Dynamic Analysis of the Urban Economy

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Foreword

One of the pleasures of being an economic theorist is the discovery that some new aspect of social life, superficially quite different from the explicit haggling of the marketplace, will actually yield to the methods of economic theory. I can remember enjoying that feeling when I first began to think about the geography of economic activity inside a city, and its codetermination along with the pattern of rents, transportation flows, and congestion. You do not have to be a pioneer to have this experience, although it helps to be a little ignorant of the literature. In this case, the tradition begins with von Thünen, and its most important contemporary representatives are Alonso, Beckmann, Mills, Mohring, Muth, Vickrey, and now Miyao.

Modern theoretical urban economics has been almost entirely a study of equilibrium configurations—patterns of residential and/or industrial location with the property that no one wishes to move. Professor Miyao has now added some explicit dynamics. This takes two forms. In the early chapters, and occasionally elsewhere, he is concerned with adjustment dynamics, the response of the model to displacements from the equilibrium pattern. Under some assumptions, he finds that the equilibrium is stable, and he is able to use stability conditions to do comparative statics in the manner of the Samuelson Correspondence Principle. In an interesting passage, he shows that other assumptions, especially those embodying externalities such as intergroup aversion or intragroup reinforcement, can result in a kind of instability. This is a lot like what is called neighborhood "tipping," and it is a merit of Miyao's analysis that it focuses attention on the parameters that govern the intensity of this instability.

In later chapters, Professor Miyao turns to a kind of equilibrium dynamics, rather like growth theory, and studies how an equilibrium city might evolve in response to exogenous forces, of which population growth is the most obvious example. Here, too, he finds a number of interesting results, including a sort of "golden rule" for transportation investment—perhaps not surprising in view of the analogy to growth theory.

I suppose the history of economic thought teaches us that where there is equilibrium, there is dynamics. What I find remarkable about the step that Miyao has taken is that he has had the imagination, ingenuity, and energy actually to find the dynamics in what must at first have seemed like an impenetrable thicket. Similarly, I remember being astonished, back in Professor Miyao's graduate-student days, that anyone should have the courage to attack a two-dimensional version of a problem that Vickrey and I had analyzed in one dimension. For the end result, a victory of clarity of mind, see Chapters 12 and 13 of this book.

When a complicated aspect of social life does yield to the methods of economic theory, a good theorist realizes that it rarely yields everything. The typical experience is that the first-order effects have the right sign, and the orders of magnitude accord with common observation. I think that such is the case with the "new urban economics" exemplified in this book. That is encouraging when it happens—certainly more encouraging than the opposite outcome!—and it gives one some confidence that the theoretical model may be useful in singling out the important effects and key parameters that govern the broad outlines of real phenomena.

Of course, the creative effort of serious application still remains. But even for the theorist there will—one hopes—always be interesting effects of more delicate order to be smuggled into the model and analyzed. Every reader of this book will have favorite examples. Someone who has recently moved from suburb to city, and likes much but not all of what he sees, might be interested in modeling "gentrification." Someone who has recently visited Memphis might be interested in modeling a city built on a river wide enough to be an effective residential barrier. I happen to fall into both categories. Professor Miyao might some day look into the statics and dynamics of transportation improvements that are highly localized and could thus possibly serve as a planning device. Good cookbooks encourage people to try their own recipes. So, as Julia Child says, "Bon appetit."

ROBERT M. SOLOW

Preface

This volume is intended to provide a dynamic analysis of economic activities in urban areas. The main theme of the book is dynamics, although related subjects such as existence, uniqueness, comparative statics, and optimality are also discussed. I believe that a dynamic analysis is urgently needed in urban economics because, despite growing interest in understanding the dynamism of urban activities, particularly from public policy viewpoints, most of the existing literature on urban economics has dealt only with determination and characterization of spatial equilibrium in static urban systems and thus has failed to shed light on the dynamic aspect of economic activities in and around urban areas. It might be said that, except for a few journal articles on urban growth and housing, the whole field of urban economics is still awaiting a systematic application of the dynamic method, which has been fully developed and widely used in economics.

In this book, I attempt to take a step toward a systematic treatment of the dynamic aspect of business and residential activities in the urban economy. The main purposes of this study are (1) to obtain some insight into the dynamic processes of complex urban relationships by constructing and analyzing simple dynamic models of the urban economy and (2) to contribute to the development of what might be called "dynamic urban economics" within the framework of general dynamic economics, as laid out by Samuelson, Solow, and others, and thereby provide a sound theoretical basis for understanding and predicting the dynamic processes of the urban economy. As it turns out, urban economics is a very fertile field for application of the conventional dynamic analysis that has been developed in connection with general equilibrium theory and economic growth theory. I hope that this book has reaped some good crops from the field and will serve as an example to show the richness of the area of dynamic urban economics.

The Introduction is a preview of my basic ideas about dynamics. Theoretical analyses of dynamic urban systems are given in the subsequent chapters. In Part 1 account is taken of the dynamic stability property of spatial equilibrium and its relation to comparative statics. The effects of various kinds of externalities on the dynamic property of the urban economy are discussed in Part 2. The long-run growth processes of the urban economy and their optimality property are presented in Part 3. In Part 4, the optimal size and configurations of an urban area in connection with agglomeration economies and traffic congestion are given.

This book grows out of my dissertation—submitted to the Massachusetts Institute of Technology in 1974—and my articles published in various journals. It is addressed primarily to colleagues in the field of urban economics and in other fields of economics. The book may also be used as supplementary reading in graduate urban economics courses. A reader who has some knowledge of calculus and linear algebra should be able to follow the main argument of this book. Familiarity with elementary set theory may be useful but is not required. References are given at the end of each chapter.

Acknowledgments

Throughout the course of my research, I have received helpful guidance and encouragement from my former thesis supervisor, Robert M. Solow, to whom I should like to express my deep appreciation. It also gives me great pleasure to acknowledge my intellectual debt to Paul A. Samuelson and Franklin M. Fisher, whose influence can be easily detected in this book. Thanks are due to Richard Arnott, Jan Brueckner, David Knapp, Edwin Mills, Leon Moses, Harry Richardson, Jerome Rothenberg, Perry Shapiro, and William Wheaton, who have given me comments and suggestions along the way. I must also acknowledge a debt of gratitude to my former teachers at Keio University, Yoshindo Chigusa and Masao Fukuoka, and to my friends, Koichi Hamada and Hajime Oniki.

Finally, special thanks are reserved for my wife, Mariko, whose cooperation and understanding made it possible for me to write this book.

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PART 4 CONGESTION AND AGGLOMERATION

Introduction

Cities are born to be dynamic. They are growing, changing, decaying, and redeveloping. Most people prefer urban life for its dynamic feelings, activities, and opportunities, which are not present in rural life. A city will lose its meaning and attractiveness when it becomes stagnant and motionless. In a sense, cities define themselves by their dynamism. In economic terms, one might define a city as a "settlement that consistently generates its economic growth from its own local economy (see Jacobs, 1970, p. 262)." There is no doubt that dynamism is one of the most important characteristics of urban processes and that no study of the urban economy could be complete without taking account of its dynamics and growth.

In this book we attempt to offer a dynamic analysis of the urban economy. The present work may be regarded as a straightforward application of well-established dynamic methods to urban economics for the purpose of analyzing the dynamic processes of urban economic activities. By using the conventional dynamic approach, this study is intended to contribute to the development of "dynamic urban economics" within the context of general dynamic economics in order to provide a sound theoretical basis for understanding the working of the urban economy.

As is well known, dynamic economics is meant to include two different, although closely related, types of analyses: the analysis of the dynamic stability property of equilibrium in a static economy and the analysis of the dynamic processes of a growing economy. The former might be called the "stability analysis" and the latter the "growth analysis." The stability analysis, developed in connection with general equilibrium analysis, assumes some adjustment mechanism to determine the dynamic paths of price or quantity variables toward an equilibrium in an economic system with given endowments of resources and technology, whereas the growth analysis offers the equation of dynamic motion for an economic system with its endowments of resources and/or technology changing over time. In this book, we are concerned with the both types of analyses as applied to urban economics.

It may be useful to illustrate how we apply the stability and growth analyses to urban location theory by using simple diagrams. First, our basic idea about application of the stability analysis can be seen in Fig. 1, where two "bid rent" curves are drawn in a monocentric city with its center at the origin. [For the concept of bid rent, see Alonso (1964).] The two bid rent curves represent the maximum rents which two groups of firms (or residents) can pay to landowners at each distance from the city center. As is well known, a group, say group 1, demanding relatively less land relative to marginal transport cost will have a steeper bid rent curve (AEB) than that (CED) of a group, say group 2, with relatively more demand for land relative to marginal transport cost. Since land should go to the highest bidder, at least in equilibrium, group 1 will occupy the inner segment of the city up to the distance x^* from the center, whereas group 2 will be accommodated in the outer segment of the city. As a result, the equilibrium market rent

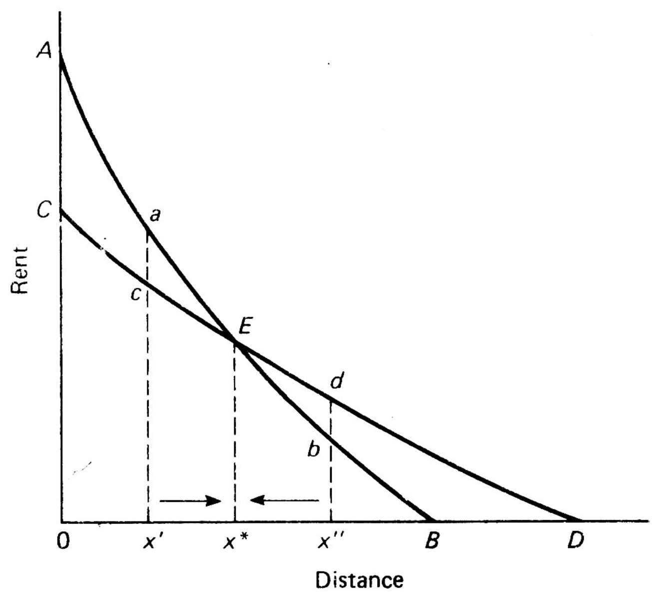

FIGURE 1

curve can be obtained by taking the upper envelope of the two bid rent curves, i.e., the curve *AED*.

Now, consider a disequilibrium situation with the initial position of the boundary between the two groups given arbitrarily, say at x', and the market rent curve represented by *AacED*. This means that group 1 is actually located between 0 and x', while group 2 is housed outside x', although between x' and x^* group 1 would be willing to pay higher rents than group 2 which actually occupies that segment of the city—a disequilibrium situation. Then it seems natural to suppose that some adjustment will take place so as to move the actual boundary between the two groups toward its equilibrium position x^*, as some members of group 1 take over the land area between x' and x^* gradually from group 2. For analytical convenience, we assume this takeover to occur continuously from x' to x^*.

If, on the other hand, the initial position of the boundary is given at x'', the market rent curve is represented by *AEbdD*, and the segment between x^* and x'' is occupied by group 1 and not by the highest bidders, i.e., group 2, for that segment of land. Then the actual position of the boundary tends to move in, continuously toward the equilibrium position, as some members of group 2 move into that segment gradually from x'' to x^*.

Thus, with the two bid rent curves as given in Fig. 1, the equilibrium boundary position seems to be dynamically stable, according to the dynamic adjustment process specified above. Our explanation so far, however, has been rather intuitive and based on partial equilibrium analysis, in that the position of the bid rent curves are fixed regardless of changes in the boundary position, which should actually affect the positions of the bid rent curves. It remains to be seen if dynamic stability can be established in a general equilibrium model which takes account of all direct and indirect effects of boundary changes during the course of dynamic adjustment. In subsequent chapters, we shall rigorously prove the dynamic stability property of spatial equilibrium in general equilibrium models of urban location with many groups of firms and residents.

Let us turn to the growth analysis as applied to urban location theory. Here again, we use a simple diagram to illustrate the main point of our argument. In Fig. 2, there is a monocentric city which is occupied by only one group of firms (or residents) and no alternative use of land is assumed for the sake of simplicity. At time 0, the group's bid rent curve, which is also the market rent curve, is given by the curve *AB* and the outer boundary of the city is located at x^0, where the opportunity cost of land is assumed to be zero. As time passes, the city may be changing in terms of its population, transport cost, demand for its output, etc. As a result, the market rent curve may shift inward or outward, depending on the direction of changes in those factors.

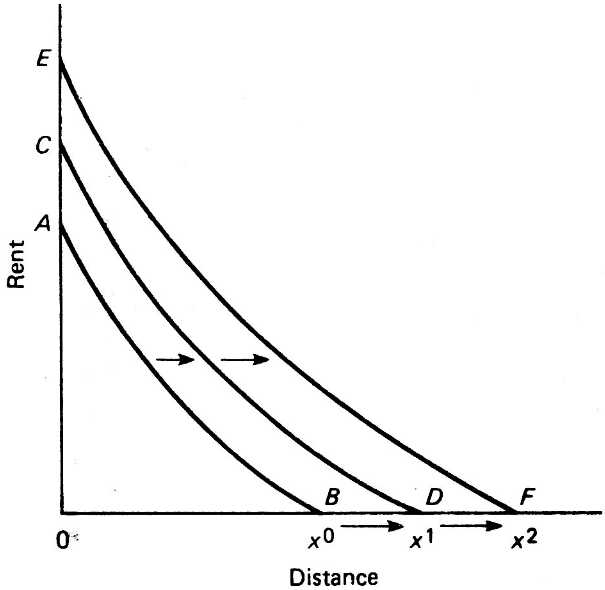

FIGURE 2

Specifically, an increase in total population coupled with a decrease in unit transport cost, say, due to social investment in urban transportation, will lead to an outward shift in the position of the market rent curve, as depicted in Fig. 2. This occurs because the reduced cost of transportation will enable existing firms (residents) to pay higher rents for each location and competition with new firms (new residents) will force them to do so. Thus, in Fig. 2 the market rent curve shifts outward from *AB* at time 0 to *CD* at time 1, and then *EF* at time 2, and correspondingly the city expands in size from x^0 to x^1, and then to x^2.

It is natural to ask whether the urban growth process as described can continue for a reasonably long period of time. As it turns out, we are able to construct simple models of urban growth, in which the total land area and the total population of the city along with other factors, if any, are growing steadily at the same rate, and such a steady-state balanced-growth equilibrium can be sustained indefinitely, given the availability of open space for the steady expansion of the urban area. In the following chapters, we shall examine the existence, uniqueness, and stability properties of a balanced growth equilibrium and explore the optimality property of such a growth path by applying the ordinary method used in economic growth theory.

Having explained our basic ideas about dynamic analysis, we are now in a position to give an overview of the main contents of the book. There are four parts on theoretical studies of urban systems with special emphasis on dynamics, growth, and agglomeration.

In Part 1, we investigate the dynamic stability property of spatial equilibrium and its relation to comparative statics in urban location models. In Chapter 1, the dynamics of industrial location is studied by setting up a production location model of the von Thünen type with many industries and introducing dynamic adjustment processes of wages and industrial boundaries. Local stability of spatial equilibrium is proved and some comparative static results are obtained. An application of the LeChatelier principle is also explored. In Chapter 2, we derive some dynamic and comparative static results in a residential location model of a closed city with many classes of households, where the city is closed in the sense that the number of households in each class is fixed exogenously, while their utility level is determined endogenously. In Chapter 3, an urban location model with both production and residential activities is presented in order to take account of the interaction of industrial and residential locations. A simple model with one industry and one household class is used to illustrate how their interaction complicates conditions for dynamic stability of spatial equilibrium. In Chapter 4, dynamics and comparative statics are considered regarding an open city in which the level of utility is exogenous while the size of each household class is endogenous, in contrast to the closed city model in Chapter 2.

In Part 2, various kinds of externalities are introduced into urban location models, and we examine how the presence of externalities affects the dynamic property of the urban economy. Our results point to the fact that certain types of externalities will weaken, if not totally destroy, the stable nature of the urban economy. Neighborhood externalities among two groups of residents are considered in Chapter 5, and we prove that an interior equilibrium with two groups coexisting in the city may be stable *or* unstable, according as the degree of externality is relatively small *or* large. In Chapter 6, we develop a general model of probabilistic location choice by many types of residents who interact among themselves in the presence of neighborhood effects. The existence, uniqueness, and stability of an equilibrium are rigorously proved. The equilibrium is shown to be stable *or* unstable, depending on whether the degree of externality is relatively small *or* large, just as in Chapter 5. In Chapter 7, we focus on production externalities such as air pollution in a simple model of an open city with both production and residential activities. If utility functions and production functions are Cobb–Douglas, an equilibrium exists, but its uniqueness and stability may or may not follow, depending on the degree of externality, as in the previous chapters.

In Part 3, urban growth models which incorporate both spatial elements and growth factors explicitly are developed to study the long-run growth