MICROSIMULATION OF RESIDENTIAL LAND DEVELOPMENT AND HOUSEHOLD LOCATION CHOICES:

BIDDING FOR LAND IN AUSTIN, TEXAS

By

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ABSTRACT

This paper investigates single-family residential development for housing market equilibria using microeconomic theory and disaggregate spatial data. Mixed logit models and notions of price competition are used to simulate household location choices for three different household segments, assuming job sites of household members are known. Consistent with bid-rent theory, housing market equilibrium was reached in an iterative fashion. The spatial allocation of new households in the region of Austin, Texas illustrates the potential shape of things to come, with endogenously determined home prices and demographic distributions, based on job access. As expected, positive spatial autocorrelation in home prices and household distributions are observed.

INTRODUCTION

An essential part of urban travel demand forecasting, prediction of future land use patterns is of great interest to policy makers, developers, planners, transportation engineers and others. Residential land constitutes roughly 60% of developed land, dominating urban areas. Moreover, the emergence of commercial, industrial, office and civic uses is spatially correlated with residential development (see, e.g., *1*), a major driver of land use change (*2*).

Numerous factors contribute to the complexity of housing location decisions. Microeconomic theory tested using disaggregate spatial data offers behavioral foundations and a better understanding of such decisions. Using a framework based on random utility maximization and bid-rent theory, this paper investigates single-family residential location choices of new households and Austin's housing market equilibrium, assuming a 25% population growth scenario.

The spatial distribution of these new households and the associated, equilibrium home prices are endogenously determined, as the outcome of a competitive housing market process involving land and transport. Both the supply of and demand for homes are modeled explicitly. Large undeveloped parcels typically are first subdivided into smaller parcels, suitable for single family dwelling units (in accordance with year 2000's parcel size distribution). On the demand side, individual households (characterized by size, income, and presence of children), compete for the locations that offer the highest household-specific random utilities. Due to the competition for homes among households, the unit price per interior square foot is bid up until the market reaches equilibrium. Each home-seeking household is allocated to the location that offers it the highest utility, and each new home is occupied by the highest bidder. This ensures optimal allocation of land in the sense that each household chooses a home that best satisfies its preference function, while developers and land owners maximize profits and/or rents. The simulation analysis offers insights into key features of single-family residential land development, including outcomes of a micro-scale bidding process. And the ready applications offer confidence that such microsimulations are computationally achievable.

The following sections discuss related research in the land use-transport modeling and residential location choice areas, the data sets and methods used here, as well as model results, major findings and future extensions.

LITERATURE REVIEW

Microeconomic theories of land use can be traced back to the early 19th century. Von Thünen (1826) first attempted to incorporate transport cost in models of land price and location choice (as reported in *3*). Under closed-system, homogenous-land and zero-entry-cost assumptions, the commodity having the highest slope for its surplus/rent profile occupies locations closest to the point market. Wingo (1961) and Alonso (1964) developed these ideas for urban cases, where equilibrium patterns emerge around a single employment center (*4*, *5*). These models treat land as homogenous and continuous and recognize only one employment center (located in the centre of an imaginary study area). Moreover, they neglect taste heterogeneity.

Herbert and Stevens (1960) determined residential prices by maximizing aggregate rents subject to constraints on (total) land availability and the number of households to be accommodated (*6*). Senior and Wilson (1974) enhanced the Herbert-Stevens model by adding an entropy term to the objective function, reflecting latent preference variation among households (*7*). Both models treat spatial elements in an aggregate manner, using an exhaustive zone-based subdivision of the region. Recent, more advanced models (e.g., *8, 9*) depict household distribution via general equilibrium and land use-transportation interactions. However, their complexity has greatly limited their application.

With advances in simulation techniques and discrete choice theory, many land use/land cover change models have been developed, yet there is no clearly superior approach. This is felt to be due largely to the multi-faceted nature of the land development process, and to differences in available data sets and modeling objectives (*10*). Some simulation models rely on artificial intelligence methods, like neural networks, generic algorithms and cellular automata (see, e.g., *11*, *12*, *13*, *14*, *15*). These models may mimic many aspects of the dynamic and complex land use system, but they generally lack behavioral foundations, to explain the process.

Most similar to the model proposed here are Waddell's UrbanSim and Gregor's LUSDR. UrbanSim (*16*, *17*, *18*, *19*) seeks to simulate the land-market interactions (and location choices) of households, firms, developers and public actors, in a random utility maximization (RUM) framework. Unfortunately, UrbanSim does not recognize the location-choice effects of household-specific travel costs. Of course, travel costs can be significant determinants of home (and work) location choices (see, e.g., *20*, *21*, *22*, *23*). While Gregor's LUSDR (2007) runs quickly, and emphasizes the stochastic nature of results, it also does not allow for such a connection, and it neglects price adjustments. In other words, there is no price movement due to competition for land, as emphasized here.

Many studies have empirically investigated residential location choice behaviors (see, e.g., *16*, *24*, *25*, *21*, *26*, *27*, *28*). These studies differ in model structure, explanatory factors, and assumptions regarding the nature of joint decision-making, and most rely on traffic analysis zones or other (somewhat arbitrarily defined) spatial units as alternatives. As disaggregate data become more available, residential location choice studies of a microscopic nature (using parcels or homes as alternatives) remain rare.

In contrast to these earlier models and methods, this investigation emphasizes parcel-level data (GIS-encoded) and considers taste heterogeneity of individual households via household-specific random utilities. The model applied here relies on bid-rent theory, which is both theoretically meaningful and practically feasible.

DATA SETS

The data sets used to calibrate the location choice models and to reach housing market equilibria in Austin came from a variety of sources, as described below.

Location Choice Survey

Bina and Kockelman (2006) undertook a survey of Austin movers in 2005. Sampling half of Travis County's recent home buyers, responses were obtained from about 900 households, or roughly 12% of all recent buyers. All deed transfers for single-family homes (including condos and duplexes) over the prior 12 months, as obtained by USA Data, provided the sampling frame. The data set contains comprehensive information on recent mover demographics, housing characteristics, reasons for relocation, and stated preferences when facing different housing and location-choice scenarios. This data set also includes the addresses of the new homes and workplace(s) of working member(s). The GIS-encoded addresses, accompanied by roadway network data, provide a direct measure of commute time (for shortest travel-time paths under free-flow conditions) for all potential locations.

Due to missing data on workplace locations (or other key variables, such as home price), the number of household records was reduced to 583. A weighting scheme was created based on a two-dimensional cross tabulation for Travis County's household population, using the 2005

Public Use Microdata Sample (PUMS) for recent home buyers in Austin. Both home value at purchase and income data were categorized as falling into one of four categories. For home price, these are as follows: less than $150,000 (33.8% of the un-weighted sample), $150,000 to $200,000 (23.3%), $200,000 to $300,000 (22.1%), and $300,000 or more (20.8%). For annual household income, these are: less than $50,000/year (21.8% of the un-weighted sample), $50,000 to $75,000 (19.4%), $75,000 to $150,000 (43.1%), and $150,000 or more per year (15.8%). Individual weights for each sample respondent are the normalized ratio of PUMS probabilities to sample probabilities, and these weights have been applied in all regression model analyses that follow.

In the weighted sample, 533 households have at least one worker, while 50 have no workers. Among working households, 209 reported that the primary motivation for the move was to allow at least one household member to be closer to work or school; interestingly, the other 324 did not report vicinity to work/school a primary reason for their move. It is believed that households with different reason(s) for relocation exhibit different sensitivities to commute time. Therefore, the sample was segmented into three groups: zero-worker households, households with at least one worker and who moved for reasons of job (or school) proximity, and households with worker(s) who moved for other reasons (e.g. marriage or divorce, birth/adoption, retirement, household member(s) left/needed smaller home, wanted to own home, wanted to live near higher quality schools, wanted newer/bigger/better home, wanted/needed less expensive housing, planned to attend or graduate from college, change of climate, health reasons, and "other").

The survey also was used to synthesize Austin's future home-seeking households, assuming the demographic distribution of households does not change significantly over time – and that new households requiring homes resemble current households who have recently purchased homes. The new households are randomly drawn from the population-weighted sample with replacement.

Land Use and Appraisal Data

The study area for the housing market equilibrium is the City of Austin and its two-mile extraterritorial jurisdiction – an approximate oval, containing 420 square miles, with the City's central business district (CBD) in its center. The City of Austin's Neighborhood Planning and Zoning Department (NPZD) provided a year-2000 land use parcel map. Undeveloped parcels over 3,000 square feet in size were considered available for single-family residential development, providing a total of 16,607 developable parcels. Due to the computational burden of large-scale microscopic studies, a 10% random sample was drawn in this study. Figure 1 depicts the study area, all undeveloped parcels in year 2000 and the 10% sample of these undeveloped parcels.

This data set also was used to determine the distribution of single-family residential parcel sizes. A series of Kolmogorov-Smirnov tests against a variety of distributions (lognormal, exponential, etc.) rejected the hypothesis that such parcel sizes follow any common parametric distributions. Therefore, large, undeveloped parcels were assumed to subdivide according to the size distribution of Austin's 20,582 recently subdivided single-family parcels in year 2000, and these smaller parcels of land are allocated to households for single-family homes. In other words, random draws from the set of recently developed single-family parcels determine new parcel sizes for subdividing plots.

The City of Austin also assembled year-2000 land use parcel data with market price information. This appraisal data was used to derive thresholds of housing price per interior square foot and to anticipate future home sizes, as characterized by local Floor-Area Ratios (FARs). The housing unit price varies significantly over the study area (from $3.7/ft^2 to $845/ft^2), but this value lies between $25/ft^2 and $250/ft^2 for over 98% of Austin's single-family homes. These two "extreme values" thus serve as starting and maximum bid prices, respectively. The FAR variable links each potential new home's interior square footage to its parcel size. FAR values are determined by land developers and are somewhat regulated by local government. Without a model component for the profit-maximization behavior of land developers (as constrained by land use regulations), a locally-determined FAR is used here: each undeveloped parcel is assumed to be developed with a FAR value randomly drawn from a normal distribution approximating its neighborhood's distribution of FAR values (for all single-family residential parcels within 0.5 mile). The simulated FAR is also constrained to lie within the lower- and upper- limits on FAR values observed in the 0.5-mile-radius neighborhoods.

Employment Location and School Quality

Due to a lack of detailed location information on all of Austin's recent home-buying households, the workers in these new, synthetic households were assigned to the traffic analysis zones (TAZs) in proportion to the 2005 zonal employment data obtained from the Capital Area Metropolitan Planning Organization (CAMPO).

School quality is another important variable in residential location choice, at least for those with (or soon to have) children (see, e.g., *29*, *30*, *31*). The 2004 accountability indicators developed by the Texas Education Agency (TEA) were used here to reflect school district quality, in the models of location choice. And a geographic file depicting location of all 11 school districts in the region was obtained from the City of Austin. Of course, future school quality is of interest in the bidding process. Ideally, expert opinion and/or a statistical model is needed to anticipate future levels of school quality. In the absence of such inputs, this paper assumes that school quality does not change over time.

LOCATION CHOICE MODEL

Estimation of a location choice model for three segments of recent Austin home buyers reveals trade-offs between housing and travel costs, and the roles of income, household size and children. A simulated process of random utility maximization (RUM) seeks to mimic household choices.

Rooted in RUM theory, logit models (*32*) of discrete choice have been widely applied to residential location choice. While the multinomial logit framework is most commonly used (see, e.g., *33*, *29*, *34*), it presumes that all unobserved factors are uncorrelated and homogeneous; such assumptions are probably unwarranted in most models of location choice. Other, more flexible models allow for correlation in such factors. For example, a multinomial probit can accommodate both correlation and heteroskedasticity (see, e.g., *35*). At present, mixed logit models (ML) are arguably the most flexible yet estimable model specification (thanks to maximum simulated likelihood estimation techniques, and a kernel logit structure). This study relies on a random-parameters interpretation of ML models, allowing systematic-utility parameters to vary over decision makers.

A ML model was estimated here using data from the recent mover survey, and according to the following specification:

$$U_{hi} = \beta_1 \frac{UNITP_i \times SQFT_i}{HHINC_h} + \beta_2 SQFT_i + \beta_3 \frac{SQFT_i}{HHSIZE_h} + \beta_4 LOT_i + \beta_5 \frac{LOT_i}{HHSIZE_h}$$
$$+ \beta_6 \left(CHILD_h \times SCHOOL_i\right) + \beta_7 \sum_{n=1}^{N_h} \left(TT_{hin}\right) + \varepsilon_{hi}$$

Here, U_{hi} is the random utility perceived by household *h* if home *i* is selected, $HHINC_h$ is the annual income of household *h*, $UNITP_i$ is the housing price per interior square foot for home *i*, $SQFT_i$ is the size (1,000 of interior square footage) of home *i*, $CHILD_h$ is an indicator variable for the presence of children (under 16 years old) for household *h*, and $SCHOOL_i$ is school quality variable of the school district where home *i* is located. N_h denotes the number of workers in household *h*, TT_{hin} is the network commute time for worker *n* in household *h* when residing in home *i*, random components (ε_{hi}) are assumed to be independent and identically distributed (IID) Gumbel error terms (across households *h* and their alternatives *i*), and the β's are the random parameters to be estimated. This model specification serves as the full specification. Statistically insignificant variables were removed to reach the final specifications for the three household segments.

The number of workers in each household is capped at 2; the commute time of the third (or fourth) listed worker is assumed to be of negligible importance in the location choice decision. Part-time workers' travel time is reduced by 50%, in order to reflect the less frequent nature and lower importance of their commute trips, as compared to those of full-time workers. The school quality parameter (β_6) is specific to households with children and is assumed to be lognormally distributed, because households should respond positively to school quality (assuming they are responsive to this variable), with only different magnitudes. The household commute time parameter (β_7) also is assumed to be lognormally distributed, reflecting the "burdensome" nature of travel. Without strong beliefs on the signs of other variables, the remaining β's are assumed to be normally distributed.

For purposes of model calibration, each household's choice set is assumed to consist of 50 home alternatives: forty-nine randomly drawn from the pool of all homes purchased by respondents in the recent mover survey, plus the chosen option. ML models are normally estimated using maximum simulated likelihood estimation (MSLE), and Train's Matlab code (downloaded from http://elsa.berkeley.edu/~train) was used to estimate model parameters for the three household segments. All parameters found to lack statistical significance were removed in a stepwise fashion, to determine the final model specifications; and Table 1 provides final model results.

For working households who indicated having moved for job- or school-access reasons, the price-to-income variable is estimated to have a strongly negative set of (random) coefficients, as expected. (Please refer to Model 1 in Table 1.) Thanks to a relatively small estimated variance, only 2.7% households (on average) are expected to find homes with higher price-to-income ratios more desirable. While the coefficients on home size also are virtually all positive, the primarily negative parameter estimates for the size-to-household parameter imply that adding 1,000 sf of interior space will cause average systematic utility increases of 0.420, 0.670 and 0.795 for 2-person, 3-person and 4-person households, respectively, but a decrease in utility of 0.330 for 1-person households. In other words, one-person households can be expected to prefer smaller homes sizes, everything else constant; this seems quite reasonable, given the burdens of maintaining a larger home. As expected, households with children favor homes located in better school districts, and households prefer shorter commute times.

Model 2, the model for worker households who have moved for other reasons (non-work/non-school access reasons) suggests that lot-size related variables impact residential location choice. Because of the small estimated variance for the price-to-income ratios, households tend to prefer less expensive homes, everything else constant. Similar to the interior square footage variable, lot sizes are predicted to reduce the average systematic utility of a 1-person household (by 2.12 utils), but increase the average systematic utility of households with two or more persons (by 0.475, 1.34 and 1.77 for 2-person, 3-person and 4-or-more-person households, respectively). School quality is not statistically significant for these household segments (worker households who moved for other reasons), but commute time was estimated to have negative impacts on home choice.

The third segment (zero-worker households, Model 3) has only 50 observations, which limits the number of statistically significant variables that can remain in the model. The home price variable is not statistically significant, suggesting that afforadability may not be an issue for many of these zero-worker home-buying household. They may have relatively low incomes, but much accumulated wealth and can afford to buy expensive homes, paying essentially whatever price is necessary in the Austin market. As confirmed by recent mover survey data, the average home price for zero-worker households ($230,000) is higher than that of working households ($217,000).

HOUSING MARKET EQUILIBRIUM

Microsimulation of single-family residential land development for housing market equilibrium was applied to the City of Austin and its 2-mile extraterritorial jurisdiction, assuming a 25% growth in household numbers (essentially a 7 to 10 year horizon). Both the supply of and demand for homes were modeled explicitly.

A spatial allocation of single-family residential land and new households was sought based on bid-rent and market equilibrium theories. In the housing market, individual households compete for parcels, which have value due to the housing structure located there (e.g. interior square footage) and their associated accessibility to workplace(s). Each household will make decisions on the trade-offs between land and transport costs, and choose a site of a particular size and accessibility that offers the highest utility. On the supply side, land developers build homes on vacant land by paying the costs of land purchase and construction. They then sell these homes to households. Locations close to employment centers reduce travel costs, and consequently are preferable from customers' perspective. Higher demand increases their price, however. In order to maximize profits, land developers will sell houses to the highest bidders. If no one will offer a price higher than the minimum cost (of land purchase and construction), the house is out of market. Prices for each location will be stable in the market equilibrium, when each occupied house is owned by the highest bidder and each household in the market resides in one housing location.

Supply Side

Large undeveloped parcels were subdivided into several pieces that are suitable for single family dwelling units, and these pieces entered the housing market as individual home locations. Of course, not all subdivided parcels will be occupied by newly-added households; only the chosen sites were assumed to be developed into single-family residential land after the housing market reaches equilibrium.

In the residential location choice models, interior square footage is an important and influential factor. A locally-determined FAR links interior square footage to parcel sizes. The newly generated residential sites, each defined by a unique combination of lot size, home size, unit price per interior square foot, school quality, and distances to potential occupants' job site(s), were then allocated to individual households based on rent-maximizing and utility-maximizing principles, wherein prices rise to ensure market clearance.

Demand Side

304,791 households resided in the study area in year 2000. With the projected 25% growth, the number of newly-added households is around 76,000 in the whole area. Since only 10% of undeveloped parcels are included on the supply side, the total number of new households should be reduced to 10%, which is 7,600, on the demand side. These households are described by annual income, household size, number (and status [full-time versus part-time]) of workers, presence of children, and the primary concerns in residential location choice. All the three general types of household (each utilizes one of the three models) are randomly drawn (with replacement) from the population-weighted survey sample.

Here, each worker's job site is assigned randomly, in proportion to 2005 employment counts (by TAZ). In the future, a model of employment (and firm locations) could improve upon this assumption. The resulting households compete for homes that offer them the highest utilities, thereby bidding up popular homes' prices, until the market clears, achieving equilibrium.

System Equilibration

Each household is assumed to choose the home that offers it the highest utility, among all considered alternatives. When a home is selected as the "best choice" by more than one household, the competition/supply-demand imbalance should increase the unit price. Following such price increases, the previous best choice becomes unaffordable or at least less preferable due to the price increase, and other, relatively more preferred homes may emerge. Via this implicit price mechanism, households withdraw from competition over home sites that are experiencing high demand. Ultimately, the model presumes that land developers sell the home/home site to the highest bidder, at the market equilibrium's highest price.

Essentially, individual households evaluate all 50 residential parcels that are randomly chosen to represent their choice set. Home evaluation depends on price (versus household income), home size, lot size, school quality, and work access/commute costs. Preference function parameter values are simulated according to the mixed logit specifications and assigned to households falling within each of the three demographic segments.

Focusing on 10% of Austin's presently undeveloped lands, randomly generated FAR values (based on local FAR conditions) and a low starting price (of just $25 per interior square foot) are assigned to each parcel. The market equilibrium for new home buyers is reached in an iterative fashion. Prices rise in steps of $\$0.50/ft^2$ when a home is desired by more than one household, and, if competition is rather fierce, so that prices reach the maximum threshold ($\$250/ft^2$), one of the competing households is randomly selected to occupy the home. This approach helps avoid spiraling of home prices in a few highly competitive cases. Finally, when each household finally is aligned with a single, utility-maximizing home site, each new home is allocated to the highest bidding household. At this stage, the housing market (for new buyers/movers) is said to have reached equilibrium. Figure 2 shows the model logic.

After allocating each newly-added household to a specific location, the average equilibrium unit price for each (large/subdivided) parcel was computed by averaging the unit prices of the occupied pieces subdivided within the parcel, and averaging occupant income was calculated as the average annual income of households who choose to reside on the parcel. Moran's I statistic (a weighted correlation coefficient, calculated using a weight matrix of inverse Euclidean-distances between parcels [see, e.g., *36*]) indicates that average equilibrium unit prices for single-family parcels have positive spatial autocorrelation over the entire region. Using Moran's I statistic, one also observes a clustering of households of similar income, as expected.

The average appraised home unit prices in year 2000 for existing single family homes in a 0.5-mile radius of each new home were calculated, in order to compare these to the predicted market equilibrium prices. Paired comparisons suggest that the predicted unit prices are higher than existing values by $24.88 per square-foot on average, which is expected in the case of new homes (since these carry greater value, on average [see, e.g., hedonic model estimates in *27*]). This finding is subject to some bias because only 379 out of the 909 occupied parcels have information on their neighbors' existing home prices (using appraisal data), and these parcels are mostly located in Central Austin, where the model-predicted home prices are likely to be quite high, thanks to strong access to employment opportunities. The insensitivity of zero-worker households to prices also may contribute to some over-estimation of new home sales prices, because price increases do not cause such households to withdraw from the bidding competition.

CONCLUSIONS

This paper developed a model for distributing new households and tracking home price fluctuations, based on microeconomic theories and microsimulation. Disaggregate spatial data facilitated model calibration and application for Austin, Texas, a medium-sized urban region. Spatial distribution of single-family residential development and the equilibrium unit price per interior square footage is determined endogenously through the utility maximization and bid-rent theories. This method ensures that each household chooses a location that offers the highest utility; and therefore allows for an optimal allocation of land.

The location choice model used here is a mixed logit model, allowing for preference variations within a RUM framework. The models for three home types reveal that working households evaluate commute time differently when choosing a home location, depending on the reasons behind their making the move. Interestingly, zero-worker households who have recently purchased a home in Austin appear to be largely price insensitive (perhaps due to accumulated wealth). Other findings are of interest as well. For example, households with children favor homes located in better school districts, home price-to-income ratios have a strongly negative impact on residential location choice for working households, and bigger homes are preferred by nearly all households, as related to household size.

The housing market is modeled to consist of supply and demand sides explicitly. The unit price per interior square footage is modeled as the outcome of households' competition for homes. Average equilibrium unit prices for residentially developed parcels have positive spatial autocorrelation over the entire region. Households of similar income cluster, as expected.

The results are reasonable and tangible. Perhaps most importantly, they suggest that microsimulation of an entire region's land market is a reasonable objective. This approach will serve as a key component in more comprehensive models of regional land use change, in which firms are tracked and non-residential land development is anticipated, to provide for simultaneous prediction of job locations. The model also can be improved by incorporating intra-regional household moves, and consideration of additional policy tools (such as roadway pricing and land regulation effects). Such approaches herald a new wave of land use modeling opportunities.

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LIST OF TABLES AND FIGURES

TABLE 1 Results of Location Choice Models for Three Household Types

Households with Worker(s) & Moved for Job-related Reasons (Model 1)				
Explanatory Variables	Mean		S.D.	
	Coef.	t-stat	Coef.	t-stat
Price-to-income ratio	-0.303	-3.77	-0.158	-2.29
Interior square footage (1,000 ft^2)	1.17	5.56	0.0149	0.123
Interior square footage (1,000 ft^2) divided by household size	-1.50	-3.52	-0.0171	-0.0470
School quality	1.04	2.23	-0.0748	-0.0646
Commute time	-2.42	-11.39	-1.62	-5.59
Number of Observations	209			
Log-likelihood at Convergence	-685.3			
Pseudo R^2	0.331			
Households with Worker(s) & Moved for Other Reasons (Model 2)				
Explanatory Variables	Mean		S.D.	
	Coef.	t-stat	Coef.	t-stat
Price-to-income ratio	-0.530	-7.77	-0.0012	-0.0143
Interior square footage (1,000 ft^2)	1.22	5.92	-0.0163	-0.135
Lot size (acre)	3.07	2.89	-0.229	-0.254
Interior square footage (1,000 ft^2) divided by household size	-1.66	-4.21	-0.0047	-0.0144
Lot size (acre) divided by household size	-5.19	-2.25	-1.79	-1.16
Commute time	-3.19	-10.11	-2.39	-6.62
Number of Observations	324			
Log-likelihood at Convergence	-1093.4			
Pseudo R^2	0.312			
Zero-Worker Households (Model 3)				
Explanatory Variables	Mean		S.D.	
	Coef.	t-stat	Coef.	t-stat
Interior square footage (1,000 ft^2)	1.71	3.22	0.0132	0.0502
Interior square footage (1,000 ft^2) divided by household size	-3.32	-3.31	-0.0255	-0.0498
Number of Observations	50			
Log-likelihood at Convergence	-187.5			
Pseudo R^2	0.235			

Note: All parameter estimates are assumed to follow normal distributions, with the exception of School quality, which is assumed to follow a lognormal. The standard deviation (S.D.) is the Choleski decomposition of the variance, so a negative S.D. is equivalent to a positive one in that they both imply a positive variance.

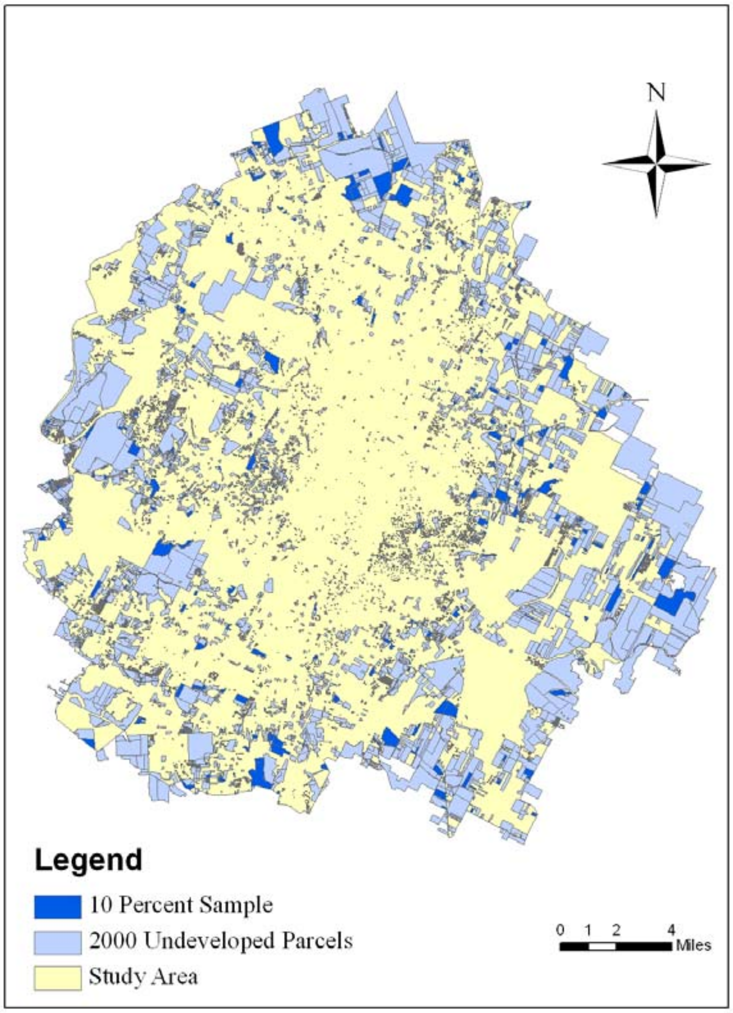

FIGURE 1 Map of study area, showing all undeveloped parcels and 10% sample.

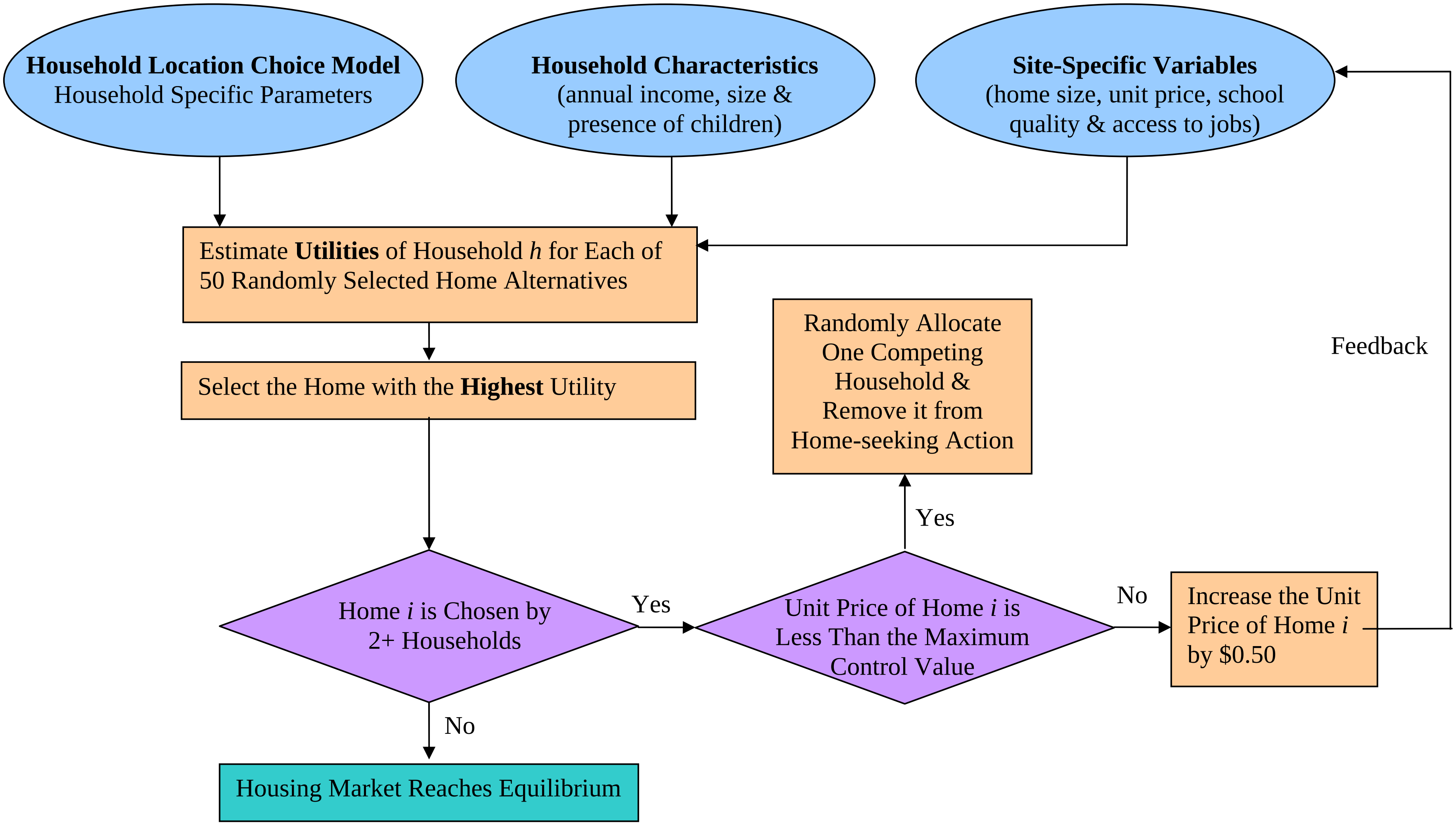

FIGURE 2 Model flowchart.