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Simulation Models for Urban Economies

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Glossary

Agglomeration economies Economies of scale that encourage the spatial concentration of production.

Discrete choice theory Theory of choice with a finite set of alternatives.

General equilibrium analysis Analysis of all markets simultaneously.

Invisible hand conjecture Economic agents rationally pursuing their own interests leads to a Pareto efficient outcome.

Monocentric city A city with a single centre of economic activity.

Numéraire commodity The commodity that is the unit of account.

Pareto efficiency The property of an economic allocation that no individual can be made better off without another becoming worse off.

Partial equilibrium analysis Analysis of a single market.

Polycentric city A city with many centres of economic activity.

Walras' Law The value of aggregate excess demand equals zero or market clearing in all but one market implies market clearing in that market.

Introduction

A simulation model is a parameterised model that is solved on the computer since it is too complex to solve analytically. Economic simulation models are widely used for forecasting and for predicting the effects of public policies. A model is calibrated to a base case situation; then parameters are altered to correspond to a particular policy; the simulated effects of the policy are measured by the difference between solution values with and without the policy in place. This article focuses on a class of economic simulation models that builds on the new urban economics, which views the urban economy from the perspective of competitive general equilibrium theory.

Background

Competitive General Equilibrium Theory

The microeconomic theory taught in economics principles classes is partial equilibrium analysis, which looks at a single market. The equilibrium price and quantity in the market are determined by the intersection of the demand and supply curves in that market. The demand curve relates the quantity demanded to the price of the good, holding household incomes and the prices of all other goods fixed. The supply curve relates the quantity supplied to the price of the good, holding technology and factor prices fixed.

General equilibrium analysis, in contrast, investigates the simultaneous determination of equilibrium in all markets. In competitive general equilibrium theory, all economic agents (firms and households) take prices as fixed. Goods, the outputs of production, and factors (and intermediate goods), the inputs, are together termed commodities. In an economy with *n* commodities, there are *n* markets, each of which must clear in equilibrium. Letting p_i denote the price of commodity *i*, equilibrium is determined simultaneously in all markets by the system of *n* equations in *n* unknowns:

$$D_i(p_1,\ldots,p_n) = S_i(p_1,\ldots,p_n), i = 1,\ldots,n \qquad [1]$$

(The equilibrium allocation is the same whether prices are measured in dollars or cents; that is, equilibrium determines only relative prices. Mathematically, this corresponds to only $n-1$ of the equations being independent – any one equation is implied by the remaining $n-1$ equations. This result is known as Walras' Law. Since equilibrium determines only relative prices, some price normalisation is employed. A common one is to set a wage rate equal to one; the corresponding type of labour is referred to as the numéraire commodity.)

The major developments in general equilibrium theory occurred during the first half of the last century. Conditions for the existence, uniqueness, and efficiency of competitive general equilibrium were derived, and Adam Smith's famous invisible hand conjecture ("[An individual is] led by an invisible hand to promote an end which was no part of his intention. Nor is it always the worse for the society that it was not part of it. By pursuing his own interest he frequently promotes that of the society more effectually than when he really intends to promote it."), that economic agents rationally pursuing their own interest leads to a socially desirable outcome, was formalised in the welfare theorems, the first stating that any competitive equilibrium is Pareto efficient – no individual can be made better off without some other individual being made worse off.

In 1950, almost all policy-oriented economic research employed partial equilibrium analysis. The next quarter century saw a general equilibrium revolution in applied microeconomic theory. In urban economics, the result was the new (now, of course, no longer new) urban economics. The new urban economics grew around a particular general equilibrium model of the urban economy, the monocentric model, which will be described in detail below. The basic monocentric model views the urban economy as having 2J + 2 markets, one market for land and another for housing at each of the J locations, a labour market, and a goods market. Any exogenous change, for example in transport technology, affects all these markets simultaneously. Extensions of the basic model allow for taxes and public services, multiple transport modes, traffic congestion, pollution, crime, and so on. The central idea is the interrelatedness of all the markets.

Computable General Equilibrium Models

In the early 1970s, fixed-point algorithms were developed for the computational solution of general equilibrium models. Since then considerable progress has been made in algorithms and computer programs (GAMS is the best known) specifically designed to solve computable general equilibrium (CGE) models. This progress, along with the enormous improvements in computational speed over the last few decades, permits the routine computer solution of large-scale general equilibrium models.

While containing considerable economic detail – multiple household groups, multiple industries/goods, and so on – most CGE models have a simple economic structure that greatly facilitates their computation. More sophisticated CGE models – for example, those that allow for strategic interaction between firms – are more difficult to solve. Most CGE models contain only a few primary factors of production – capital, labour (perhaps two types), and perhaps energy or land – and assume constant returns to scale in production at the level of the firm. Each good's unit cost (the cost of producing one unit of the good) can then be written as a function of only the prices of the primary factors, and each good's unit factor demand functions (cost-minimising quantities of primary factors that together produce a unit of output at minimum cost) straightforwardly calculated. Perfect competition is typically assumed, which implies that firms set price equal to unit cost. The prices of all goods can then be expressed as functions of only the primary factor prices. Since a household's income is a function of its factor endowment and the primary factor prices, its demand for each of the goods can be calculated on the basis of its tastes, endowment, and primary factor prices. Summing over all households gives the aggregate demand for each good, as a function of the primary factor prices. The derived aggregate demand for primary factor *j*, as a function of the primary factor prices, is then calculated as the aggregate demand for good *i* times the unit demand for factor *j* in the production of good *i*, summed over all goods. If there are *F* primary factors of production, setting these aggregate factor demands equal to the corresponding aggregate factor supplies yields a system of $F-1$ independent equations. Thus, in a model with 25 industries, 50 household groups, and 2 primary factors of production, the determination of equilibrium reduces to the solution of one equation in one unknown. Having obtained the equilibrium primary factor prices, the equilibrium goods prices are calculated from the unit cost functions, from which the equilibrium allocation is determined. Taxes can be treated straightforwardly by introducing tax wedges between producer and consumer prices.

Computable general equilibrium models are used extensively in international trade, tax, agricultural, and environmental policy analysis. In these areas, policy debate is increasingly becoming a numbers game between simulation models designed from different economic perspectives. At the least, this numbers game focuses and structures the policy debate. But, when well constructed, CGE models also have considerable value in quantifying the importance of various channels through which a policy impacts the economy, and in providing precise estimates of the gains and losses to various groups from the policy's implementation.

Urban policy debate has not yet reached this level of sophistication, mainly because most policy makers are local and do not have the resources or the technical capacity to work with large-scale simulation models. They are however increasingly being used by metropolitan planning agencies in planning land use and transportation and in performing environmental impact assessments. Urban economic simulation models have also been influential in forming urban economists' opinions concerning the relative desirability of alternative policies.

New Urban Economic Simulation Models: The First Generation

The first generation of new urban economic simulation models were CGE models that employed the monocentric (city) model as their theoretical foundation. Their level of spatial resolution is lower than that required for neighbourhood analysis but higher than that in interregional or international analyses.

The monocentric model describes the general equilibrium of a simple, circular city/metropolitan area. The city has a fixed population, *N*, of identical households, each of which is endowed with one unit of labour and has an equal share in land ownership. Households receive utility from a consumption good, *c*, and housing, *h* (measured in terms of housing unit floor area): $u = u(c,h)$. The spatial structure is simple. All nonresidential activities occur at a point in space, the central business district (CBD), which is surrounded by housing extending to the urban boundary. Distance from the CBD is denoted by *x*. Each day each household commutes radially to the CBD to work and to shop, at a cost of *t* units of the composite good per year for each unit distance it lives from the CBD. The production structure too is simple. There are constant returns to scale in goods production, with labour as the sole input. The output is the numéraire composite good, one unit of which can be used as either a unit of consumption or a unit of housing capital. Housing producers use a constant returns to scale housing production function, with land and housing capital as inputs, to produce floor space. Industry structure is competitive in all markets. Let *w* denote the wage, $r(x)$ equilibrium land rent per unit area of land at *x*, and $p(x)$ equilibrium housing rent per unit area of floor space at *x*.

The rest of the section describes how the model's competitive general equilibrium can be solved, and how the model can be applied to analyse the effects of a property tax (**Figure 1**).

A household is free to choose where in the city it lives. Consequently, to offset higher commuting costs at more distant locations, housing rent falls off with distance to the CBD such that households receive the same equilibrium utility level at all settled locations. Turn to Figure 1, which plots budget lines and the equilibrium indifference curve, corresponding to the equilibrium utility level, U_0, in *h*–*c* space. Now consider a household that lives right next to the CBD and hence incurs no commuting costs. Where θ is its income from land ownership, its budget constraint is given by:

$$w + \theta = c + p(0)h \qquad [2]$$

The household divides its labour and land income between consumption and housing rent. From the definition of equilibrium, the household is maximising its utility subject to its budget constraint. This, plus the condition that the household receives the equilibrium utility level, implies that the household's budget constraint is tangent to the equilibrium indifference curve. This determines the slope of its budget constraint, which is housing rent at the city centre, $p(0)$, as well as its consumption and housing, $c(0,U_0)$ and $h(0,U_0)$. Perform the same exercise for the household living at x'. Its budget constraint is $w + \theta = c + p(x')h + tx'$; this household has the same income as the household at the CBD and divides it between consumption, housing rent $p(x')h$, and commuting costs tx'. Repeating for all locations yields the function $p^\wedge(x;U_0)$ – equilibrium housing rent at location *x* with the equilibrium utility level U_0 – as well as $c(x;U_0)$ and $h(x;U_0)$ (**Figure 2**).

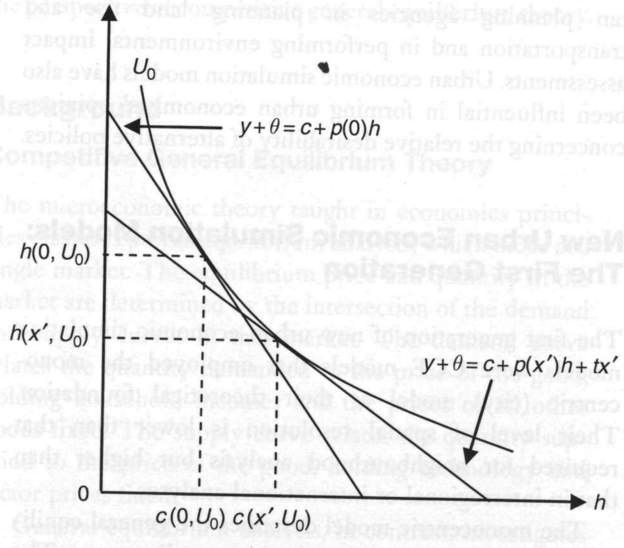

Figure 1 How housing rents and household consumption bundles change with distance from the CBD.

Now consider a housing firm, which uses land, *L*, and capital, *K*, to produce floor space according to the production function $F = F(K,L)$. Since housing production exhibits constant returns to scale, the function can be written in intensive form as $f = f(k)$, where $f = F/L$ and $k = K/L$. The problem facing a housing firm at *x* is to choose the capital–land ratio so as to maximise profit per unit area of land: $\max_k \pi(x) = p(x)f(k) - k - r(x)$, which is portrayed geometrically in Figure 2. The firm will add capital to the land to the point where the increase in housing rental income from adding an extra unit of capital, $p(x)f'(k)$, equals the cost of that extra unit, 1. Thus, $k(x;U_0) = k^\wedge(p^\wedge(x;U_0))$. Competition between housing firms drives profit to zero, so that (per unit area of land) land rent is determined as the residual between housing revenue and nonland costs, as indicated in the diagram. Thus, land rent at a location can be derived from the housing rent there, yielding the function $r^\wedge(x;U_0)$.

The boundary of residential settlement, x^*, occurs where the land rent is zero: $r^\wedge(x^*;U_0) = 0$, which can be rewritten as $x^* = x^*(U_0)$. Finally, the equilibrium utility level is determined by the condition that the amount of floor space constructed is just the right amount to house the population:

$$\int_0^{x^*(U_0)} \left[\frac{f(k(x;\,U_0))}{h(x;\,U_0)}\right] A(x)\,dx = N \qquad [3]$$

where $A(x)$ is the area of the land at *x*. $f(k(x;U_0))/h(x;U_0)$ is the housing floor area at *x* per unit area of land divided by the housing floor area per household at *x*, conditional on U_0, and is therefore the number of households

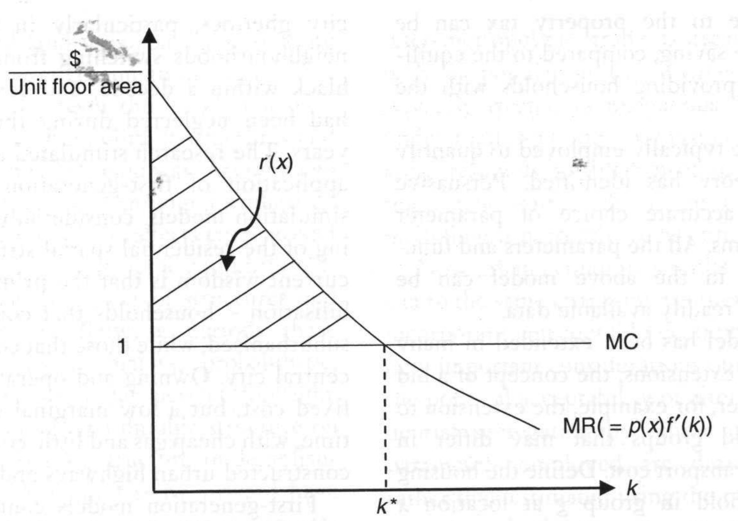

Figure 2 The relationship between land and housing rent, and the determination of the capital–land ratio in housing.

accommodated per unit area of land at *x* with utility U_0. Summing over all locations from the CBD to the urban boundary, the left-hand side in eqn [3] therefore gives the number of households that can be accommodated in the city, which in equilibrium equals the household population. At all locations, an increase in the utility level leads to a decrease in housing and land rent and consequently a decrease in the floor-area ratio, an increase in housing demand, and a decrease in household population density. The increase in utility also leads to a decrease in the urban boundary, which combined with the decrease in population density implies a decrease in the household population that can be accommodated. Thus, there is a unique utility level that satisfies eqn [3].

This is such a simple model that, with simple functional forms, a closed-form solution can be derived. It will be instructive nonetheless to consider how the model could be solved on the computer. A brute-force approach to the model's computer solution might proceed as follows. Discretise space so that the CBD is surrounded by concentric circles, each occupying a unit area, indexing the circles by $j = 1, \ldots, \mathcal{J}$, from the CBD outwards. There are then $2\mathcal{J}+2$ markets – land and housing markets at each location, a labour market, and a composite good market. The composite good is the numéraire good and the wage rate equals one labour unit's output of the composite good. That leaves $2\mathcal{J}$ equilibrium prices to be determined. Since computation time increases considerably more rapidly than linearly in the number of variables to be solved for, this brute-force approach would likely be computationally costly. A superior computational approach exploits the economic structure of the problem, solving one equation, eqn [3] above, in one unknown, U_0. The left-hand side of eqn [3] can be interpreted as the quantity of households demanded (the number of households that can be accommodated) and the right-hand side as the quantity of households supplied. Defining $Z(U_0)$ to be the excess demand for households, and discretising space as above, the equilibrium level of utility is the zero of:

$$Z(U_0) = \sum_{i=1}^{\mathcal{J}} \frac{f\left(k_j(U_0)\right)}{h_j(U_0)} - N \qquad [4]$$

This equation can be solved numerically as follows: Set a reasonable domain for U_0, say from U' to U''. Calculate whether excess demand is positive or negative at the midpoint. If positive, the equilibrium point lies between U' and $(U' + U'')/2$. Take the midpoint of this interval, $(3U' + U'')/4$. If excess demand is negative there, then the equilibrium point lies between $(3U' + U'')/4$ and $(U' + U'')/2$. Take the midpoint of this interval, $(5U' + 3U'')/8$, etc. Proceed until a guess of U_0 is found that yields sufficiently low excess demand. A more sophisticated algorithm takes a starting point, $U_0^{(i)}$, calculates both the excess demand and the derivative of the excess demand function with respect to U_0 there, and then guesses the zero of the function as the intersection of the tangent line with the U_0-axis, $U_0^{(ii)}$. It then calculates the excess demand and the derivative of the excess demand function at this second guess of U_0, and proceeds until a guess of U_0 is found that yields sufficiently low excess demand. The values of the other variables are then solved for.

In this very simple model, the property tax is modelled as a tax wedge between the consumer and producer housing rents. A household's housing demand depends on the consumer rent, and a housing firm's choice of capital–land ratio on the producer rent. Since the model is general equilibrium, disposition of the revenue raised from the property tax needs to be considered. The property tax revenue might be split equally among households, or used to replace lump-sum tax revenue.

The efficiency loss due to the property tax can be measured as the resource saving, compared to the equilibrium, from efficiently providing households with the equilibrium utility level.

Simulation models are typically employed to quantify various effects that theory has identified. Persuasive quantification requires accurate choice of parameter values and functional forms. All the parameters and functional forms employed in the above model can be estimated on the basis of readily available data.

The monocentric model has been extended in many ways. For many of these extensions, the concept of a bid rent is employed. Consider, for example, the extension to treat multiple household groups that may differ in income, tastes, and unit transport cost. Define the housing bid rent b^g of a household in group g at location x associated with utility u^g, $b^g(x,u^g)$, to be the maximum amount that a household in group g can pay in rent per unit floor area at x consistent with achieving utility u^g. It is calculated in the same way as housing rent was in Figure 1. Define a household group's family of bid-rent functions and curves analogously. Since all households in a group must receive the same utility in equilibrium, each group has an equilibrium bid-rent curve. Then apply two principles. First, housing at a particular location goes to that household group that can afford to pay the most per unit floor area for it. Second, the housing rent at a particular location equals the maximum of the household group bid rents there. The determination of equilibrium then entails calculating a vector of utility levels, one for each group, such that, when the two principles are applied, the excess demand for each household group equals zero.

In the 1970s, new urban economic simulation models were extended to add land in CBD goods production, multiple transport modes, congestion in transportation (with land allocated to roads, and travel speed on a section of road related to the traffic per unit width of road), and zoning and other land use regulations.

In the quarter century after the Second World War, the most significant change in the spatial structure of US cities was the residential suburbanisation of the middle class, lagged considerably by the suburbanisation of jobs. At the time, there were two principal competing explanations. The first was that the phenomenon was explainable in terms of the comparative static properties of the monocentric city model with respect to population, income, and transport costs. Metropolitan area populations, average incomes, and car ownership rates grew rapidly over the period. The second was that middle-class suburbanisation was a flight from the blight of decaying and crime-ridden central cities. Massive migration of African Americans from the rural south to northern cities, combined with discrimination in suburban housing markets, caused rapid expansion of central city ghettoes, particularly in the 1950s, with many neighbourhoods switching from being all white to all black within a decade, and central city infrastructure had been neglected during the Depression and War years. The research stimulated by the debate, including application of first-generation new urban economic simulation models, considerably improved understanding of the residential spatial structure of US cities. The current wisdom is that the primary cause was automobilisation – households that could afford to own a car suburbanised, while those that could not remained in the central city. Owning and operating a car entails a high fixed cost, but a low marginal cost, particularly at the time, with cheap gas and little congestion on the recently constructed urban highways and freeways.

First-generation models continue to be constructed today. Their primary weaknesses are that they assume all nonresidential economy to occur at the CBD and treat the urban economy as static. Their primary strengths are their general equilibrium approach, which ensures sound welfare analysis, and their conceptual integrity.

New Urban Economic Simulation Models: Subsequent Developments

Considerable progress has been made since 1980 in the development of new urban economic simulation models. Alex Anas has been the pioneer in many of these developments.

One step forward has been the application of discrete choice theory. In standard consumer choice theory, faced with a choice between bundles of goods, a household chooses one with certainty. In discrete choice theory, an external observer cannot determine a household's tastes exactly, and so can make only probabilistic statements about its choices. This concept is implemented by assuming that a household's utility includes a systematic (or deterministic) component based on its observable characteristics and an idiosyncratic (or stochastic) component based on its unobservable characteristics. To illustrate, suppose that a household has a choice of living downtown (location 1) or in the suburbs (location 2). The systematic component of its utility associated with living downtown is U^1 and in the suburbs is U^2. The most common, logit formulation of the theory predicts that the probability that the household lives downtown is:

$$\mathrm{P}^1 = \exp\left[\alpha \mathrm{U}^1\right] \div \left\{\exp\left[\alpha \mathrm{U}^1\right] + \exp\left[\alpha \mathrm{U}^2\right]\right\} \qquad [5]$$

where α is a parameter measuring the importance of the systematic component of utility relative to the idiosyncratic component. The discrete choice formulation accommodates unobservable heterogeneity and the observed spatial mixing of land uses and, by smoothing aggregate behaviour, facilitates computation.

Another step forward has been the development of dynamic models treating the durability of structures and infrastructure in an economically sound way. Account can then be taken of how a city's history, through its inherited stock of structures and infrastructure, affects current land use. Within each period a static general equilibrium is solved for, taking as given the stocks of structures and infrastructure over locations. Between periods these stocks evolve, with developers making probabilistic, profit-maximising conversions under perfect foresight. A conversion may entail building a durable structure on vacant land, modifying an existing structure, or demolishing the current structure. Yet other steps forward have been more detailed treatments of passenger transportation using static traffic network equilibrium models, and of industry-specific freight transportation and production using input–output data.

The monocentric model's assumption that all employment is at the CBD is unrealistic. Within metropolitan areas, employment has been decentralising rapidly and in some metropolitan areas is now as decentralised as residences. Employment has become more dispersed and suburban subcentres have been mushrooming. Suburban firms sacrifice the higher total factor productivity downtown deriving from economies of agglomeration, but benefit from lower wages and office rents. New urban economic simulation models that account for employment decentralisation are currently under development. They assume that a firm's total factor productivity depends on its proximity to other firms in the same and related industries.

Reflecting improvements in data collection, the development of GIS systems, solution algorithms, and computational speed, current models are descriptively considerably richer than the first-generation models. A central choice in constructing an urban economic simulation model is the level of spatial aggregation. The more spatially aggregated is the model, the lower are run times, but also the larger the aggregation loss, the less spatially detailed is the output, and the less spatially detailed are the policies that can be analysed. (Simulation models should allow the user to vary the level of aggregation depending on the application, but very rarely do.) Current models are being applied to simulate the effects of a wide range of policies, especially those that deal with the connections between transportation, land use, and the environment, at the metropolitan level. Analyses of environmental policies, congestion pricing in transportation, and land use policies aimed at reducing travel have been the focus of recent interest.

This progress notwithstanding, there remains considerable scope for modelling improvements. Due to data deficiencies rather than conceptual inadequacies, inter-metropolitan trade is treated crudely. The time path of population by income-demographic group is typically treated as exogenous, even though it is well understood how net migration between metropolitan areas responds to differences in their economic conditions. Uncertainty about the future is important but modelling it persuasively has proved elusive.

New urban economic simulation models are also subject to the same criticisms as other CGE models: (1) They incorporate considerable economic detail but treat crudely important considerations outside economics, such as the political acceptability of alternative policies and residential segregation by ethnic group. (2) Most of the parameters employed are drawn from other sources rather than estimated using the model's theoretical structure to guide the econometric specification. There is no intrinsic reason why this should be the case. It is rather an accident of intellectual history that new urban economic simulation modellers and spatial econometricians have not yet teamed up. (3) Testing of the models is problematic. One can calibrate a model for 1990, generate a forecast for 2000, and compare the 2000 forecast with the actual situation at that time; the process is called validation. But the modeller can always ascribe a poor forecast to exceptional circumstances, which inevitably arise. For example, a land use and transportation forecasting model of the Los Angeles metropolitan area could not reasonably have been expected to predict the subprime mortgage crisis, even though it will have a major impact on the spatial development of the metropolitan area.

New urban economic simulation models have now been employed for over 30 years. Have they been successful? Remarkably, there has been no systematic attempt to test how well they have forecast, or to modify their structure and parameters in light of discrepancies between forecast and realisation. The first generation of new urban economic simulation models failed seriously in one important respect. By not incorporating agglomeration economies, they overlooked the very significant decentralisation of employment that would occur in the years ahead and is continuing. The current generation of new urban economic simulation models is starting to rectify this oversight. Since the first generation of models ignored the durability of structures, their forecasts were long run and hence gave a misleading impression of the sensitivity of urban spatial structure to policy change over practical planning horizons. Whatever their success in forecasting, the first-generation models have been useful in identifying the potentially large efficiency losses deriving from various types of land use controls, such as height restrictions and urban growth boundaries, and from taxes and distortions such as unpriced auto congestion, and in structuring policy debate, particularly among urban economists.

Other Urban Economic Forecasting Models

City and metropolitan planning agencies routinely do forecasting. They need to forecast traffic levels for highway planning, the size of employment subcentres for planning the location of rail and light-rail transit stations, population and demographic composition for facility (e.g., schools) and land use planning, and so on. It is not surprising therefore that there are many different types of urban forecasting models that have economic elements.

Three types of models are routinely used and well developed.

- Traffic forecasting models. These models have firm economic foundations, being based on discrete choice theory. Their structure is hierarchical. The first stage is trip generation, the second trip distribution, the third modal choice, and the fourth route choice. Their weak link is land use forecasting model at the trip generation stage.
- Demographic forecasting models. These models move the population forward period by period, forecasting births, deaths, and net migration by income-demographic group. Often their economic foundations are weak; for example, they often neglect the channel from population to housing prices to net migration. Demographic forecasts are typically done at the state or regional level, and then the forecast population is mechanically distributed over space.
- Employment forecasting models. There is a standard method for employment forecasting at the metropolitan level. The metropolitan area's employment is separated into export base employment by industry and local employment. The metropolitan area's employment in a particular export base industry is forecast on the basis of projected employment growth for that industry at the national (or state or regional) level, as well as the metropolitan area's share (and change of share) of national employment. Summing over industries gives a forecast of export base metropolitan employment. Applying the assumption that each export base job supports a given number of local jobs gives a forecast of total metropolitan employment. Methods differ for allocating total metropolitan employment over metropolitan locations.

The employment and demographic forecasts need to be reconciled. The reconciled forecasts then serve as one input into trip generation forecasts.

Land use forecasting has been the weak link of metropolitan forecasting models. Most modern land use forecasts use some variant of the Lowry model, which was the first to develop a systematic procedure for moving from a spatial employment forecast to a land use forecast. Employment generates residential land use, which in turn generates commercial land use. New construction fills the gap between the needed and existing floor space. The Lowry model is not a full economic model since it contains no markets. The best-known model in the Lowry tradition is UrbanSim.

Two other lines of development in urban simulation modelling that started in the 1960s bear note. The first, the Herbert-Stevens model, forecasts land use as the output of a linear programming optimisation problem. While linear programming has been supplanted by more sophisticated, nonlinear equation solving methods, the basic approach is sound when externalities are unimportant. The second was the NBER model. While well informed by the urban economics of the time, the model's ambitious conception was not matched by its execution because of data limitations and conceptual inconsistencies in the formulation of its different submodels, which compromised coherence.

The Future

There have been three major developments that are bound to have considerable influence on the future of urban economic simulation modelling: (1) the huge amount of high-resolution spatial data that is being generated through satellite imaging and from improved access to census microdata; (2) continuing improvements in the speed of computation; and (3) the development of spatial and nonparametric econometrics. These developments will facilitate the construction of all types of spatial urban simulation models. One can envision three classes of urban economic simulation models that may evolve in response to these developments. The first, which may be termed parcel microsimulation models, will move individual parcels of land forward in time based on transition probabilities estimated econometrically from historical experience. In some ways, such models are analogous to traffic microsimulation models that simulate traffic flow by moving individual cars stochastically. The second class, which may be termed surface simulation models, will view the metropolitan area in terms of spatial surfaces (or layers) – rent surfaces, value surfaces, and various types of density surfaces – and will forecast how these surfaces change shape over time, using econometric estimation based on historical experience. The third class will be like current new urban economic simulation models, but will permit many more zones and will accommodate flexible aggregation. In first pass analysis, a model with fewer zones will be employed, and once the policy options have been narrowed down, a more disaggregated model will be used for more detailed comparison of the remaining policy options.

The new urban economic simulation models will provide forecasts that have less spatial detail than the other two classes of urban economic simulation model but, since they solve for market-clearing prices, their forecasts will have a coherence and consistency that the other two types lack. Consider, for example, the spatial labour market. Using adaptive expectations, the other two types of models will forecast the quantity of labour demanded at different locations and commuting patterns independently, which will lead to labour market imbalances that will somehow have to be resolved. The new urban economic models, in contrast, have location-specific wage rates adjusting to clear the labour market at each location. The greater coherence and consistency of the new urban economic simulation models will make the output easier to understand, but the computation of equilibrium prices increases run times substantially.

A new urban economic simulation model of the Los Angeles region, LA-Plan, is currently under development that represents the state of the art. It will combine geocoded data from many different data sources on a GIS platform, including the actual traffic networks with link congestion functions, satellite data at a spatial resolution of about 1 m^2 per pixel that can be used to estimate the coverage and height of buildings, census data on population by income-demographic-ethnic group and on jobs by NAICS code at the block level, the current input–output matrix across industries by NAICS code, up-to-date data on freight traffic, detailed spatial pollution emissions data for mobile and stationary sources, property value data from assessment records, comprehensive zoning data, etc. In the prototype model, these data will be aggregated into some one hundred zones. Each zone will have its own market for each type of labour, as well as rental and asset markets for floor area by quality and zoning category. An environmental module will map data on spatial pollution emissions into data on spatial pollution concentrations. Time will be divided up into periods. Between successive periods, profit-maximising conversions of structures will occur; in each zone, the stock of each structure type will be increased through construction and conversions from other structure types and vacant land, and decreased through demolition and conversions to other structure type and vacant land. Within each period and zone, markets will allocate floor area in each structure type across residential, commercial, and industrial land uses, consistent with zoning restrictions, as well as the different types of labour across industries, generating a derived demand for passenger and freight transportation. The populations of the various groups, as well as imports and exports by industry, will be forecast exogenously. Technical change will be incorporated by exogenous modifications to the production structure. To what extent agglomeration economies will be incorporated has yet to be determined. The conceptual strength of the model is that every detail is consistent with the theory of competitive general equilibrium, while its principal weakness is that most sources of economic growth are treated exogenously.

Conclusions

New urban economic simulation models have now come of age. The technology and the theory are now there to develop economically sound and consistent dynamic forecasting models of land use, transportation, and environmental quality in a metropolitan area, at a high level of spatial detail. These models can incorporate state-of-the-art network transportation models, as well as pollution emission and concentration models, can draw on data from many sources via a GIS system, and can display visual output using sophisticated mapping software.

See also: New Urban Economics and Residential Location.

Further Reading

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