NON-DIVERSIFIABLE RISK AND QUANTITY DISCOUNTS IN TAIWANESE URBAN LAND MARKETS

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ABSTRACT

Land assembly and subdivision costs are negligible in residential land markets in certain land readjustment districts of Taichung City, Taiwan. Our empirical investigation finds evidence for significant quantity discounts in the case of land sales in these post-consolidated markets. This finding contradicts the prediction of the Le Chatelier-Braun Principle put forward in the work of Lin and Evans (2000). 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 hypothesis.

Keywords: Non-diversifiable risk; land price; parcel size; spatial statistics; Taiwan

INTRODUCTION

The relationship between land value and parcel size is of interest from both 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; Muth, 1969) and assumes 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 empirical investigations.[1] Meanwhile, assessors often ignore parcel size when estimating unit land prices (Keefe, 1997; Thorsnes and McMillen, 1998) and thus effectively also assume a linear relationship between land values and parcel sizes.

However, a considerable number of recent studies have identified non-linear relationships between the total price of urban land and parcel size, and such research has incited controversy regarding 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 relatively recent additions to this literature. The most popular explanation for such non-linear pricing involves the transaction cost argument postulated by Colwell and Sirmans (1978, 1980, 1993). According to this argument, the observed non-linear pricing, in the context of either quantity discounts or quantity premiums, is because transaction costs associated with

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

land assembly and subdivision make arbitrage across parcel sizes unprofitable in a perfectly competitive world (Colwell and Munneke, 1999).[2] This is particularly evident for subdivision costs in the U.S., where developers generally have to provide a significant amount of infrastructure, with the result that only a portion of the land bought by developers can be sold to end users (Lin and Evans, 2000). Consequently, many studies rationalize the prevalence of quantity discounts in U.S. urban regions in terms of the existence of land subdivision costs.

In contrast to U.S. developers, those who invest in post-consolidation urban land markets in Taiwan do not expect significant subdivision costs because major infrastructure is normally in existence prior the completion of urban land consolidation projects,[3] and thus entire parcels can be sold to end users. This contrast makes Taiwan's urban land readjustment districts, which are areas covered by urban land consolidation projects, an interesting laboratory to explore empirical urban land pricing structures. Lin and Evans (2000) attribute to the Le Chatelier-Braun Principle the significant quantity premiums identified using ordinary least squares regressions in the industrial land market at Neihu Readjustment District, Taipei City in October 1996 and April 1997. However, they also concede that land assembly costs may be another possible factor in determining the observed price structures in their study. This is considered a limitation of their work because no information about assembly activities is available to assess their impact on empirical land pricing.

Similar to Lin and Evans (2000), the major purpose of the current study is to explore the empirical relationships between land price and parcel size in the context of post-consolidation urban land markets in Taiwan. Nevertheless, this paper differs from Lin and Evans (2000) and other existing studies in three important respects.

First, land assembly costs are negligible in the studied land readjustment districts. This is because consolidation projects diminish undersized parcels and produce development-ready parcels (Taichung City Government, 2002). Each parcel in this study is at least about the size of a typical single-dwelling residential parcel.[4] In contrast, the smallest parcel in the study of Lin and Evans (2000) is arguably too small for appropriate industry use, given the local market.[5] The buyer may envisage assembly, anticipate holdout costs in the future and thus require a price discount in advance. Furthermore, zoning ordinances in the studied districts

[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] An urban land consolidation project is an integrated land improvement project that aims to readjust undeveloped and irregularly shaped urban land according to city planning guidelines. After the readjustment, each piece of land is directly connected with a road, and can be immediately used for construction (Department of Land Administration, 2009). The readjusted land can be reassigned to the original landowners who consequently receive a smaller area than they originally owned. In return for paying the expenses of the public facilities and engineering construction within the readjustment district, the government receives cash from the original landowners and/or keeps the land that remains after the original landowners are reassigned and land for public use is allocated (Hsieh, 2007).

[4] In the studied land markets, a typical parcel size has an area of about 82.645 m².

[5] The average parcel size was 225.1335 m² in the Neihu Readjustment District, Taipei City in May 1994 (Department of Economic Development, 2004). Lin and Evans (2000) showed a smallest parcel of 137.34 m², which is about only 61% of the average parcel area.

eliminate any incentives to develop large parcels as a means of capitalizing on floor area bonuses. The maximum lot coverage and floor area ratio (FAR) are 60 percent and 220 percent respectively. Given these constraints, 3- and 4-storey dwellings are deemed more profitable developments than high-rise apartment buildings, which require large parcels and can be designed to secure floor area bonuses.[6] These effectively weaken the holdout problem associated with the bargaining power of contiguous parcels and thus significantly reduce net land assembly costs.

Second, we use precise transaction dates and parcel locations and map these onto the spatial-temporal data structure associated with land sales. Few land pricing studies to date have location information that is as accurate as parcel centroid x-y coordinates. Such research consequently fails to take advantage of modeling possible spatial correlations in their empirical hedonic equations. Isakson and Ecker (2001) and Ecker and Isakson (2005) are two exceptions. Although modeling dependence over space has grown to be better known, joint modeling of errors across both time and space offers further possible advantages (Pace et al., 2000). Our study uses accurate transaction dates and parcel locations of land sale samples and further involves spatial-temporal regressions to improve empirical estimations.[7]

Third, assembly and subdivision records are used to investigate their impacts on the land pricing structure. Although many articles support the transaction cost hypothesis, we are aware of none that identify land parcels as assembled or subdivided. In this study, we are able to track both assembly and subdivision records of sample parcels.

In contrast to Lin and Evans's (2000) findings, our analyses indicate that significant quantity discounts prevail in the context of residential land sales in the land readjustment districts of Taichung City, Taiwan. As expected, assembly and subdivision activities do not significantly impact the land price structure. Furthermore, the discounts are larger for land sales in R-2 districts than for those in R-1 districts. Overall, the results are consistent with Brownstone and De Vany's (1991) non-diversifiable risk explanation, but undermine Lin and Evans's (2000) Le Chatelier-Braun Principle in explaining the pricing structure in the studied post-consolidation residential land markets. We note that the present study does not refute the transaction cost explanation that is supported in the existing literature, postulated by Colwell and Sirmans (1978, 1980, 1993), regarding pre-consolidation land prices in Taiwan and other countries.

The following section of this article reviews the relevant literature and aims to provide explanations for the observed nonlinear land pricing. Next, we describe the dataset, and we follow that with a section that describes the empirical spatial-tempo regressions used to examine value-size relationships. Thereafter, we present a set of empirical results and offer our conclusions.

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[6] Floor area bonuses usually can be granted to developments which feature open spaces and parking that is available for public use.
[7] We failed to identify applications of spatial-temporal regressions to land sales.

EXPLANATIONS FOR THE OBSERVED NONLINEAR PRICING

This section briefly reviews the four theoretical arguments for nonlinear pricing relationships between land price and parcel size: (1) the transaction costs associated with land assembly and subdivision, (2) non-diversifiable risk in the context of land investments, (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 hypothesis. They argue that the transaction costs of altering parcel size prevent arbitrage to eliminate pricing nonlinearities. Such transaction costs include the installation of streets and sidewalks - thus allowing only a proportion of the land to be sold to house purchasers - as well as utility services in subdivision activities, the removal of physical capital such as streets, pipes, and cabling, and any 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 the proportionate price of pre-subdivided raw land plus the per-parcel cost of performing the subdivision. The resulting land pricing is concave and quantity discounts exist in the land markets. On the other hand, the price of a parcel of land to be assembled must incorporate all anticipated assembly costs. This process results in quantity premiums. The empirical non-linear pricing observed in the market reflects the imbalance between the subdivision and assembly costs.

In contrast to the transaction cost hypothesis, the non-diversifiable risk hypothesis, as 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 that may spill over from neighboring parcels. Although this may alleviate the external effects, the process of investing in large parcels may be associated with substantial non-diversifiable risk.[8] On the other hand, holding small parcels may incur agency risk in the context of future development projects.[9] The risk premium associated with parcel size is therefore U-shaped. The size-value function must be concave in equilibrium and quantity discounts may prevail in land markets to prevent arbitrage. If zoning constrains externalities and eliminates the use of parcel size as a control instrument, then the size-value relationship approaches linear and discounts sink towards zero.
Wolverton (1997) put forward the law of diminishing marginal utility to explain price concavity as a function of parcel size. Wolverton concluded that quantity discounts may reflect the exchange between land consumption and consumption of other goods and services. To consume more land usually diminishes the consumption of other goods and services. As the foregone goods and services increase in value, land price must decrease to reflect the land's lessened relative utility.

[8] According to Brownstone and De Vany (1991, p.701), purchasing large parcels reduces investors' ability to diversify risk; thus, large parcels are associated with substantial non-diversifiable risk.
[9] The agency risk increases as the number of land owners involved in future developments increases (Brownstone and De Vany, 1991).

In contrast, the Le Chatelier-Braun Principle predicts the prevalence of quantity premiums in land markets. The principle applies when maximizing a variable and states that, as a constraint is relaxed, the maximum value of a variable that is subject to constraints cannot decrease and may indeed increase, all other things being equal (Samuelson, 1983). Lin and Evans (2000) argue that land price per unit is the variable to be maximized and that 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, with the result that its price per unit may be higher and is unlikely to be lower (Lin and Evans, 2000).

LAND PRICING DATA

The working data set in this study consists of 346 parcels of vacant residential land zoned as R-1 districts (mainly for the development of single-unit detached/semi-detached dwellings) and R-2 districts (for all types of residential development), sold by the Taichung City Government at public auctions to recoup its land consolidation costs.[10] We obtained relevant sale information from the Land Readjustment Section of the Land Administration Bureau of the city government. We cross-checked the data with official records from the land offices to ensure information accuracy whenever possible. Supported by the land office records, these sales are genuine arm's-length market transactions, like those in Taipei City's land readjustment district as considered by Lin and Evans (2000). The sales in our study span a 12-year period (1994-2005) and are located within five recently completed urban land readjustment districts (Phases 7 to 11).[11] The five land consolidation projects started in February 1990 and ended in August 1997, and each took 3 to 6.5 years to complete. The projects consolidated 984.77 hectares of land and created a total 557.86 hectares of construction site area.[12]

In these land readjustment districts, the government demolishes physical capital such as buildings and streets whenever necessary, consolidates fragmented parcels, reallocates land ownership, and furnishes the land with new public infrastructure including streets, sidewalks, sewer ditches, parking lots, and green space (Taichung City Government, 2002). Each landowner is given back a parcel of development-ready land that is more or less rectangular, faces a road, and is in roughly the same location as his or her original holding (Lin and Evans, 2000). As a result, no significant costs are incurred to subdivide land in such areas (Lin and Evans, 2000), since infrastructure generally constitutes the most important component of subdivision costs (Colwell and Munneke, 1999; Lin and Evans, 2000). Moreover, the residential zoning ordinances of the five readjustment districts eliminate the benefits that developers receive when parcel sizes are increased. The maximum lot coverage and floor-

[10] The number of observations in this study is reasonable compared with those from several previous studies. For example, Tabushi (1996) uses 444, Wolverton (1997) uses 46, Isakson (1997) uses 363, Lin and Evans (2000) use 50, Isakson and Ecker (2001) use 277, and Guntermann and Thomas (2005) list 48 observations for their studies.
[11] Land consolidation occurs in countries such as Japan, Germany, and Taiwan where land holdings are likely to be small and fragmented (Lin and Evans, 2000).
[12] 1 hectare = 2.471 acres.

area ratios permitted in the studied residential zones are 60 percent and 220 percent respectively. Consequently, the local market expects land parcels in these areas to be developed into 3-story to 4-story dwellings, neither of which are associated with FAR bonuses. No significant cost associated with removing physical capital or linked to the holdout problem is expected in the context of parcel assembly. Overall, the primary transaction costs incurred in land assembly and subdivision activities for parcels in the two residential zones of the five readjustment districts are land office fees, which are negligible.

The 346 parcels in our sample range in size from about 74 (759) to around 3,000 (32,297) square meters (square feet).[13] Each parcel sold for between NT$ 800,000 and NT$ 200,630,764; the mean sales price was NT $21,254,569. Table 1 lists relevant univariate statistics for the data. The TMD67 corner coordinates of each parcel are geo-coded and aggregated by the land offices of Taichung City.[14] For this study, the centroid coordinates of each parcel are computed with AutoCAD, a computer-aided design software package.

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 sale 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
Cpd	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. *Cpd* = 1 for a corner parcel with depth is over 20 meters and 0 otherwise.
3. *Road* = 1 for a parcel located on a major road and 0 otherwise.
4. *Company* (*Partner*) =1 if a buyer is a company (partnership).
5. *Ph*8, *Ph*9, *Ph*10, and *Ph*11 are dummy variables for Phase 8 Land Readjustment District through Phase 11 Land Readjustment

[13] 1 m^2 = 10.7639 ft^2.
[14] Details regarding TMD67 coordinates can be found at the website of the Land Survey Bureau, Ministry of Interior, R.O.C. (Taiwan) (http://www.lsb.gov.tw/lsb/lsbeng/04_knowledge/01_list.php).

EMPIRICAL MODELS

Each parcel in this study is individually zoned into R-1 or R-2 districts. 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.[15] The first stage relies on the logit equation to explain the propensity of land to be zoned into various categories, while the second stage focuses on hedonic pricing equations. This approach allows the implicit prices of land attributes to vary across zoning categories and resolves the selectivity bias (Colwell and Sirmans, 1993).

In this study, the logit that determines zoning classification is:

$$\text{Prob}[\text{k}_\text{i} = 1] = \exp(\alpha' \text{v}_\text{i}) \Big/ \left[1 + \exp(\alpha' \text{v}_\text{i})\right] \qquad (1)$$

where i indexes the observation, k = 0 for a parcel zoned in R-1 districts and k = 1 for a parcel zoned in R-2 districts, v is a vector of explanatory variables, and α represents the associated parameters.[16] Variables include the logarithm of parcel size and the same six location characteristics as those that appear in the hedonic pricing model described below. Then a selection variable is computed as $\lambda_{\text{ik}} = \phi(H_{\text{ik}}) / \Phi(H_{\text{ik}})$, where $H_{\text{ik}} = \Phi^{-1}(PR_{\text{ik}})$, ϕ and Φ are the PDF and CDF of the standard normal distribution, respectively, and PR is the probability predicted by equation (1). The selection variable is subsequently introduced into the hedonic regressions as an explanatory variable to correct the potential selectivity bias.[17]

The hedonic pricing regressions in this article are Pace et al.'s (2000) spatial-temporal linear models (STLMs)[18] that can be empirically specified as follows: [19]

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

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

[16] Please see Lee (1983) for a list of assumptions regarding the joint and marginal distributions of disturbances in this model.

[17] The empirical results are similar regardless of whether the selection variable is included in or excluded from the regressions.

[18] Pace et al. (2000) show that their STLMs outperform various spatial and non-spatial models.

[19] 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 it exists (Brasington, 2004).

where P denotes the vector of observations of total land price, A is the vector of observations regarding parcel size; Z represents the matrix of observations of the independent variables pertaining to site, buyer, and location characteristics other than parcel size; T is the matrix that specifies relevant temporal relationships among previous observations, S denotes the matrix that specifies the relevant 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 represented as two dummy variables. *Road* assumes a value of 1 for a parcel located on a major road and 0 otherwise.[20] *Cpd* = 1 for a corner parcel with a depth of over 20 meters and 0 otherwise.[21] This variable aims to capture the influence of both corner and depth characteristics for sample sites. For a residential site, a corner location may have negative implications (Appraisal Institute, 2001). Although characterized by easier access, corner locations often suffer from setback requirements as well as from increased traffic noise. Deeper sites are more likely to be associated with surplus land or to require extra paths to service the rear areas of the sites in future developments. In Taiwan, such paths can be sold to house purchasers[22], and they should be treated as a part of on-site improvements, such as landscaping, for future development projects. It should be emphasized that the paths are not accounted for in the transaction costs associated with altering parcel sizes. The buyer dummy variables are *Company* and *Partner* if a buyer is a company or a partnership, respectively. The location characteristics include four dummy and two distance variables. *Ph*8, *Ph*9, *Ph*10, and *Ph*11 denote Taichung City's Phase 8 Land Readjustment District through Phase 11 Land Readjustment District. *DCentral* and *DBeitun* measure the distances of each parcel to the Central Shopping Area and the Beitun Shopping Area, respectively, in kilometers.[23]

Both the spatial and the temporal weight matrices, S and T, are lower triangular since STLMs require the observations to be temporally ordered and conditioned only upon previous transactions. S and T serve as the nearest neighbor matrices in this study. To construct S, the Euclidean distances d_{ij} between every pair of observations j and i for every prior observation ($j < i$) are computed. The distances are subsequently sorted to determine the closest previously sold neighbor for each observation. The final spatial weight matrix features a 1 in each row and is filled with zeroes otherwise. Similarly, the temporal weight matrix contains non-zero weights only for the m sales events from the most recent public auction. Each row of T has m values of $1/m$ and zeroes otherwise.

[20] A major road is 12 meters wide. Estimation results are qualitatively the same if a major road is defined to be 15 meters wide.
[21] Twenty meters is the maximum depth of a house in the markets under study and is consistent with the recommendations of local developers.
[22] The associated paths usually contribute less to land value than other on-site improvements.
[23] The two distances are highly correlated with distances to 31 other landmarks, including shopping areas, train stations, colleges, museums, large parks, and freeway interchanges in Taichung City. The correlations among these distances are often as high as 0.8 or even higher.

The parcel size lags are included to capture the atypical size effect and expectations related to future market conditions. The market may force a parcel of atypical size to sell at a discount.[24] However, successful sales of atypical large parcels may indicate bullish expectations regarding future market conditions. The price lags may catch price feedbacks from local land market transactions. A thriving high-priced sales market may generate positive feedback momentum.

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

$$\ln P_{\mathrm{k}} = \beta_{\mathrm{k0}} + Z_{\mathrm{k}}\theta_{\mathrm{k}} + \ln A_{\mathrm{k}}\beta_{\mathrm{k1}} + DS_{\mathrm{k}} \ln A_{\mathrm{k}}\beta_{\mathrm{kDS}} + DA_{\mathrm{k}} \ln A_{\mathrm{k}}\beta_{\mathrm{kDA}} + T_{\mathrm{k}} \ln A_{\mathrm{k}}\beta_{\mathrm{k2}}$$
$$+ S_{\mathrm{k}} \ln A_{\mathrm{k}}\beta_{\mathrm{k3}} + S_{\mathrm{k}}T_{\mathrm{k}} \ln A_{\mathrm{k}}\beta_{\mathrm{k4}} + T_{\mathrm{k}}S_{\mathrm{k}} \ln A_{\mathrm{k}}\beta_{\mathrm{k5}} + \pi_{\mathrm{kT}}T_{\mathrm{k}} \ln P_{\mathrm{k}} + \pi_{\mathrm{kS}}S_{\mathrm{k}} \ln P_{\mathrm{k}}$$
$$+ \pi_{\mathrm{kST}}S_{\mathrm{k}}T_{\mathrm{k}} \ln P_{\mathrm{k}} + \pi_{\mathrm{kTS}}T_{\mathrm{k}}S_{\mathrm{k}} \ln P_{\mathrm{k}} + \gamma_{\mathrm{k}}\lambda_{\mathrm{k}} + \varepsilon_{\mathrm{k}}$$

where *DS* (DA) is the vector of observations regarding the dummy variable that indicates whether a parcel is subdivided (assembled) within 180 days following a sale.[25]

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 STLM assumptions 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:

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

[24] This is analogous to a common saying in housing markets research, stated in Brasington (2004): Never own the largest (or the smallest) building on the block because the market will force any such house to sell at a discount.

[25] The 180-day dummy variable, suggested by local developers, is consistent with the development schedule in the markets under study. 90-, 120-, 150-, 210-, 240-, or 270-day dummy variables produce similar results, except for the fact that the 90- and 270-day subdivision dummies exhibit statistically significant and positive coefficients for R2 samples. The coefficients of the subdivision dummies range from 0.02 to 0.03. This result may reflect the ability of the parcels to generate cash flow sooner than parcels that are not subdivided within a few days following the transaction.

ESTIMATION RESULTS

Tables 2 through 5 list estimates for Equations (2) and (3).[26] Following Lee and Pace (2006) and Gujarati (2006), this study adopts the Ramsey RESET test to verify the comprehensiveness of the explanatory variables. The resulting statistics are not significant at any conventional levels and serve only to support the regression specifications used in this study. The results are remarkable for the high levels of explanatory power across R-1 and R-2 districts as well as for their specifications. This complements Pace et al.'s (2000) study regarding housing prices[27] and supports their use in spatial-temporal regressions. As expected, all specifications feature significant spatial and temporal lags. This suggests the importance of previous and neighboring sales and reflects the influence of investors' market knowledge on land prices. Investors appear to take into account both parcel sizes and the prices of prior and adjacent land sales. Specifically, consistent with the atypical size effect, the coefficients of parcel size lag appear to suggest that an atypical sized parcel would be sold at a discount. The price lag coefficients confirm that a thriving high-priced sales scenario can generate positive feedback momentum in our studied markets.

In Tables 2 and 3, the parcel size coefficients are always positive and are significant at the 1% level. However, their values are never greater than 1 – a result that fails to support the Le Chatelier-Braun Principle. This is in marked contrast to Lin and Evans's (2000) observations from an industrial park in Taipei, Taiwan. The size coefficients for R-1 parcels in Table 2 are around 0.95 and are significantly smaller than 1 at approximately the 10% level using one-tailed t-tests. Although this evidence may seem weak, the R-2 samples provide strong evidence for the presence of quantity discounts. In Table 3, the size variable features coefficients of around 0.80 across various specifications. These coefficients are all significantly less than 1 at the 1% level. Comparing the size elasticities in Tables 2 and 3 reveals a more substantial quantity discount in the R-2 district than in the R-1 district. This pattern is consistent with the notion that zoning constrains externalities and eliminates the use of parcel size as a control instrument. The differences in size elasticities cannot be easily explained by the law of diminishing marginal utility proposed by Wolverton (1997).

[26] This study runs piece-wise regressions to explore the possible co-existence of quantity premiums and discounts across various segments of the size range of the samples under study. This possibility is eliminated by a grid search that separates quantity premiums from quantity discounts.

[27] The spatial-temporal models of Pace et al. (2000) feature R-square values of close to 9.0.

Table 2: Estimation results for R-1 district parcels

	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***
Cpd	-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	
RESET	0.71		1.43		1.43	
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. *Cpd* = 1 for a corner parcel whose depth is greater than 20 meters and 0 otherwise.
4. *Road* = 1 for a parcel located on a major road and 0 otherwise.
5. *Company* (*Partner*) = 1 if a buyer is a company (partnership).
6. *Ph*8, *Ph*9, *Ph*10, and *Ph*11 are dummy variables for Phase 8 Land Readjustment District through Phase 11 Land Readjustment District.
7. *DCentral (DBeitun)* denotes the distance to Beitun Shopping Area (Central Shopping Area).
8. λ is the selection variable.
9. RESET is the Ramsey RESET test statistic that introduces the square and cubic powers of predicted ln*P* as an additional repressor.
10. The sample size is reduced due to the 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***
Cpd	-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	
RESET	1.16		1.42		0.833	
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. *Cpd* = 1 for a corner parcel whose depth is greater than 20 meters and 0 otherwise.
4. *Road* = 1 for a parcel located on a major road and 0 otherwise.
5. *Company* (*Partner*) = 1 if a buyer is a company (partnership).
6. *Ph*8, *Ph*9, *Ph*10, and *Ph*11 are dummy variables for Phase 8 Land Readjustment District through Phase 11 Land Readjustment District.
7. *DCentral (DBeitun)* denotes the distance to Beitun Shopping Area (Central Shopping Area).
8. λ is the selection variable.
9. RESET is the Ramsey RESET test statistic that introduces the square and cubic powers of predicted ln*P* as an additional repressor.
10. The sample size is reduced due to the temporal weight matrix.

Table 4: Results with assembly/subdivision dummy variables 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***
ln*A***DS*	0.00	0.13	0.00	-0.07	0.00	-0.05
ln*A***DA*	0.01	0.74	0.01	1.20	0.01	1.20
Cpd	-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	
RESET	0.70		1.22		1.22	
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. *Cpd* = 1 for a corner parcel whose depth is greater than 20 meters and 0 otherwise.
4. *Road* = 1 for a parcel located on a major road and 0 otherwise.
5. *Company* (*Partner*) = 1 if a buyer is a company (partnership).
6. *Ph*8, *Ph*9, *Ph*10, and *Ph*11 are dummy variables for Phase 8 Land Readjustment District through Phase 11 Land Readjustment District.
7. *DCentral (DBeitun)* denotes the distance to Beitun Shopping Area (Central Shopping Area).
8. λ is the selection variable.
9. RESET is the Ramsey RESET test statistic that introduces the square and cubic powers of predicted ln*P* as an additional repressor.
10. The sample size is reduced due to the temporal weight matrix.

Table 5: Results with assembly/subdivision dummy variables 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
Cpd	-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	
RESET	1.99		2.20		1.48	
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. *Cpd* = 1 for a corner parcel whose depth is greater than 20 meters and 0 otherwise.
4. *Road* = 1 for a parcel located on a major road and 0 otherwise.
5. *Company* (*Partner*) = 1 if a buyer is a company (partnership).
6. *Ph*8, *Ph*9, *Ph*10, and *Ph*11 are dummy variables for Phase 8 Land Readjustment District through Phase 11 Land Readjustment District.
7. *DCentral (DBeitun)* denotes the distance to Beitun Shopping Area (Central Shopping Area).
8. λ is the selection variable.
9. RESET is the Ramsey RESET test statistic that introduces the square and cubic powers of predicted ln*P* as an additional repressor.
10. The sample size is reduced due to the temporal weight matrix.

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 minimally. 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 demonstrate that the observed quantity discounts are not driven by 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 hypothesis regarding the relationship between parcel size and land value.

Consistent with Lin and Evans (2000), the empirical estimates indicate higher land prices for parcels that are adjacent to main roads. The land-price equations reveal an insignificant and negative corner-depth impact on land prices in R-1 districts and a significant and negative impact in R-2 districts. This implies that the opportunity cost of surplus land and associated paths is higher in R-2 districts than in R-1 districts. This may reflect the fact that land price per square meter is generally higher in R-2 districts than in R-1 districts. We emphasize that the associated paths can be sold to house purchasers and are not a part of the transaction costs associated with altering parcel sizes.

Consistent with Lin and Evans (2000), buyer characteristics are irrelevant for vacant land transactions in the R-1 districts. In contrast, and consistent with Isakson (1997), these characteristics influence transaction prices in the R-2 districts. As pointed out by Isakson (1997), buyer characteristics may reflect differences in tax positions, speculative interests, purchasing power, and so on. However, they may also act as proxies for property characteristics (Isakson, 1997). No specific relationships can be hypothesized since buyer characteristics capture more than one effect.

The equations exhibit significant and negative coefficients on the land readjustment district dummy variables. This suggests that parcels in Phase 7 will command higher prices than those in other phases. The coefficients reveal that the lowest prices for vacant land parcels are in Phase 8, followed by Phase 10. For parcels in R-1 (R-2) districts, Phase 11 demands lower (higher) location premiums than Phase 9. Distances to the Central Shopping Area and the Beitun Shopping Area never have significant coefficients in the empirical price equations. This is likely because the location variability of sample parcels is already mostly captured by dummy variables associated with the land consolidation phases whose areas range between 120.35 hectares and 353.40 hectares.[28]

The selection variable, λ, exhibits significant coefficients in the R-2 land price equations, indicating the presence of selection bias. However, it is associated with insignificant coefficients in the case of R-1. The significant and positive coefficients indicate that the

[28] 353.40 hectares equals 873.270 acres, which is only about 1/3 of the maximum parcel size (2690 acres) in Isakson's (1997) samples.

zoning authorities simply follow the market - consequently, the R-2 zoning is not substantially different from what would occur if a free market were to determine land use (McMillen and McDonald, 1989). The insignificant R-1 regression coefficients suggest that externalities are probably important determinants in zoning these land parcels (McMillen and McDonald, 1989).

CONCLUSIONS

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

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

REFERENCES

Appraisal Institute, *The Appraisal of Real Estate*, 12th edition. Chicago, Illinois: Appraisal Institute, 2001.

Atack, J. and R.A. Margo, Location, Location, Location! The Price Gradient for Vacant Urban Land: New York, 1835-1990. *Journal of Real Estate Finance and Economics*, 1998, 16, 151-172.

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

Brownstone, D. and A. De Vany, Zoning, Returns to Scale, and the Value of Undeveloped Land. *The Review of Economics and Statistics*, 1991, 73, 699-704.

Colwell, P.F. and C.F. Sirmans, Area, Time, Centrality and the Value of Urban Land. *Land Economics*, 1978, 54, 514-519.

Colwell, P.F. and C.F. Sirmans, Non-Linear Urban Land Prices. *Urban Geography*, 1980, 1, 141-152.

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

Colwell, P.F. and H.J. Munneke, The Structure of Urban Land Prices. *Journal of Urban Economics*, 1997, 41, 321-336.

Colwell, P.F. and H.J. Munneke, Land Prices and Land Assembly in the CBD. *Journal of Real Estate Finance and Economics*, 1999, 18: 163-180.

Department of Economic Development, *2004 Survey on Firms at Taipei Neihu Technology Park, Dawan Southern Section Industrial Park, and Nankang Software Park*. Taipei City, Taiwan: Taipei City Government, 2004.

Department of Land Administration, *Zone Expropriation Business Operation*, 2009. Taipei: Department of Land Administration, Ministry of Interior

Ecker, M.D. and H.R. Isakson, A Unified Convex-Concave Model of Urban Land Values. *Regional Science and Urban Economics*, 2005, 35, 265-277.

Fujita, M. *Urban Economic Theory*. New York: Cambridge University Press, 1989.

Gujarati, D.N. *Essentials of Econometrics*. Singapore: McGraw-Hill, 2006.

Guntermann, K.L. and G. Thomas, Parcel Size, Location and Commercial Land Values. *Journal of Real Estate Research*, 2005, 27, 343-354.

Hsieh, Jing-chi. *Land Readjustment*. Taipei: Wu-Nan Book Inc., 2007.

Isakson, H.R., An Empirical Analysis of the Determinants of the Value of Vacant Land. *Journal of Real Estate Research*, 1997, 13, 103-114.

Isakson, H.R. and M.D. Ecker, An Analysis of the Influence of Location in the Market for Undeveloped Urban Fringe Land. *Land Economics*, 2001, 66, 30-41.

Keefe, J.E. The Land Value Curve. *Assessment Journal*, 1997, 4, 31-35.

Lee, L.-F. Some Approaches to the Correction of Selectivity Bias. *Review of Economic Studies*, 1982, 49, 355-372.

Lee, L.-F. Notes and Comments Generalized Econometric Models with Selectivity. *Econometrica*, 1983 51, 507-513.

Lee, M.-L. and R.K. Pace, Local Housing Prices and Mortgage Refinancing in U.S. Cities. *Property Management*, 2006, 24, 427-441.

Lin, T.-C. and A.W. Evans, The Relationship Between the Price of Land and Size of Plot When Plots Are Small. *Land Economics*, 2000, 76, 386-394.

McMillen, D.P. and J.F. McDonald, Selectivity Bias in Urban Land Value Functions. *Land Economics*, 1989, 65, 341-351.

Mills, E.S., *Studies in the Structure of the Urban Economy*. Baltimore: Johns Hopkins University Press, 1972.

Muth, R.F., *Cities and Housing*. Chicago: University of Chicago Press, 1969.

Pace, R.K., R. Barry, O.W. Gilley, and C.F. Sirmans, A Method for Spatial-Temporal Forecasting with an Application to Real Estate Prices. *International Journal of Forecasting*, 2000, 16, 229-246.

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

Samuelson, P.A., *Foundations of Economic Analysis*. Cambridge: Harvard University Press, 1983.

Tabuchi, T., "Quantity Premia in Real Property Markets. *Land Economics*, 1996, 72: 206-217.

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

Thorsnes, P. and D.P. McMillen, Land Value and Parcel Size: A Semiparametric analysis. *Journal of Real Estate Finance and Economics*, 1998, 17, 233-244.

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

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

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