A hedonic regression analysis of Houston metropolitan tax appraised land market values

by

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ABSTRACT

The objective of this thesis is to provide insight that policy makers can use to assess the impact of land values on prospective flood control projects in the Houston metropolitan area. Various land characteristics are regressed against county tax appraisal data on parcels of agricultural land sold within the Houston metropolitan statistical area over a 5-year period. Hedonic regressions of data from three counties found there is not a willingness to pay more for land located within any specific zip codes in the study area. However, some school district boundaries, especially those with higher median household incomes, correlate positively with higher property valuations. Land parcel size, commercial land use codes, residential improvements, paved road access, and certain suburban school districts were found to be statistically related to tax appraisals of market values.

Forecasts made using tax appraisal data overestimate the actual comparable sales price of land sold in 2018. It appears that there is a relationship between better road access to transportation networks and the subdivision of farms for development, so County Commissioners and the Texas Department of Transportation should carefully weigh the risks of increasing population densities as a result of new roads constructed within and around the water pooling areas of U.S. Army Corps of Engineer levees, bypass channels, dry basin reservoirs, detention ponds, and diversion tunnels. Additionally, the strategic use of agricultural conservation easements offers a less costly alternative to fee simple property acquisitions for managing development along Cypress Creek and other tributaries of the Buffalo Bayou waterway.

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CHAPTER I: INTRODUCTION

The Houston metropolitan area has experienced three deadly floods over the last five years including the "2015 Memorial Day Flood" that resulted in 7 deaths, the "2016 Tax Day Flood" that caused 10 deaths and the 2017 Hurricane Harvey Flood in which 107 people perished. The U.S. Army Corps of Engineers (USACE) invited the public to submit comments by November 2, 2020 on a proposed levee on Cypress Creek to manage the 500-year floodplain where most of these fatalities occurred, but other ways to mitigate flooding in Houston are also being discussed in the public forum. One idea is to conserve hydrologically influential farmlands on the Katy Prairie for use as extended dry basins to slow the rate of flow of storm water into the city of Houston's waterways during severe storm events. This is a new school of thought based on the Dutch "welcome the river" strategy of using conservation easements to mitigate flooding into residential communities. However, the valuation and donation of conservation easements to execute this type strategy is a difficult and complicated process that is being scrutinized by the U.S. Internal Revenue Service (IRS) according to the Appraisal Institute (Roddewig 2020). Keeping in mind that the cost of building a third reservoir was a key factor in the USACE not moving forward since 1940 with construction of the Cypress Creek Levee, this research explores land value trends and the implicit markets for land on the rural-urban fringe of the city of Houston.

The goal is to provide information that can be factored into the decision-making process for future infrastructure projects around the Cypress Creek tributary of the Buffalo Bayou waterway that flows into Harris county and the city of Houston. It is hoped that a better understanding of the land valuation process on the rural-urban fringe

will facilitate the donation of agricultural easements by private landowners for the public benefit of flood mitigation in the Greater Houston area. This thesis analyzes the defining characteristics of land that impact market value appraisals at the county level on the rural-urban fringe of the city of Houston. Regression analysis using county tax appraisal valuation data serves as a proxy for commercial comparable sales data that is unavailable to the public as a matter of state law in "non-disclosure" states such as Texas. Using this data to draw conclusions of property values generally takes the form of three recognized approaches: The Cost Approach to Value, the Market Approach to Value and, the Income Approach to Value (Watson 2019). In the case of agricultural conservation easement donations, the IRS requires that the land be valued based on "fair market value," so this research uses on the Market Approach to Value also known as the Comparable Sales method.

Commercial real estate developers, homebuilders, speculators, recreational land buyers and agribusiness are all competitive participants in the market for land within 50 kilometers or 31 miles of a large city. This distance of 50 kilometers is a real estate rule of thumb, sometimes referred to as the "Drive until you qualify" distance for first time home buyers. Previous research delineates most metropolitan centers to a 28-kilometer symmetric circle based on land price gradients, but the spillover effect of suburban business district sub-centers often extends the gradient according to Eckhardt Bode at the Kiel Institute for the World Economy (Bode 2008). Using historical data on land values, there are techniques that can analyze the past behavior of time series variables to predict the future. However, to make these extrapolations, explanatory variables must be identified that can be used to make these predictions. This study proposes a hedonic land

valuation model previously described by Tsoodle, Featherstone and Golden (2005) as a variable selection technique for identifying predictor variables from the data.

The variable-selection procedure compares land characteristics with tax appraisals of market value. Statistically significant land characteristics are explained using economic theory, on a county by county basis, beginning on the southern shores of Galveston county on the Gulf of Mexico and then progressing northwest to the western part of the Texas rice belt along the Brazos and Colorado rivers in Fort Bend county. In-sample forecasts are made and the results are compared to actual comparable sales information to test the predictive power of explanatory variables identified through hedonic regressions of tax appraisal data. It is hoped that this method is useful to policy makers and urban planners when predicting the effect of land values on prospective flood control infrastructure projects and agricultural land conservation easements intended for flood mitigation in the Houston metropolitan statistical area.

CHAPTER II: LITERATURE REVIEW

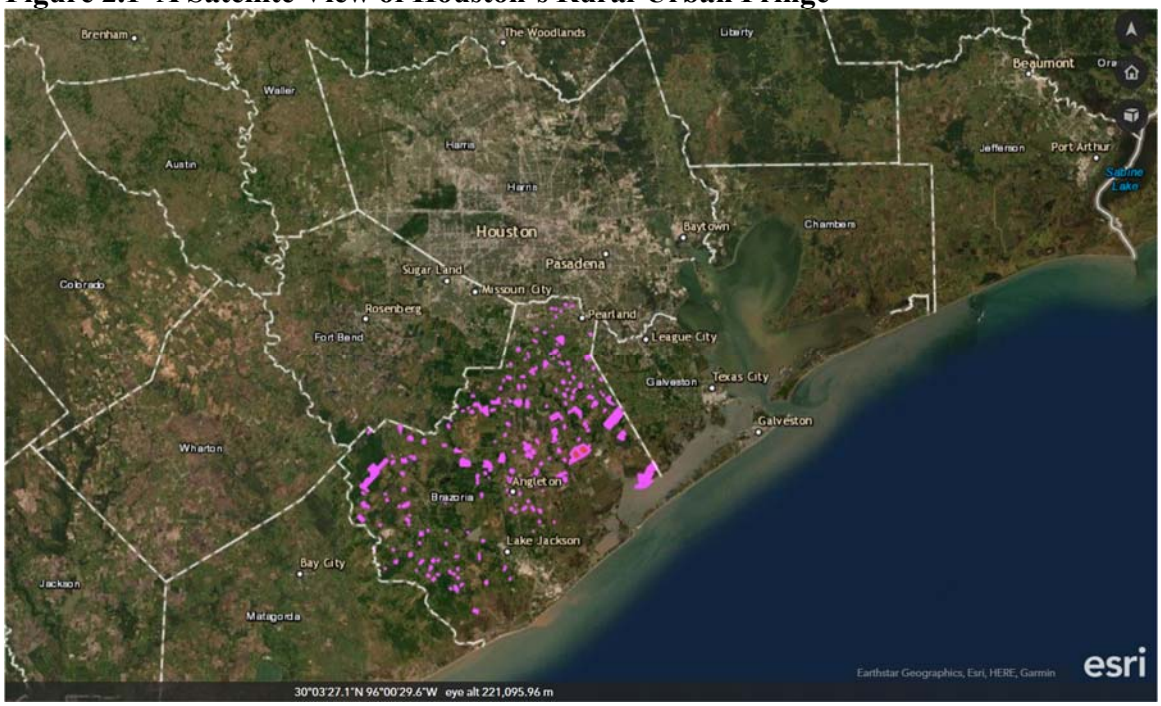
The value of land guides the evolution of urban economies and generates revenue for local governance so a better understanding of land valuation processes is of great interest to both private and public decision makers (Munneke and Womack 2020). However, four major problems detract from the appeal of using tax appraised land market values (TAMV) in the hedonic analysis of land value trends on the edge of a growing city:

- First, public access to comparable sales data in the county tax registries is often prohibited by state statue in "non-disclosure" states such as Texas.
- Second, farmland changes ownership infrequently, so only a small number of sales are usually recorded each year in rural counties.
- Third, the reported prices of some land transactions may be distorted if the sale is between family members or friends and therefore the sale is not open to competitive bidding.
- Fourth, recording errors may occur, such as recording the address of the seller rather than the address of the property being sold, or reporting false land-use codes (Ma 2012).

Land value is influenced by three competing market interests, namely, the investment/land development market, the recreational/consumptive land market and the agricultural production land market (Glenn Hager; Texas Comptroller of Public Accounts 2018). Consequently, land on the urban fringe is valued not only for agricultural production, but also for potential uses arising from urban expansion as well. Land in transition from predominantly agricultural use-value expectations to more market-value performance is valued as much for anticipated future urban rents as for current agricultural

rents (Capozza and Helsley 1989). Agricultural land parcels near the urban fringe are likely to be divided into smaller pieces and surrounded by other land uses or in other words, “fragmented”. Continuous patterns of urban commercial and residential land use at the city center typically break up into smaller patches showing a wider variety of land uses at the urban fringe including residential, commercial, industrial and natural resource-based activities, including agricultural production (Irwin 2007). These patterns are illustrated in the homogenous grey colored urban center of Houston (Figure 2.1,) the green colored reservoirs and waterways of the greater metropolitan area and mixed grey and green fractal patterns on the periphery of the city. Land parcels sold in Brazoria county from 2012 to 2018 are highlighted in pink in Figure 2.1. The ArcGIS© geographic information system (GIS) reference was supplied courtesy of the Brazoria county Central Appraisal District.

Figure 2.1 A Satellite View of Houston’s Rural-Urban Fringe



Source: Earthstar Geographics - GIS reference zip file provided by Brazoria county CAD

Land sells for agricultural use at a great enough distance from the city, but closer to the urban boundary though it is being used for agricultural use, it sells for a premium equal to the present value of future increases in rent that are expected after it is converted to urban use (Cavailhes and Wavresky 2003). The distance at which farmland values stop being influenced by the potential conversion premium defines the extent of the urban fringe. This may correspond to the distance where the marginal effect of expected urban growth as measured by population growth becomes statistically equal to zero (Delbecq, Kuethe and Borchers 2014). Nonagricultural demands for agricultural land at the rural-urban interface have become increasingly important in many areas so it is important to represent the capital gains inherent in farmland in areas facing nonagricultural pressures.

Nonagricultural pressures can be gauged by the total value of housing permits (collected from the U.S. Census Bureau) issued in the county in which the farm is located and by measures of population density and, by population growth rates in each county in the preceding year, all obtained from the U.S. Census Bureau (Goodwin, Mishra and Ortalo-Magn'e 2003). Land ownership may be thought of as a bundle of rights, one of which is to develop the land up to the allowable zoning density (Lynch and Lovell 2002).

A plot of land is comparable to a financial call option with the underlying asset being the property and with an exercise price equal to the cost of construction of a residential subdivision or commercial warehouse or other improvement (Morri and Benedetto 2019). Real option theory implies that agricultural land contains an option to develop at the optimal time (development option), and developed land contains an option to redevelop the existing improvements to a higher and better use (redevelopment option). Both raw and developed land contain an option to sell or completely abandon the

property (abandonment option). One of the difficulties encountered in establishing the appropriate land use for a parcel is the determination of the timing of conversion to urban use by improvement. Real estate development projects are irreversible, all or nothing, capital intensive decisions made under conditions of uncertainty, so the flexibility of real options is helpful in managing risk in the face of uncertainty.

A method commonly used for valuing real options under conditions of uncertainty is a capitalization method called Discounted Cash Flow (DCF) analysis. This method is based on the principle of anticipation since value is created by the anticipation of future rents. DCF analysis is based on projected cash flow and return expectations, capital requirements and the timing of future acquisitions. For example, the maximum price that a farmer would be willing to pay for a particular piece of land for agricultural production, at time t, is equal to the summed and discounted expected future stream of earnings from this land (Fichtinger 2011). Discounted cash flow analysis is a widely accepted real estate valuation method within the income approach to value, but the Appraisal Institute warns that the DCF method is vulnerable to misuse and misapplication if assumptions are made that are not consistent with market evidence and prevailing market attitudes.

Consequently, the Appraisal Institute recommends Regression Analysis Tools for determining when and if relationships between property characteristics and price trends are recognized by the market (Uniform Standards of Professional Appraisal Practice 2020) because investors need sufficient information to compare expected returns from real options against the returns to be expected from other equivalent capital investments (Brealey, Myers and Allen 2017). Statistical applications and analyses can provide effective ways to solve and communicate valuation problems (Wolverton 2009).

CHPATER III: CONCEPTUAL MODEL

Statistical forecasting is the estimation of the expected value of a dependent variable for observations that are not part of the sample data set. Forecasts are generated via regression by estimating an equation for the dependent variable to be forecasted, and substituting values for each of the independent variables (for the observations to be forecasted) into the equation (Studenmund 2016). A time series is a set of observations on a quantitative variable collected over time, such as sales, costs, profits, inventory, customer counts, and so on. The sequence of the observed values is ordered by a time parameter in time series regressions, so the order of the data is of considerable importance (Granger and Newbold 1986). The time series model used in this study of property tax valuations is the hedonic regression model applied by Tsoodle, Featherstone, and Golden (TFG) in their work on estimating the market value of land in Kansas (2005).

The theoretical foundation for hedonic regressions like the TFG land valuation model was outlined by Rosen in 1974 in his work on revealed prices and implicit markets. In the hedonic regression model, a class of differentiated products is completely described by a vector of objectively measured characteristics (Rosen 1974). A central assumption in Rosen's work is the concept of indivisibility: 'two 6-foot cars are not equivalent to one 12 feet in length'. This is a reasonable assumption for a study of land values because certain characteristics such as the distance of a parcel from a city center is an essential and defining characteristic that cannot be divided from the parcel. The "null hypothesis" of this study is that there is zero correlation between land characteristics and county tax appraisals of land value. If our analysis does not find evidence of significant correlations, then we can accept the null hypothesis as true that there are no relationships between the identified land characteristics and tax appraised market values. However, if

regression analysis finds statistically significant correlations then we must reject the null hypothesis and use economic and business theory along with regression coefficients to explain how and why the identified land characteristics are valued by the market. Binary (dummy) variables are used in the proposed model to analyze the significance of date sold, road access, land use codes, school district codes, and zip codes as they may or may not relate to appraised market values.

If statistically significant characteristics are identified by the regressions, then their regression coefficients provide general guidance in terms of the price elasticity on the degree of relevance that each land characteristic is assigned by tax appraisers when they assess property values. This study also uses binary variables to determine if the geospatial boundaries, such as school districts and zip codes, are statistically significant to agricultural land values. The land area of the average school district in the United States is 237 square miles and the land area of the average zip code is 90 square miles. Zip codes are used to determine the "Distance to the City Center" since this is the most granular situs information that was obtained from all of the county tax appraisal districts. Relative importance is quantified as the proportionate contribution each significant land characteristic makes to R^2, considering both the unique contribution of each defining land characteristic by itself and also by its incremental contribution when combined with the other significant characteristics (Johnson and Lebreton 2004).

Techniques that analyze the past behavior of a variable to predict the future are sometimes referred to as extrapolation models (Ragsdale 2007). The estimated regression function for this research is a "Quadratic Trend" model because land values usually present an upward curved trend line over time, so for example a model where X_1 is a

continuous variable such as land size and X_2 is a binary variable such as county road access:

$$\boldsymbol{Log\ \widehat{Y}t\ \ =\ b0\ +\ Log\ bX_{1t}\ +\ b_2X^2{}_{2t}} + \varepsilon_t \qquad \text{(Equation 1)}$$

A hedonic version of this quadratic trend model that features a double log rescaling for easier interpretation of the regression coefficients is the form illustrated in equation 2 and henceforth referred to as the "TFG model." The assumption of a featureless plain by the TFG model (Tsoodle, Featherstone and Golden 2005) is also a good fit for the coastal prairies and floodplains that largely make up the farmlands around the city of Houston which are the focus of this study:

(Equation 2)

$$\text{Log (Total Tax Appraised Market Value)} = \beta_0 + \beta_1 * \text{Log (Land Size in Acres)} + \beta_2 * \text{Log (Distance to Downtown Houston))} + \beta_3 * \text{(Binary Variable for Road Access)} + \beta_4 * \text{(Binary Variable for Land Use Code)} + \beta_5 * \text{(Binary Variable for Year Sold 2015)} + \beta_6 * \text{(Binary Variable for Year Sold 2016)} + \beta_7 * \text{(Binary Variable for Year Sold 2017)} + \beta_8 * \text{(Binary Variable for Year Sold 2018)} + \beta_9 * \text{(Binary Variable for Preferred School District)}$$

The Land Sale Price Per Acre (LSPA) in the original TFG model has been replaced with Total Tax Appraised Market Value (TAMV) as the dependent variable (Y). This is time-series data so the "Year Sold/Year of Deed Title" is modeled using binary/dummy variables, in the same manner as the original TFG model. However, references to the cities of Kansas City and Wichita and "Kansas communities with populations over 10,000 people" in the TFG model are replaced with a single reference to "distance to the city center" because this a study of land values around the city of Houston, Texas. Tax

appraised market values are used in the hedonic regressions instead of actual sales prices because sales price data was unavailable.

CHAPTER IV: METHODS

Tax appraised market values (TAMV) are used as general proxies of fair market values because comparable sales information is not available to the public by law in "non-disclosure" states such as Texas. Land characteristics are regressed against TAMV data to identify predictor variables for agricultural land prices on the rural-urban fringe. Multiple land characteristics are good for hedonic regression analysis using the comparable sales approach to valuation. Regression analysis tools are common spreadsheet software features so appraisers can use Microsoft's Excel© Data Analysis ToolPak to identify significant relationships between various property characteristics and comparable county appraisals of land market values. This study uses the Tsoodle, Featherstone and Golden (TFG) non-linear hedonic regression analysis model because it is a good fit for the analysis of TAMV time series data pooled inside cross sectional county panels. Furthermore, the assumption of a featureless plain by the TFG model is appropriate for the coastal prairies and floodplains found within the boundaries of the study area.

Multiple land characteristics are hedonically regressed against time series data from each of the counties in the study. Land characteristics describing distance to the central business district, land size, commercial land use, rural residential land use, road access, zip codes, school district boundaries, deed title dates and in some cases - agricultural use value, are compared or regressed against county tax appraisals of market value. Microsoft's Excel spreadsheet software is used in combination with the TFG hedonic time series regression model to estimate which parcel characteristics are

statistically related to tax appraisals of market, provided all other conditions, are held constant, “ceteris paribus.”

Changes in population and economic conditions are addressed by modeling deed title dates as a time element in the time-series model with an “intercept dummy variable”, which is a binary variable that takes on the values of 0 or 1, depending on the qualitative attribute of “Year Sold” or “Deed Title Year.” Binary variables are used to determine if the geospatial boundaries of school districts and zip codes are statistically significant to agricultural land values. The land area of the average school district in the United States is 237 square miles and the land area of the average zip code is 90 square miles. Zip codes are used to determine the “Distance to the City Center” since this was the most granular situs information obtained from all five of the county tax appraisal districts in the study area. Relative importance is quantified as the proportionate contribution each predictor makes to R^2, considering both the unique contribution of each predictor by itself and its incremental contribution when combined with the other predictors (Uniform Standards of Professional Appraisal Practice 2020-2021 Edition 2020).

Economic theory about cities and differences in land rent, the marginal elasticity of demand for land resources, variance from estimations of value, population growth rates and differences in median household incomes are used to explain the relevance of any statistically significant relationship found between the identifying characteristics of agricultural land parcels sold during the study period and TAMV data. The variables identified as statistically significant in the times series regressions are used to make in-sample forecasts that are tested for robustness against actual comparable sales data.

CHAPTER V: RESULTS

Ordinary least square regressions of time series data from each of the county entities identified five land characteristics that are significantly correlated with tax appraisals for agricultural land on the rural-urban fringe of the city of Houston:

- Land Size – per acre values decrease with size
- Residential land use
- "Commercial" land use codes for agricultural land adjacent to distribution centers
- Frontage road access
- Suburban school districts with higher median household incomes

Each of the panels of county data provided opportunities for analysis using economic theory.

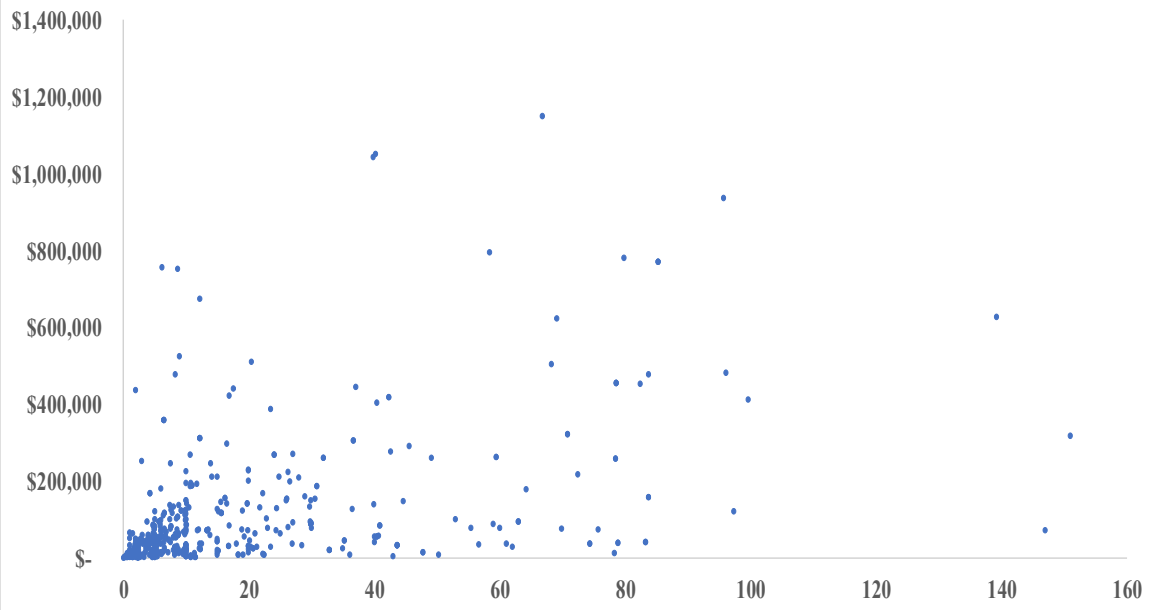
5.1 Galveston county

The simple scatter plot of Galveston county data in Figure 5.1 compares land parcel size to tax appraised market value. Galveston county is not only proximate to the fourth largest city in the United States, but its southern shores are on the Gulf of Mexico, so oceanfront amenities increase the value of properties that offer recreational, commercial and resort development options. The scatter plot in Figure 5.1 illustrates that waterfront amenities can result in high land valuations for agricultural parcels smaller than 20 acres in size and the average parcel size sold in Galveston county during the time series of this data set was 18.02 acres (Table 5.1).

Table 5.1 DESCRIPTIVE STATISTICS FOR GALVESTON COUNTY

	Total Tax Appraised Value	Land Size in Acres	Distance to City Center in Miles
Mean	$97,771.59	18.021	43.807
Median	$44,300.00	9.948	37.500
Mode	$20,000.00	10.000	37.500
Standard Deviation	$138,302.79	22.615	11.909

Figure 5.1 Total Tax Appraised Market Values and Parcel Acres Galveston County



Excel can generate linear trend forecasts based on county data as illustrated in Table 5.2. The TREND function can determine if "Land Size in Acres" should be considered as the explanatory value in an Excel Trend analysis. Sensitivity testing around land parcel size can establish a statistical reference from which appraisers can make adjustments to opinions of value based on other variables such residential structures to each subject property.

Table 5.2 Land Value Predictions based on Land Size in Galveston County

Preferred Land Size Purchase	Predicted Land Value Based on Size	Predicted Price Per Acre
5	$ 144,024.40	$ 28,804.88
10	$ 151,210.68	$ 15,121.07
15	$ 158,396.97	$ 10,559.80
40	$ 194,328.38	$ 4,858.21
100	$ 280,563.76	$ 2,805.64
320	$ 596,760.18	$ 1,864.88
640	$ 1,056,682.25	$ 1,651.07

Proximity to downtown Houston is statistically significant to property values in Galveston county, but the relationship results in a negative coefficient, meaning that land values typically go lower as the distance to downtown Houston increases. This highlights the importance of central business districts to land values in this county despite the presence of high value oceanfront properties. Most school districts in Galveston county are not good predictors of land value except where large differences in median household income are present on the edges of towns and cities, and in those cases statistically significant relationships can be found between school district boundaries and property values. This can be seen in Table 5.3 where parcels located in the Clear Creek Independent School District are positively correlated with higher tax appraised land market values.

Table 5.3 Land Size is Statistically Significant in Galveston County

Column1	*Coefficients*	*Standard Error*	*t Stat*	*P-value*
Intercept	-558.191	417.823	-1.336	0.182
Log Land Size	**0.674**	0.039	17.362	**0.000**
Log Distance to CC	**-5.454**	1.425	-3.828	**0.000**
Clear Creek ISD-S15 &S16	**1.069**	0.394	2.711	**0.007**
Galveston ISD -S10	0.532	0.290	1.838	0.067
Dickinson ISD-S11	0.520	0.294	1.768	0.078
Hitchcock ISD- S14	-0.473	0.249	-1.900	0.058
Santa Fe ISD-S17	0.450	0.279	1.614	0.107
Texas City ISD-S18	0.026	0.369	0.071	0.943
Year Sold 2013	0.219	0.153	1.431	0.153
Year Sold 2014	0.339	0.177	1.910	0.057
Year Sold 2015	0.240	0.181	1.327	0.185
Year Sold 2016	0.443	0.196	2.263	0.024
Year Sold 2017	0.088	0.171	0.513	0.608
Year Sold 2018	0.351	0.153	2.296	0.022
Zip Code	0.007	0.005	1.372	0.171

In theory, the socio-economic differences between, for example, the Hitchcock Independent School District (ISD) which has a median household income of $43,363 versus the adjacent Clear Creek ISD which has a median household income of $80,185 (U.S. Census Bureau American Community Survey 2010) may explain correlations between higher property values in certain school districts. More rural parts of a county are less densely populated, offer fewer urban amenities and host less commercial activity within their taxing jurisdictions than urban and suburban areas, so rural school districts are not endowed with the same property tax revenue streams as more urban school districts. This has been the source of litigation in Texas resulting in a state managed property tax redistribution mechanism called the "Robinhood Plan" (Brendel 2010).

5.2 Brazoria county

Brazoria county is exposed to serious storm surge flooding from the Gulf of Mexico and riverine flooding from the Brazos river, so a county wide "freeboard" building permit restriction requires all residential and commercial structures constructed

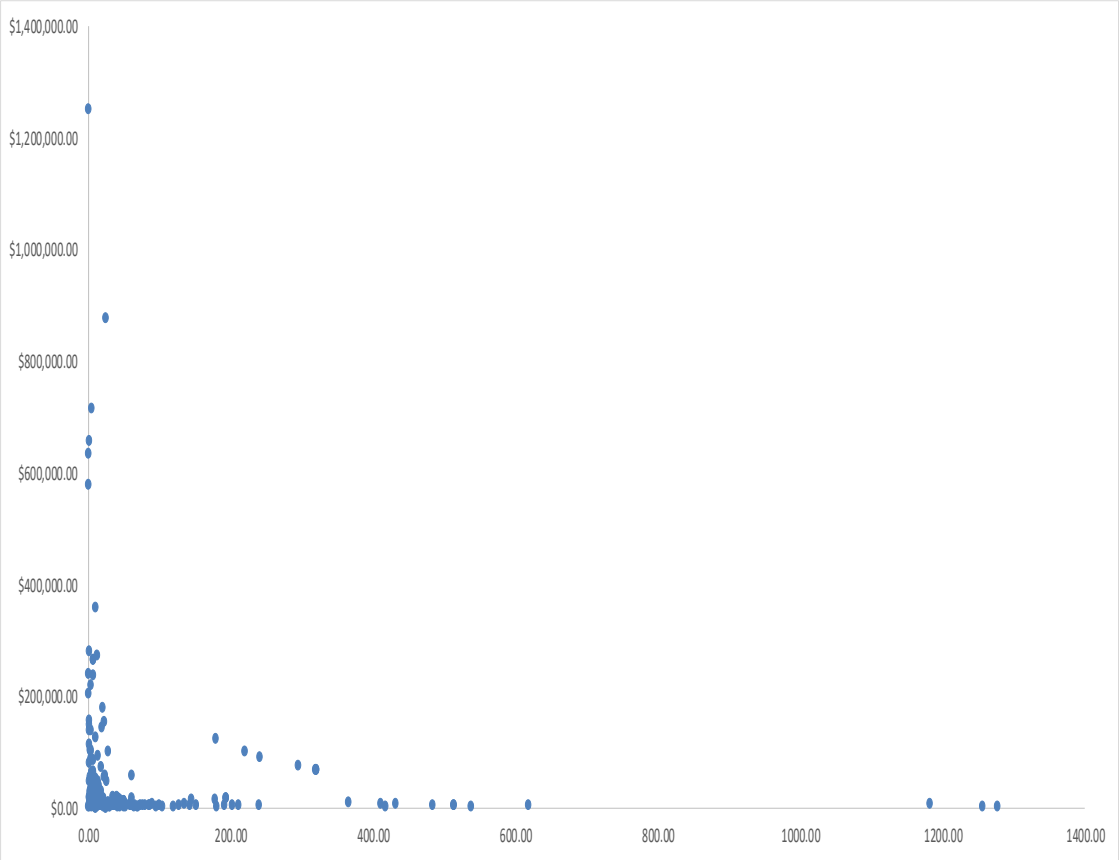
after 2007 to be build 2 feet above the floodplain. Most of the newer structures are also concentrated along a state highway that terminates at the port city of Freeport, Texas. The importance of State Highway 288 to economic growth in Brazoria county is highlighted by $97 million invested by the Texas Department of Transportation in the construction of 15 miles of a new express tollway connection that opened on November 16, 2020.

Table 5.4 Agricultural Rents are related to Land Values in Brazoria county

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	3.088	3.296	0.937	0.349
Log of Ag Cash Rental	**0.557**	0.046	12.241	**0.000**
Log of Distance to City Center	**1.694**	0.830	2.042	**0.042**
DAlvin ISD	0.535	0.497	1.075	0.283
DAngleton ISD	0.315	0.249	1.265	0.207
DBrazosport ISD	-0.609	0.500	-1.218	0.224
DColumbia-Brazoria ISD	-0.197	0.212	-0.928	0.354
DPearland ISD	**1.703**	0.995	1.712	**0.088**
Sold D2016	-0.114	0.175	-0.648	0.517
Sold D2017	0.092	0.177	0.518	0.605
Sold D2018	-0.083	0.169	-0.491	0.624
County Road Access	**-0.449**	0.129	-3.496	**0.001**

The dependent variable (Log Y hat) is converted from “Total” tax appraised market value (TAMV) to “Per Acre” tax appraised market value (TAMV) in Table 5.5 where we can see the sign for the regression coefficient of “Land Size” is negative in contrast to the positive regression coefficient seen previously in the Galveston county regression (Table 5.3). In contrast to Galveston county, there are many sales transactions observed of parcels larger than 200 acres. The mean size in acres per transaction in Brazoria county (Appendix B) is 49.11 acres, but valuations higher than $500,000 per acre in Figure 5.2 are significant and likely due to either rural residential structures or mineral resources.

Figure 5.2 Per Acre Tax Appraised Market Value and Parcel Size in Brazoria County



The P-value for agricultural cash rental income consistently increases when Land Size is included in the calculations, no matter whether "Total TAMV" or "Per Acre TAMV" is used in the regressions since small parcels are predictably more valuable on a "Per Acre" basis and small parcels are predictably less valuable on an agricultural productivity basis in Brazoria county.

Table 5.5 Per Acre Tax Appraisals of Value in Brazoria county

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	1.929	1.431	1.347	0.179
Log of Land Size	-0.174	0.092	-1.896	**0.059**
Log of Ag Cash Rental	0.007	0.085	0.083	0.934
Log of Distance to City Cente	0.714	0.357	2.001	**0.046**
DAlvin ISD	0.239	0.214	1.116	0.265
DAngleton ISD	0.129	0.107	1.204	0.229
DBrazosport ISD	-0.294	0.215	-1.366	0.173
DColumbia-Brazoria ISD	-0.085	0.091	-0.928	0.354
DPearland ISD	0.718	0.428	1.679	0.094
Sold D2016	-0.041	0.075	-0.548	0.584
Sold D2017	0.058	0.076	0.758	0.449
Sold D2018	-0.017	0.073	-0.227	0.820
County Road Access	**-0.192**	0.055	-3.476	**0.001**

5.3 Fort Bend County

Surprisingly, however, in Table 5.5, the distance to downtown Houston is not significantly correlated with TAMVs in Fort Bend county and the average distance to the city center for parcels sold between 2016 and 2018 is 40.8 miles (Appendix C). Good suburban schools and excellent highways into downtown Houston apparently decrease the importance of distances to downtown Houston from Fort Bend county. Prior economic research on land values found that fast growing metropolitan suburbs have their own industrial clusters of local economic activity (Bode 2008). Consequently, commercial land use codes are statistically significant in counties experiencing high population growth as indicated by a low P-value in Table 5.5 for land categorized simultaneously as “agricultural” and “commercial miscellaneous.” I interviewed county appraisers and a land auctioneer to better understand this phenomenon and was told for

example, that construction of an Amazon© distribution center or some other industrial development changes the "land type" appraisal codes for adjacent agricultural parcels from "native pasture" to "commercial miscellaneous." Commercial miscellaneous codes for agricultural land reflect market expectations for urban rents from the subdivision of farms into smaller parcels and the subsequent development of those parcels within 3-5 years. Residential structures change land use and are positively correlated to higher property values in Fort Bend county even when the rest of the land continues to be used for agricultural production as illustrated by the low P-value for rural residential property in Table 5.5 and this variable may also be capturing the vector of recreational hobby farms that may serve as primary residences for professionals that commute to downtown Houston for employment.

Table 5.6 Five Predictors of Land Value in Fort Bend county

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	35.442	39.307	0.902	0.367
Log of Land Size	**0.404**	0.018	22.270	**0.000**
Log of Distance to City Center	0.247	0.186	1.324	0.186
Zip	0.000	0.001	-0.793	0.428
Year_Sold 2016	0.029	0.052	0.564	0.573
Year_Sold 2017	0.119	0.049	2.427	**0.015**
Year_Sold 2018	0.073	0.048	1.519	0.129
Year-Sold-2019	**0.201**	0.049	4.097	**0.000**
Lamar School District	0.067	0.044	1.509	0.132
Needville School District	0.054	0.045	1.213	0.225
Fort Bend School District	**-0.252**	0.071	-3.560	**0.000**
Stafford School District	-0.046	0.493	-0.094	0.925
Katy School District	**0.598**	0.168	3.554	**0.000**
County Road	**0.178**	0.032	5.555	**0.000**
Commercial Land Use	**0.586**	0.100	5.842	**0.000**
Rural Residential Land Use	**0.216**	0.053	4.104	**0.000**

In the Table 5.6 summary output from regressions of Fort Bend county data, the units of the dependent value are thousands of dollars. A positive coefficient indicates that for agricultural land each unit percent increase in land size in Fort Bend county causes estimated value to increase by 0.404 percent /acre, so if land size increases by one acre, the price increases by 0.4*(change in acres) *($1000). All the regression coefficients from the statistically significant "predictor" variables identified in Table 5.6 are used to extrapolate predictions of Tax Appraised Market Value for any hypothetical land size:

Hypothetical $\hat{Y}_{2018}$= 35.441 + 0.404% increase in price*(change in Land Size in Acres) + exp (0.178)-1 percent (County Road) + exp (0.586)-1 percent (Commercial Miscellaneous) + exp (0.598)-1 percent (Katy School District) + exp (0.216)-1 (Rural Residential) +0.029*(Year Sold 2016) + 0.0119*(Year Sold 2017) + 0.073*(Year Sold 2018) + 0.201*(Year Sold 2019) + Ɛ (Stochastic Error Term)

Case Study $\hat{Y}_{2018}$= 35.442 + $0.412^{*}X$ **(% change in Land Size) + Ɛ (Stochastic Error Term)**

According to Featherstone (Featherstone et al., 1993) the relative effect on price due to binary variables (Gj), for each binary coefficient, the percentage change in land price with the presence (j) of the binary factor can be calculated using the following equation:

G(j) = exp (binary coefficient) - 1

For example, the percentage change in land price due to the presence of a residential structure is calculated this way:

% change in Tax Appraised Market Value (TAMV) = exp (0.216) -1

Commercial miscellaneous land codes, assigned by the county when farmland is adjacent to new development, increases appraised land value (TAMV) by exp (0.615)-1 percent /acre. The assignment of commercial land type codes to agricultural land by county tax

appraisers was found from telephone interviews to be the result of a *spillover effect* from actual commercial development adjacent to the agricultural land. Appraisers weigh the cluster effect of adjacent commercial property in their opinions of market value for the entire surrounding agricultural area because commercial developments are proceeded by improved road access to major transportation networks. Location within the Katy school district increases TAMV by exp (0.552)-1 percent and county roads increase tax appraised market valuations by exp (0.201)-1 percent. The Fort Bend county model has an R^2 value of 0.334 and a computed F-statistic 66.142 indicating that all five of the explanatory values considered jointly have a statistically significant influence on appraised values at the 99% confidence level. No serious cases of multicollinearity among the explanatory values were detected as seen in the Appendix A.

Table 5.7 Predicted Prices Per Acre using Tax Appraisal Data

Parcel Acquistion Size in Acres	Predicted Total Market Value	Predicted Value Per Acre
5.00	$169,076.06	$33,815.21
10.00	$257,552.94	$25,755.29
20.00	$434,506.69	$21,725.33
40.00	$788,414.19	$19,710.35
50.00	$965,367.93	$19,307.36
60.00	$1,142,321.68	$19,038.69

Prices are overestimated using tax appraised market values, so hedonic regression analysis should be used with actual comparable sales pricing data whenever possible (Table 5.7). The tax appraisal data is better at predicting the values of smaller parcels. The availability of data can be a challenge, so pooling data from several sources may be useful in analyzing relationships between explanatory variables and land values.

Table 5.8 Actual Prices Paid in 2018 for Agricultural Land

Total Parcel Size In Acres	Total Market Value	Sale Amount Per Acre
5.16	$130,000.00	$25,212.34
10.01	$110,000.00	$10,988.44
15.96	$198,250.00	$12,418.50
44.19	$244,077.00	$5,523.86
47.90	$439,810.00	$9,181.26
67.36	$285,161.00	$4,233.45

Comparable sales data purchased from the AcreValue Granular Corteva Agriscience™ Company did not contain any information about most of the explanatory variables analyzed in this study, so it would be interesting to see how the data analytics for land values on the rural-urban fringe can be improved through greater access to other data sources such as the National Realtors Association Multiple Listing Service. Hedonic regressions using actual sales price information and can be expected to yield more precise estimations of future land values.

CHAPTER VI: CONCLUSIONS

Hedonic regressions of time series data from three county tax appraisal offices indicate that a change in a significant land characteristic, such as the addition of a residential structure to a parcel of agricultural land, can be expected to effect appraisal values in a predictable way. It would be a rare occurrence for the correlations found in this study to happen by accident. It should be noted that the regression model output describes both statistically significant values that have predictive power (low p-values) but also high variability (low R-squared numbers). The high variability is not what econometricians hope to see but even noisy, high-variability data can have a significant trend (Ogee 2014). The trend indicates that the predictors (relevant characteristics) provide information about the estimated market value response even though many of the data points fall far away from the regression line.

In looking at the tax appraisal data there are reported prices for some land transactions that are outliers, perhaps land sales between family members or friends that were not open to competitive bidding. Recording errors were noted, such as recording the address of the seller rather than the address of the property being sold. The high degree of variability found in tax appraisal data as well as the lagged time impact of regional economic trends on elasticity values indicate that spreadsheet-based regression analysis cannot by itself replace the professional, ground-proofed opinions of an experienced appraiser. Estimations of land values using tax appraisal data overestimated actual comparable sales prices for land sold in 2018 so it is recommended that future researchers use actual comparable sales prices for the hedonic regression analysis of land values whenever such data can be obtained. It would be interesting to see hedonic regressions of

data from the National Realtors Association's Multiple Listing Service registry of actual real estate prices, however tax appraisal data can identify land characteristics that are related to opinions of market value formed by county tax appraisals.

Regression trend lines based on tax appraisal data indicate that price differentiation between real estate properties is based on certain key identifying characteristics for each parcel. These five identifying characteristics are significant to land markets on the urban fringe, specifically:

- Land size
- Residential land use
- Location within relatively more affluent school district boundaries
- Proximity to new land development
- Good road access to transportation networks

Regressing these land characteristics against county property tax appraisals reveals how market attitudes value "raw" land on the rural-urban fringe of Houston. Economic theory about urban land rents and hedonic pricing provide strategic insights on how these land variables can be managed so that land development is developed in ways that will increase the ability of the Houston area to recover more quickly from future severe storm events. For example, county commissioners have publicly called for more research on the use of agricultural lands as dry basin reservoirs to mitigate risks to life and property from storms like Hurricane Harvey (Powell 2019). The TFG Hedonic Regression Land Valuation method can estimate the fair market values of agricultural conservation easements that will needed to implement this strategy.

Agricultural conservation easements are perpetual and these easements permanently ride with deed titles, so conservation easements may offer a low-cost method for privately managing land and land parcel sizes around future flood control infrastructures built along Cypress Creek and other tributaries of the Buffalo Bayou waterway. The binary variable for rural residential land use is statistically significant in Fort Bend county and this variable includes the vector of recreational hobby farms. It could be said that hobby farms present a hurdle to implementing large scale agricultural conservation easements for use as wide dry basin reservoirs. Certainly, the costs required to solicit small easement donations from a large number of hobby farm landowners will be greater than negotiating easement donations from a few large-scale farms. However, the benefit of working with hobby farm owners with rural residential structures on their property is that such easements will be less costly than simple fee property acquisitions. Using data from Waller county, to analyze parcel sizes and the statistical significance of rural residential land use on the Katy Prairie since stormwater from Waller county drains into neighboring Harris and Fort Bend counties.

Land parcel size, paved road access, commercial land use codes, residential improvements, and certain suburban school districts are all related to tax appraised land market values along the Cypress Creek tributary of Buffalo Bayou. Of the five variables identified in this study as predictors of land values in Fort Bend county, the two land characteristics that county commissioners can directly manage are “Road access” and “Land Size.” Forecasts based on these two explanatory variables of “Road Access” and “Land Size” generally reflect comparable sales prices of land parcels actually sold in 2018, so these two land characteristics qualify as predictor variables. Better road access

to transportation networks quickly leads to expectations of higher urban rents and subdivisions of farms into smaller parcels which can be sold and developed within 3-5 years. This relationship between new roads and accelerated rates of land development indicates that the strategic placement of new roads can be used at the county level to channel development of new housing stock away from Federal Emergency Management Administration (FEMA) repetitive flood risk areas.

The Greater Houston Flood Mitigation Consortium is a panel of experts that is examining flooding issues in collaboration with Rice University. The Consortium is studying a long-standing U.S. Army Corps of Engineers (USACE) proposal to build a "third reservoir" west of Houston to supplement protection to the city of Houston provided by two existing USACE wide dry basin reservoirs that have been developed int city parks and to some extent were developed into residential neighborhoods like the Cinco Ranch subdivision. Estimates of the cost of building a third reservoir are about $500 million and the funds would come from a mixture of state, federal and local government funds. This plan has been referred to as "Plan 7" and would require the construction of a long Dutch type levee without gates south of Cypress Creek to canalize extreme storm water flows onto rice farms and undeveloped pasture land on the Katy Prairie. The construction of a levee without gates would allow most of the new reservoir area to remain productive farmland and pastureland subject to occasional flooding when stormwater needs to be detained during severe storm events. The results of this study indicate that the two predictor variables of "Road Access" and "Land Size" can be managed to direct new residential development away from any new USACE levees, dry basin reservoirs, and bypass channels. Additionally, the use of agricultural conservation easements is a way to

prevent the development of residential subdivisions where flood waters may pool around USACE dry reservoirs and levees during the most severe storm events. The private maintenance of working farms will also save county tax payers from the responsibility of assuming the costly and ongoing public maintenance of multi-use parkland along tributaries of the Buffalo Bayou waterway in the Greater Houston area.

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APPENDIX A: MULTICOLLINEARITY TEST FOR LAND CHARACTERISTICS IN FORT BEND COUNTY

Column1	*Log of Land Size*	*Katy School District*	*County Road*	*CommercialCode*	*Rural Residential Land Use*	*Year_Sold 2016*	*Year_Sold 2017*	*Year_Sold 2018*	*Year-Sold-2019*	*Year-Sold-2020*
Log of Land Size	1.000									
Katy School District	-0.022	1.000								
County Road	-0.006	-0.004	1.000							
Commercial Misc. LandCode	-0.105	-0.013	-0.028	1.000						
Rural Residential Land Use	-0.052	-0.029	-0.007	0.111	1.000					
Year_Sold 2016	0.101	-0.015	-0.097	-0.006	-0.009	1.000				
Year_Sold 2017	-0.002	0.048	0.021	0.022	0.055	-0.244	1.000			
Year_Sold 2018	0.004	-0.050	0.072	0.053	-0.008	-0.263	-0.300	1.000		
Year-Sold-2019	-0.049	0.024	0.025	-0.078	-0.064	-0.245	-0.280	-0.302	1.000	
Year-Sold-2020	-0.055	-0.008	-0.038	0.008	0.030	-0.188	-0.214	-0.232	-0.216	1.000

APPENDIX B: DESCRIPTIVE STATISTICS FOR BRAZORIA COUNTY

Column 1	Total Tax Appraised Market Value	Land Size in Acres	Ag Rental Income	Distance to Houston City Center in Miles
MEAN	$994,290.83	49.11	$911.07	42.73
MEDIAN	$206,012.66	14.95	$172.50	42.80
MODE	$3,571,920.00	10.00	$115.00	42.80
STDEV.	$3,324,232.82	140.55	$6,024.81	11.55

APPENDIX C: DESCRIPTIVE STATISTICS FOR FORT BEND COUNTY

Column 1	Total Tax Appraised Market Value	Land Size in Acres	Ag Rental Income	Distance to Houston's City Center in Miles
MEAN	$483,628	35.02	$8,120	40.8
MEDIAN	$285,880	11.00	$2,005	41.3
MODE	$12,920	1.00	$0	41.3
STDEV.	$881,692	102.82	$22,539	7.4

APPENDIX E: PUBLIC LETTER TO USACE 1

U.S. Army Corps of Engineers, Galveston District

October 27, 2020

Attention: Commander, USACE Galveston District,

Colonel Timothy Vail

Subject: Buffalo Bayou Texas Resiliency Study

P.O. Box 1229

Galveston, TX77553-1229

Dear Colonel Vail,

I respectfully submit to the United States Army Corps of Engineers (USACE) the results of my recent research on land valuation processes in the Houston metropolitan area. A copy of my study is provided with this letter.

The objective of my research is to provide insights on the impact of land values to future flood control projects, specifically projects in the upper Cypress Creek watershed. Empirical evidence from my three-county study indicates that there is a relationship between the construction of new roads and the subdivision of large working farms into smaller parcels for sale to investors and developers. Subsequent development of the small parcels into residential and commercial properties increases population densities. Consequently, I recommend that county commissioners and the Texas Department of Transportation limit plans for road construction around new USACE levees, bypass channels, dry basin reservoirs, detention ponds and diversion tunnels to reduce loss of life estimations in the flood risk assessments of the USACE Buffalo Bayou Texas Resiliency Study.

Additionally, another way to reduce the population's exposure to flood risks and minimize cost would be to explore the acquisition of agricultural conservation easements by qualified organizations with the approval and cooperation of the USACE, Galveston District, in lieu of fee simple property acquisitions to prevent the development of residential subdivisions within and around the pool fill areas of USACE dry basin reservoirs and levees.

I appreciate your consideration of the supporting evidence for these proposals found within my enclosed research paper. Your response to this letter would be highly appreciated.

Respectfully submitted,

Randy K Hobert

Randy K. Hobert