discounts among distressed property sales in the Las Vegas Metro Area (LVMA) from 2004 to 2007. They also estimate the effects of foreclosure spillovers on non-distressed properties from January 2008 to June 2009 (Daneshvary & Clauretie, 2012). During this time, the housing market in LVMA underwent drastic changes. From early 2001 to 2007, the LVMA housing stock boomed from 500,000 to 731,000 properties and the median house price increased from $155,000 to $310,000. This was followed by one of the most drastic decreases in housing prices during the recession years of 2007-2009 (Daneshvary & Clauretie, 2012). Using Spatial Autoregressive Model with Autoregressive Disturbances (SARAR) models, they find that the foreclosure discount is approximately 10 percent less than the discount rate found in previous papers, thereby suggesting the presence of spatial effects.

Similar to Harding, et al (2009), Daneshvary and Clauretie's analysis (2012), estimate the spillover effects of distressed sales on non-distressed sales within various distance bands 0-528ft (.1 mile), 529-1320ft (.25 mile) , and 1321ft to 2460ft (.5 mile). However, they are interested in uncovering the short-term effects associated with REO sales within the 3 to 6 months of a non-distress sale near the height of the crisis in 2008 and 2009. They find that the spillover effect of an additional REO within 528ft is associated with a 1.1 percent decline in non-distressed sales price; an additional REO sale within the 529-1320ft ring causes a -0.07 decline.

STUDY AREA

The Lake Mead reservoir was created by the construction of the Hoover Dam in 1931. The Dam was a means to harness the power of the Colorado and to supply hydroelectric power to a growing population in the southwest. In 1964 the Lake and the surrounding land became the first federally declared National Recreation Area (NRA). The declaration of the NRA area preserved the lake for fishing, boating, and other recreation. The surrounding land also provides hiking trails, camping grounds, and wilderness preserves. There are nine main access points to Lake Mead NRA, which totals 1.5 million acres. The NRA is located in Southeastern Nevada and spans the Arizona border. According to the National Park Service (NPS), the Lake Mead NRA was the fifth most visited site in 2012 with 6.2 million visitors. In addition to the recreational visitors, about 4.5 million vehicles used U.S. Highway 93 linking Boulder City, to south Hoover Dam in 2012, with all 23 miles of the highway are located in the recreation area (NPS, 2015). In 2011, Lake Mead NRA visitors spent $246 million in nearby communities, which supported 2,965 local jobs. For 2011, it resulted in $13 billion of direct spending by 279 million park visitors in communities within 60 miles of a national park (NPS, 2015). Thus the park receives a large number of tourists despite its highly publicized environmental deterioration.

Water levels have been steadily declining since 2000, with the exception of 2011 when there was a brief rise in water levels due to heavy winter snowfall in the mountains of Wyoming, Utah, and Colorado (NPR, 2011). In addition to being used for recreation, the reservoir stores water for parts of Arizona, Southern California, southern Nevada and northern Mexico. Since 2007 water managers have been implementing and proposing conservation programs and techniques. These include a "shortage sharing" agreement among western states, that reduces their allotment of the Colorado River. Other water conservation techniques include incentives for homeowners, to convert grass to desert landscaping, and farmers to leave fields fallow (McGlade, 2015; Quinlan, 2010). Plans also include the building of new reservoirs, to catch and save excess water sent downstream from Lake Mead that would otherwise go unused.

Given the Lake's significance, its environmental degradation has received a great deal of media attention since 2010. Published photos often show the white bath tub ring that surrounds the Lake due to water declines (Figure 4.1), which serves as an emblem of climate change consequences in the Southwest (McGlade, 2015; NPR, 2011 Quinlan, 2010). In spite of these water level drops, recent reports suggest that tourism has increased within the last few years. Although, tourism at the park was highest in 1998, before the start of the severe declines in 2000, according to park officials, spring and summer attendance was up 47% and 30 % this year relative to 2014. Park officials claim that the rise is indicative of an improving economy (Glionna, 2015).

Because the Lake is preserved for recreation, development within the confines of the NRA is strictly prohibited. As a result, the closest single family residence is within one mile of the NRA entrance and over 4 miles from the Lakefront. Although, there are no properties on the lake, single family properties in both Henderson, an affluent suburb of Las Vegas, and Boulder City, which hosts the main entrance to the park and its official visitor center, have a number of SFR that have a view Lake Mead. However, it is still not clear whether recreation access to the Lake is capitalized in property values and whether water level drops impacted these values. One complication is that

Lake Mead is located within 45 to 60 minutes of the Las Vegas strip, which is the primary tourist attraction and driver of the economy within the region. A second complication is caused by the drastic ebbs and flows of the housing market from 2000 to 2010.

DATA

Figure 4.2 maps the geographic location of all non-distressed single family transactions within the study region in the year 2000. Figure 4.2 also displays the three NRA entrances closest to the LVMA.

Housing sales price, structural characteristics, and distress indicators for Clark County were obtained from DataQuick. Because distress properties and non-distress properties represent unique submarkets, only non-distressed models are included in the analysis. Additionally, I eliminate atypical and unlikely observations. These properties are defined as those that are less than $50.00 per building square foot (sqft) or greater than $500 per sqft. I also eliminated properties with lots less than 1500 sqft or greater than 45,000 sqft, and with a building size less than 800 or above 5,000 sqft. Parameters for elimination were based off of those in Clauretie & Daneshvary (2009) hedonic study of foreclosure discount in the LVMA from November 2004 to November 2007.

I use ArcGis to create the distress indicator variable, which is the number of distress sales that sold in the same year as a non-distress sale and is located within 500ft of the non-distress property. I also use ArcGis to calculate the network distance from each sale to the closest entrance to the Lake Mead National Recreation Area (NRA). Network distance is calculated using street networks (Figure 4.3), thus it indicates the travel cost, in terms of driving time, from each property to the closest entry station, and displays the major highway access near Lake Mead NRA.

Figure 4.4 displays fluctuations in Lake Mead water level quarterly, and shows that, aside from seasonal fluctuations and a short lived incline in 2011, lake levels have been steadily declining since 2000. This data is publically available by the United States Bureau of Reclamation (USBR, 2015).

METHODS

OVERVIEW

In the standard hedonic framework (Rosen, 1974), a hedonic price model applied to an environmental problem via the housing market can typically be written:

$$\mathbf{P} = f(\mathbf{S}, \mathbf{N}, \mathbf{E}, \boldsymbol{\varepsilon}), \tag{4.1}$$

where **P** is a vector of housing prices; **S**, **N**, and **E** are respectively matrices of structural, neighborhood, and environmental variables; and $\boldsymbol{\varepsilon}$ is a vector of error terms. The partial derivative of f with respect to explanatory variable j is an implicit price that represents the marginal willingness to pay for the characteristic it represents.

The classical hedonic framework analyzed by Rosen (1974) requires stringent idealized conditions to hold, including market equilibrium with perfect competition, perfect information for buyers and sellers, and a continuum of products. Such conditions likely do not hold in LVMA due to the high rates of foreclosures. However, Benkard and Bajari (2005) proved that the hedonic pricing method is still valid when competition is imperfect, there is no continuity of products, and not all product characteristics are observable, which is often the case in housing markets. Moreover, Bajari and Benkard (2005, p. 1241) showed that if demand is given by the hedonic model then there exists a hedonic price function.

Although, the hedonic framework is still feasible in spite of the volatile housing market, another potential problem is the high percentage of distressed properties in my sample. Coulson and Zabel (2013) argue that in addition to not being in equilibrium, a market with a high percentage of foreclosed properties is likely composed of two submarkets - one with and the other without foreclosed properties – with different buyers operating in each submarket, suggesting a different hedonic price function across these two submarkets. Indeed, because of their owners' precarious finances, distressed properties are often in poorer physical condition than non-distressed properties, so implicit prices for the structural characteristics of the latter likely differ from those of the former (Harding, et al., 2012). There are means to account for differences within the foreclosure market. These include specifying a hedonic model that includes a foreclosure indicator and interactions that allow account for differences among distress properties. However, to avoid such specifications, I exclude distressed properties from the analysis, and only examine non-distressed properties.

In an effort to control for variations in sales price due to time, I use 58 hedonic models, one for each quarter year within the study time frame, to estimate the value of recreation access. I then examine how these estimated effects vary with water levels over time. This approach has two primary benefits, 1) it utilizes the primary mechanism by which water levels would be capitalized in non-water front homes, which is through recreation access, 2) it controls for seasonal fluctuations in water level and for intra annual fluctuations in sales price and foreclosure spillover effects, which I discuss shortly.

Given the number of models, I use graphs, as well as traditional summary statistics table (Tables 4.1 and 4.2) to show how quarterly level means and standard deviations for housing price and structural characteristics vary over the study time frame (Figure 4.5, 4.6, 4.7).

As in other hedonic studies, the final model accounts for structural, neighborhood, and environmental characteristics. Structural characteristics include square footage of the lot and of the structure it supports, the number of bedrooms and bathrooms, and the age of a property. What is unique to this study, in addition to the estimation of 58 quarter level models, is the specific environmental characteristic, water levels in Lake Mead, and how it is measured. The specified hedonic models are also unique in that they account for possible foreclosure spillover effects on non-distress sales. Figure 4.8 displays quarter level means and standard deviations for both foreclosure spillover effects and network distance.

RECREATION ACCESS AN INDICATOR FOR LAKE LEVELS

Like Phaneuf *et al.* (2008), I use a hedonic framework to link recreation access to housing prices. In this context, network distance, the time it takes to drive from each property to one of three closest NRA entrances, is a measure of recreation access. I hypothesize that network distance to an entrance is positively capitalized in the LVMA housing market, and that capitalization rates vary with water declines over time. This relationship rests on three assumptions. The first assumption is that recreation decisions are reflected in the housing market. The second assumption is that deterioration of recreation quality will subsequently reduce the value of recreation access and also be reflected in sales price. The third assumption is that the water level in Lake Mead, which has consistently fallen during the time frame of the study, is the primary indicator of recreation quality.

FORECLOSURE SPILLOVER EFFECTS

The LVMA housing market saw unprecedented growth during the early part of the decade, as well as unforeseen levels of foreclosures during 2008-2009 (see price graph in Figure 4 5, and foreclosure spillover graph in Figure 4.8). Year 2007 all the way through to the early part of 2010 saw an unprecedented rise in distress sales, thereby causing distress sale spillover effects on non-distress sales. To estimate spillover effects, I first obtained the count of all distress sales within 500ft of each non-distressed sale, since prior analysis of the Las Vegas housing market find that foreclosure spillover effects are strongest within this range (Harding *et al.*, 2009; Daneshvary and Clauretie, 2012). I use a quadratic specification for the distressed sale effect, since both previous studies demonstrate that the there is a diminishing marginal effect associated with the number of distress sales.

In addition to the geographic dimensions of a foreclosure effect, I consider the temporal range of the foreclosure externality on surrounding non distress sales. Because the spillover effects are primarily associated with the condition of a property, it can influence non-distressed sales up to 12 months prior to a foreclosure sale, peaks after a foreclosure sale and prior to an REO sale, and persist for 12 months after an REO sale (Harding *et al.*, 2009). Given the wide range of temporal effects after a distressed sale on a non-distress sale, I consider all distressed sales that take place within the same year as the non-distressed sale. Although this range is longer than the 3 and 6 month range specified in Daneshvary and Clauretie, (2012), it is well within the confines suggested by Harding *et al.*, (2009). I do not distinguish between types of sales, since the discount premium associated does not appear to vary with the type of sale (Daneshvary and Clauretie, 2012).

SPATIAL DEPENDENCE AND MODEL

In linear regression models, omitting an explanatory variable that is correlated with one or more explanatory variables results in biased and inconsistent estimates (Kennedy, 2003). Omitted variables in hedonic studies are often location-specific factors, such as school quality or crime rate.

Furthermore, it is well known that housing values are influenced by nearby properties and hence susceptible to spatial interactions; ignoring this spatial dependence may lead to biased and inconsistent estimators (Anselin & Arribas-Bel, 2013). Unlike standard models, spatial hedonic models account for spatial dependence but the only additional location specific variable is the number of distressed properties nearby, and binary indicators for properties in Boulder City, which has significantly lower property density than in the rest of the LVMA. Other standard neighborhood variables (e.g. school quality, crime rates) are not included because the impact of locally constant neighborhood variables is captured by spatial interaction terms.

A Moran's I statistic (Cliff & Ord, 1981), confirmed ($p<0.01$) the presence of spatial autocorrelation in the logarithm of sale prices. Empirical results from Moran's I correlograms, estimated for each quarter, suggest that spatial dependence of sales price was statistically significant up to 10 km, however a spatial model with spatial effect coefficients outside the range of -1 to 1 interval suggest model miss specification. However, weight matrices with a 2 km bandwidth result in 58 well specified spatial models. Let n designate sample size and q the number of explanatory variables including a constant term. In matrix form, the Spatial Autoregressive Model with Autoregressive Disturbances (SARAR) models I considered can be written:

$$\begin{cases} \log(\mathbf{P}) = \lambda \mathbf{W} \log(\mathbf{P}) + \mathbf{X}\boldsymbol{\beta} + \mathbf{u}, \\ \mathbf{u} = \rho \mathbf{W}\mathbf{u} + \boldsymbol{\varepsilon}, \end{cases} \tag{4.2}$$

where:

- $\mathbf{P}$ is an $n \times 1$ vector of single family residential property prices;
- λ and ρ ($|\rho|<1$, $|\lambda|<1$) are respectively unknown spatial lag and spatial error parameters;
- $\mathbf{W}$ is an $n \times n$ spatial weight matrix, which reflects spatial interactions;
- $\mathbf{X}$ is an $n \times q$ matrix of exogenous explanatory variables;

- **β** is a $q \times 1$ vector of unknown coefficients;
- **u** is an $n \times 1$ vector of correlated residuals; and
- **ε** is an $n \times 1$ vector of independently distributed errors with zero mean.

When ρ=0, Equation (4.2) reduces to a spatial lag model and when λ=0, it becomes a spatial error model; setting both λ and ρ to 0 yields a simple linear regression model. In Equation(4.2), the term $\lambda \mathbf{W} \log(\mathbf{P})$ reflects the impact of prices of neighboring properties and accounts for locally constant omitted variables, while **u** captures residual spatial autocorrelation.

I estimated my SARAR models using both Maximum Likelihood (ML) and Generalized Spatial Two-Stage Least Squares (GS2SLS), because ML estimation can lead to inconsistent estimators when errors are heteroskedastic (Arraiz, *et al.*, 2010). The preferred approach is the GS2SLS estimator proposed by Arraiz *et al.* (2010) because it yields consistent parameter estimates (λ, **β**, and ρ in Equation (4.2)) even in the presence of heteroskedastic errors.

WEIGHT MATRIX

The off diagonal weights for my starting weight matrix is given by $\mathrm{w}_{ij} = (1 + (d_{ij} / b)^2)^{-1}$, for $d_{ij} \le b$ and 0 otherwise, where d_{ij} is the straight line distance between properties i and j; and d=2.00 km is the bandwidth parameter that yields 58 well specified models. Since the weight matrix **W** captures spatial interactions with nearby properties and a property does not spatially interact with its own selling price, the diagonal terms of **W a**re 0. I facilitate the interpretation of results, I normalized the rows of **W**to sum to 1.

INTERPRETING RESULTS

Interpreting the results from a SARAR model is more involved than interpreting results from a simple linear regression because of the spatial lag term $\lambda \mathbf{W} \log(\mathbf{P})$, which contains feedback effects from surrounding properties. However, the purpose of the study is to first uncover if the NRA is capitalized in property value and examine if capitalization rates over time vary with water levels. Therefore, the significance, size, and temporal relationship of the explanatory variables will sufficiently address the aims of the study. For a description of the spatial lag variable and its interpretation see Chapter 3.

RESULTS

Results were estimated using Stata 13. Due to the number of estimates associated with the 58 models, I present regression results in graphical form. Figure 4.7 to Figure 4.13 present point estimates and 95 percent confidence intervals (CI) for variables of interest. For brevity, I only present results from the weight matrix with starting weights $w_{ij} = (1 + (d_{ij} / b)^2)^{-1}$ and a distance band of 2 km estimated via GS2SLS in order to avoid biases due to heteroskedasticity.

TEMPORAL, SPATIAL, AND FORECLOSURE EFFECTS

I examined a number of model specifications at the quarterly and annual level. Within the annual specification I included interaction terms between the quarter level indicator and structural, and environmental characteristics, as well as the distress and distress squared variable, to account for intra annual temporal effects among sales price. However, high VIF factors indicated the presence of multicollinearity. Although eliminating variables associated with high variance inflation factors (VIF) reduced multicollinearity, insignificant distress and housing age variables, as well as spatial error coefficients beyond the acceptable (-1,1) range, suggested specification problems. Insignificant foreclosure variables were especially disconcerting given that Daneshvary and

Clauretie (2012) also specified a SARAR model estimated via GS2SLS and found that distress variables are negative and significant for both 2008 and 2009.

However, quarterly level models, although more cumbersome to interpret, were associated with relatively consistent structural and distress variables. Furthermore spatial error coefficients for all quarterly models were within the acceptable range. Quarterly models also did not suffer from multicollinearity. Finally, as stated earlier, summary statistics and regression results suggest a considerable quarterly level variation among housing prices and distress externalities.

Both Harding *et al.* and Daneshvary and Clauretie (2012) suggest that foreclosure spillover effects are strongest within 300-500 feet of a non-distressed sale for the LVMA, although negative effects were also significant beyond 2000 feet. I tried rings ranging from 300 to 2000 and similar to Daneshvary and Clauretie (2012), I also found negative and significant distress spillover effects associated with ring specifications from 500-2000ft. Finally, I estimated models using various network distance specifications, e.g. linear, log, and quadratic specifications and with distance bands ranging from 2 to 5 km, as well as models with only data from Henderson and Boulder (the communities closest to the NRA). Distance effects varied only slightly with different specifications; all specifications, however, suggested that distance effects were primarily insignificant, and in some cases distance from the NRA was positively capitalized in the housing market for some years outside of the worst period of the housing market crisis (2008-2009). These results suggest that distance does not explain variation in sale prices during this period analyzed.

Finally, Table 4.3 and 4.4 display estimates for λ and ρ (respectively the spatial lag and spatial error parameters), which are both statistically significant and have acceptable values (absolute values under one), confirming the presence of spatial effects.

Discussion and Interpretation of Results

Figures 4.9-4.15 display how point coefficients for each quarter vary over time.

Figures 4.9 and 4.10 display the logs of lot and building size. Consistent with the hedonic literature, both are significant and positively capitalized in the housing market.

Figure 4.11 shows that an additional bathroom is associated with an increase in price, but CI indicate that this coefficient loses significance for a few quarters in 2009 and 2010, although the positive effect of an additional bathroom is relatively stable over time.

Figure 4.12 suggest that an additional bedroom is associated with a drop in sale price. Typically, additional bedrooms and bathrooms are associated with a premium. However, because both have also been associated with reduced sale prices (Anderson, 1985; Raymond, 2002).

Likewise, capitalization effects of age vary. In some markets age is an amenity when age is associated with historic value, but older homes typically sell for less than newer ones. Figure 4.13 suggests that age has a negative effect on sale price, although the age variable loses statistical significance from the end of 2006 until the beginning of 2008, which is the period just preceding the housing market crisis.

Despite minor variations in significance levels among the 58 quarterly models, the signs and significance levels of structural characteristics are compatibles with those of previous, related hedonic studies, which gives confidence in model results.

Let us now consider the impact of distressed sales. Figure 4.14 suggests that spillover effects do not impair sales price during the early part of the decade, which corresponds to a relatively stable period for the LVMA housing market. However, additional neighboring foreclosures started negatively affect home values from the middle 2002 to the middle of 2005. Summary statistics for sale prices (Figure 4. 5) show that housing prices drastically increased during that time. As for age, however, additional neighborhood foreclosures are not significant prior to 2008 when the foreclosure rates began to soar. From this point on and until until the second quarter of 2014 foreclosure effects remain negative and highly significant. These effects are largest relative to distress effects from 2002-2005 within this time frame.

Finally, Figure 4.15 displays price effects associated with network distance to the closest NRA entrance. Results suggest that proximity to Lake Mead is not impacting the local housing market. The coefficient of distance from the NRA is even positive and significant from mid-2004 to 2005 and from mid-2010 to 2012, although it remains insignificant for the remaining study time. As mentioned earlier, this result is robust to the various model specifications I tested, which suggests that the NRA is not explaining variations of the LVMA housing market. This result indicates that despite the number of local visitors to the Lake Mead NRA, amenities associated with the park are essentially dwarfed by the amenity value associated with the Las Vegas strip. The "strip" is the primary driver of the Las Vegas economy, as well as larger housing market dynamics within the LVMA. Likewise, any positive effect associated with being away from the park suggests that proximity to the central Las Vegas Area, rather than the park, is associated with an amenity. Furthermore, the low residential density near the NRA does not allow houses to capture amenities associated with the NRA. To locals, this area may be viewed as undesirable because of the noise and traffic associated with the large number of visitors.

CONCLUSIONS

In this chapter, I explored if proximity to Lake Mead is reflected in the housing market of the LVMA as a first step to analyze impacts of declining water levels in Lake Mead, which have taken place since 2000. In order to control for spatial and temporal effects, I estimated quarterly spatial hedonic models for each quarter of the period spanning 2000 to the first half of 2014. Each model accounted for foreclosure spillover effects via counts of the number of foreclosures that happened during the year of sale of each property. To my knowledge, my study is a rare example of hedonic study in such a dynamic urban market during a troubled period. Since the Lake Mead NRA receives millions of visitors every year, I initially hypothesized that proximity to this major park would be positively capitalized in LVMA housing market and that it would vary over time to reflect dropping water levels in Lake Mead.

Interestingly, however, my results show that proximity to the Lake Mead NRA is not positively capitalized in the regional housing market, and that its value is not influenced by fluctuating water levels. During a few years, network distance from the Lake was even positively capitalized within the housing market, suggesting that homes farther away from this recreation site fetch higher values. This result suggests that, despite the number of visitors that Lake Mead NRA receives every year, its value is dwarfed by the Las Vegas strip. This suggests that the value of the Lake Mead NRA cannot be appropriately captured by hedonic pricing. A better approach in this case would be travel cost and contingent valuation (see Chapter 2). In addition, the latter would also allow quantifying the existence value of Lake Mead and its surrounding park.

Future work regarding Lake Mead and the LVMA should include data about the number of visitors at entry points. This data would allow one to see if residential prices vary with the variation of number of visitors over years. This study would also benefit from additional information regarding the real estate market in Boulder and Henderson, the two communities adjacent to Lake Mead. Evidence indicating that these locations are less desirable than homes more centrally located with further support the findings of the study and further validate the estimates associated with network distance. Finally, obtaining data on visitors points of origin would reveal the proportion of visitors from surrounding regions, vs. those that travel outside the LVMA. If few visitors come from the immediate area, this would suggest that the Lake is primarily valued for recreation, and therefore is not capitalized in the local housing market.

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Table 4.1: Quarter Level Mean and Standard Deviation of Price & Structural Characteristics for Single Residential Transactions in Las Vegas Metro Area: (2000-2007)

	Price ($)		Lot size (sqft)		Home size (sqft)		bathrooms		bedrooms		Age (years)	
Quarter	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
2000q1	176473	137564.2	7979.175	5376.634	2299.626	847.69	2.428	0.677	3.342	0.778	26.704	12.605
2000q2	177529.7	128348.9	7712.782	4959.810	2269.384	795.379	2.428	0.673	3.318	0.755	26.373	12.515
2000q3	177678.2	122168.5	7677.325	4888.695	2302.031	796.355	2.437	0.662	3.366	0.770	25.808	12.446
2000q4	175463.9	121252.9	7599.180	4839.004	2230.804	782.792	2.394	0.652	3.298	0.755	26.188	12.625
2001q1	177872.9	87816.53	7323.740	4393.476	2343.806	802.379	2.477	0.670	3.356	0.772	22.878	12.066
2001q2	175530	94491.89	7549.785	4726.175	2264.398	763.631	2.425	0.653	3.314	0.767	25.279	12.197
2001q3	179115.5	94611.57	7464.314	4463.730	2286.230	763.555	2.442	0.701	3.365	0.785	25.198	12.435
2001q4	177090.3	100275.4	7391.372	4491.765	2233.651	757.624	2.399	0.659	3.301	0.757	25.443	12.385
2002q1	184786.5	101249.5	7515.042	4789.017	2287.154	806.609	2.432	0.673	3.341	0.764	24.931	12.397
2002q2	189966.2	100474.6	7431.361	4435.490	2310.917	800.936	2.457	0.680	3.352	0.781	24.373	12.275
2002q3	191169.1	90018.33	7337.013	4252.544	2321.648	778.837	2.472	0.658	3.364	0.781	23.829	11.990
2002q4	197344.4	103885.5	7496.409	4882.919	2325.851	812.078	2.473	0.688	3.364	0.806	23.746	12.252
2003q1	202054.7	99027.22	7299.063	4392.398	2335.975	787.788	2.493	0.668	3.354	0.792	22.975	12.023
2003q2	208475.5	105958.2	7351.637	4362.809	2348.394	804.755	2.509	0.718	3.380	0.795	23.461	12.241
2003q3	219728	114495.3	7374.283	4536.977	2375.398	809.989	2.522	0.671	3.398	0.776	22.797	11.764
2003q4	224564	113999.2	7320.75	4721.267	2316.735	806.532	2.495	0.690	3.356	0.784	23.398	12.778
2004q1	251670.5	130122.9	7207.171	4438.936	2333.695	816.671	2.518	0.700	3.349	0.774	22.483	12.718
2004q2	286965	156676.8	7186.579	4624.908	2280.057	821.943	2.472	0.701	3.346	0.785	23.220	13.278
2004q3	303596.4	160096.4	7050.096	4245.401	2240.128	794.261	2.446	0.691	3.334	0.771	23.612	13.399
2004q4	310653.1	170889.4	7079.166	4250.842	2252.281	802.054	2.448	0.689	3.353	0.781	23.596	14.483
2005q1	324323.9	179943.4	7258.587	4633.662	2290.085	846.972	2.477	0.733	3.310	0.781	23.322	14.069
2005q2	342221.7	193797.8	7374.961	4804.120	2295.285	829.040	2.483	0.724	3.314	0.770	23.557	14.116
2005q3	360308.8	191710.2	7477.202	5046.203	2364.253	868.598	2.522	0.722	3.337	0.785	22.491	13.593
2005q4	354050.6	173488.6	7480.557	4893.063	2335.927	833.588	2.466	0.723	3.307	0.828	22.474	14.224
2006q1	369810.8	193284.8	7306.104	4537.914	2362.850	825.362	2.503	0.721	3.312	0.796	21.852	13.624
2006q2	383413.4	206311.8	7592.679	4453.809	2411.609	854.975	2.518	0.729	3.311	0.788	21.791	13.311
2006q3	375083.8	209685.1	7535.242	4523.567	2386.947	876.448	2.508	0.736	3.341	0.833	22.431	14.450
2006q4	374753.2	215731.4	7769.018	5412.207	2403.771	885.902	2.513	0.738	3.335	0.813	22.115	14.039

Table 4.2: Quarterly Mean and Standard Deviation of Price & Characteristics for SFR in Las Vegas Metro (2007-2014)

	Price ($)		Lot size (sqft)		Home size (sqft)		bathrooms		bedrooms		Age (years)	
Quarter	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std.Dev.	Mean	Std. Dev.	Mean	Std.Dev.
2007q1	388144.1	222499.3	7787.399	4721.782	2435.441	844.335	2.528	0.735	3.287	0.789	20.964	13.368
2007q2	382122.2	211762.1	7884.963	5058.619	2475.645	913.106	2.553	0.759	3.325	0.855	21.506	13.156
2007q3	365950.9	210038.6	7730.913	4294.077	2459.694	892.547	2.512	0.755	3.280	0.843	22.071	13.843
2007q4	337805.5	226501.0	6977.871	4960.840	2426.31	919.298	2.700	0.8650	3.197	0.867	19.584	14.179
2008q1	330375.	181935.4	8048.018	5468.004	2503.816	862.834	2.538	0.724	3.251	0.788	20.887	13.802
2008q2	324570.9	185429.6	7657.856	4874.944	2509.719	872.143	2.589	0.754	3.217	0.823	19.486	12.894
2008q3	283869.0	150907.3	7293.377	4744.171	2488.994	826.414	2.613	0.715	3.291	0.836	18.445	12.966
2008q4	291468.3	194114.7	6529.832	3814.335	2628.179	894.841	2.790	0.770	3.372	0.819	14.618	12.512
2009q1	266132.7	174238.6	7543.303	5200.966	2644.305	930.413	2.746	0.740	3.436	0.835	16.951	12.490
2009q2	305358.2	317545.4	7454.873	4386.803	2706.617	953.915	2.689	0.753	3.370	0.839	16.823	12.046
2009q3	259265.1	210377.4	8195.955	5610.518	2664.794	924.009	2.722	0.810	3.344	0.782	17.843	11.607
2009q4	248013.7	201018.1	6973.768	4642.478	2530.283	847.075	2.694	0.711	3.329	0.818	17.052	11.532
2010q1	215689.1	125074.6	7602.454	5435.106	2554.486	885.516	2.656	0.736	3.366	0.901	18.058	12.388
2010q2	220116.2	139898.7	7428.278	4474.533	2565.616	876.656	2.671	0.765	3.315	0.820	17.911	12.009
2010q3	225177.0	166483.9	7465.742	5025.544	2614.911	878.397	2.708	0.745	3.371	0.867	17.530	11.459
2010q4	231400.2	166331.6	7605.086	5464.609	2601.905	875.898	2.727	0.708	3.332	0.848	15.791	10.693
2011q1	232390.9	151051.9	7781.661	5379.098	2698.574	983.926	2.782	0.836	3.369	0.853	16.427	11.096
2011q2	210684.5	140395.3	7384.394	4697.349	2556.179	886.622	2.698	0.739	3.272	0.816	16.504	10.669
2011q3	214568.4	149927.1	7524.606	5044.263	2644.646	913.321	2.734	0.761	3.340	0.826	16.420	10.369
2011q4	208322.8	134106.5	7535.191	5152.260	2602.704	895.054	2.715	0.750	3.323	0.824	16.374	10.944
2012q1	253007.8	238263.1	7541.000	5633.549	2637.925	864.171	2.771	0.796	3.278	0.793	15.638	10.524
2012q2	234241.2	185356.1	7963.962	5280.29	2682.715	920.712	2.741	0.792	3.336	0.873	17.034	11.071
2012q3	246606.0	239955.9	7748.160	5145.05	2606.014	875.033	2.687	0.739	3.365	0.855	17.771	12.213
2012q4	222985.0	150556.0	7610.887	5134.16	2589.755	900.246	2.685	0.749	3.351	0.848	17.800	11.993
2013q1	227824.2	191023.5	7200.651	5070.768	2567.718	870.074	2.698	0.721	3.400	0.831	17.447	11.827
2013q2	233362.6	140028.9	7183.843	4612.719	2552.756	862.573	2.677	0.713	3.356	0.813	17.638	12.188
2013q3	227591.9	129581.6	7225.457	4939.557	2480.923	836.801	2.640	0.714	3.347	0.790	18.428	12.653
2013q4	227285.7	120771.1	7066.057	4759.723	2480.079	850.3969	2.636	0.697	3.366	0.799	18.263	12.512
2014q1	229150.4	122296.2	7108.920	4753.307	2464.199	812.1893	2.616	0.682	3.376	0.798	19.054	13.268
2014q2	232544	122401.7	6972.911	4581.878	2438.537	810.4847	2.615	0.693	3.340	0.795	18.931	13.424

Table 4.3: Regression Results by Quarter (2000-2006)

	Price ($)	Lot size (sqft)	Home size (sqft)	number of bathrooms	number of bedrooms	Count distress	Count distress_sq	network	labmda	
rh2000q1	0.206***	0.751***	0.030**	-0.038***	-0.003	-0.015	0.002	0.005	0.242***	0.748***
2000q2	0.154***	0.715***	0.025**	-0.021***	-0.003	-0.009*	-0.001	0.002	0.510***	0.852***
2000q3	0.186***	0.766***	0.009	-0.020***	-0.002	0.000	0.001	0.0049	0.331***	0.839***
2000q4	0.194***	0.743***	0.046***	-0.040***	-0.003	-0.017	0.006	0.0038	0.262***	0.827***
2001q1	0.148***	0.753***	0.033***	-0.038***	-0.001	-0.009	0.002	0.0011	0.323***	0.657***
2001q2	0.184***	0.670***	0.0370***	-0.017***	-0.002	-0.006	0.002	0.0019*	0.313***	0.556***
2001q3	0.174***	0.686***	0.033***	-0.020***	-0.003	-0.007	0.001	0.002	0.320***	0.548***
2001q4	0.178***	0.652***	0.039***	-0.012***	-0.002	0.001	0.001	0.0014	0.359***	0.654***
2002q1	0.206***	0.677***	0.046***	-0.034***	-0.003	-0.011	0.005	0.0017	0.282***	0.477***
2002q2	0.173***	0.670***	0.043***	-0.028***	-0.002	-0.009*	0.002	0.0013	0.352***	0.630***
2002q3	0.198***	0.672***	0.046***	-0.031***	-0.003	-0.016***	0.006	0.0028**	0.298***	0.675***
2002q4	0.189***	0.701***	0.046***	-0.026***	-0.003	-0.002	0.000	0.0021	0.278***	0.732***
2003q1	0.153***	0.707***	0.039***	-0.028***	-0.003	-0.020***	0.002	0.0014	0.359***	0.436***
2003q2	0.182***	0.717***	0.042***	-0.036***	-0.002	-0.017***	0.006	0.0023	0.357***	0.751***
2003q3	0.196***	0.726***	0.042***	-0.035***	-0.004	-0.009**	0.001	0.0014	0.324***	0.770***
2003q4	0.186***	0.716***	0.029***	-0.025***	-0.004	-0.090*	0.001	0.0024	0.381***	0.736***
2004q1	0.149***	0.714***	0.041***	-0.031***	-0.005	-0.012***	0.001***	0.0023	0.420***	0.634***
2004q2	0.168***	0.700***	0.042***	-0.027***	-0.005	-0.009***	0.001***	0.004***	0.445***	0.592***
2004q3	0.145***	0.687***	0.032***	-0.015***	-0.005	-0.010***	0.000	0.004**	0.416***	0.663***
2004q4	0.156***	0.661***	0.056***	-0.012***	-0.004	-0.013***	0.000	0.003**	0.398***	0.511***
2005q1	0.144***	0.696***	0.059***	-0.034***	-0.003	-0.012***	0.000	0.003**	0.403***	0.409***
2005q2	0.172***	0.681***	0.032***	-0.005	-0.004	-0.011***	0.001	0.003**	0.408***	0.580***
2005q3	0.175***	0.685***	0.052***	-0.020***	-0.003	-0.005	0.000	0.004**	0.375***	0.529***
2005q4	0.124***	0.735***	0.040***	-0.033***	-0.001	-0.012***	0.001	0.002*	0.383***	0.212***
2006q1	0.179***	0.724***	0.053***	-0.029***	-0.000**	-0.003	0.000	0.002	0.331***	0.30***
2006q2	0.174***	0.725***	0.070***	-0.038***	-0.003*	-0.000	0.000	0.002	0.334***	0.313***
2006q3	0.152***	0.779***	0.051***	-0.024***	-0.001	-0.011**	0.001	0.001	0.328***	0.431***
2006q4	0.176***	0.730***	0.058***	-0.040***	-0.000**	-0.004	0.001***	0.002	0.268***	0.346***

Table 4.4: Regression Results by Quarter (2007-2014)

	Price ($)	Lot size (sqft)	Home size)	bathrooms	bedrooms	distress	distress_sq	distance	lambda	rho
2007q1	0.186***	0.736***	0.1021***	-0.043***	-0.001	-0.0211**	0.006	0.001	0.340***	0.240***
2007q2	0.177***	0.793***	0.0587***	-0.039***	-0.001	-0.005	0.001	0.002	0.295***	0.168**
2007q3	0.191***	0.781***	0.0809***	-0.032***	-0.001	-0.004	-0.003	0.002	0.336***	0.142*
2007q4	0.228***	0.886***	0.0529***	0.078***	-0.000**	0.023	-0.008	0.000	0.200***	0.136
2008q1	0.183***	0.823***	0.0548***	-0.051***	-0.002	-0.016	0.002	0.000	0.252***	0.145*
2008q2	0.201***	0.740***	0.0606***	-0.039***	-0.004	0.011	-0.002	0.004	0.354***	0.351***
2008q3	0.231***	0.790***	0.0476***	-0.055***	-0.003	-0.019***	0.002**	-0.001	0.300***	0.289***
2008q4	0.238***	0.713***	0.0609***	-0.043***	-0.006	-0.038***	0.002	0.001	0.190***	0.469***
2009q1	0.191***	0.873***	0.0476**	-0.072***	-0.006	-0.040***	0.002***	0.002	0.198***	0.323***
2009q2	0.2052***	1.028***	0.024	-0.044***	-0.002	-0.036***	0.002***	0.000	0.445***	0.454***
2009q3	0.222***	0.902***	0.0296	-0.042***	-0.008	-0.0471***	0.002***	0.003	0.294***	0.390***
2009q4	0.1026***	1.034***	0.0455*	-0.075***	-0.007	-0.0551***	0.005	0.000	0.326***	0.434*
2010q1	0.1711***	1.087***	0.0276	-0.098***	-0.003	-0.029***	0.002**	0.002	0.267***	0.212***
2010q2	0.2115***	0.942***	0.029**	-0.073***	-0.005	-0.050***	0.002***	0.002**	0.365***	0.413***
2010q3	0.2226***	0.955***	0.049***	-0.072***	-0.005	-0.038***	0.002***	0.004***	0.264***	0.336***
2010q4	0.1619***	1.004***	0.0027	-0.061***	-0.008	-0.092***	0.009***	0.007	0.298***	0.395***
2011q1	0.1529***	0.954***	0.0683**	-0.072***	-0.006	-0.056***	0.005***	0.005**	0.271***	0.316***
2011q2	0.1676***	1.129***	0.029***	-0.098***	-0.005	-0.025***	0.001***	0.006**	0.265***	0.583***
2011q3	0.178***	1.110***	0.021	-0.068***	-0.006	-0.040***	0.003***	0.005*	0.209***	0.506***
2011q4	0.181***	1.01***	0.053***	-0.059***	-0.005	-0.016**	0.001***	0.006	0.284***	0.558***
2012q1	0.0384	1.2549***	0.052***	-0.102***	-0.005*	0.008***	0.000***	0.003	0.499***	0.373***
2012q2	0.110***	0.9717***	0.061***	-0.053***	-0.003	-0.077***	0.009	0.002	0.484***	0.371***
2012q3	0.171***	0.8755***	0.048***	-0.010	-0.009	-0.035***	0.002	-0.001	0.476***	0.509***
2012q4	0.130***	0.959***	0.043***	-0.051***	-0.004	-0.031***	0.001	-0.001	0.393***	0.499***
2013q1	0.193***	0.7968***	0.051***	-0.020***	-0.007	-0.048***	0.006	0.005	0.389***	0.598***
2013q2	0.195***	0.8254***	0.046***	-0.047**	-0.005	-0.031***	0.003***	0.002	0.433***	0.549***
2013q3	0.176***	0.8418***	0.038***	-0.037***	-0.004	-0.0181***	0.003	0.002	0.398***	0.667***
2013q4	0.182***	0.8429***	0.033***	-0.046***	-0.004	-0.011**	0.002	0.003	0.420***	0.609***
2014q1	0.206***	0.7569***	0.060***	-0.032***	-0.004	0.015	-0.008*	0.002	0.399***	0.644***
2014q2	0.173***	0.846***	0.030***	0.039***	-0.003	-0.022***	0.005	0.003	0.406***	0.645***

Figure 4.1: Lake Mead with Visible Signs of Water Level Depletion

Source: Hobson, Jeremy. 2014. "America’s Largest Reservoir Keeps Shrinking." *Here and Now with Jeremy Hobson and Robin Young* WBUR

Figure 4. 2: Geographic location of Non-distressed Single Family Sales

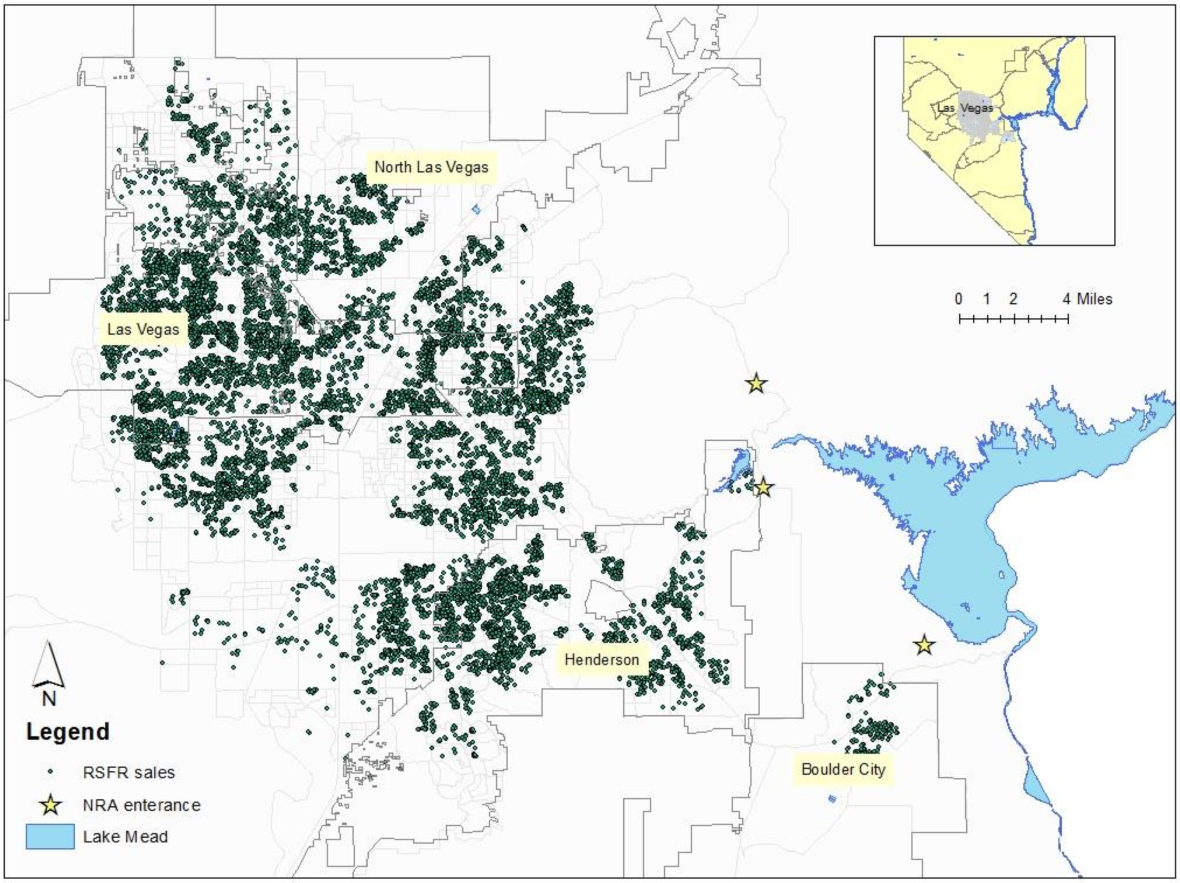
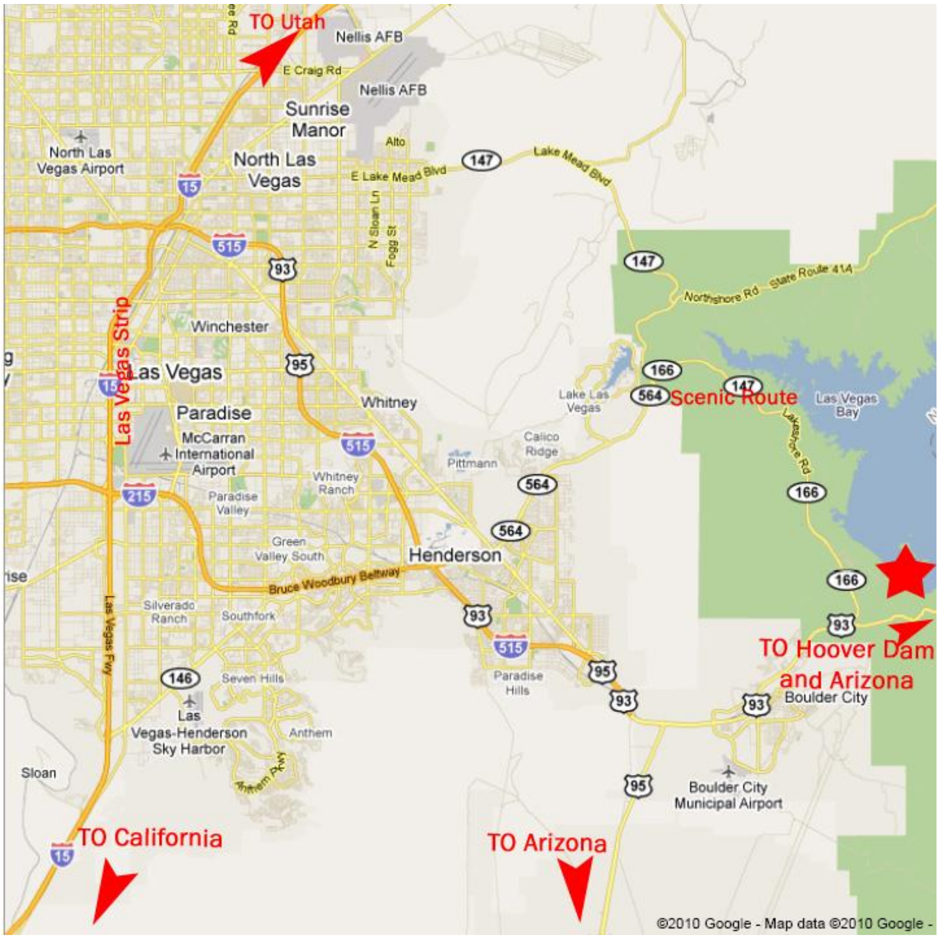


Figure 4.3: Map of Street Network in the Las Vegas Metro Area and Approximate Location of NRA Entrances



Source: Google Maps

Figure 4.4: Lake Mead Water Levels (feet) 2000-2014

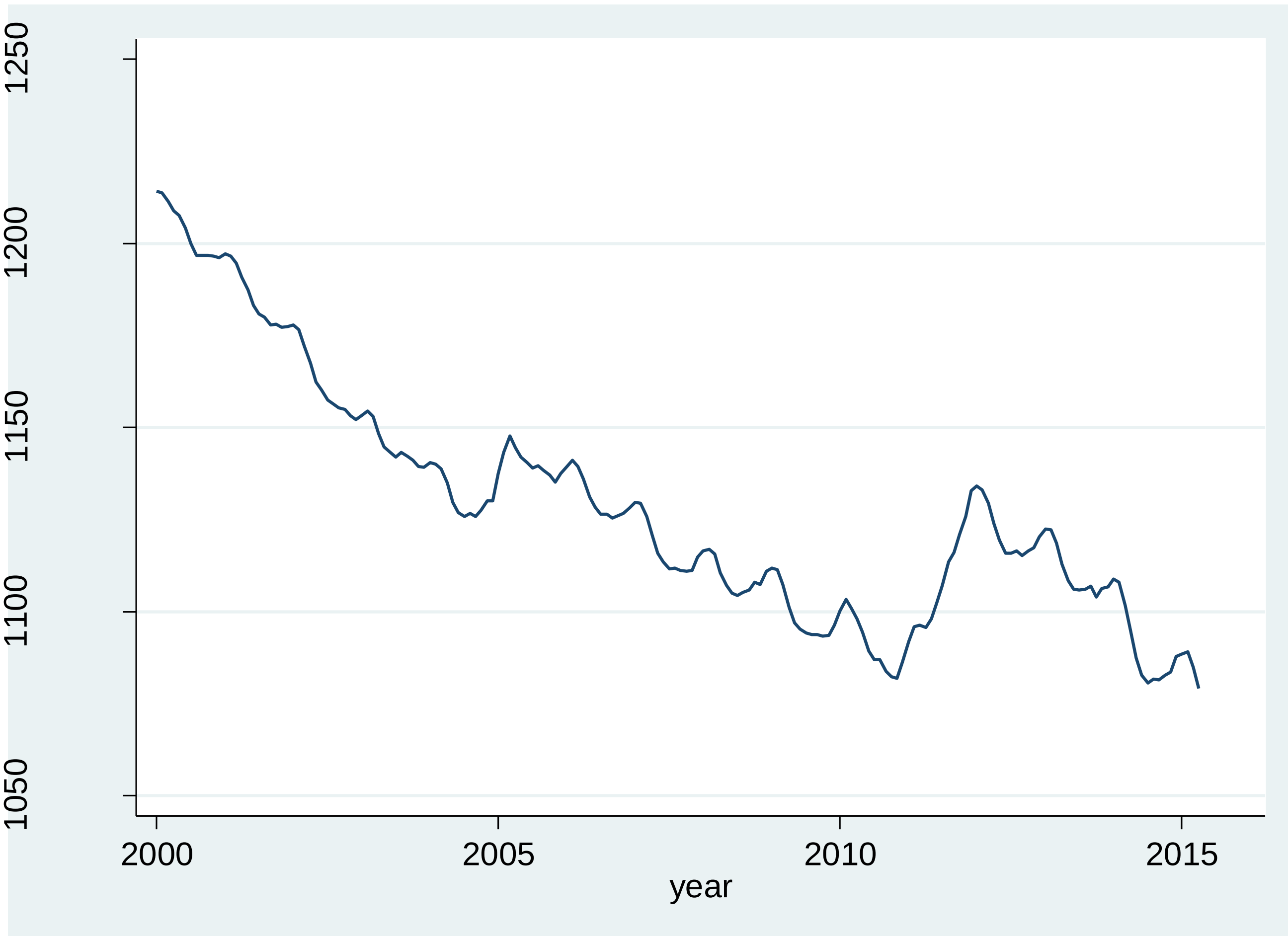
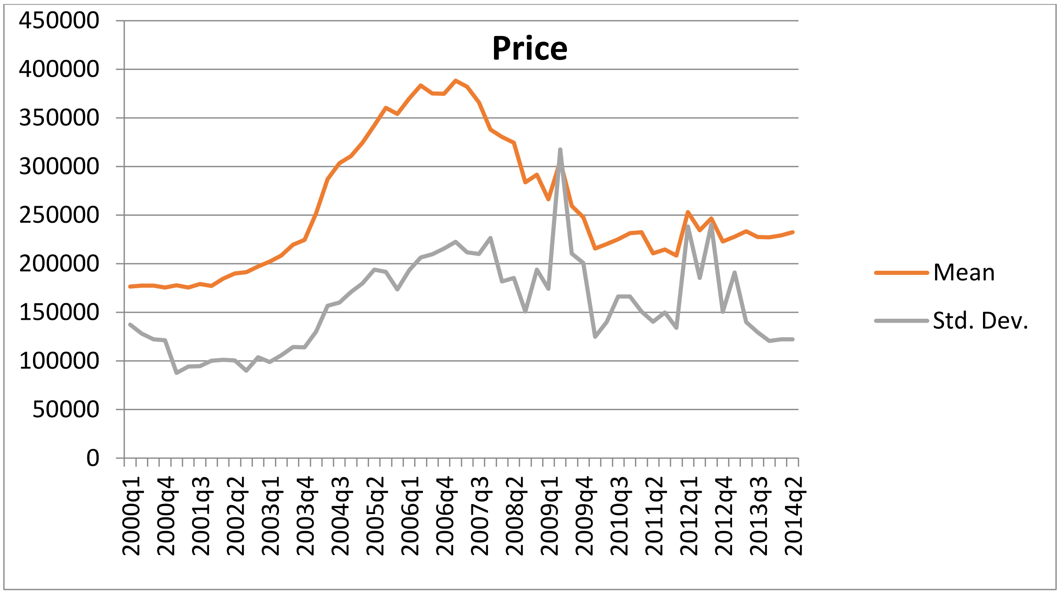


Figure 4.5: Quarter Level Summary Statistics for Price Lot sqft



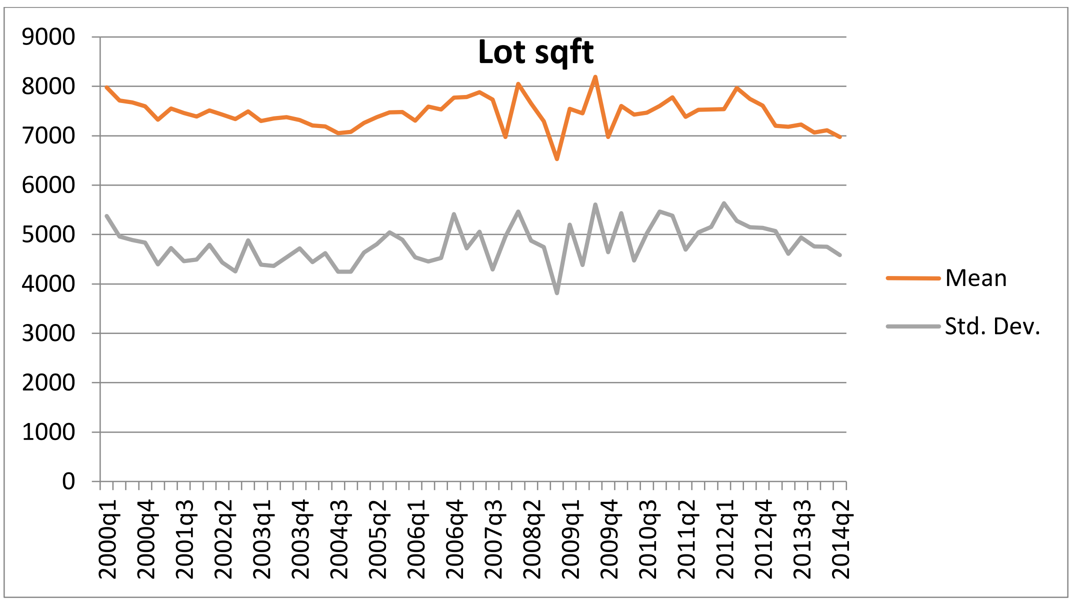
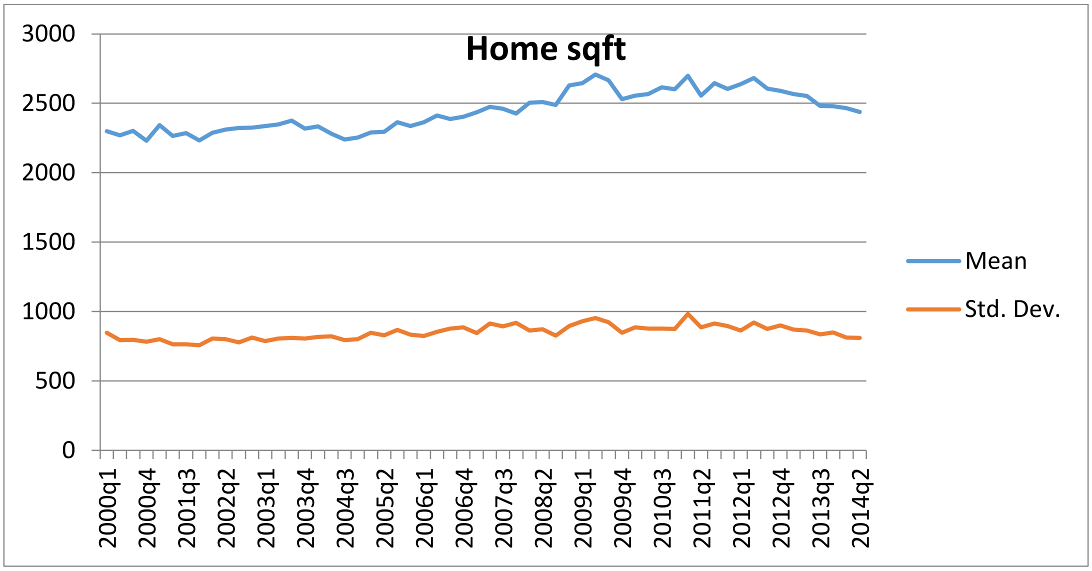


Figure 4.6: Quarter Level Summary Statistics for Home sqft and Baths



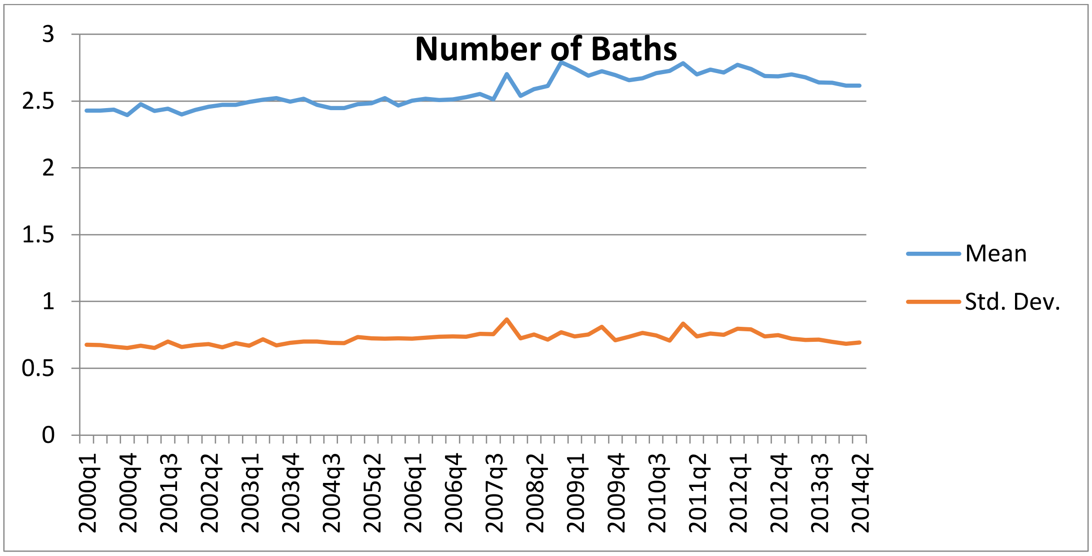


Figure 4.7: Quarter Level Summary Statistics for Age of Home

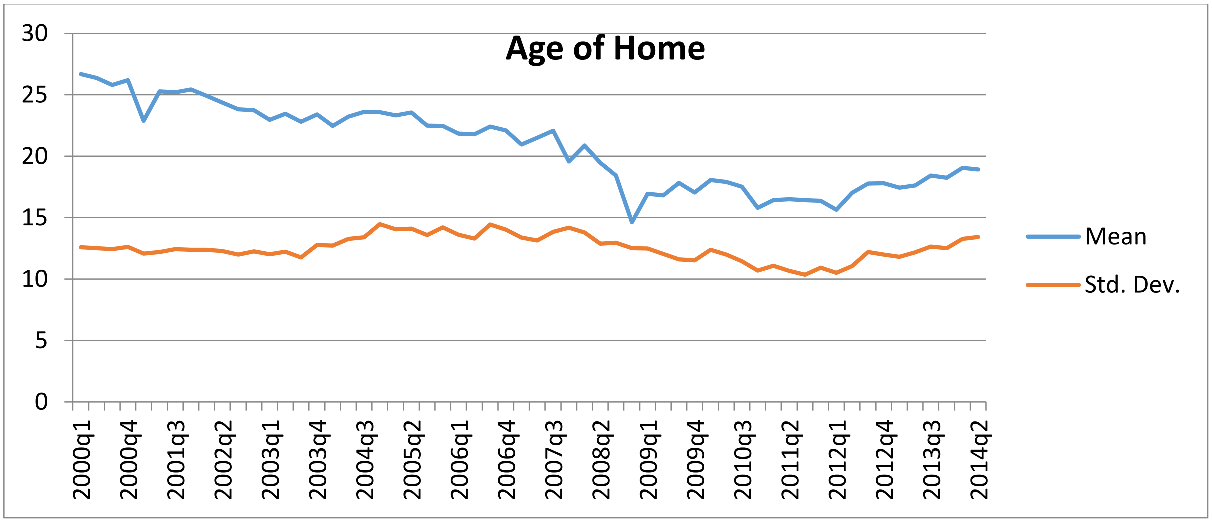
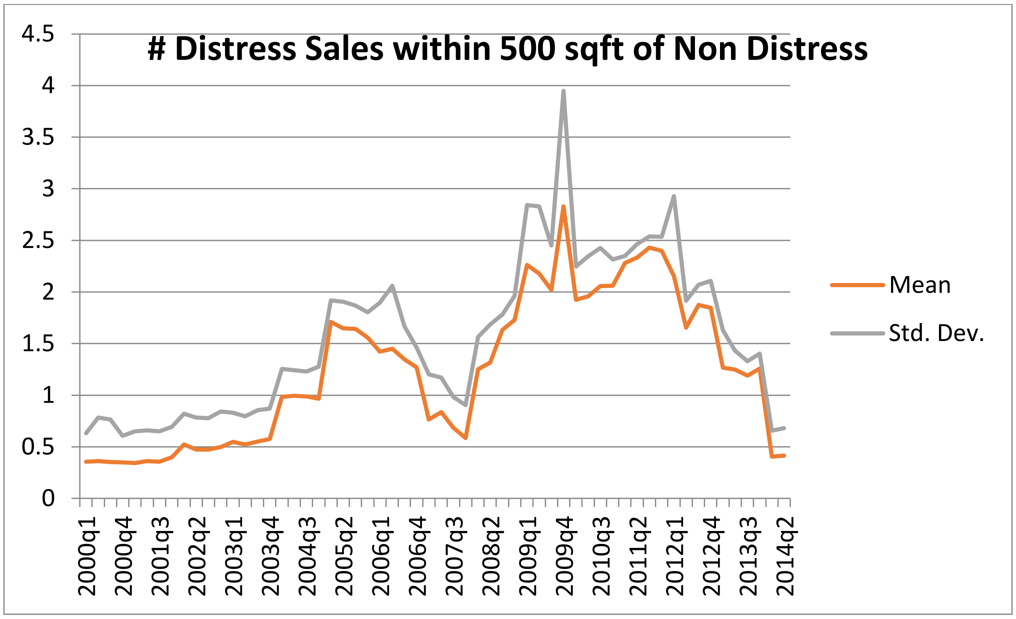


Figure 4.8: Quarter Level Summary Statistics for Distress and Distance



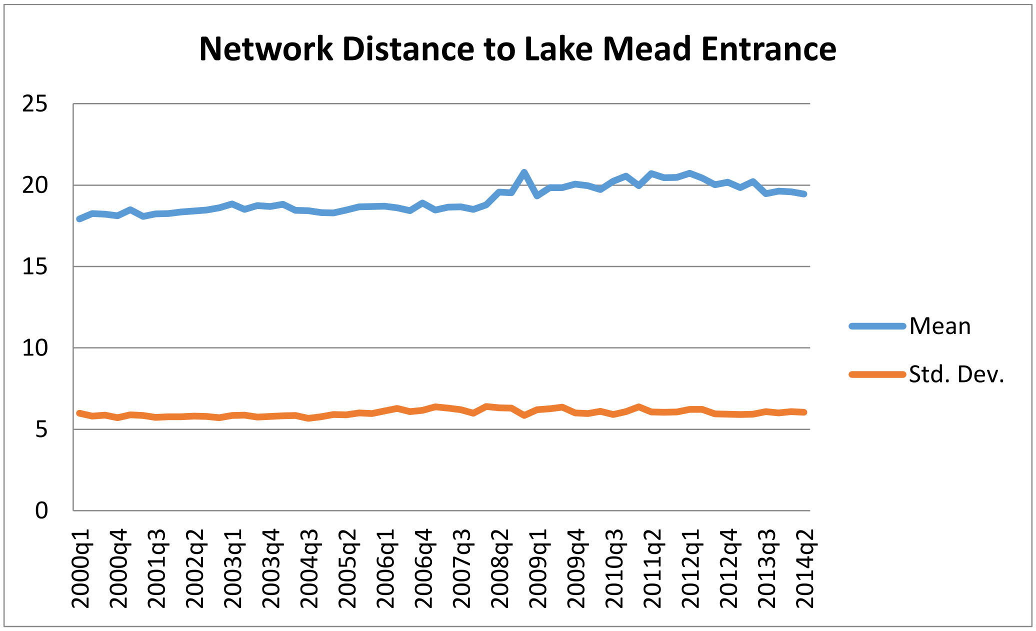


Figure 4.9: Quarterly Point Estimates of Elasticity of Lot Size and 95 % Confidence Interval

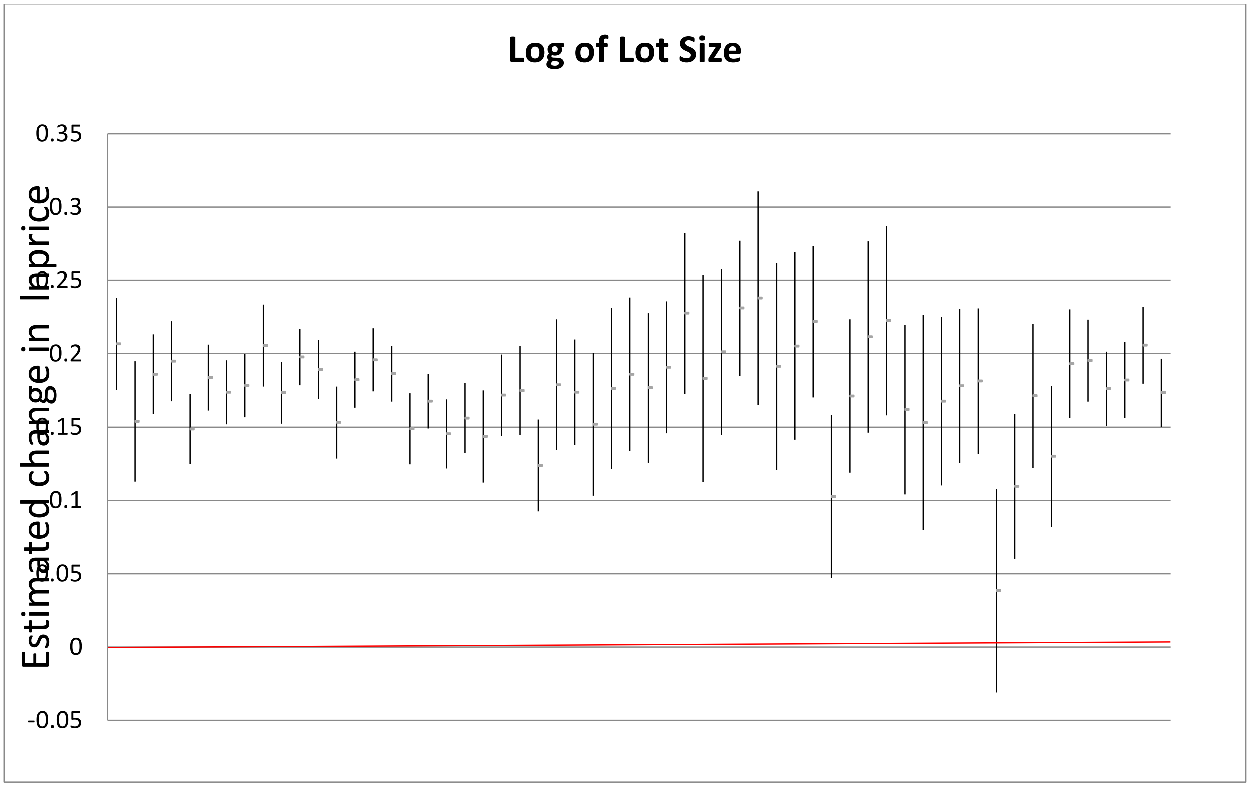


Figure 4.10: Quarterly Point Estimates of Elasticity of Building Size and 95 % Confidence Interval

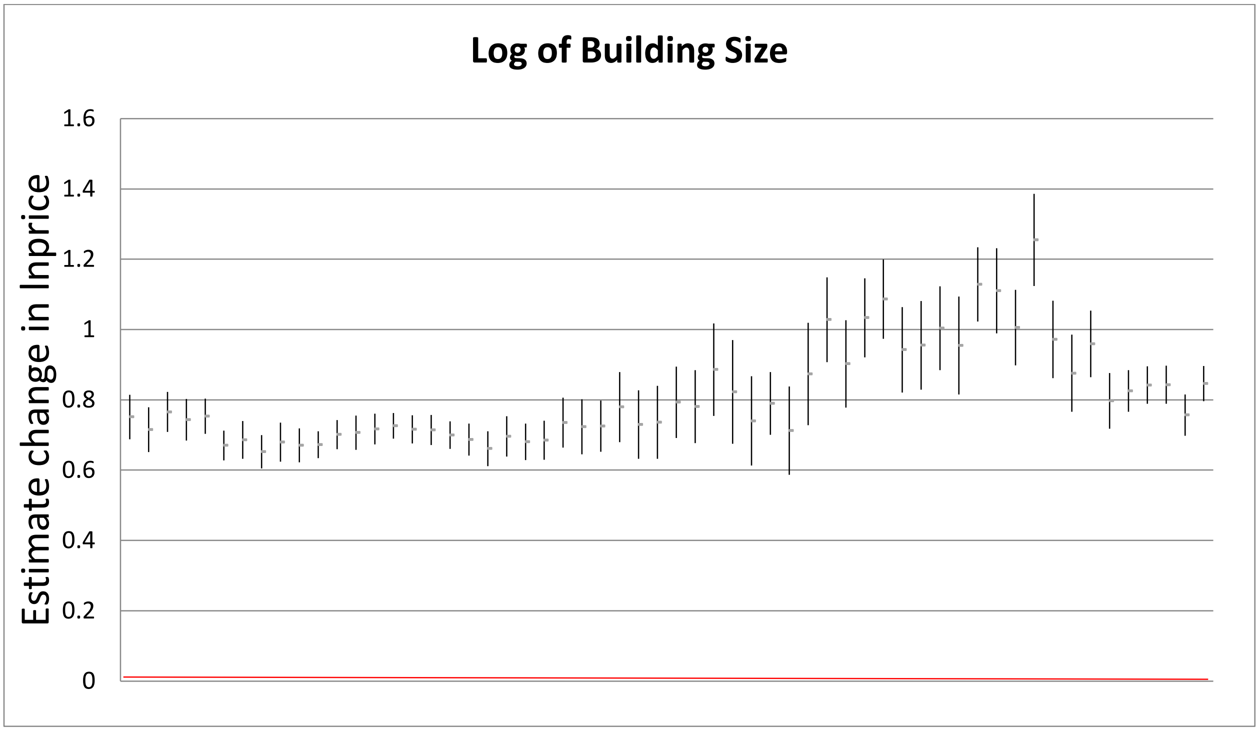


Figure 4.11: Quarterly Point Estimates of Semi Elasticity of Additional Bathroom and 95 % Confidence Interval

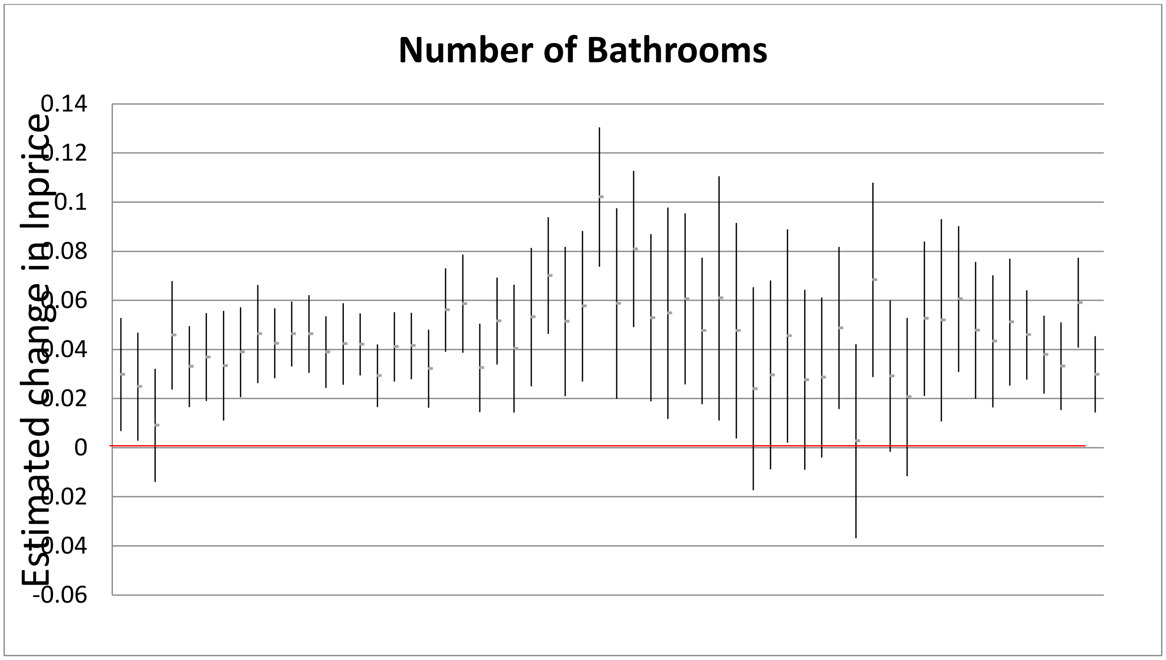


Figure 4.12: Quarterly Point Estimates of Semi Elasticity of Additional Bedroom and 95%Confidence Interval

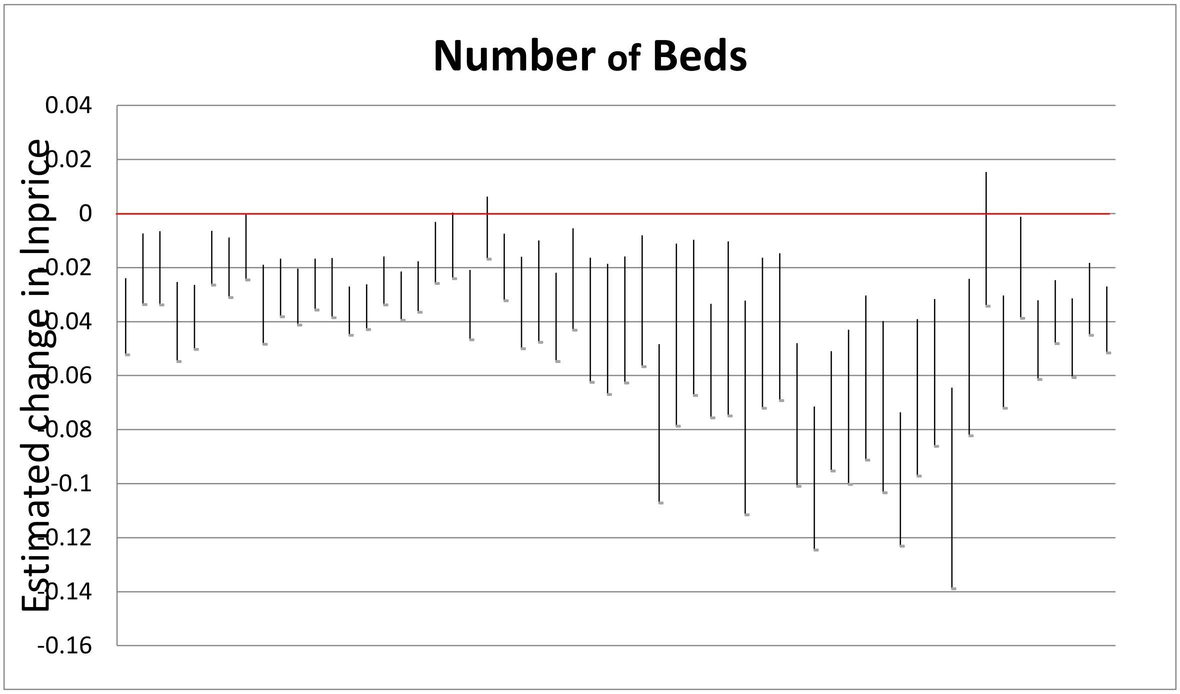


Figure 4.13: Quarterly Point Estimates of Semi Elasticity of Age and 95 % Confidence Interval

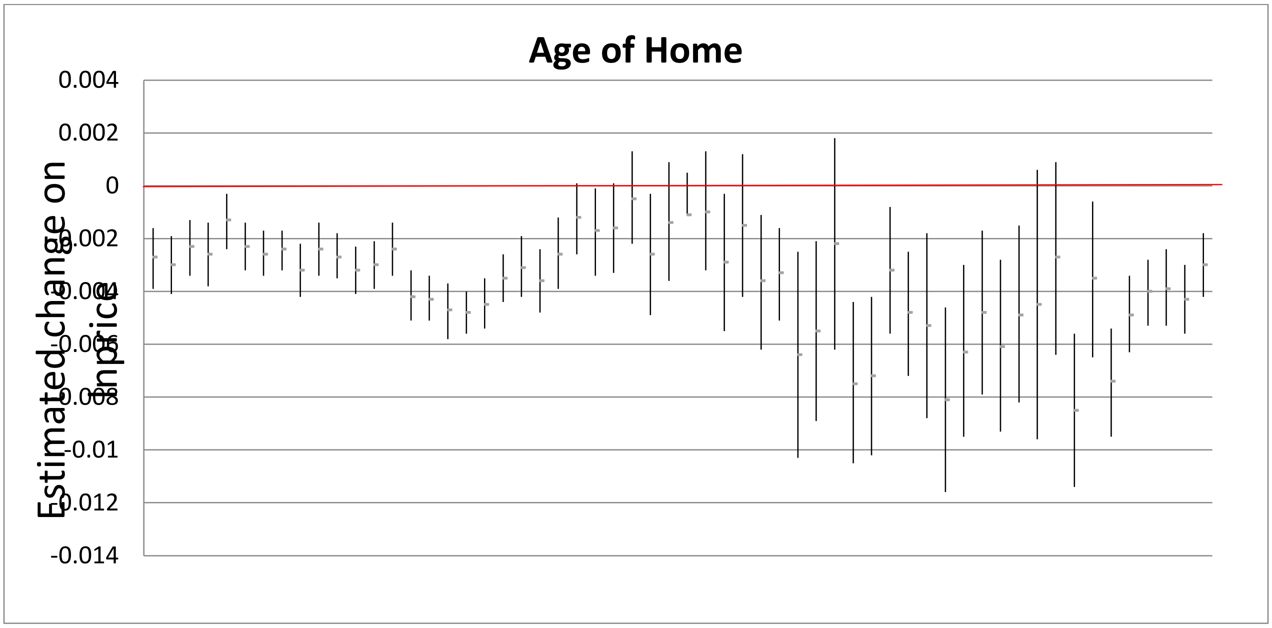


Figure 4.14: Quarterly Point Estimates of Semi Elasticity of Additional Distress Property and 95 % Confidence Interval

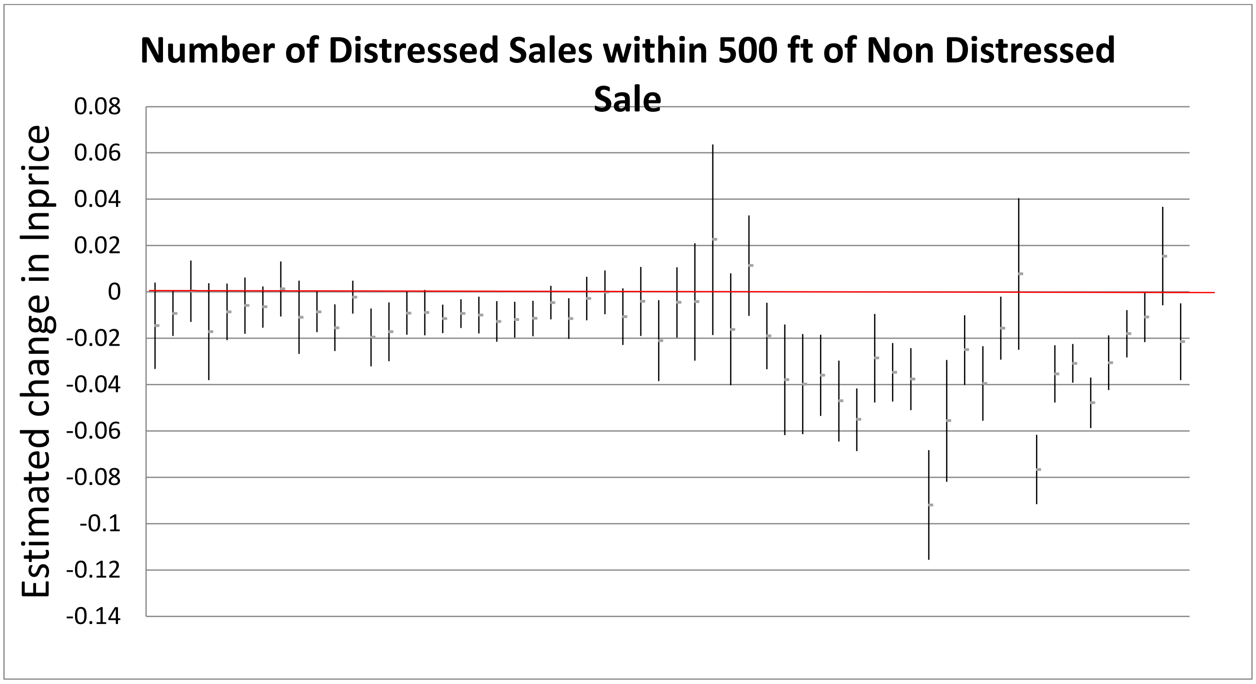
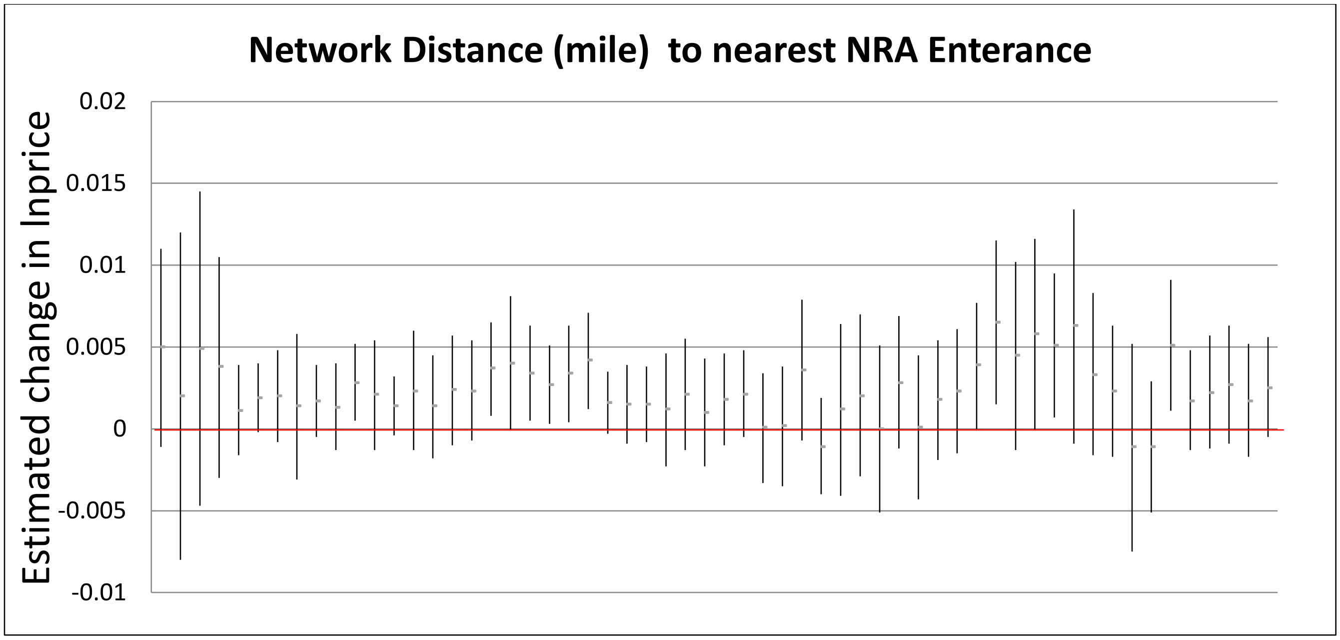


Figure 4.15: Quarterly Point Estimates of Semi Elasticity of Distance and 95 % Confidence Interval



Chapter 5: Summary and Conclusions

In this dissertation I presented three essays. In Chapter 2, I summarized economic valuation techniques and recent papers pertaining to site quality of waterbodies. I find that waterbodies are generally an amenity and that deterioration of water comes with an economic cost that is negatively capitalized in the real estate market. This process reduces the number of trips taken to water recreation sites. Additionally, persons who do not directly use water sites are willing to pay to preserve and ensure future existence of these sites. Although the results are consistent, most of these studies focus on estimating the costs associated with chemical makeup of water or sea level rise. Few studies, however, estimate the consequences associated with falling water levels, which severely impacts waterbodies in the arid Southwest. Furthermore, many of these existing studies do not examine how the premium associated with water varies with space or economic conditions.

I addressed gaps in the literature in Both the second and third essays I used a spatial hedonic model to estimate the costs of environmental deterioration of the Salton Sea in the agricultural areas of Riverside and Imperial County, CA. The Sea is subject to a number of water quality issues including falling water levels and worsening air quality. In the case of the Salton Sea, the severe environmental degradation has transformed this one time amenity to a disamenity such that homes located farther from the Sea sell for more than those closer to the Sea. Furthermore, I find that the deteriorating air quality, another consequence of drops in water levels, is negatively capitalized in the housing market.

Lake Mead, like Salton Sea, is another waterbody that is drying up. However, unlike the Sea, Lake Mead enjoys over 6 million visitors a year. Given that the lake is still a tourist attraction, I hypothesized that recreation access to the Lake Mead NRA will be associated with increases in sales price. However, it may be the case that decreasing water levels can decrease the premium of recreation access to the Lake. To test this hypothesis for the Las Vegas Area, I specify a spatial hedonic model, similar to the one used to estimate the costs of the Salton Sea, for each quarter year from 2000-2014. During this entire duration, water levels have been consistently declining. I also account for foreclosure spillover effects given the rise in foreclosures for the LVMA in 2008 and 2009. Results suggest that recreation access to Lake Mead is not capitalized in the local real estate market. This result is consistent for time periods before, during, and after the "Great Recession." However, for a few years prior to the recession and after the recession in 2011, homes located farther from the Lake were associated with higher selling prices, suggesting that perhaps the lack of residential density and urban amenities near the Lake make it less desirable than homes more centrally located near Las Vegas.

Results from both case studies indicate that economic valuation of declining water levels and water quality remains a promising area of future research. Whereas the Salton Sea results indicate that other seas worldwide (e.g., Aral Sea) may impose substantial economic costs to real estate, the unexpected Lake Mead results suggest that location to urban centers may diminish the negative economic impact of climate change on water levels.

Exploration of waterbodies from varied regions, under varying economic conditions and proximity to urban centers, appears warranted. The relation between real estate values and waterbody quality may have a more nuanced relationship than previous hedonic studies would suggest. This area of research may feature more prominently in coming decades, in light of forecasts of increasingly threatened inland waterbodies due to climate change.