URBAN LAND VALUES AND REAL OPTIONS

by

Robert Angus Grovenstein, Jr.

(Under the Direction of Professor Henry Munneke)

ABSTRACT

Vacant urban land exists in major metropolitan areas and begs the question, “why has the property never been developed.” The purpose of this dissertation is to provide an answer to this question by estimating the real option values associated with vacant land ownership. Real options included in this dissertation are the development option and option to seek a zoning change. The methodology utilized in this dissertation includes option pricing and empirical analysis. The first paper estimates land values where development is limited to a single use allowed by zoning. Land is valued by specific land use categories. The second paper estimates land value using a residual technique when a zoning change allows for higher valued land uses.

INDEX WORDS: Real options, Land values, Urban land, Vacant land, Development, Zoning change

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DEDICATION

To my wife, parents, and siblings – thanks for your love and support during this process.

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CHAPTER 1

INTRODUCTION

The literature regarding land ownership and the embedded real options is very thin. Why does vacant land have value? There are several possible answers. First of all land could have value because it generates revenues. Revenues from land could come from supporting animal growth, timber, or any form of crop production. Valuing such a parcel of land is a relatively simple process when compared to properties that do not generate revenues. Consider a parcel of land that has no current use and generates no income. It has recently sold in the market place for a substantial amount of money. Why would someone be willing to pay money for a parcel of land that, at first glance, is worth very little? The value of this parcel is derived from the real options associated with ownership. The most obvious option the owner has is to use the land for reasons mentioned above (support animals, timber, crop production). In addition the owner has the option to develop the property into the particular zoning class that exists for the parcel. This option can be exercised today or at any time in the future subject to zoning constraints and other building restrictions. If the option is exercised today, the owner will receive the selling price less any costs of development. This concept that land is a residual value from development has been established in previous literature. The time to build must be incorporated. It may be more beneficial to wait to develop as market information is introduced through time. A compound option of redevelopment also exists. So, even if development occurs today the owner has the option in the future to redevelop into a different structure. In addition to the development options, there is an option to seek a zoning change. The land could be worth more if it was zoned commercial instead of the current residential zoning. The value of the zoning change option is directly related to the probability of the zoning change being accepted. If there is no chance of a zoning change the zoning change option is worthless. On the other hand, if a major thoroughfare has been developed next to a residential home, the value of the parcel of land will increase drastically due to a higher probability of a zoning change to commercial. Each of the previously mentioned options has value and the land value is the sum of the option values.

Stock prices reflect market information. If the market perceives company ABC as a good acquisition, the price reflects a premium. Land transaction prices reflect the value of each of the real options in a similar way. The first example is a property that has no future options. A developer purchases a parcel of land to build a spec home. After development of the house at a cost X, he sells the home for price P. Assuming the cost includes his expected return the net cash flow upon sale is zero. Thus, the value of the land without future options, or the intrinsic value (LV_i) of development, can be expressed as P minus X. This intrinsic value can be determined empirically using improved properties and vacant land. If this intrinsic value includes no options, it is the minimum-selling price given its zoning and building permit constraints. Generally speaking, land prices differ from the intrinsic value because the real options often have value.

The difference between the actual selling price of land and LV_i represents the option value embedded in ownership of that parcel. The following expresses this relationship with each option described.

$$Land\ Price = LV_i + delay\ option + redevelopment\ option + zoning\ option \qquad (1.1)$$

Previous research has shown that the value to delay is approximately 6% of the intrinsic value. The option values differ drastically from property to property. The only constraint on option values is that they be greater than or equal to zero. This is true for all options because there is only potential for gains from an option. Even if it is not optimal to exercise an option, it has value since there is some chance of being in the money in the future. The focus of this dissertation is estimating the value of the development option and the zoning change option.

1.1 Literature Review

Academic research in financial options has become increasingly popular since the work of Merton (1973) and Black and Scholes (1973). Improvements in computational efficiency and continuous time finance have resulted in numerous theoretical papers. Real options have only recently been analyzed in a similar framework. One of the earliest papers to recognize real options was Brennan and Schwartz (1985) using a mineral extraction example. Brennan and Schwartz showed that the net present value analysis would lead to non-optimal extraction of the mineral since there is a value to waiting that is lost once excavation begins. Other real options within the finance literature include research and development and abandonment of projects that have already begun. Many investment decisions in real estate can be viewed in a similar framework.[1] One real option in real estate is the development decision a vacant landowner faces. The real option to develop vacant land in some aspect is the focus of this study.

One of the first studies that utilized a real options framework in a real estate context was Titman (1985). Titman used a real options approach to analyze development of vacant land. Seen under a financial option framework, the option is the vacant land, the underlying asset is the developed property, the exercise price is the cost of development and there is no set maturity to this option. The cost of development is assumed to be constant through time. Uncertainty within this model comes from the price of the developed parcel of land. A binomial lattice is used to determine the optimal building scale and the date of development. The results of this paper provided information on the optimal building size and the value of vacant land. Williams (1991) contributed to this work by adding another source of uncertainty. Both the revenues from the developed property and the cost of development are assumed to follow a geometric Weiner process. The optimal density and timing of development are computed numerically.

Titman and Williams determine the theoretical value of land. Quigg (1993) combined the theoretical framework similar to Williams (1991) with an empirical approach to determine the option value of waiting to develop. Quigg uses the price of the developed property as a state variable instead of the revenue

[1] Other theoretical, real option research in real estate includes Grenadier (1995, 1996), Geltner, Riddiough, and Stojanovic (1996), and Holland, Ott, and Riddiough (2000).

generated by the property. Results showed that waiting to develop represents 6% of the value of the vacant land for the Seattle area.

The second paper in this dissertation recognizes that landowner's face a real option to seek a zoning change. Previous research in the area of zoning has focused on land use planning. Does zoning have an impact on values of urban land? Is zoning an efficient method of allocating supply of land in a particular city? Fischel provides an overview of zoning research and zoning does typically impacts land values by controlling growth. Gunnelin (2001) analyzes the option to change the use of a property. His research uses three state variables and a finite difference method to examine the relationships of redevelopment from one use into another when costs change through time.

1.2 Anticipated Results

The goal for both studies is an estimate of value for each option. All options have some positive value since the option holder can choose not to exercise if it is not beneficial. Previous research has estimated a 6% delay premium embedded in the development option. However, data for this research consists of a different market so this is not necessarily an anticipated result. This is the first study that treats seeking a zoning change as an option. It is expected that for some properties, the zoning change option represent a significant value to the landowner.

CHAPTER 2

DEVELOPMENT VALUE:

A REAL OPTIONS APPROACH USING EMPIRICAL DATA

INTRODUCTION

Owners of vacant urban land have the ability to make improvements subject to governmental restrictions. This development of vacant land represents a real option held by the landowner and is exercised at the landowner's discretion. The landowner has the ability to postpone development until future market information becomes available. Therefore, the real option to develop has no set expiration date. Uncertainty about future prices has been shown to benefit investors when real option analysis is utilized for decision-making, while the standard net present value criteria may lead to non-optimal decisions. This paper combines an empirical methodology and a theoretical options approach to determine development option value. The delay premium embedded in the real option to develop is also estimated to explain the existence of vacant land in densely populated areas[2].

Research in financial options has become increasingly popular since the work of Merton (1973) and Black and Scholes (1973). Improvements in computational efficiency and continuous time finance have resulted in numerous

[2] Titman (1985) introduced this delay premium as an explanation for why vacant urban land exists. This research showed that rational landowners postpone development until changes in market prices become known.

theoretical papers. Real options have only recently been analyzed in a similar framework even though differences between real options and financial options exist. Financial options come in the form of a contract. Real options are not as rigid as their financial counterparts and are best viewed as a particular action. The framework for real options is described as a way of thinking about future uncertainty. Decisions are made based on a more complex strategy that uses future uncertainty to the advantage of the option holder. In both cases, the option is a right to take an action in the future. The real options framework was introduced by Brennan and Schwartz (1985) using a mineral extraction example since excavation is time consuming and future prices are uncertain. Brennan and Schwartz (1985) showed that the net present value analysis would lead to non-optimal extraction of minerals because there is a value to waiting that is lost once excavation begins. Other real options include research and development, expansion, and abandonment of projects that have already begun. Many investment decisions in real estate are viewed in a similar framework.[3] One real option in real estate is the development decision a vacant landowner faces. The real option to develop vacant land is the focus of the current research.

One of the earliest studies that utilized a real options framework in a real estate context was Titman (1985). Titman used a real options approach to analyze development of vacant land. Seen under a financial option framework, ownership of vacant land represents the option, the underlying asset is the developed property, and the exercise price is the cost of development. As

[3] Other theoretical, real option research in real estate includes Grenadier (1995, 1996), Geltner, Riddiough and Stojanovic (1996), and Holland, Ott and Riddiough (2000).

previously stated, there is no expiration date for this option. The cost of development is assumed to be constant through time. Uncertainty within this model comes from the price of the developed parcel of land. A binomial lattice is used to determine the optimal building scale and the date of development. The results of Titman's (1985) paper provided information on the optimal building size and the value of vacant land. Williams (1991) contributed to this work by adding another source of uncertainty. Both the revenues from the developed property and the cost of development are assumed to follow a geometric Weiner process. The optimal density and timing of development are computed numerically. Titman and Williams determine the theoretical value of land.

Quigg (1993) combines a theoretical framework similar to Williams (1991) with an empirical approach to test the option-pricing model and to determine the option value of waiting to develop. Instead of the revenue generated by the property, Quigg (1993) uses the price of the developed property as a state variable. Results showed that waiting to develop represents 6% of the value of the vacant land for the Seattle area. The cost elasticity of development was a parameter Quigg (1993) assumed to be between .9 and 1. Cost elasticity has a major impact on both the option value and the intrinsic value because of its role in determining the optimal building size. The current research uses actual construction cost data to estimate cost elasticities and finds elasticities inconsistent with the previous work of Quigg (1993). In addition, a sensitivity analysis is performed to test the implications of the cost elasticity differences.

The current research uses a framework similar to Quigg (1993) by combining empirical work with the theoretical options approach to value vacant land within the city of Chicago. The theoretical value of vacant land includes the intrinsic value of developing today and a time premium of delay because the owner can choose to wait and develop at a later date. The intrinsic value is the difference between the price of a newly developed property and the cost of the improvements constructed on the vacant parcel of land. This study determines the intrinsic value of developing a vacant parcel of land empirically. The difference between the theoretical value and the intrinsic value is the delay premium inherent in the real option of developing vacant land.

The model and theoretical assumptions for this chapter are provided in Section 2.1. Section 2.2 describes the various data sources. Section 2.3 is a discussion of the empirical estimation followed by the results in section 2.4. Section 2.5 concludes the chapter and includes topics of further research regarding real options inherent in land ownership.

2.1 MODEL

A residual model for valuing vacant land is used where the owner of vacant land holds a real option to develop. Vacant land represents this option held by the owner. To exercise this real option, a landowner will experience a development cost, X, and in return receive a strike price, P, upon development completion. The cost of development is determined by,

$$X = q^{\gamma} x_{t,y} \tag{2.1}$$

where q is the number of square feet, γ is the cost elasticity of building size, and xt,y is the cost per square foot that depends on the type of development, t, and the year, y.

The price of the underlying asset, the developed property, is given by

$$P = q^{\phi}\varepsilon \tag{2.2}$$

where ϕ is the price elasticity of the building size and ε is a vector of other property attributes. A developer expects to receive this price when development of the property is complete.

Several assumptions regarding this residual approach are as follows. All developers are price takers and no single development impacts prices in the marketplace. Development is instantaneous. This implies that development is irreversible and that the developer may not abandon the project during the development process. Developers maximize the value of the land by building to the optimal building size, *q**. Optimal building size is determined by maximizing the residual function, $V(q) = P(q) - X(q) = q^{\phi}\varepsilon - q^{\gamma}x_{t,y}$, with respect to *q* subject to the zoning constraints. This results[4] in the following estimate of optimal building size function:

$$q^* = \begin{cases} \left(\gamma x_{t,y} / \phi\varepsilon\right)^{\left(1/(\phi-\gamma)\right)} & \text{for } q^* < \delta \\ \delta & \text{for } q^* \geq \delta. \end{cases} \tag{2.3}$$

[4] The result in Equation 3 is slightly different than Quigg's (1993) research. There appears to be a misreported exponent of $\left(\gamma/(\phi-\gamma)\right)$ from the derivative of the residual function. The impact of this understates the optimal building size for $\gamma < 1$ which leads to lower values of the development option.

Maximum building size[5] allowed by the zoning code is denoted as δ. It may be suggested that the maximization of the residual function by building size is not a necessary assumption. However, developers could develop smaller initial structures in order to increase the value of future redevelopment options. The assumption made does not allow for this flexibility.

To obtain a real option price for the vacant land, a theoretical option-pricing model is utilized. The previously mentioned price of the developed property and the cost of development are the underlying state variables incorporating future uncertainty. Both follow a similar geometric Weiner process. The development cost evolves through time by

$$dX / X = \alpha_x dt + \sigma_x dz_x \tag{2.4}$$

where α_x is the constant drift term, dt is a small time increment, σ^2_x is the constant variance, and dz_x is a Weiner process. The price of the developed property also follows a similar geometric Brownian motion with constant drift, α_p, and constant variance, σ^2_p. This process is given by

$$dP / P = \left(\alpha_p - x_2\right)dt + \sigma_p dz_p \tag{2.5}$$

where x_2 is the cash flow from the developed property. The two Weiner processes have a constant correlation of $\rho * dt$.

Standard assumptions for continuous time finance are required for the theoretical model. There exists a riskless rate of interest, i, that is constant in the market for both borrowers and lenders. It is also possible to replicate the

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[5] The maximum building size is computed using the floor to area ratio (FAR) and the lot size; $\delta = FAR * LOTSIZ$.

contingent claims on the processes and the replicated portfolio is priced in the market. The future cash flows are risk adjusted and discounted by the risk-free rate. The standard procedure for this risk adjustment is to change the drifts of the two state variables from α_x and α_p to $v_x = \alpha_x - \lambda_x\sigma_x$ and $v_p = \alpha_p - \lambda_p\sigma_p$. The mean excess return per unit of standard deviation is given by the respective λ. Under these assumptions the value function $V(P,X)$ must satisfy the partial differential equation:

$$0 = .5\sigma_x^2 X^2 V_{xx} + \sigma_{xp} XPV_{xp} + .5\sigma_p^2 P^2 V_{pp} + v_x XV_x + v_p PV_p - iV + \beta P. \qquad (2.6)$$

A change of variables to $z = P/X$ and $W(z) = V/X$ yields

$$0 = .5\omega^2 z^2 W'' + \left(v_p - v_x\right) zW' + \left(v_x - i\right)W + \beta z \qquad (2.7)$$

where,

$$\omega^2 = \sigma_x^2 - 2\rho\sigma_x\sigma_p + \sigma_p^2.$$

The solution to the above partial differential equation is given by

$$V\left(P,X\right) = X\left(Az^j + k\right) \qquad (2.8)$$

where,

$$A = \left(z^* - 1 - k\right)\left(z^*\right)^{-j},$$

$$z^* = j\left(1+k\right)/\left(j-1\right),$$

$$k = \beta z/\left(i - v_x\right),$$

$$j = \omega^{-2}\left\{.5\omega^2 + v_x - v_p + \left[\omega^2\left(.25\omega^2 - v_p - v_x + 2i\right) + \left(v_x - v_p\right)^2\right]\right\},$$

$$z = P / X \, .$$

The change of variable *z* is the price to cost ratio. There exists a hurdle ratio for the price to cost ratio of *1+k* that determines whether or not it is optimal to develop. Using the hurdle rate, the intrinsic value can take one of two values described as

$$V^I\left(P,X\right) = \begin{cases} P - X & \text{for } z \geq 1+\text{k} \\ \beta P \big/ i - v_x & \text{for } z<1+\text{k}. \end{cases} \tag{2.9}$$

This result is calculated by taking the limit of Equation 2.8 as ω approaches zero and can be described as follows. The intrinsic land value is the residual of price and cost if the property is developed today. If the hurdle ratio is not met, the vacant parcel is not developed and the landowner keeps the vacant property for the income it generates. The undeveloped property is then valued as a perpetuity. Intrinsic value is an estimate of the land if developed today but does not incorporate the value of delay. The result of the theoretical estimation in Equation 2.8, *V(P,X)*, incorporates uncertainty of future cost and price. This value is a combination of the intrinsic value and the delay option premium. Theoretical option values vary across vacant parcels depending on the characteristics of the developed property as the characteristics affect price and cost.

To compute the theoretical option prices several parameters must be assigned values. Since the sample period is similar to Quigg (1993) many parameter values are the same. The risk free rate, *i*, is assumed to be 8%. The drift parameters for both state variables, v_i, are assumed to be 3%. The income to the undeveloped parcels of land, β, is assumed to be 1% of the total improved value. The income variable implies a land to value ratio of 20%[6] with the other assumed parameters. The annual standard deviation of cost is assumed to be 5% and the standard deviations of specific property prices are estimated using the results from the hedonic estimations. The price volatilities in the current research differ from Quigg's (1993) research. Previous research computed the implied volatilities from the options model in order to test the predicting power of the theoretical model. This paper estimates annual price volatilities using transaction level data[7].

2.2 Data

This research uses various data sets covering a time period from January 1986 to December 1993[8] in the city of Chicago. The property level data comes from Real Estate Data, Inc. (REDI) which compiles transaction-based information from public records on properties sold for more than $50,000 within Cook county. Transfer declarations are required by law to provide accurate transaction information and REDI collects data from this source. The observations used in this research represent a random sample of all transactions that occurred during the time period. Property types include both vacant parcels of land and income producing properties developed as residential, commercial, and industrial. Since the data includes only income producing properties, the residential data only

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[6] The 20% land to developed value ratio can be obtained from equation 9. The 1% income divided by 5% implies that land is 20% of the total value after development, *P*.

[7] Annual price volatilities are computed using the hedonic estimation results to create an index over the holding period. The result is an annual price volatility range from 16% to 30%.

[8] The majority of the data for this paper has been used in previous research by Munneke (1996) and Colwell and Munneke (1997).

Table 2.1
Summary Statistics

	Improved Properties			Vacant Parcels		
Observations		2034			836	
	Mean	Min	Max	Mean	Min	Max
PRICE ($,000s)	473.18	50	83000	**	**	**
LOTSIZ (sq. feet)	25854	858	1599088	41642	1344	1655280
ROAD (miles)	3.78	0	9.72	2.85	0	9.25
RAIL (miles)	2.94	0	9.79	2.58	0	9.18
UCBD (miles	6.65	0	19.92	5.39	0.5	15.21
UNORTH (miles)	16.4	0	26.17	16.33	0.5	25.63
q (sq. feet)	22171	180	1130000	**	**	**
AGE (years)	52.1	0	100	**	**	**
Year						
1987	0.09	0	1	0.15	0	1
1988	0.15	0	1	0.19	0	1
1989	0.21	0	1	0.19	0	1
1990	0.16	0	1	0.12	0	1
1991	0.11	0	1	0.09	0	1
1992	0.07	0	1	0.06	0	1
1993	0.06	0	1	0.04	0	1

*** Not observable for vacant parcels.*

consists of multi-family properties. Information for each transaction includes selling price, date of sale, lot size, various building characteristics, current zoning, and location. The improved properties include 2,034 observations while the vacant data set includes 836 parcels of land.

Legal descriptions of properties in Chicago are defined by the rectangular survey system. Under this system, sections are defined as a one-mile by one-mile square and a quarter section is a ½-mile by ½-mile square. Both vacant and developed properties are identified as belonging to a specific quarter section[9].

[9] The center of the quarter section identifies the location of each property.

This quarter section identification allows for a straight-line distance calculation to any other quarter section or the central business district (*UCBD*), which is defined as the corner of State and Madison. Other distance variables used are distance to a road center (*UROAD*), distance to a rail center (*URAIL*) and distance from the southern most boundary of Chicago (*UNORTH*). A road or rail center is a quarter section that has more than 20% of its area allotted to roads or railroads respectively. Descriptive statistics on improved and vacant parcels are provided in Table 2.1.

The development cost data is obtained from the 1994 Means Square Foot Costs (Means) manual. This annual publication is commonly used throughout the industry to estimate costs for a number of specific building types. One benefit of using Means is that a schedule of average cost per square foot and building size is provided for each building type. Means also provides a historical cost index that varies across major metropolitan areas.

2.3 EMPIRICAL ESTIMATIONS

Several steps are involved in empirically estimating the improved value of a vacant parcel of land. The first step is to estimate a pricing mechanism for types of real estate in the city of Chicago. This involves a hedonic estimation for each of the specific land use categories. The next step involves estimating cost elasticities using the Means cost data. The pricing mechanism and the corresponding cost information can be used to determine the optimal building size. The optimal building is then used to determine the total price of the developed parcel.

The initial hedonic equation is done for specific property types. The broad zoning categories are separated into more precise land uses. Commercial properties are broken down into small retail, large retail and office space. The industrial properties are divided into light manufacturing, heavy manufacturing and warehouse/storage uses. The hedonic specification for each type is

$$\log P_i = c + \phi \log q_i + \psi \log LOTSIZ_i + a'U_i + b'AGE_i + \hat{d}'YEAR_i + \varepsilon_i \quad (2.10)$$

Independent variables are building square footage (q), lot square footage (LSF) a vector of distances, a vector of ages and a vector of yearly dummies. Distance variables are not all increasing distances from the respective point or quarter section. The actual distances from the central business district and from the south boundary are used because these impact values across the entire city. The distance from a road or rail center do not have the same impact. It has been found that these centers impact values for properties within a two-mile radius. Therefore, the other two distance variables, *UROAD* and *URAIL*, take on values between negative two and zero. For example, if a parcel is over two miles from one road center, the *UROAD* variable is recorded as zero because that road center does not impact property value. However, if the parcel is within the road center section, *UROAD* will take on a value of negative two indicating a large impact on property value. This technique allows the impact on price to decline as the distance increases to two miles and then become negligible. Equation 2.10 provides the necessary pricing information for each property type.

Table 2.2
Cost per Square Foot and Elasticities

Land Use	Cost per Square Foot	Elasticity
Commercial		
Small Retail	\$71.70	0.799
Large Retail	\$56.00	0.918
Office	\$88.00	0.830
Industrial		
Light Manufacturing	\$60.55	0.889
Heavy Industrial	\$75.70	0.859
Warehouse	\$53.20	0.839
Residential		
High Density	\$70.00	0.700

Cost elasticities are estimated[10] for each land use using the Means schedule of average square foot cost and building size. Ordinary least squares can estimate the cost elasticity, γ, from equation

$$\ln\left(\textit{total cost}\right) = c + \gamma \ln\left(q\right). \qquad (2.11)$$

A summary of the cost per square foot and cost elasticities are provided in Table 2.2. Optimal building size for each parcel of land is now estimated using Equation 2.3 and the following information: hedonic estimates from each land use, cost information and vacant parcel characteristics. Equation 2.3 explicitly accounts for the maximum allowed building size depending on the zoning restriction. The optimal building is viewed as a hypothetical improvement on a vacant parcel of land. Cost of developing the parcel into the optimal size is a straightforward calculation using the cost function from Equation 2.1.

[10] The models for estimating the cost elasticity have an R-squared ranging from .95 to .99.

Table 2.3
Developed Residential Properties

R-squared	0.5318	
N	524	
Variable	Coeff.	*t* value
CONSTANT	5.61028	10.41
log(q)	0.39610	8.05
log(LOTSIZ)	0.34856	4.74
UCBD	-0.02546	1.93
UROAD	0.09869	0.94
URAIL	0.22310	3.42
UNORTH	0.03186	7.22
AGE	-0.00608	1.05
AGESQ	-0.00003	0.61
Year		
1987	-0.14040	1.47
1988	0.07681	0.94
1989	0.28006	3.74
1990	0.36563	4.74
1991	0.25399	3.07
1992	0.13830	1.14
1993	0.44990	3.97

Note: The dependent variable is the log(Price) of a developed property.

A predicted selling price, $\hat{P}$, of the newly developed parcel is obtained using the hedonic regression estimates from Equation 2.10 because these estimates provide a market pricing mechanism for improved properties. Since the vacant parcel of land is being developed, the observable parcel characteristics are used with the optimal building size. The predicted selling price is given by

$$\hat{P}_i = q_i^{*\hat{\phi}} LOTSIZ_i^{\hat{\psi}} \exp\left\{\hat{c} + \hat{a}'U_i + \hat{d}'YEAR_i\right\}. \tag{2.12}$$

Table 2.4
Developed Commercial Properties

	Office		Small Retail		Large Retail	
R-squared	0.7086		0.5036		0.4941	
N	65		278		397	
Variable	Coeff.	*t* value	Coeff.	*t* value	Coeff.	*t* value
CONSTANT	8.19512	3.25	6.25971	12.11	7.41087	13.76
log(q)	0.45484	2.43	0.25159	4.65	0.52346	10.06
log(LOTSIZ)	0.16078	0.58	0.37383	7.18	0.07741	1.25
UCBD	-0.15030	2.08	-0.00533	0.33	-0.03716	2.47
UROAD	-0.35165	0.63	-0.07289	0.71	-0.06952	0.71
URAIL	0.80163	2.55	0.20963	2.84	0.40758	5.88
UNORTH	-0.02728	1.01	0.02613	3.98	0.01644	2.28
AGE	-0.01040	0.37	-0.01043	1.80	-0.02315	3.91
AGESQ	0.00004	0.15	0.00010	1.62	0.00015	2.93
Year						
1987	0.44525	0.85	-0.10252	-0.67	0.20367	1.46
1988	1.26675	2.31	0.25881	1.83	0.37363	3.05
1989	1.29637	2.81	0.18981	1.49	0.44963	4.23
1990	1.24371	2.52	0.37381	2.90	0.32454	2.94
1991	1.16352	2.22	0.28165	2.03	0.37629	2.96
1992	1.60017	2.50	0.25501	1.82	0.45412	3.48
1993	1.04597	1.72	0.43908	2.68	0.55731	3.95

Note: The dependent variable for each model is the log(Price) of a developed property.

The observable characteristics of the vacant parcels include a vector of distances, *U*, lot size in square feet, *LOTSIZ*, and *YEAR*. These variables represent the same information for vacant and improved parcels. It is important to recognize that age drops out of the equation because the vacant parcel is developed to a new building. Hedonic estimates used to predict this improved price introduce a redevelopment option into the price since current improved parcel transactions include this premium. The argument against this is as follows. First, the property is newly developed and age is a good indicator of

Table 2.5
Developed Industrial Properties

	Light		Heavy		Warehouse	
R-squared	0.4876		0.6071		0.5833	
N	313		131		351	
Variable	Coeff.	*t* value	Coeff.	*t* value	Coeff.	*t* value
CONSTANT	6.39506	12.34	5.61704	6.36	5.51352	11.13
log(q)	0.30463	5.52	0.25860	3.08	0.50514	8.97
log(LOTSIZ)	0.29768	5.26	0.49531	6.29	0.17224	3.23
UCBD	-0.03287	1.96	-0.05743	1.97	-0.02368	1.30
UROAD	-0.19664	2.49	-0.04765	0.36	-0.24038	2.63
URAIL	0.26151	3.84	0.34777	3.15	0.12310	1.62
UNORTH	0.04213	4.47	0.02752	1.58	0.05670	5.00
AGE	-0.01386	2.52	-0.03384	2.82	-0.01377	2.23
AGESQ	0.00008	1.70	0.00025	2.34	0.00004	0.63
Year						
1987	-0.05821	0.45	0.17032	0.76	-0.04330	0.32
1988	0.16198	1.37	0.42639	2.16	0.27871	2.52
1989	0.15051	1.30	0.65881	3.11	0.38109	3.35
1990	0.19359	1.63	0.18121	0.74	0.34316	2.47
1991	0.15851	1.17	0.40028	1.72	0.40228	2.75
1992	0.33845	2.23	0.70001	2.23	0.18112	1.03
1993	0.37498	2.26	-0.15357	0.49	0.61786	3.29

Note: The dependent variable for each model is the log(Price) of a developed property.

redevelopment option value. Second, the property is developed into a building size that maximizes the land value. Both of these could imply that the redevelopment option value has been minimized.

At this point, the vacant land parcels have a predicted selling price after being developed to an optimal building size of a particular use. This does not indicate whether it is optimal to develop. The option-pricing model determines if it is optimal to develop and incorporates the value of delay using the estimates of predicted selling price and total development cost. The theoretical option value from Equation 2.8 is the sum of the intrinsic value and the delay option premium. The intrinsic value from Equation 2.9 represents the value of the option embedded in land without delay, which should be a lower bound of price for the vacant parcel.

2.4 RESULTS

The current research estimates the real option value of development for urban parcels of vacant land in Chicago by making several empirical estimations and incorporating the results into a theoretical option model. This section provides empirical results from the methodology explained in the previous section and presents real option values of development and delay.

The initial step was a series of hedonic estimations for improved properties of various land uses. The hedonic results are provided in Tables 2.3-2.5. One particular variable of importance is the price elasticity, ϕ, that impacts the development option value in two ways. First, the price elasticity is used to determine the optimal building size, q^*. Secondly, it is used in determining the predicted selling price of the newly developed parcel. The price elasticities range from .305 for light manufacturing to .576 for residential. Other coefficient estimates show expected relationships across property types. The lot size coefficient is positive but surprisingly insignificant in some cases. All distance to the central business district coefficients are negative indicating properties close to the central business district sell for a premium, although not all are significant. Previous research has found insignificance in distance to downtown. All of the

Table 2.6
Option Premiums

Land Use	Option Value	Intrinsic Value	Option Premium
Commercial			
Small Retail	$213,292	$208,792	0.0210
Large Retail	$381,577	$356,699	0.0712
Office	$1,128,161	$983,461	0.0803
Industrial			
Light Manufacturing	$260,500	$257,311	0.0122
Heavy Industrial	$280,564	$264,482	0.0573
Warehouse	$982,455	$857,715	0.1129
Residential			
High Density	$532,164	$471,263	0.1153

Note: The option premium is calculated by:
(option value - intrinsic value) / option value for each observation and not the average option valuie and intrinsic value.

UNORTH coefficients were positive except for the office properties. The explanation for this is that office space increases in value from the lower city boundary up to the downtown area. From this point northward, office properties decline in price. The effect north of downtown dominates the otherwise normal upward pricing from south to north. The distance to a railroad center is positive for all properties and significant in most cases. A majority of the distance to a road center coefficients are negative indicating that properties closer to a road center have a premium. Coefficients for the yearly dummy variables are mostly positive over time indicating an upward trend in property prices throughout the sample period.

The estimated values of the land are summarized in Table 2.6 along with the delay option premiums. The mean intrinsic values range from $208,792 to $983,461. The mean option values range from $213,292 to $1,128,161. The delay option premiums vary across land use types with industrial warehouse having the highest delay premium of approximately 11%. Land used for light industrial space has the lowest delay premium of approximately 1%. There is no reason to believe that the various land uses would have similar option premiums. The land uses with the smallest delay premium will be developed relatively soon after purchase while properties with higher delay premiums are held longer. Previous research has offered this as a rational for why vacant parcels exist in urban areas.

One contribution of this paper is the estimated cost elasticities from actual cost data. A sensitivity of this parameter has been provided to show the impact of cost elasticity on option value. Previous research of Quigg (1993) uses a cost elasticity between .9 and 1. Using a cost elasticity of .95 for all properties option values have been computed with a summary in Table 2.7. These results show that a higher cost elasticity will lead to smaller option values. The reason for this decrease in option value is that a higher cost elasticity leads to smaller optimal building sizes because returns to scale are smaller. However, the intrinsic values also decline for the same reason. The smaller optimal building size decreases the value of both option value and intrinsic. Since a higher cost elasticity impacts both values, there is no major impact on the delay premium. The real impacts of

Table 2.7
Sensitivity of Cost Elasticity

Land Use	Option Value for Current Elasticity	Option Value for .95 Elasticity	Option Value Error
Commercial			
Small Retail	$213,292	$126,878	0.4051
Large Retail	$381,577	$276,053	0.2765
Office	$1,128,161	$489,098	0.5665
Industrial			
Light Manufacturing	$260,500	$199,600	0.2338
Heavy Industrial	$280,564	$185,387	0.3392
Warehouse	$982,455	$248,765	0.7468
Residential			
High Density	$532,164	$154,854	0.7090

Note: The option value error measures how much the higher elasticity understates the land value.

an overstated cost elasticity are smaller optimal building sizes and an understated estimation of the development option.

Owners of vacant urban land have the right but not the obligation to make improvements on the property subject to governmental restrictions. Embedded in this option is the option to delay development until future uncertainty becomes known. The results from this research show that the real option values to develop vary due to the different prices for specific land uses and cost of development. At the same time, delay premiums vary and possibly indicate a rational order of the option exercise into the future. Parcels with little delay premiums should be exercised first followed by land uses that show high delay premiums. This paper offers several contributions to the existing research. The estimation of cost elasticities should improve the estimation of real option values and the disaggregated data allows for a more specific analysis of vacant parcel values within the urban area.

2.5 Summary

This paper estimates the value of the development option along with the delay option embedded in development using a combination of empirical work and theoretical option pricing following a general framework of Quigg (1993). The empirical work involves a hedonic estimation of developed properties within the city limits of Chicago. These empirical results were used to estimate the value of a property developed today and a residual approach to land valuation was implemented. To find the optimal building size for a parcel, the residual function[11] was maximized subject to the zoning constraint. This revealed the size of a hypothetical building that maximizes land value. Using the optimal building size and the cost elasticity estimates based on an industry measure of development costs, the improved value and development costs are computed. A theoretical options model then prices the option value of development. The intrinsic value represents a lower bound for the value of vacant urban land while the theoretical option value includes the option to delay development.

The overall results for the delay premium are consistent with previous research. Evidence suggests that delay premiums are on average 6.7% of the total development option. Obviously, there is no reason to believe that option premiums are constant across specific land use categories or within specific land

[11] The residual function is the difference between newly developed price and development costs.

use categories. While Quigg (1993) bases her results on the broad land use categories of residential, commercial and industrial, the current study disaggregates these categories. Results indicate that delay premiums within and across land use categories do vary. The delay premiums should provide insights into the order in which properties are developed. Land uses with lower delay premiums should be developed sooner than types with higher delay premiums because this option is lost when development is exercised. The results indicate that developers of small retail and light manufacturing should be developing relatively soon while developers of office space and high density residential have incentives to delay investment. The disaggregated results provide greater insight.

Another contribution of this paper is the empirically estimated development cost elasticities which differ from Quigg (1993). Results for the delay premium are consistent with previous research even though elasticities differ; however, elasticity differences do lead to inconsistent total option or land values. The sensitivity analysis shows that an overstated cost elasticity results in an understated development option value from 23% to 75%. There was no expectation that option values would be similar because this research uses a different metropolitan area. Even though costs of development are similar for Seattle and Chicago, different data sets lead to price differences through the hedonic estimation of developed properties.

Further empirical research is warranted on this subject. It may be possible to empirically test whether the optimal building scale and timing of development are actually displayed in the market. Information on the vacant land parcels after the sale and development would have to be gathered for vacant land transactions. Several other real options in real estate have room for consideration. These include the compound option of redevelopment and how seeking a zoning change affects land values.

CHAPTER 3

DEVELOPMENT VALUE:

ZONING CHANGES AND LAND USE CHOICE

INTRODUCTION

The real options literature has established that vacant urban land has value due to the development option. This option has been valued using both discrete time and continuous time financial models. In addition, these models have been used to explain optimal development decisions, which include the optimal timing and scale of development. These papers include but are not limited to Titman (1985), Williams (1991), and Capozza & Li (1994). Quigg (1993) and Grovenstein, Kau and Munneke (2003) use a real options framework with empirical data to determine the option value of waiting to develop and Quigg (1993) tests the predictability of theoretical option pricing of land. In each of these studies, the development option value and delay have been estimated assuming land is developed into, and only into, the land use allowed by the current zoning. The purpose of this study is to estimate the value of development recognizing the potential to develop a parcel into a land use other than what is currently allowed by the zoning code. The analysis will also show that the option to seek a zoning change is a valuable real option embedded in owning land.

The effects of land use choice have been studied theoretically by Geltner, Riddiough, and Stojanovic (1996). This research allows for a landowner to develop into either of two land uses allowed by the current zoning code. Each land use follows a similar geometric process and numerical results are used to support several theoretical findings. The value of vacant land with multiple land use possibilities must be as high as the parcel if constrained to one use. The possibility of multiple land uses increases the uncertainty and therefore the potential gain from waiting. Empirical results from the current research support the findings of Geltner et al. (1996).

Zoning regulations in an urban area can be used to manage nuisances, as well as possible means of controlling growth. If zoning is a true constraint, then zoning may impact the value of land. Embedded in the multi-land use problem lies an option to seek a zoning change since this allows for a number of potential developable properties. The ability to seek a zoning change is a right held by the landowner and therefore, a real option that has value to the owner of vacant urban land.

The chapter is presented in the following order. A brief literature review is given in Section 3.1, and a description of the data is provided in Section 3.2. Section 3.3 introduces the model for the paper and provides estimation results. Section 3.4 is a discussion of the zoning change premium followed by a summary that concludes the chapter in Section 3.5.

3.1 Literature Review

The majority of the previous real option research on development considers development into a use allowed by the existing zoning category. One of the first studies that incorporates a real options framework in a real estate context is Titman (1985). Titman uses a real options approach to analyze development of vacant land. Seen under a financial option framework, the option is the vacant land, the underlying asset is the developed property, and the exercise price is the cost of development. Unlike a typical financial option, this real option has no set maturity. The cost of development is assumed to be constant through time. Uncertainty within this model comes from the price of the developed parcel of land. A binomial lattice is used to determine the optimal building scale and the date of development. The results of Titman's (1985) paper provide information on the optimal building size and the value of vacant land. Williams (1991) extends the work in this area by adding another source of uncertainty. The additional state variable is the cost associated with development since they too change over time. Both the revenues from the developed property and the cost of development are assumed to follow a geometric Brownian motion. The optimal density and timing of development are computed numerically. Titman (1985) and Williams (1991) determine the theoretical value of land.

Quigg (1993) combines the theoretical framework similar to Williams (1991) with an empirical approach to determine the option value of waiting to develop and to test the predictability of theoretical option pricing of land. Quigg uses the price of the developed property as a state variable instead of the revenue generated by the property. Results show that waiting to develop represents 6% of the value of the vacant land for the Seattle area and that theoretical option pricing models do a good job of predicting land values.

Using a similar model to Quigg (1993), Grovenstein, Kau and Munneke (2003) estimate land values and delay premiums associated with development within the city limits of Chicago. One contribution of this research is a segregated data set into more specific land use categories. Cost elasticities are estimated using industry measures of cost per square foot. A sensitivity analysis of cost elasticity is provided and shows that an overstated cost elasticity leads to larger building sizes though an impact in delay premiums is not consistent.

Gunnelin (2001) is one of several articles that explicitly recognizes changing the use of the property as the real option of redevelopment. This theoretical research uses three state variables: the value under the current use, the value of the new use, and the construction cost of redevelopment. Optimal timing and value of redevelopment are explored through numerical simulations. A concave redevelopment boundary implies a diversification effect when costs become equal.

Previous research has not considered changing the zoning of the property prior to development. The current research considers this change before development, therefore providing the landowner greater flexibility in the development decision. The option to seek a zoning change has value and landowners may strategically exercise this option to maximize wealth. Results from the current research are reinforced by actual zoning changes that occurred during the sample period.

2.2 Data

This research uses various data sets covering a time period from January 1986 to December 1993[12] in the city of Chicago. The property level data comes from Real Estate Data, Inc. (REDI) which compiles transaction-based information from public records on properties sold for more than $50,000 within Cook county. Transfer declarations are required by law to provide accurate transaction information and REDI collects data from this source. The observations used in this research represent a random sample of all transactions that occurred during the time period. Property types include both vacant parcels of land and income producing properties developed as residential, commercial, and industrial. Since the data includes only income producing properties, the residential data only consists of multi-family properties. Information for each transaction includes selling price (*P*), date of sale, lot size (*LOTSIZ*), age, current zoning, and location. The improved properties include 2,034 observations while the vacant data set includes 836 parcels of land.

Legal descriptions of properties in Chicago are defined by the rectangular survey system. Under this system, sections are defined as one mile by one mile square and a quarter section is a half mile by half mile square. For this study all properties are identified as being located at the center of a specific quarter section. This quarter section identification allows for a straight-line distance calculation to any other quarter section or the central business district (*UCBD*), which is defined as the corner of State and Madison. Other distances can also be

[12] The majority of the data for this paper has been used in previous research by Munneke (1996) and Colwell and Munneke (1997).

Table 3.1
Summary Statistics

	Improved Properties			Vacant Parcels		
Observations		2034			836	
	Mean	Min	Max	Mean	Min	Max
PRICE ($,000s)	473.18	50	83000	**	**	**
LOTSIZ (sq. feet)	25854	858	1599088	41642	1344	1655280
ROAD (miles)	3.78	0	9.72	2.85	0	9.25
RAIL (miles)	2.94	0	9.79	2.58	0	9.18
UCBD (miles	6.65	0	19.92	5.39	0.5	15.21
UNORTH (miles)	16.4	0	26.17	16.33	0.5	25.63
q (sq. feet)	22171	180	1130000	**	**	**
AGE (years)	52.1	0	100	**	**	**
Year						
1987	0.09	0	1	0.15	0	1
1988	0.15	0	1	0.19	0	1
1989	0.21	0	1	0.19	0	1
1990	0.16	0	1	0.12	0	1
1991	0.11	0	1	0.09	0	1
1992	0.07	0	1	0.06	0	1
1993	0.06	0	1	0.04	0	1

*** Not observable for vacant parcels.*

measured to identify the location of each parcel in respect to factors that have been previously shown to impact value. These distances are distance to a road center,(*UROAD*), distance to a rail center (*URAIL*) and distance from the southern most boundary of Chicago (*UNORTH*). A road or rail center is a quarter section that has more than 20% of its area allotted to roads or railroads respectively. Descriptive statistics on improved and vacant parcels are provided in Table 3.1.

The development cost data was obtained from the 1994 Means Square Foot Costs (Means) manual. This annual publication is commonly used throughout the industry to estimate costs for a number of specific building types.

One benefit of using Means is that a schedule of average cost per square foot and building size is provided for each building type. Means also provides a historical cost index that varies across major metropolitan areas. Chicago is listed so actual cost data for the Chicago market is being used and an index provides accurate estimations over the sample period.

The zoning information has been collected from the Chicago Zoning Ordinance. This annual publication is a collection of zoning maps consisting of one-mile by one-mile sections. The maps from 1986 were compared to the map from 1994 and all differences were recorded. A transparent grid was placed over each map and the total change was recorded. This provides an estimate of the portion of each section that underwent a zoning change. Some quarter sections had no zoning changes while other quarters experienced 80% change. In addition, the zoning categories for each property have been collected for the beginning and end of the sample period.

3.3 Model

The underlying model for this paper has been used in previous research[13], but the impact of a zoning change has not been explored. This model treats land as an option where vacant landowners may exercise the development option at any point in time subject to legal restrictions. To exercise this option, a landowner experiences a cost, X, to develop a vacant parcel, and receives a price, P, upon completion of development. The cost of development is determined by

[13] Quigg (1993) and Grovenstein, Kau, and Munneke (2003) utilize this residual approach with an options model to value land.

Table 3.2
Cost per Square Foot and Elasticities

Land Use	Cost per Square Foot	Elasticity
Commercial	$70.00	0.85
Industrial	$65.00	0.87
Residential	$70.00	0.70

$$X = q^{\gamma} x_{t,y}, \tag{3.1}$$

where q is the number of square feet, γ, is the cost elasticity of building size, and $x_{t,y}$ is the cost per square foot that depends on the type of development, t, and the year, y. The average cost[14] per square foot is collected from the Means Square Foot Costs manual, and the cost elasticity, γ, has been estimated using ordinary least squares. The cost elasticities are assumed constant through time for each property type. The results of the cost elasticity estimation are found in Table 3.2. Higher elasticities lead to smaller building sizes since the returns to scale are not as large.

The price of the underlying asset, the developed property, is given by

$$P = q^{\phi} \varepsilon, \tag{3.2}$$

where ϕ is the price elasticity of the building size and ε is a vector of other property attributes. The difference between price and cost is the residual estimate of the land value. It is also considered the payoff of exercising the development option at any point in time.

[14] An index is provided in Means to adjust for inflation during the sample period. The average square foot costs in Table 1 are in 1994 dollars.

Basic assumptions included in this model are as follows. All developers are price takers so that no development impacts prices in the market. Development is irreversible. Once the option to develop is exercised, the developer completes the development. Also, the developer builds to the optimal building size, *q**, which is determined by maximizing $V(q) = P(q) - X(q) = q^{\phi}\varepsilon - q^{\gamma}x_{t,y}$ with respect to *q* subject to the zoning constraints. The result yields[15]

$$q^{*} = \begin{cases} \left(\gamma x_{t,y} / \phi\varepsilon\right)^{(1/(\phi-\gamma))} & \text{for } q^{*} < \delta \\ \delta & \text{for } q^{*} \geq \delta, \end{cases} \tag{3.3}$$

where δ is the maximum building size set by the floor-area ratio from the zoning code. The optimal building size maximizes the current value of the land, and therefore minimizes any redevelopment options that always exist for an improved property. It also implies that developers do not have the option to partially develop a smaller building in order to strategically expand in the future. A different *q** is estimated for each development type according to the zoning categories.

The residual function used to value land does not incorporate the delay premium embedded in the real option of development. A theoretical model presented in the next section is used to value each property where future uncertainty exists and includes the delay premium.

[15] The result in Equation (3) is slightly different than the previous research of Quigg. The previous research misreports an exponent of $\left(\gamma/(\phi-\gamma)\right)$ which underestimates q* for $\gamma < 1$.

3.3.1 Development Option Value with Delay

To determine the development option value with delay, a theoretical options model is used. Theoretical option pricing incorporates the uncertainty through time and allows for time to be a factor in the option value. Development costs are determined by Equation 3.1, and the price of the developed property is estimated by Equation 3.2. Both price and cost are underlying state variables that change over time and follow similar Weiner processes. Development costs follow a geometric Brownian motion,

$$dX / X = \alpha_x dt + \sigma_x dz_x, \tag{3.4}$$

where α_x is the constant drift, dt is a small time increment, σ_x is the constant variance, and dz_x is a Weiner process. The price of the developed property also follows a geometric Brownian motion with constant drift, α_p, and constant variance, σ_p. This process is given by

$$dP / P = \left(\alpha_p - x_2\right) dt + \sigma_p dz_p, \tag{3.5}$$

where x_2 is a cash flow from the developed property. The cash flow stream from the developed property is one difference between the stochastic processes, but the price and cost differ over time due to other parameter differences. The two Weiner processes have a correlation of ρ*dt.

The value of the underlying property, $V_d(X,P)$, is the solution of the partial differential equation,

$$0 = .5\sigma_x^2 X^2 V_{xx} + \sigma_{xp} XPV_{xp} + .5\sigma_p^2 P^2 V_{pp} + v_x XV_x + v_p PV_p - iV + \beta P. \tag{3.6}$$

Through a change of variables, the solution is given by

$$V_d\left(P, X\right) = X\left(Az^j + k\right), \tag{3.7}$$

where

$$A = \left(z^* - 1 - k\right)\left(z^*\right)^{-j},$$

$$z^* = j\left(1 + k\right) / \left(j - 1\right),$$

$$k = Bz / \left(i - v_x\right),$$

$$j = \omega^{-2}\left\{.5\omega^2 + v_x - v_p + \left[\omega^2\left(.25\omega^2 - v_p - v_x + 2i\right) + \left(v_x - v_p\right)^2\right]\right\},$$

$$z = P / X.$$

Parameters must be assigned values to compute the theoretical option value of development. The risk free rate, *i*, is assumed to be 8% which is consistent with market rates during the sample period. The risk adjusted drift parameters for both state variables, v_i, are assumed to be 3% and represent the expected annual appreciation rate. The income to the undeveloped properties, β, is assumed to be 1% of the total property value after improvement. The annual standard deviation of cost is 5%, and the standard deviations of specific property prices are estimated using the results from the hedonic estimation. Annual price volatilities range from 20% for industrial to 23% for residential. The result of the theoretical estimation is the value of developing with the delay option. Delay premiums allow landowners the ability to wait until market information becomes known. Properties with low delay premiums should be developed sooner than those with higher delay premiums.

3.3.2 Price and Cost Estimations

Several empirical estimations are done to provide price information about the various property types. This estimation involves a hedonic model[16] of properties that have been developed. The developed properties are separated into the three zoning categories and a price equation is estimated for each. The hedonic equation is expressed as

$$\log P_i = c + \phi \log q_i + \psi \log LOTSIZ_i + a'U_i + b'AGE_i + \hat{d}'YEAR_i + \varepsilon_i \qquad (3.8)$$

The independent variables are building square footage (q), the lot square footage (LSF), and the age of the property (AGE). U is a vector of distance variables that describe the location within the city. The north variable, ($UNORTH$) is used to incorporate the upward trend in prices that exists from south to north. Vector $YEAR$ consists of dummy variables indicating the year the transaction occurred. The yearly dummy variable for 1986 is omitted.

The results from the hedonic estimations provided in Table 3.3 show expected relationships for each of the variables. Building size and lot size are both positive and significant. The yearly dummy variables show that prices are rising through time. Age has a negative impact on value. The various distance variables provide consistent estimates that explain urban areas. First, all properties decrease in value as the distance to the central business district increases. This is a fundamental relationship of urban land values. Residential properties have a positive relationship with distance to a road center while commercial and industrial properties are negatively related.

[16] Rosen (1974) provides the basic theory behind hedonic estimation.

Table 3.3
Developed Property Hedonic Estimations

	Residential		Commercial		Industrial	
R-squared	0.5318		0.5342		0.5806	
N	524		910		812	
Variable	Coeff.	*t* value	Coeff.	*t* value	Coeff.	*t* value
CONSTANT	5.61028	10.41	6.84204	19.75	5.53928	18.04
log(q)	0.39610	8.05	0.44296	17.63	0.36769	10.42
log(LOTSIZ)	0.34856	4.74	0.22311	6.48	0.32029	9.48
UCBD	-0.02546	1.93	-0.05081	4.95	-0.02518	2.19
UROAD	0.09869	0.94	-0.18262	2.71	-0.21955	3.95
URAIL	0.22310	3.42	0.34548	7.13	0.22034	4.77
UNORTH	0.03186	7.22	0.02054	4.46	0.04341	6.48
AGE	-0.00608	1.05	-0.01725	4.66	-0.01426	3.19
AGESQ	-0.00003	0.61	0.00010	2.88	0.00007	1.70
Year						
1987	-0.14040	1.47	0.00734	0.08	-0.05069	0.59
1988	0.07681	0.94	0.23182	2.66	0.24756	3.34
1989	0.28006	3.74	0.27592	3.64	0.35062	4.65
1990	0.36563	4.74	0.27361	3.44	0.22659	2.74
1991	0.25399	3.07	0.24046	2.68	0.29923	3.24
1992	0.13830	1.14	0.30958	3.29	0.34197	3.14
1993	0.44990	3.97	0.49267	4.77	0.41977	3.71

Note: The dependent variable for each model is the log(Price) of a developed property.

Using the estimates from the hedonic regressions and the characteristics of the vacant parcels, a predicted selling price, $\hat{P}$, of the hypothetical improved parcel may be obtained. This is given by

$$\hat{P}_i = q_i^{*\hat{\phi}} LOTSIZ_i^{\hat{\psi}} \exp\left\{\hat{c} + \hat{a}'U_i + \hat{d}'YEAR_i\right\}, \tag{3.9}$$

where $q*$ is the optimal square footage estimated in Equation 3.3 for the development of the parcel. The intuitive explanation of this predicted price is that it represents the value of the improved parcel if it were developed today. Since the estimated price, $\hat{P}$, assumes a new building developed optimally to $q*$, the redevelopment option value is negligible. For each vacant parcel, three estimates of improved prices are determined.

The cost of development is a straightforward calculation using the cost information in Table 3.2 and the optimal building size from Equation 3.3. A cost of development is estimated for each of the three hypothetical development uses. The theoretical model uses the respective price and cost under each use and provides a development option value of land that includes the delay premium. Prices under each of the land uses are required because this information is necessary to make rational decisions on land use choice.

3.3.3 Multinomial Logit

The effect of multiple land use types on development value is incorporated into this paper through a multinomial logit. An expected land use allows for a method to weigh the respective development values. The multinomial logit is used to estimate the likelihood of a change, and at the same time, estimate the probability of changing into other zoning categories. This estimation provides zoning category probabilities for each parcel.

Zoning around a parcel impacts the ability to change uses. Using the zoning category that exists at the end of the sample period as the dependent variable results in predictions of future land use. The characteristics used to estimate the multinomial logit are lot size, total zoning change for the particular quarter section, and a previously introduced vector of distance variables used to describe location within the city. The total zoning change is defined as a portion

Table 3.4
Multinomial Logit Estimation

	Commercial		Residential	
N	318		317	
Variable	Coeff.	Chi-Square	Coeff.	Chi-Square
CONSTANT	-11.0600	65.93	-1.5678	2.42
log(LOTSIZ)	1.1313	99.64	0.1174	1.52
UCBD	-0.0854	2.07	0.1182	9.62
UNORTH	-0.0493	2.03	-0.0342	2.31
UROAD	-0.6706	5.64	-0.8291	14.93
URAIL	-0.4416	14.93	-0.4983	5.88
TZCHNG	0.0045	4.98	-0.0013	0.57

Note: The limited dependent variable is the zoning category at the end of the sample period.

of the quarter section that underwent a zoning change over the sample period. A level of zoning change activity is meant to capture information on the effect of surrounding properties and the propensity for change. The propensity of change should allow for better predictions of change and capture areas where no change is really possible.

The results of this model provide a predicted probability that the parcel is zoned into a particular category, so there are three probability estimates. One of the three probabilities represents the chance that there are no zoning changes at all. In this case the zoning category is the same at both points in time. For example, the properties zoned residential at the end of the sample period have a probability of starting out as residential. If a residential property has an 80% chance of ending up residential, there exists a 20% chance of a change that is divided between industrial and commercial. These weights are used to estimate development value and the zoning change premium in Section 3.4.

The multinomial logit results are found in Table 3.4. Zoning category is the dependent variable where the zoning category left out is industrial. The majority of the variables were found to be significant. Large lot size leads to an increased chance of a commercial property though residential properties are typically larger in size than industrial. Longer distances to the central business district lead to a higher chance of residential zoning. This is an expected result for the city of Chicago due to suburban neighborhoods and the location of income producing residential properties. Industrial properties are most likely located close to a railroad, which is not surprising since industrial properties need a relatively inexpensive source of transportation. Evidence from the multinomial logit shows that industrial properties are more likely to be located in the northern part of Chicago. Quarter sections with higher zoning change activity are more likely to have more commercial properties than residential or industrial. Probability estimates are used in the next section to determine option values.

3.4. Development Option Value

The empirical estimation and the option-pricing model provide three possible development values for each respective land use. The current use allowed by zoning results in an intrinsic value attainable through exercise of the development option. The two other land uses represent an uncertain development option but there exists some likelihood that the parcel will change zoning categories. A zoning change allows a land use(s) that could provide higher development value. The multinomial logit from the previous section provides probabilities of future zoning categories that are used to weigh the

Table 3.5
Option Summary

	Intrinsic Value	Option Value	Delay Premium	Zoning Change Premium
Residential				
One Use	$506,394	$574,346	10.59%	**
Multiple Uses	$524,254	$589,251	10.39%	7.89%
Commercial				
One Use	$479,487	$509,020	5.49%	**
Multiple Uses	$560,710	$599,090	6.59%	16.48%
Industrial				
One Use	$368,319	$378,827	2.77%	**
Multiple Uses	$715,253	$759,609	6.09%	125.85%

** The one use case does not allow for changes in land use.
Delay premium is the average of each parcel and not the delay premium estimated by the average intrinsic and option value in this table.

respective development values. Since owners only seek financially feasible zoning changes, only uses that possess higher than current development values are used in the weighted value.

Properties currently in the zoning that allows for the highest valued use take the same value as in the one use case because change does not benefit the landowner. Other properties are valued using a weighted average of the probabilities from the multinomial logit and respective development values. From our sample of 813 vacant parcels, 558 indicate a situation where a change would benefit the current landowner.

Table 3.5 provides a summary of land values where multiple land uses are allowed. The intrinsic value of development is the value of land if development occurs today so there is no delay premium. The option value is estimated from Equation 3.7 and is the sum of the intrinsic value and the development delay premium. A zoning change premium represents the value added by seeking the potential zoning change and does not exist in the one land use case. The multiple land use case estimates are average values of a weighting of current use value and other land use values that exceed the current use.

Both the single land use case and multiple land use results are provided for each zoning category to allow comparison of the current research to previous research. For all zoning categories, using multiple land uses leads to higher average intrinsic values and option values. This finding supports previous research by Geltner et al. (1996) that theoretically showed land use choice increases value of development.

The zoning change premium ZP_i is calculated by a percentage change in intrinsic values;

$$ZP_i = \frac{MZV_i - CZV_i}{CZV_i}, \tag{3.10}$$

where MZV_i is intrinsic development value that considers multiple categories and CZV_i is the intrinsic value under the current zoning category. Properties zoned residentially have the lowest premium because the majority of the properties currently in the highest use are residential. Industrial properties have the highest potential gain in a zoning change because the development option values are lowest in this use. Even though residential land has the highest development value, there still exists a zoning change premium. Potential zoning changes have value to the landowner for all three current zoning categories.

Evidence suggests that zoning change premiums explain zoning changes that occurred in the city of Chicago. During the sample period, there were 70 actual zoning changes out of the 836 vacant parcels. Industrial properties had the highest percentage of vacant parcels that started off as industrial and switched to another use. This zoning change activity is consistent with the current research that indicates industrial properties have the highest zoning change premium. Vacant commercial properties underwent the second most zoning changes followed by zoning changes out of residential. This indicates that landowners do behave strategically when affecting the zoning of a parcel.

Multiple land uses impact the delay premium embedded in the development option. Previous research of Geltner et al. (1996) found that land use choice resulted in a higher potential to gain from waiting and thus a higher delay premium. The delay premiums seem to support this finding as well. Average delay premiums for industrial properties increased from 2.8% to 6.1% (117%) while commercial properties rose from 5.49% to 6.59% (20%). Residential delay option values declined slightly (.2%) which does not seem to be significant since only 6 parcels changed out of residential during the sample period. These results also suggest that larger potential gains from changing uses will lead to increased delay premiums since the payoff is substantial.

One topic that has not been addressed is the cost of seeking a zoning change. Typically, municipalities will have a zoning change request fee of some dollar amount, but this represents a small portion of the total cost. The major cost comes from the opportunity cost associated with the time to request the change. Unfortunately, this cost is unobservable so the actual cost of seeking a zoning change is difficult to measure. If total costs were measurable the result would be a downward shift in the zoning change premium. Including a measure of costs decreases the zoning change premium and leads to fewer parcels benefiting from a change. None of these impacts of zoning change costs would take from the overall findings of this research.

3.5 SUMMARY

This research estimates the value of development recognizing the potential to develop a parcel into multiple land uses. Three land values are estimated for each vacant parcel using a model previously employed by Quigg (1993) and Grovenstein, Kau & Munneke (2003). Only one of these values is currently allowed by the zoning code but may change over time due to a zoning change. A multinomial logit provides an expected land use based on physical characteristics of the parcel, locational variables, and a measure of zoning change activity. Potential uses that provide higher option values are weighted with the current use value to estimate development values. The potential to develop into multiple uses increases the value of land above the previous research that restrains the land use to a single use. Both the single land use results and the multi-land use results are provided to show increases in intrinsic and option values.

The empirical results of this paper support the theoretical research of Geltner et al. (1996). Multiple land use selections increase the value of land and impacts delay premiums because of added uncertainty. As expected, an increase in delay premiums is largest for parcels with much to gain from a change. When the parcel is likely to be in the highest valued use, delay premiums changes are not significant. This research also incorporates the likelihood of land use changes where previous research assumes landowners could choose from land uses allowed within a zoning category.

Actual zoning changes that occurred during the sample period support the zoning change option value results. Industrial properties, which have the highest zoning change premium, have the highest rate of zoning change. Residential has the least rate of change and the lowest zoning change premium. These actual rates of zoning change suggest that landowners are exercising the option to seek a zoning change rationally.

CHAPTER 4

CONCLUSION

This dissertation is a series of two papers that provides research into the area of vacant land in an urban setting. The research estimates the value of the development option along with the delay option embedded in development using a combination of empirical work and theoretical option pricing following a general framework of Quigg (1993). The empirical work involves a hedonic estimation of developed properties within the city limits of Chicago. These empirical results were used to estimate the value of a property developed today and a residual approach to land valuation was implemented. To find the optimal building size for a parcel, the residual function was maximized subject to the zoning constraint. This revealed the size of a hypothetical building that maximizes land value. Using the optimal building size and the cost elasticity estimates based on an industry measure of development costs, the improved value and development costs are computed. A theoretical options model then prices the option value of development. The intrinsic value represents a lower bound for the value of vacant urban land while the theoretical option value includes the option to delay development.

The overall results for the delay premium are consistent with previous research. Evidence suggests that delay premiums are on average 6.7% of the total development option. Obviously, there is no reason to believe that option premiums are constant across specific land use categories or within specific land use categories. While Quigg (1993) bases her results on the broad land use categories of residential, commercial and industrial, the current study disaggregates these categories. Results indicate that delay premiums within and across land use categories do vary. The delay premiums should provide insights into the order in which properties are developed. Land uses with lower delay premiums should be developed sooner than types with higher delay premiums because this option is lost when development is exercised. The results indicate that developers of small retail and light manufacturing should be developing relatively soon while developers of office space and high density residential have incentives to delay investment. The disaggregated results provide greater insight.

Another contribution of this paper is the empirically estimated development cost elasticities which differ from Quigg (1993). Results for the delay premium are consistent with previous research even though elasticities differ; however, elasticity differences do lead to inconsistent total option or land values. The sensitivity analysis shows that an overstated cost elasticity results in an understated development option value from 23% to 75%. There was no expectation that option values would be similar because this research uses a different metropolitan area. Even though costs of development are similar for Seattle and Chicago, different data sets will lead to price differences through the hedonic estimation of developed properties.

The second paper estimates the value of development recognizing the potential to develop a parcel into multiple land uses. Three land values are estimated for each vacant parcel using a model previously employed by Quigg (1993) and Grovenstein, Kau & Munneke (2003). Only one of these values is currently allowed by the zoning code but may change over time due to a zoning change. A multinomial logit provides an expected land use based on physical characteristics of the parcel, locational variables, and a measure of zoning change activity. Potential uses that provide higher option values are weighted with the current use value to estimate development values. The potential to develop into multiple uses increases the value of land above the previous research that restrains the land use to a single use. Both the single land use results and the multi-land use results are provided to show increases in intrinsic and option values.

The empirical results of this paper support the theoretical research of Geltner et al. (1996). Multiple land use selections increase the value of land and impacts delay premiums because of added uncertainty. As expected, an increase in delay premiums is largest for parcels with much to gain from a change. When the parcel is likely to be in the highest valued use, delay premiums changes are not significant. This research also incorporates the likelihood of land use changes where previous research assumes landowners could choose from land uses allowed within a zoning category.

Actual zoning changes that occurred during the sample period support the zoning change option value results. Industrial properties, which have the highest zoning change premium, have the highest rate of zoning change. Residential has the least rate of change and the lowest zoning change premium. These actual rates of zoning change suggest that landowners are exercising the option to seek a zoning change rationally.

Further empirical research is warranted on this subject. It may be possible to empirically test whether the optimal building scale and timing of development are actually displayed in the market. Information on the vacant land parcels after the sale and development would have to be gathered for vacant land transactions.

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APPENDIX A

SUMMARY STATISTICS FOR DATA

The appendix provides a summary of the data used in this research. Tables A.1 through A.3 are summary statistics of the developed properties for the three zoning categories. The price variable is the actual selling price of the property. The building square foot (BSF) variable is a measure of area of a developed property. Distance to the central business district (UCBD) is a measure in miles. Distance from the southern most boundary of Chicago (UNORTH) is measured in miles. The distances from a road center and a rail center (UROAD & URAIL) are measured from the quarter that has a high concentration of road or rail respectively. The measuring is slightly different for these two distance variables. Previous research has shown that the impact of the rail or road center only has a significant impact if the property lies within a 2-mile radius. A zero distance implies that the parcel is two or more miles from the quarter section with a high concentration. A parcel in the quarter section uses a distance of negative two miles. This provides a variable that will give the largest impact to the parcels closer to the concentration and no impact on properties two or more miles away. The total zoning change variable (TZCHNG) measures the amount of zoning change in a particular quarter section. Each quarter section was divided into 400 square units and the zoning change was recorded by adding up the number of unit changes. The age of the property is time since

Table A.1
Developed Residential Summary Statistics

Observations	526			

	MIN	MAX	MEAN	STD
PRICE (in '000s)	50.00	8695.88	388.14	607.51
BSF (in 000's)	2.43	637.50	20.21	40.05
LOTSIZ (in acres)	0.05	23.50	14.92	337.59
UCBD	1.58	19.92	7.61	2.03
UNORTH	1.50	25.63	17.75	6.58
UROAD	-2.00	0.00	-0.07	0.26
URAIL	-2.00	0.00	-0.24	0.48
TZCHNG	0.00	214.00	27.82	39.35
AGE	10.00	100.00	60.33	19.53
Year Sold				
1987	0	1	0.09	0.28
1988	0	1	0.13	0.34
1989	0	1	0.18	0.39
1990	0	1	0.17	0.37
1991	0	1	0.13	0.33
1992	0	1	0.05	0.21
1993	0	1	0.05	0.22

initial development. It is not an effective age that incorporates major improvements or overhauls of the property. The vector of dummy variables indicating the year the property was sold can be used to determine the portion of the sample sold in particular year by looking at the mean.

The vacant data summary statistics in Table A.4 provide similar information as the developed residential, commercial, and industrial property. The two variables that are not included are the building size and the age of the property because development has not occurred yet. Distances are calculated the same way for vacant parcels.

Table A.2
Developed Commercial Summary Statistics

Observations	911

	MIN	MAX	MEAN	STD
PRICE (in '000s)	50.00	83000.00	480.69	3117.17
BSF (in 000's)	0.18	712.00	13.12	51.82
LOTSIZ (in acres)	0.02	14.35	0.25	0.58
UCBD	0.00	15.89	7.06	2.93
UNORTH	0.00	26.17	16.17	6.17
UROAD	-1.50	0.00	-0.17	0.39
URAIL	-2.00	0.00	-0.41	0.57
TZCHNG	0.00	365.00	24.72	41.76
AGE	0.00	100.00	53.62	26.39
Year Sold				
1987	0	1	0.08	0.28
1988	0	1	0.12	0.32
1989	0	1	0.24	0.43
1990	0	1	0.18	0.38
1991	0	1	0.11	0.31
1992	0	1	0.09	0.29
1993	0	1	0.07	0.25

Table A.3
Developed Industrial Summary Statistics

Observations 813

	MIN	MAX	MEAN	STD
PRICE (in '000s)	50.00	12000.00	519.87	870.21
BSF (in 000's)	0.84	1130.00	33.59	64.11
LOTSIZ (in acres)	0.04	36.71	1.23	2.70
UCBD	0.50	14.81	5.58	2.91
UNORTH	1.00	25.63	15.78	4.73
UROAD	-2.00	0.00	-0.38	0.56
URAIL	-2.00	0.00	-0.64	0.64
TZCHNG	0.00	365.00	43.64	61.36
AGE	1.00	100.00	45.06	23.52
Year Sold				
1987	0	1	0.11	0.31
1988	0	1	0.19	0.39
1989	0	1	0.19	0.39
1990	0	1	0.13	0.34
1991	0	1	0.09	0.29
1992	0	1	0.06	0.23
1993	0	1	0.05	0.22

Table A.4
Vacant Parcel Summary Statistics

Observations	891

	MIN	MAX	MEAN	STD
PRICE (in '000s)	50	48000	**	**
LOTSIZ (in acres)	0.03	38.00	1.00	3.03
UCBD	0.50	15.21	5.30	3.18
UNORTH	0.50	25.63	16.32	4.88
UROAD	-2.00	0.00	-0.39	0.54
URAIL	-2.00	0.00	-0.43	0.57
TZCHNG	0.00	365.00	46.84	57.73
Year Sold				
1987	0	1	0.14	0.35
1988	0	1	0.19	0.39
1989	0	1	0.20	0.40
1990	0	1	0.12	0.32
1991	0	1	0.08	0.28
1992	0	1	0.06	0.24
1993	0	1	0.06	0.23