Non-Diversifiable Risk and Quantity Discounts in Urban Land Markets

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Abstract

Many studies investigate the relationship between land price and parcel size in urban markets. Majority of them claim their evidence supporting the transaction cost explanation postulated by Colwell and Sirmans (1978, 1980, and 1993). However land assembly and subdivision costs are negligible at the residential land markets in the land re-adjustment districts, Taichung City, Taiwan. Our empirical investigation finds significant quantity discounts prevailing among land sales at these markets. Moreover the discounts are larger for land sales zoned in R-2 districts than those zoned in R-1 districts. These results are consistent with Brownstone and De Vany's (1991) non-diversifiable risk explanation.

Keywords: Non-diversifiable risk; Land price; Parcel size; Spatial statistics; Taiwan

1. Introduction

The relationship between land value and parcel size is a subject of interest in the literature, both from a theoretical and a practical perspective. Conventional urban theory generally ignores the effect of parcel size on urban land value (for example, Fujita, 1989; Mills, 1972, and Muth, 1969) and presumes a linear value-size relationship (Tabuchi, 1996; Thorsnes and McMillen, 1998; Ecker and Isakson, 2005). Accordingly most early studies, including Reuter (1973) and Atack and Margo (1998), assume a proportional value-size function in their empirical investigation.[1] Meanwhile assessors often ignore parcel size when estimating unit land prices (Keefe, 1997; Thorsnes and McMillen, 1998), and thus effectively assume a linear relationship between land values and parcel size.

However a considerable number of recent studies discover non-linear relationships between the total price of urban land and parcel size and raise controversy over the shape of the value-size function. Colwell and Munneke (1999), Isakson and Ecker (2001), Ecker and Isakson (2005), and Guntermann and Thomas (2005) are the relatively recent additions to this literature. Among the various explanations circulated in the literature, the most popular explanation for the non-linear pricing is the transaction cost argument postulated by Colwell and Sirmans (1978, 1980, and 1993). According to this argument, the observed non-linear pricing, either quantity discounts or quantity premiums, is because transaction costs associated with land assembly and subdivision make arbitrage across parcel sizes unprofitable in a perfectly competitive world (Colwell and Munneke, 1999).[2] This is evident, particularly for subdivision costs, in U.S. where developers generally have to provide significant amount of infrastructure and thus only a portion of the land brought by developers can be sold on to final users (Lin and Evans, 2000). Consequently many studies rationalize the prevalence of quantity discounts in U.S. urban regions by the presence of land subdivision costs.

In contrast to developers in U.S. cities, investors at land re-adjustment districts in Taiwan do not expect significant subdivision costs because major infrastructure has been provided before the completion of re-adjustment projects and thus entire parcels can be sold on to final users. This contrast makes Taiwan's land re-adjustment districts an interesting laboratory to explore empirical urban land pricing structures. Based on this feature, Lin and Evans (2000) attribute the significant quantity premiums in the industrial land market at Neihu Re-adjustment District, Taipei City to the Le Chatelier-Braun Principle. However they have to admit that land assembly costs may be the other possible cause determining the observed price structure in their study. This is because no information about assembly activities is available to assess their influence on the empirical land pricing results.

Similar to Lin and Evan (2000), the major purpose of the current study is to explore the empirical relationship between land price and parcel size at land re-adjustment districts in Taiwan. Nevertheless this paper differs from Lin and Evan (2000) and other existing studies in three important aspects. First, land assembly costs are negligible in the studied land re-adjustment districts. This is because re-adjustment projects diminish undersized parcels and produce developable parcels (Taichung City Government, 2002). Furthermore zoning ordinance in the studied districts eliminates the incentives to develop large parcels. These effectively weaken the handout problem associated the bargaining power of contiguous parcels, and thus reduce significantly land assembly costs. Second, precise transaction dates and parcel locations are obtained to utilize the rich information in spatial-temporal data structure of land sales. Few studies on land pricing have location information as accurate as parcel centroid x-y coordinates and obtain the benefits from modeling spatial correlation in their empirical hedonic equations. Isakson and Ecker (2001) and Ecker and Isakson (2005) are two exceptions. While modeling dependence over space has become better known, joint modeling of errors in both time and space offers further gains (Pace et al., 2000). This study has accurate transaction dates and parcel locations of land sale samples and is able to apply spatial-temporal regressions to improve empirical estimation further.[3] Third, assembly and subdivision records are secured to investigate their impact on the land pricing structure. Although many articles support the transaction cost explanation, as we are aware of, none of them can identify land parcels as assembled or subdivided. By contrast, this study is able to track assembly and subdivision records of sample parcels.

In contrast to Lin and Evan’s (2000) finding, our analyses indicate that significant quantity discounts prevail among residential land sales at the land re-adjustment districts, Taichung City, Taiwan. As expected, assembly and subdivision activities do not alter the land price structure significantly. Furthermore the discounts are larger for land sales zoned in R-2 districts than those zoned in R-1 districts. Overall the results are consistent with Brownstone and De Vany’s (1991) non-diversifiable risk explanation but against Lin and Evan’s (2000) Le Chatelier-Braun Principle in explaining the pricing structure in the studied residential land markets.

The following section of this article reviews the literature on the explanations for the relevant nonlinear land pricing. Next the data set is described. The following section describes the empirical spatial-tempo regressions used to examine the value-size relationship. The next section presents the empirical results. The final section concludes this paper.

2. Explanations for the Nonlinear Pricing

The section briefly reviews the four theoretical arguments for the nonlinear price relationship between land price and parcel size: (1) the transaction costs associated with land assembly and subdivision, and (2) the non-diversifiable risk in land investment, (3) the law of diminishing marginal utility, and (4) the Le Chatelier-Braun Principle.

Colwell and Sirmans (1980) and Colwell and Munneke (1999) propose the transaction cost explanation. This explanation argues that transaction costs of altering parcel size prevent arbitrage to eliminate nonlinearity in prices. The transaction costs include the costs of installing streets and sidewalks, thus only proportion of land could be sold on to house purchasers, as well as utility services in subdivision activities and may involve the cost of removing physical capital such as streets, pipes, and wires as well as the costs associated with the uncertainty of the holdout problem in assembling parcels of land. The developer is expected to fully recoup these costs.

In a perfectly competitive equilibrium, the price of a subdivided parcel equals to the proportionate price of pre-subdivided raw land plus the cost of the subdivision per parcel. Thus the resultant land pricing are concave and quantity discounts are observed in land markets. On the other hand, the price of a parcel of land to be assembled must incorporates the expected assembly costs. This incorporation results quantity premiums. The empirical non-linear pricing observed in the market reflects the dominance between the subdivision and assembly costs.

In contrast to the transaction cost explanation, the non-diversifiable risk explanation, put forward by Brownstone and De Vany (1991), starts with incomplete land markets. This explanation contends that parcel size is a mechanism to make control compatible with use and to internalize externalities spilled over from neighboring parcels. Although alleviating the external effects, investing large parcels are associated with great non-diversifiable risk.[4] On the other hand, holding small parcels may incur agency risk in future development projects.[5] The risk premium associated with parcel size is therefore U-shaped. As a result, the size-value function must be concave in equilibrium and quantity discounts prevails in land markets to prevent arbitrage. If zoning constraints externalities and eliminates the use of parcel size as a control instrument, then the size-value relationship approaches linear and discounts come close to zero.

Wolverton (1997) put forward the law of diminishing marginal utility to explain the price concavity in parcel size. In this explanation, quantity discounts reflect the exchange between land consumption and consumption of other goods and services. To consume more land usually requires less consumption of other goods and services. As the goods and services forgone become more valued, land price must decrease to reflect land’s lessened relative utility.

In contrast the Le Chatelier-Braun Principle predicts the prevalence of quantity premiums in land markets. The principle states that the maximum value of a variable can not be less and may be more, if the variable is being maximized subject to constraints and one of the constraints is relaxed, other things being equal (Samuelson, 1983). Lin and Evans (2000) argue land price pre unit is the variable to be maximized and parcel size is the constraint in the case of the land value-size function. The owner of a larger parcel is less constrained than the owner of a smaller one and so is its price per unit may be higher and is unlikely to be lower (Lin and Evans, 2000, p.387).

3. Land Pricing Data

The working data set in this study consists of 346 parcels of vacant residential land zoned R-1 districts (mainly for development of single-unit detached/semi-detached dwellings) and R-2 districts (for all types of residential development), sold by Taichung City Government at public auctions to recoup its land consolidation costs.[6] The sale information is obtained form the Land Readjustment Section of the Land Administration Bureau of the city government. The data are cross-checked with their official records from the land offices for information accuracy, whenever possible. Supported by the land office records, these sales are genuine arm-length market transactions, like those in the land-consolidated project in Taipei City in Lin and Evans (2000). The sales in our study span a 12-year period (1994-2005) and are located at five recently completed urban land consolidated areas (Phase 7 to Phase 11).[7] The five projects started in February 1990 and ended in August 1997, and each takes around 3 to 6.5 years. The projects consolidate 984.77 hectares of land (ranging between 120.35 hectares to 353.40 hectares) and create 557.86 hectares of construction sites (ranging from 72.55 hectares to 202.55 hectares) in total.[8]

In these land consolidation projects, the government demolishes physical capitals such as buildings, streets, and so on whenever necessary, consolidates fragmented parcels, reallocates land ownership, and furnishes with new public infrastructure, including streets, sidewalks, as well as sewer ditches, parking lots, green space etc. to land in consolidated areas (Taichung City Government, 2002). In such areas, each landowner receives back a parcel of land which is suitable for development, more or less rectangular and fronts onto a road, and roughly in the location of his or her previous holding (Lin and Evans, 2000). As a result, no significant costs occur for subdividing land in such areas (Lin and Evans, 2000) since infrastructure constitutes the most important component of subdivision costs (Colwell and Munneke 1999; Lin and Evans, 2000). Moreover the residential zoning ordinance of the five consolidated areas eliminates the benefits for developers to increase parcel sizes. Particularly the maximum lot coverage and floor-area ratio (FAR) allowed in the studied residential zones is 60 percent and 220 percent respectively. Consequently the local market expects land parcels in these areas to be developed into 3-floor to 4-floor dwellings, which often invite no FAR bonus. In this situation no significant cost of removing physical capital and the holdout problem are expected for assembling parcels. Overall the main transaction costs incurred in land assembly and subdivision activities for parcels in the two residential zones of the five consolidated areas are land office fees whose amount is by no means significant.

The 346 sample parcels range in size from about 74 (759) to around 3,000 (32,297) square meters (square feet).[9] Each parcel sold for between NT$ 800,000 and NT$ 200,630,764; the mean selling price is around NT$21,254,569. Table 1 contains the univariate statistics for the data. The TMD67 corner coordinates of each parcel are geo-coded and provided by the land offices of Taichung City.[10] For this study, the centroid coordinates of each parcel are computed with AutoCAD, a suite of computer-aided design software.

4. The Empirical Models

Each parcel in this study is zoned into R-1 or R-2 districts individually. The zoning classification may introduce selectivity bias in empirical land pricing equations if zoning authorities consider land values when making zoning decisions (Wallace, 1988; McMillen and McDonald, 1989). McMillen and McDonald (1989) present a two-stage process based on Lee (1982) to correct this bias.[11] The fist stage consists of the logit equation to explain the propensity of land to be zoned into various categories, and the second stage consists of the hedonic pricing equations. This approach allows the implicit prices of land attributes to vary across zoning categories and solves the selectivity bias (Colwell and Sirmans, 1993).

In this study, the logit that determines zoning classification is

$$\mathrm{Prob}[\mathrm{k_i}=1]=\exp(\alpha'\mathrm{v_i})\Big/\Big[1+\exp(\alpha'\mathrm{v_i})\Big] \qquad (1)$$

where i indexes the observation, k = 0, 1 for a parcel zoned in R-1 districts and R-2 districts respectively, v is a vector of explanatory variables, and α is the associated parameters.[12] The variables are the logarithm of parcel size and the same 6 location characteristics as those in the hedonic pricing model described below. Then a selection variable is computed as $\lambda_{\mathrm{ik}}=\phi(H_{\mathrm{ik}})/\Phi(H_{\mathrm{ik}})$ where $H_{\mathrm{ik}}=\Phi^{-1}(PR_{\mathrm{ik}})$, ϕ and Φ are the PDF and CDF of the standard normal distribution, PR is the probability predicted in equation (1). The selection variable is introduced into the hedonic regressions as an explanatory variable later to correct the potential selectivity bias.

The hedonic pricing regressions in this article are Pace, Barry, Gilley, and Sirmans's (2000) spatial-temporal linear models (STLMs) and are empirically specified as follows:[13]

$$\begin{aligned} \ln P_{\mathrm{k}} = {} & \beta_{\mathrm{k}0} + Z_{\mathrm{k}}\theta_{\mathrm{k}} + \ln A_{\mathrm{k}}\beta_{\mathrm{k}1} + T_{\mathrm{k}} \ln A_{\mathrm{k}}\beta_{\mathrm{k}2} + S_{\mathrm{k}} \ln A_{\mathrm{k}}\beta_{\mathrm{k}3} + S_{\mathrm{k}}T_{\mathrm{k}} \ln A_{\mathrm{k}}\beta_{\mathrm{k}4} + T_{\mathrm{k}}S_{\mathrm{k}} \ln A_{\mathrm{k}}\beta_{\mathrm{k}5} \\ & + \pi_{\mathrm{kT}}T_{\mathrm{k}} \ln P_{\mathrm{k}} + \pi_{\mathrm{kS}}S_{\mathrm{k}} \ln P_{\mathrm{k}} + \pi_{\mathrm{kST}}S_{\mathrm{k}}T_{\mathrm{k}} \ln P_{\mathrm{k}} + \pi_{\mathrm{kTS}}T_{\mathrm{k}}S_{\mathrm{k}} \ln P_{\mathrm{k}} + \gamma_{\mathrm{k}}\lambda_{\mathrm{k}} + \varepsilon_{\mathrm{k}} \end{aligned} \qquad (2)$$

where *P* denotes the vector of observations on total land price, A is the vector of observations on parcel size, *Z* represents the matrix of observations on the independent variables containing site, buyer, and location characteristics other than parcel size, *T* is the matrix specifying temporal relations among previous observations, *S* denotes the matrix specifying spatial relations among previous observations, θ, β, π, and γ are the associated parameters, and ε denotes a vector of normal *iid* errors.

The site characteristics in Matrix *Z* are two dummy variables. *Road* takes the value of 1 for a parcel located in a major road and 0 otherwise.[14] *Depth* = 1 for a non-corner parcel whose depth is over 20 meters and 0 otherwise.[15] This variable is to capture the need to build on-site private streets to service houses built in future development. The streets can be sold on to house purchasers, and therefore are not a part of transaction costs of altering parcel sizes. The buyer dummies are *Company* and *Partner* if a buyer is a company and a partnership respectively. The location characteristics include four dummies and two distance variables. *Ph*8, *Ph*9, *Ph*10, and *Ph*11 denote Phase 8 to Phase 11 of the land consolidated areas in Taichung City. *DCentral* and *DBeitun* measures the distances of each parcel to Central Shopping Area and Beitun Shopping Area in kilometers.[16]

Both the spatial and temporal weigh matrices, *S* and *T*, are lower triangular since STLMs require the observations are temporal ordered and condition only upon previous transaction.

S and *T* are nearest neighbor matrices in this study. To construct *S*, the Euclidean distance d_{ij} between every pairs of observations *j* and *i* for every prior observation ($j < i$) are computed. The distances are subsequently sorted to find out the closest previously sold neighbor of each observation. The final spatial weigh matrix has a 1 in each row and contains 0s otherwise. Similarly, the temporal weight matrix contains non-zero weights only for the *m* observations sold in the most recent public auction. Each row of *T* has *m* values of 1/*m* and 0s otherwise.

The parcel size lags are included to capture the atypical size effect and expectation of future market condition. The market may force a parcel of atypical size to sell at a discount.[17] However successful sales of atypical large parcel may indicate bullish expectations of future market condition. The price lags are to catch price feedbacks from local land market transactions. Thriving high-priced sales may create positive feedback momentum.

To further remove the impacts of assembly and subdivision costs on the land value-size relationship, we expand the above regressions as below:

$$\begin{aligned}\ln P_{\mathrm{k}} = {} & \beta_{\mathrm{k}0} + Z_{\mathrm{k}}\theta_{\mathrm{k}} + \ln A_{\mathrm{k}}\beta_{\mathrm{k}1} + DS_{\mathrm{k}} \ln A_{\mathrm{k}}\beta_{\mathrm{kDS}} + DA_{\mathrm{k}} \ln A_{\mathrm{k}}\beta_{\mathrm{kDA}} + T_{\mathrm{k}} \ln A_{\mathrm{k}}\beta_{\mathrm{k}2} \\ & + S_{\mathrm{k}} \ln A_{\mathrm{k}}\beta_{\mathrm{k}3} + S_{\mathrm{k}}T_{\mathrm{k}} \ln A_{\mathrm{k}}\beta_{\mathrm{k}4} + T_{\mathrm{k}}S_{\mathrm{k}} \ln A_{\mathrm{k}}\beta_{\mathrm{k}5} + \pi_{\mathrm{kT}}T_{\mathrm{k}} \ln P_{\mathrm{k}} + \pi_{\mathrm{kS}}S_{\mathrm{k}} \ln P_{\mathrm{k}} \\ & + \pi_{\mathrm{kST}}S_{\mathrm{k}}T_{\mathrm{k}} \ln P_{\mathrm{k}} + \pi_{\mathrm{kTS}}T_{\mathrm{k}}S_{\mathrm{k}} \ln P_{\mathrm{k}} + \gamma_{\mathrm{k}}\lambda_{\mathrm{k}} + \varepsilon_{\mathrm{k}}\end{aligned} \tag{3}$$

where *DS* (DA) is the vector of observations on the dummy indicating whether a parcel is subdivided (assembled) after sale within 180 days.[18]

The STLM regressions synthesize the autoregressive distributed lag model of time series and the mixed regressive spatially autoregressive model of spatial econometrics (Pace et al., 2000). The assumptions in STLMs are summarized by Pace et al. (2000) as follows:

(a) $\underset{(n\times n)(n\times 1)}{S\ [1]} = \underset{(n\times 1)}{[1]},\ \underset{(n\times n)(n\times 1)}{T\ [1]} = \underset{(n\times 1)}{[1]}$

(b) $\mathrm{j} \geq \mathrm{i} \leftrightarrow S_{\mathrm{ij}} = 0$ and $T_{\mathrm{ij}} = 0$

(c) $-1 < \pi < 1$

(d) $S_{\mathrm{ij}} \geq 0, T_{\mathrm{ij}} \geq 0$

(e) $\varepsilon \sim N(0, \sigma^2 I)$

The profile log-likelihood function in the parameters π is:

$$L(\pi) = \ln\left|I - \pi_s S - \pi_T T - \pi_{ST} ST - \pi_{TS} TS\right| - (n/2)\ln(SSE(\pi)).$$

5. Estimation Results

Tables 2 to 5 contain the estimates for Equation (2) and Equation (3). The results are remarkable for the high levels of explanatory power across R-1 and R-2 districts as well as specifications. This complements Pace et al.'s (2000) study on housing prices[19] and supports their promotion for spatial-temporal regression. As expected, all specifications contain significant spatial and temporal lags. This indicates the importance of previous and neighboring sales and reflects the influence of investors' market knowledge on land prices. Particularly, when making investment, investors appear to take into account both parcel sizes and prices of prior and nearby land sales.

In Tables 2 and 3, the parcel size coefficients are always positive and significant at 1% level. However, their values are never greater than 1 and thus do not support the Le Chatelier-Braun Principle. This is in marked contrast to Lin and Evans's (2000) observation in the light industry park at Taipei, Taiwan. The size coefficients for R-1 parcels in Table 2 are about 0.95 and significantly smaller than 1 at around 10% level on one-tailed t-tests. While this evidence appears to be weak, the R-2 samples provide strong evidence for the presence of quantity discounts. In Table 3, the size variable has coefficients around 0.80 across various specifications. These coefficients are all significantly less than 1 at 1% level. Comparing the size elasticities in Table 2 and 3 reveals a greater quantity discount present in the R-2 district than the R-1 district. This pattern is consistent with the notion that zoning constraints externalities and eliminates the use of parcel size as a control instrument. The difference in size elasticities can not be easily explained by the law of diminishing marginal utility put forward by Wolverton (1997).

Tables 4 and 5 confirm the insignificance of assembly/ subdivision costs in the studied areas. The interactions with assembly/subdivision dummies are not significant at any conventional levels. Moreover the estimated elasticities change very little. The size coefficients range from 0.93 to 0.94 for R-1 parcels in Table 4 and from 0.79 to 0.81 for R-2 parcels in Table 5. These results demonstrated the observed quantity discounts are not driven by the transaction costs, as argued by Colwell and Sirmans (1980) and Colwell and Munneke (1999). Overall the estimated size elasticities support Brownstone and De Vany's (1991) non-diversifiable risk explanation for the relationship between parcel size and land value.

Consistent with Lin and Evans (2000), the empirical estimates indicate higher land prices for parcels located on main roads than otherwise. The land-price equations reveal insignificant and negative impact of parcel depth on land prices in R-1 districts and significant and negative impact in R-2 districts. This implies the need to allocate land for building on-site private streets decreases land price in R-2 districts and does not in R-1 districts. This may be because parcel sizes under house owners' private control in the future are larger in R-1 than in R-2 districts. Consequently the allocation has different impact on land prices in these districts.

Consistent with Lin and Evans (2000), buyer characteristics do not matter in vacant land transaction in the R-1 districts. In contrast, consistent with Isakson (1997), these characteristics influence transaction prices in the R-2 districts. As pointed out by Isakson (1997), buyer characteristics could reflect differences in tax positions, speculative interest, purchasing power, and so on. However they may act as proxies for property characteristics as well (Isakson, 1997). No specific sign are expected since buyer characteristics capture more than one effect.

The equations exhibit significant and negative coefficients on the consolidation phase dummies. This indicates parcels located in Phase 7 demand higher prices than those on other phases. The coefficients reveal lowest prices for vacant land parcels in Phase 8, followed by Phase 10. For parcels in R-1 (R-2) districts, Phase 11 demands higher (lower) location premiums than Phase 9. Distances to Central Shopping Area and Beitun Shopping Area never have significant coefficients in the empirical price equations. This is likely because location variation of sample parcels is already most captured by the dummies of the land consolidation phases whose areas range only between 120.35 hectares to 353.40 hectares.[20]

6. Conclusions

A considerable number of studies have examined the relationship between land price and parcel size in urban markets. Most of these studies claim their evidence supporting the transaction cost explanation postulated by Colwell and Sirmans (1978, 1980, and 1993). This study contributes to the existing literature by studying the relationship in the markets where land assembly and subdivision costs are negligible.

The empirical results reveal the prevalence of quantity discounts in these markets. This contradicts the prediction of the Le Chatelier-Braun Principle proposed by Lin and Evans (2000). Furthermore the discounts are larger for land sales in R-2 districts than those in R-1 districts. Overall these results support Brownstone and De Vany’s (1991) non-diversifiable risk explanation. The evidence remains clear even when assembly and subdivision activities are explicitly incorporated into the empirical spatial-temporal regressions.

Endnotes:

[1] Colwell and Munneke (1997) show the correct value-size relationship is critical to the measurement of the land value-distance gradient to CBD, which is the focus of the standard urban model.

[2] Quantity discounts (premiums), also termed plattage (plottage) prevail in the land market when total price is an increasing concave (convex) function of parcel size (Colwell and Sirmans, 1980; Tabuchi, 1996).

[3] We have not found applications of spatial-temporal regressions to land sales.

[4] According to Brownstone and De Vany, (1991, p.701), holding large parcels reduce investors' ability of diversify risk, and thus are associated with great non-diversifiable risk.

[5] The agency risk increases as the number of land owners involved in future development increases (Brownstone and De Vany, 1991).

[6] The number of observations in this study is reasonable compared with those in several previous studies. For example Tabushi (1996) has 444, Wolverton (1997) has 46, Isakson (1997) has 363, Lin and Evans (2000) have 50, Isakson and Ecker (2001) have 277, and Guntermann and Thomas (2005) have 48 observations for their studies respectively.

[7] Land consolidation occurs in counties such as Japan, Germany, and Taiwan where land holdings are likely to be small and fragmented (Lin and Evans, 2000).

[8] 1 hectare = 2.471 acres.

[9] 1 $m^2 = 10.7639$ ft^2.

[10] Details about TMD67 coordinates can be found at the web site of Land Survey Bureau, Ministry of Interior, R.O.C. (Taiwan) (http://www.lsb.gov.tw/lsb/lsbeng/04_knowledge/01_list.php).

[11] Colwell and Munneke (1999) follow the two-stage procedure to address this form of sample selection bias in their land value-size study.

[12] Please see Lee (1983) for the assumptions about the joint and marginal distributions of disturbances in this model.

[13] In this article, the logit is not spatial-temporal and the hedonic regressions are spatial-temporal. Brasington (2004) adopts a similar approach. While imperfect, the sample selection process may still ameliorate the selectivity bias if exists (Brasington, 2004).

[14] A major road is a 12 meter-wide road. Estimation results are qualitatively the same when a major road is defined to be 15 meter-wide.

[15] 20-meter depth is the maximum depth of a house in local markets and is suggested by a local developer.

[16] The two distances are highly correlated with distances to other 31 landmarks, including shopping areas, train stations, colleges, museums, large parks, and freeway interchanges in Taichung City. The correlations among the distances are often as high as 0.8 or higher.

[17] This is an analogue to a common saying in housing markets stated in Brasington (2004): Never own the largest (or the smallest) on the block because the market will force such a house to sell at a discount.

[18] The180-day dummy, suggested by local developers, is consistent with the development schedule in local markets. The 90-, 120-, 150-, 210-, 240-, or 270-day dummies produce similar results, except the 90-, 210-, 240-, and 270-day subdivision dummies have statistically significant and positive coefficients for R2 samples. The coefficients of the subdivision dummies range from 0.02 to 0.03. They may reflect the capability of the parcels to generate cash flow earlier than parcels that are not subdivided within these days of transaction.

[19] The spatial-temporal models of Pace et al.s (2000) study have R-squares close to 9.0.

[20] 353.40 hectares equal 873.270 acres which is only about 1/3 of the maximum parcel size (2690 acres) in Isakson's (1997) samples.

References

1. Atack, Jeremy and Robert A. Margo (1998). “Location, Location, Location! The Price Gradient for Vacant Urban Land: New York, 1835-1990,” *Journal of Real Estate Finance and Economics* 16, 151-172.

2. Brasington, David M. (2004). “House Prices and the Structure of Local Government: An Application of Spatial Statistics,” *Journal of Real Estate Finance and Economics* 29, 211-231.

3. Brownstone, David and Arthur De Vany (1991). “Zoning, Returns to Scale, and the Value of Undeveloped Land,” *The Review of Economics and Statistics* 73, 699-704.

4. Colwell, Peter F. and C. F. Sirmans. (1978). “Area, Time, Centrality and the Value of Urban Land,” *Land Economics* 54, 514-519.

5. Colwell, Peter F. and C. F. Sirmans. (1980). “Non-Linear Urban land prices,” *Urban Geograph* 1, 141-152.

6. Colwell, Peter F. and C. F. Sirmans. (1993). “A Comment on Zoning, Returns to Scale, and the Value of Undeveloped Land,” *The Review of Economics and Statistics* 75, 783-786.

7. Colwell, Peter F. and Henry J. Munneke. (1997). “The Structure of Urban Land Prices,” *Journal of Urban Economics* 41, 321-336.

8. Colwell, Peter F. and Henry J. Munneke. (1999). “Land Prices and Land Assembly in the CBD,” *Journal of Real Estate Finance and Economics* 18: 163-180.

9. Ecker, Mark D. and Hans R. Isakson. (2005). “A Unified Convex-Concave Model of Urban Land Values,” *Regional Science and Urban Economics* 35, 265-277.

10. Fujita, Masahisa. (1989). *Urban Economic Theory*. New York: Cambridge University Press.

11. Guntermann, Karl L. and Gareth Thomas. (2005). “Parcel Size, Location and Commercial Land Values,” *Journal of Real Estate Research* 27, 243-354.

12. Isakson, Hans R. (1997). “An Empirical Analysis of the Determinants of the Value of Vacant Land,” *Journal of Real Estate Research* 13, 103-114.

13. Isakson, Hans R. and Mark D. Ecker (2001). “An Analysis of the Influence of Location in the Market for Undeveloped Urban Fringe Land,” *Land Economics* 66, 30-41.

14. Keefe, John E. (1997). “The Land Value Curve,” *Assessment Journal* 4, 31-35.

15. Lee, Lung-Fei (1982). “Some Approaches to the Correction of Selectivity Bias,” *Review of Economic Studies* 49, 355-372.

16. Lee, Lung-Fei (1983). “Notes and Comments Generalized Econometric Models with Selectivity,” Econometrica 51, 507-513.

17. Lin, Tzu-Chin and Alan W. Evans. (2000). "The Relationship Between the Price of Land and Size of Plot When Plots Are Small," *Land Economics* 76, 386-394.

18. McMillen, Daniel P. and John F. McDonald. (1989). "Selectivity Bias in Urban Land Value Functions," *Land Economics* 65, 341-351.

19. Mills, Edwin S. (1972). *Studies in the Structure of the Urban Economy*. Baltimore: Johns Hopkins University Press.

20. Muth, Richard F. (1969). *Cities and Housing*. Chicago: University of Chicago Press.

21. Pace, R. Kelley, Ronald Barry, Otis W. Gilley, and C.F. Sirmans. (2000). "A Method for Spatial-Temporal Forecasting with an Application to Real Estate Prices," *International Journal of Forecasting* 16, 229-246.

22. Reuter, Frederick H. (1973). "Externalities in Urban Property Markets: An Empirical Test of the Zoning Ordinance of Pittsburgh," *Journal of Law and Economics* 16, 313-349.

23. Samuelson, Paul A. (1983). *Foundations of Economic Analysis*. Cambridge: Harvard University Press.

24. Tabuchi, Takatoshi. (1996). "Quantity Premia in Real Property Markets," *Land Economics* 72: 206-217.

25. Taichung City Government. (2002). *Tacihung City's Urban Land Consolidation Achievements*. Taichung City, Taiwan: Taichung City Government.

26. Thorsnes, Paul and Daniel P. McMillen. (1998). "Land Value and Parcel Size: A Semiparametric analysis," *Journal of Real Estate Finance and Economics* 17, 233-244.

27. Wallace, Nancy E. (1988). "The Market Effects of Zoning Undeveloped Land: Does Zoning Follow the Market?" *Journal of Urban Economics* 23, 307-326.

28. Wolverton, Marvin L. (1997). "Empirical Study of the Relationship between Residential Lot Price, Size, and View," *Journal of Property Valuation and Investment* 15, 48-57.

Table 1: Descriptive statistics

Panel A	Full Sample		R-1 Subsample		R-2 Subsample	
Variable	Mean (Std. Dev.)	Minimum (Maximum)	Mean (Std. Dev.)	Minimum (Maximum)	Mean (Std. Dev.)	Minimum (Maximum)
Total selling price	21,254.57	800.00	22,003.96	800.00	20,165.03	1,883.88
(NT$ 1, 000)	(21,249.38)	(200,630.76)	(20,297.30)	(117,033.46)	(22,591.65)	(200,630.76)
Size	498.20	73.89	563.95	73.89	402.60	102.33
(square meters)	(423.58)	(3,000.49)	(440.73)	(2,807.860)	(378.90)	(3,000.49)
DCentral	4.49	2.02	4.48	2.21	4.51	2.02
(km)	(1.13)	(6.25)	(1.13)	(6.25)	(1.12)	(5.87)
Dbeitun	3.83	1.26	3.57	1.26	4.20	1.52
(km)	(1.60)	(6.90)	(1.49)	(6.86)	(1.69)	(6.90)
Panel B	Frequency	Percent	Frequency	Percent	Frequency	Percent
Depth	259	74.86	146	71.22	113	80.14
Road	255	73.70	151	73.66	104	73.76
Company	12	3.47	8	3.90	4	2.84
Partner	67	19.36	40	19.51	27	19.15
Phase 7	117	33.82	58	28.29	59	41.84
Phase 8	5	1.45	1	0.49	4	2.84
Phase 9	74	21.39	49	23.90	25	17.73
Phase 10	101	29.19	73	35.61	28	19.86
Phase 11	49	14.16	24	11.71	25	17.73
Sample size	346		205		141	

Note:

1. *DCentral (DBeitun) denotes the distance to* Beitun Shopping Area (Central Shopping Area).
2. *Depth* = 1 for a non-corner parcel whose depth is over 20 meters and 0 otherwise.
3. *Road* takes the value of 1 for a parcel located in a major road and 0 for otherwise.
4. *Company* (*Partner*) =1 if a buyer is a company (partnership).
5. *Ph*8, *Ph*9, *Ph*10, and *Ph*11 are dummies for Phase 8 to Phase 11 of the land consolidated areas in Taichung City.

Table 2: Estimation results for parcels in R-1 districts

	Specification 1		Specification 2		Specification 3	
	Estimates	*t*	Estimates	*t*	Estimates	*t*
Intercept	-10.19	-2.10**	-12.02	-2.70***	-10.22	-2.48***
ln*A*	0.95	26.87***	0.95	29.41***	0.95	29.58***
Depth	-0.05	-1.11				
Road	0.10	1.91*	0.11	2.09**	0.11	2.27**
Company	-0.05	-0.53				
Partner	0.02	0.38				
*Ph*8	-2.31	-5.17***	-2.55	-6.06***	-2.47	-6.38***
*Ph*9	-0.57	-3.28***	-0.33	-5.67***	-0.35	-6.10***
*Ph*10	-1.02	-3.07***	-0.69	-9.23***	-0.71	-9.98***
*Ph*11	-0.75	-2.11**	-0.44	-3.09***	-0.48	-3.59***
DCentral	0.03	0.39				
DBeitun	-0.10	-1.05				
S(ln*A*)	-0.22	-0.96	-0.26	-1.11		
T(ln*A*)	0.19	2.12**	0.22	2.60**	0.19	2.34**
ST(ln*A*)	0.14	0.49	0.17	0.59		
TS(ln*A*)	-1.80	-5.68***	-1.83	-5.89***	-1.80	-5.89***
S(ln*P*)	0.16	0.58	0.23	0.83		
T(ln*P*)	0.37	6.19***	0.38	6.44***	0.38	6.63***
ST(ln*P*)	-0.10	-0.57	-0.11	-0.66		
TS(ln*P*)	2.03	4.07***	2.19	4.52***	2.06	4.42***
λ	179.53	0.96	116.04	0.91	119.49	0.95
Log-likelihood	-255.34		-257.49		-258.88	
R^2	0.91		0.91		0.91	
SSE	12.22		12.48		12.66	
n	204		204		204	

Note:

1. ln*A* (ln*P*)denotes the logarithm of parcel size (total price).
2. *DCentral (DBeitun) denotes the distance to* Beitun Shopping Area (Central Shopping Area).
3. *Depth* = 1 for a non-corner parcel whose depth is over 20 meters and 0 otherwise.
4. *Road* takes the value of 1 for a parcel located in a major road and 0 for otherwise.
5. *Company* (*Partner*) =1 if a buyer is a company (partnership).
6. *Ph*8, *Ph*9, *Ph*10, and *Ph*11 are dummies for Phase 8 to Phase 11 of the land consolidated areas in Taichung City.
7. λ is the selection variable.
8. The sample size is reduced because of the construction of temporal weight matrix.

Table 3: Estimation results for parcels in R-2 districts

	Specification 1		Specification 2		Specification 3	
	Estimates	*t*	Estimates	*t*	Estimates	*t*
Intercept	-133.49	-2.50***	-114.01	-2.45**	-112.00	-2.41**
ln*A*	0.80	16.47***	0.80	17.96***	0.82	18.29***
Depth	-0.19	-3.03***	-0.18	-3.01***	-0.16	-2.71***
Road	0.09	1.74*	0.09	1.85*	0.11	2.20**
Company	-0.28	-1.84*	-0.25	-1.63	-0.33	-2.35**
Partner	-0.07	-1.39				
*Ph*8	-1.99	-10.42***	-1.92	-11.57***	-1.82	-12.48***
*Ph*9	-0.30	-1.29	-0.44	-6.23***	-0.39	-5.80***
*Ph*10	-0.62	-1.74*	-0.87	-10.64***	-0.84	-10.41***
*Ph*11	-0.07	-0.20	-0.31	-2.98***	-0.20	-2.55***
DCentral	-0.02	-0.36				
DBeitun	0.07	0.73				
S(ln*A*)	0.14	0.56	0.11	0.46		
T(ln*A*)	-0.21	-1.98**	-0.23	-2.26**	-0.24	-2.48***
ST(ln*A*)	0.10	0.28	0.17	0.50		
TS(ln*A*)	0.34	1.20	0.27	1.00		
S(ln*P*)	0.02	0.07	0.05	0.24		
T(ln*P*)	0.29	6.11***	0.29	6.32***	0.31	7.14***
ST(ln*P*)	-0.05	-0.23	-0.09	-0.45		
TS(ln*P*)	-0.11	-0.48	-0.08	-0.33		
λ	44.13	2.54***	37.86	2.49***	37.75	2.48***
log-likelihood	-80.42		-81.98		-87.71	
R^2	0.95		0.94		0.94	
SSE	4.00		4.11		4.54	
n	116		116		116	

Note:

1. ln*A* (ln*P*)denotes the logarithm of parcel size (total price).
2. *DCentral (DBeitun) denotes the distance to* Beitun Shopping Area (Central Shopping Area).
3. *Depth* = 1 for a non-corner parcel whose depth is over 20 meters and 0 otherwise.
4. *Road* takes the value of 1 for a parcel located in a major road and 0 for otherwise.
5. *Company* (*Partner*) =1 if a buyer is a company (partnership).
6. *Ph*8, *Ph*9, *Ph*10, and *Ph*11 are dummies for Phase 8 to Phase 11 of the land consolidated areas in Taichung City.
7. λ is the selection variable.
8. The sample size is reduced because of the construction of temporal weight matrix.

Table 4: Results with assembly/subdivision dummies for parcels in R-1 districts

	Specification 1		Specification 2		Specification 3	
	Estimates	*t*	Estimates	*t*	Estimates	*t*
Intercept	-10.08	-2.06**	-11.31	-2.51***	-9.57	-2.29**
ln*A*	0.94	24.36***	0.93	26.22***	0.93	26.38***
lnA*DS	0.00	0.13	0.00	-0.07	0.00	-0.05
lnA*DA	0.01	0.74	0.01	1.20	0.01	1.20
Depth	-0.04	-0.96				
Road	0.10	1.88*	0.11	2.08**	0.11	2.24**
Company	-0.05	-0.50				
Partner	0.02	0.49				
*Ph*8	-2.31	-5.14***	-2.52	-5.92***	-2.45	-6.29***
*Ph*9	-0.55	-3.14***	-0.34	-5.70***	-0.35	-6.14***
*Ph*10	-1.02	-3.05***	-0.70	-9.30***	-0.72	-10.04***
*Ph*11	-0.74	-2.09**	-0.43	-3.08***	-0.48	-3.59***
DCentral	0.04	0.45				
DBeitun	-0.09	-1.01				
S(ln*A*)	-0.22	-0.95	-0.25	-1.07		
T(ln*A*)	0.20	2.17**	0.22	2.62***	0.20	2.36**
ST(ln*A*)	0.15	0.54	0.18	0.65		
TS(ln*A*)	-1.80	-5.66***	-1.82	-5.84***	-1.78	-5.83***
S(ln*P*)	0.16	0.56	0.21	0.78		
T(ln*P*)	0.38	6.14***	0.38	6.41***	0.38	6.58***
ST(ln*P*)	-0.11	-0.61	-0.13	-0.73		
TS(ln*P*)	2.02	4.01***	2.12	4.34***	1.99	4.23***
λ	186.85	1.00	111.91	0.88	115.52	0.92
log-likelihood	-254.95		-256.66		-258.06	
R^2	0.91		0.91		0.91	
SSE	12.18		12.38		12.55	
n	204		204		204	

Note:

1. ln*A* (ln*P*)denotes the logarithm of parcel size (total price).
2. *DS* (DA) is a dummy indicating whether a parcel is subdivided (assembled).
3. *DCentral (DBeitun) denotes the distance to* Beitun Shopping Area (Central Shopping Area).
4. *Depth* = 1 for a non-corner parcel whose depth is over 20 meters and 0 otherwise.
5. *Road* takes the value of 1 for a parcel located in a major road and 0 for otherwise.
6. *Company* (*Partner*) =1 if a buyer is a company (partnership).
7. *Ph*8, *Ph*9, *Ph*10, and *Ph*11 are dummies for Phase 8 to Phase 11 of the land consolidated areas in Taichung City.
8. λ is the selection variable.
9. The sample size is reduced because of the construction of temporal weight matrix.

Table 5: Results with assembly/subdivision dummies for parcels in R-2 districts

	Specification 1		Specification 2		Specification 3	
	Estimates	*t*	Estimates	*t*	Estimates	*t*
Intercept	-132.27	-2.48***	-115.05	-2.47**	-114.50	-2.48***
ln*A*	0.79	16.10***	0.79	17.73***	0.81	18.11***
ln*A***DS*	0.01	0.59	0.01	0.61	0.02	1.09
ln*A***DA*	0.02	1.56	0.02	1.52	0.02	1.56
Depth	-0.18	-2.85***	-0.17	-2.82***	-0.16	-2.73***
Road	0.10	1.97**	0.10	2.00**	0.12	2.37**
Company	-0.33	-2.13**	-0.32	-2.08**	-0.39	-2.79***
Partner	-0.09	-1.69*	-0.09	-1.75*	-0.10	-1.99**
*Ph*8	-1.98	-10.41***	-1.91	-11.60***	-1.81	-12.61***
*Ph*9	-0.27	-1.16	-0.41	-5.86***	-0.36	-5.43***
*Ph*10	-0.59	-1.67*	-0.88	-10.82***	-0.86	-10.71***
*Ph*11	-0.03	-0.09	-0.32	-3.07***	-0.19	-2.53***
DCentral	-0.03	-0.46				
DBeitun	0.08	0.83				
S(ln*A*)	0.10	0.42	0.07	0.29		
T(ln*A*)	-0.20	-1.89*	-0.19	-1.83*	-0.20	-2.05**
ST(ln*A*)	0.04	0.11	0.01	0.02		
TS(ln*A*)	0.36	1.29	0.30	1.15		
S(ln*P*)	0.02	0.10	0.04	0.20		
T(ln*P*)	0.30	6.27***	0.29	6.31***	0.31	7.26***
ST(ln*P*)	-0.01	-0.06	0.01	0.03		
TS(ln*P*)	-0.13	-0.53	-0.11	-0.49		
λ	43.73	2.52***	38.29	2.52***	38.50	2.55***
log-likelihood	-78.53		-78.97		-83.76	
R2	0.95		0.95		0.94	
SSE	3.8728		3.90		4.24	
n	116		116		116	

Note:

1. ln*A* (ln*P*)denotes the logarithm of parcel size (total price).
2. *DS* (DA) is a dummy indicating whether a parcel is subdivided (assembled).
3. *DCentral (DBeitun) denotes the distance to* Beitun Shopping Area (Central Shopping Area).
4. *Depth* = 1 for a non-corner parcel whose depth is over 20 meters and 0 otherwise.
5. *Road* takes the value of 1 for a parcel located in a major road and 0 for otherwise.
6. *Company* (*Partner*) =1 if a buyer is a company (partnership).
7. *Ph*8, *Ph*9, *Ph*10, and *Ph*11 are dummies for Phase 8 to Phase 11 of the land consolidated areas in Taichung City.
8. λ is the selection variable.
9. The sample size is reduced because of the construction of temporal weight matrix.