CHAPTER 1

Introduction

1.1 Nature of the book

The history of cities is almost as old as that of civilization. Cities have been centers of wealth and power, innovation and decadence, dreams and frustrations. During the past several decades, many countries have experienced rapid urbanization. As a consequence, a large proportion of the world's population now resides in cities. Yet cities are among the most complex human creations, and in many ways the least understood. This became dramatically clear with the eruption of urban problems throughout the world starting in the late 1950s. Since that time, a great number of scientists in various fields have endeavored to develop a better understanding of cities. With respect to economics in particular, these urban problems have triggered the birth of a new field, namely *urban economics*.

Modern urban land use theory, which forms the core of urban economics, is essentially a revival of von Thünen's theory (1826) of agricultural land use. Despite its monumental contribution to scientific thought, von Thünen's theory languished for more than a century without attracting the widespread attention of economists.[1] During that time, cities grew extensively and eventually outpaced the traditional concepts of urban design. The resulting rise in urban problems since the late 1950s has manifested an urgent need for a comprehensive theory of modern urban systems and, in particular, has helped to refocus the attention of location theorists and economists on the seminal work of von Thünen. Following the pioneering work of Isard (1956), Beckmann (1957), and Wingo (1961), Alonso (1964) succeeded in generalizing von Thünen's central concept of *bid rent curves* to an urban context. Since that time, urban economic theory has advanced rapidly, inspiring a great deal of theoretical and empirical work. Prominent among the efforts in this area are the works of Muth (1969), Mills (1972a), Henderson (1977), Kanemoto (1980), and Miyao (1981), to name a few.[2] The central purpose of this book, together

with the planned second book, is to present in a unified manner the state of the art of the economic theory of urban land use and city size, including both positive and normative aspects of the theory.

In most Western societies, land is allocated among alternative uses mainly by means of private markets, with more or less public regulations. In such societies, the current spatial structure of a city is thus the outcome of billions of individual actions taken in the past. Hence, one might suspect that the outcome of such unregulated individual actions would be near chaos. However, the history of science suggests to the contrary that the larger the number of individual actors in a system, the stronger are the regularities it will exhibit. Indeed, many studies have revealed that strong regularities exist in the spatial structure of different urban areas. The task of *positive theory* is to provide explanations for these regularities and to suggest testable hypotheses for further investigation. We will not, however, be content with the mere confirmation of regularities. The existence of regularities does not necessarily imply that the given spatial structure of a city is a desirable one. Hence, we shall also be interested in *normative theory* for identifying the efficient spatial structure and size of cities, and for suggesting means of achieving them. This viewpoint was eloquently expressed by Lösch (1954, p. 4): "No! The real duty of the economist is not to explain our sorry reality, but to improve it. The question of the best location is far more dignified than the determination of the actual one."

The theory of urban land use and city size is an especially appealing topic of study because much of traditional economic theory cannot be readily applied. Although traditional economic theory aptly describes competitive markets typical of most Western societies, it is essentially designed to deal with spaceless problems. Hence, many of the basic assumptions of this theory are no longer appropriate for spatial problems such as land use. First, one generally finds empirically that households, as well as many firms and government agencies, choose one and only one location. As will be explained in the next section, this implies, in the terminology of traditional economic theory, that there is a strong *nonconvexity* in consumers' preferences and production technologies. Second, since the essence of cities is the presence of many people and firms in close quarters, *externalities* are a common feature. Public services, noise, pollution, and traffic congestion all involve externalities. Moreover, the necessity of nonprice interactions such as information exchange through face-to-face communication is one of the major reasons that people and firms locate in a city. Third, the existence of distance among cities implies that the producers of local goods (both public and private goods) can enjoy a monopolistic situation. The same is true for producers

of neighborhood services within each city. Hence, *oligopolistic* or *monopolistic competition* is a common feature of urban markets. Finally, buildings and other urban infrastructures are among the most durable of all human products, and this limits the usefulness of classical static theory. Because many spatial phenomena such as urban sprawl and renewal can be treated in a satisfactory way only within a *dynamic* framework, we must eventually combine urban land use theory with capital theory. Clearly, the city is fertile ground for economic study.

1.2 Bid rent function approach

This book aims not only to summarize the main results of existing theory, but also to present them in a unified manner. For this purpose, we adopt the *bid rent function approach*, which was introduced into an agricultural land use model by von Thünen (1826) and later extended to an urban context by Alonso (1964). This approach is essentially the same as the *indirect utility function approach*, which was introduced into an urban land use model by Solow (1973). Hence, it is also closely related to the *duality approach* of modern microeconomics.

The main focus of urban economic theory is, of course, land. But in economic terms, land is a complex object endowed with dual characteristics. First, land is a *commodity* in the usual economic sense. But, second, unlike other commodities, land is completely immobile. Hence, each piece of land is associated with a unique *location* in geographical space. These dual characteristics of land induce strong nonconvexity in consumers' preferences (as in production technologies). In particular, each household generally chooses to reside at one and only one location. This implies that the preferences of each household exhibit strong nonconvexity. To understand this, let us consider land consumption at two possible locations. If the consumption of all other goods is fixed, then Figure 1.1 describes the consumption space for a household, where s_1 and s_2 represent the consumption of land at location 1 and location 2, respectively. Hence, if at each given land price ratio R_1/R_2 the household never consumes land at both locations, this implies that its indifference curves must exhibit some concavity, as in Figure 1.1.[3]

In order to avoid the mathematical difficulties associated with this nonconvexity in preferences, we shall follow traditional location theory by adopting two convenient assumptions.[4] First, it is assumed *a priori* that each household chooses one and only one location. Hence, the consumption space for each household can be defined separately at each location in terms of the consumption of land at that location together with the consumption of all other goods. Second, the number of households

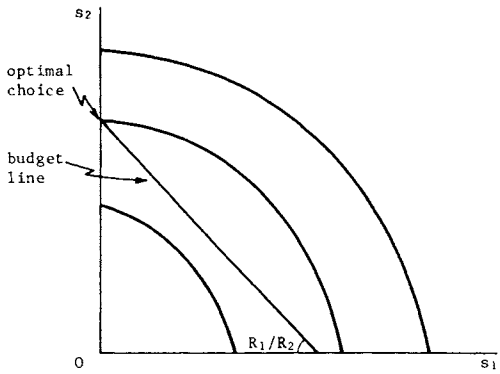


Figure 1.1. Concave indifference curves and the choice of a single location.

of each type is assumed to be so large that their distribution throughout the city can safely be represented in terms of a density function.[5] These two assumptions enable us to employ the bid rent function approach in determining the equilibrium location of each household as well as the equilibrium and optimal land use patterns of the city. A bid rent function essentially describes a particular household's ability to pay for land (at each location) under each fixed utility level. This function can be considered to be a transformation that maps indifference curves in consumption space into corresponding indifference curves in urban space (with dimensions of location and land rent), that is, *bid rent curves*. Given these indifference curves defined in urban space, one can graphically analyze the locational choice of the household. Moreover, since bid rent curves are defined in terms of monetary bid per unit of land, they are comparable among different land users. We will therefore be able to analyze competition for land among different agents, again graphically in urban space. Mathematically, it turns out that the bid rent function is the inverse of the indirect utility function (also of the expenditure function). Therefore, one can also use the powerful tools associated with these functions in modern microeconomics. Hence, not surprisingly, with this approach one can develop modern land use theory not only more rigorously but also more simply than with traditional methods.

1.3 Scope and plan of the book

The scope of this book is limited to the *static* theory of *residential* land use and city size. Namely, in the context of the standard monocentric city

model, we examine the *stationary* (or *long-run*) equilibrium and optimal patterns of residential land use under a given set of time-invariant data.[6] The extensions of the theory to a general equilibrium framework (i.e., simultaneous determination of location of both households and firms) and to a dynamic framework will be considered in the planned second book referred to in the Preface.

In particular, this static approach assumes that both the land price P (i.e., asset price of land) and land rent R per unit of land at each location are *constant* over time. Hence, provided that land can be used for urban purposes without additional cost, it follows that land price is always related to land rent by the simple identity,

$$P = \int_0^\infty e^{-\gamma\tau} R \, d\tau = \frac{R}{\gamma}, \tag{1.1}$$

where γ is the time discount rate (or interest rate), which is assumed to be common for all market participants. Hence, in this book we focus only on the equilibrium pattern of land rent R.

The main body of the book consists of two parts. Part I develops the basic theory of residential land use and city size within the context of a monocentric city in the absence of externalities. This part consists of four chapters, which can be briefly summarized as follows.

In Chapter 2, a simple, *basic model* of residential choice is introduced. The *bid rent function* and (bid-max) *lot size function* are defined. The relationship between these functions and the relevant concepts of standard microeconomics (i.e., indirect utility functions, expenditure functions, and Marshallian and Hicksian demand functions) is explained. By using the concept of *bid rent curves*, we examine how the equilibrium location of the household is determined in the city. We also examine the relative locations of households having different bid rent functions. In the second half of Chapter 2, we extend the basic model by introducing the time cost of commuting as well as differences in family structure. We also introduce the Muth model of housing industry.

In Chapter 3, we assume that all households in the city are identical. Under this condition, we first examine the *equilibrium structure* of residential land as determined through a competitive land market. Depending on the specification of migration possibilities and the form of landownership, we consider the following four market models: (a) the closed-city model under absentee landownership, (b) the closed-city model under public landownership, (c) the open-city model under absentee landownership, and (d) the open-city model under public landownership. For each case, the existence and uniqueness of equilibrium are explained by means of a

constructive graphical method based on the concept of *boundary rent curves*. We then consider the case of the closed-city model under absentee landownership and, by using the same boundary rent curve approach, study graphically the *comparative statics* of equilibrium spatial structure in terms of population, transport cost, income, agricultural rent, and land taxation and zoning.

Next, we study the *optimal allocation* of residential land and households within the city, and examine the relationship between the optimal land use and equilibrium land use patterns. The optimal land use problem is formulated in terms of the *Herbert–Stevens model (HS model)*. We show that by appropriately changing the two parameters (target utility level and population) of the HS model, we can obtain the equilibrium solution for each of the four market models by solving some HS model. From this, we can conclude that in the present context, land use equilibria are always efficient. Finally, we return to the Muth model of housing industry and examine changes in land use intensity in the city.

In Chapter 4, we extend the analyses of Chapter 3 to the case of a city with multiple household types. We focus mainly on the closed-city model under absentee landownership.

Having examined the spatial structure of cities in the previous three chapters, we turn our attention in Chapter 5 from spatial structure to *urban aggregates*. That is, within the same context of monocentric cities, we examine the relations among urban macrovariables such as the population, total income, total land rent, and total transport cost for a given city. The concepts of *population supply functions* and *population cost functions* are introduced. We also discuss the *causes of city formation* and examine the *equilibrium and optimal city size* in various contexts. This chapter thus provides a connection between urban land use theory and city-system theory.

In Part II, we extend the basic theory of Part I by introducing various kinds of externalities. This development involves three separate chapters, which can be summarized as follows.

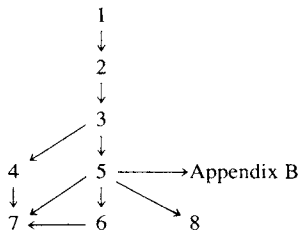
In Chapter 6, we introduce local public goods and examine how to achieve the efficient provision of these goods among cities or within a city. We consider four kinds of local public goods: *pure city goods*, *congestible city goods*, *neighborhood goods*, and *superneighborhood goods*.

In Chapter 7, we focus on the *negative externalities* that arise as consequences of interactions among households themselves. In particular, we consider three types of such externalities: *crowding externalities*, *racial externalities*, and *traffic congestion* associated with commuting. In the presence of each type of externality, we examine the *first-best policies* and various *second-best policies* for enhancing the efficiency of land markets.

Finally, in Chapter 8, we examine the roles of *external economies* and *product variety* in city formation. In particular, we develop the *external economy model* and the *monopolistic competition model* of urban agglomeration and examine the relationship between the two models. We show that the urban aggregates derived from the two models have the same structural relationship. Thus, from the viewpoint of descriptive analyses of urban aggregates, the monopolistic competition model can be considered to be a specific example of the external economy model. However, from the viewpoint of normative analyses, the two models lead to substantially different results. Thus, in empirical implementations of these models, it is essential to identify which model more closely represents the actual city economy.

Three appendixes follow the main text. In Appendix A, we review some of the basic mathematical concepts and results from consumer theory that have been used in the text. Appendix B is an extension of Chapter 5. In this appendix, we show that under a set of reasonable assumptions on transport cost function and land distribution, a simple general relationship holds between the total transport cost and total differential rent of a city. Appendix C provides proofs for some of the results in the text.

Finally, the logical structure of this book is summarized in the following diagram:



Notes

1. For an excellent appraisal of von Thünen's achievements from the viewpoint of modern economic theory, see Samuelson (1983), who states that "Thünen belongs to the Pantheon with Leon Walras, John Stuart Mill, and Adam Smith" (p. 1482).
2. For an early history of the development of urban economic theory, see, e.g., Alonso (1964, Ch. 1). For recent developments in urban economic theory, see the survey articles by Richardson (1977a), Anas and Dendrinos (1976), Wheaton (1979), Fujita (1986a), Wildasin (1986b), and Miyao and Kanemoto (1987) and the survey articles in Mills (1987).
3. Recall that in the traditional literature of general equilibrium analysis (e.g., Debreu 1959; Arrow and Hahn 1971), economists have treated land as just

another commodity by attaching a locational index to it. A drawback of this approach is that one can no longer assume that preferences of consumers (and technologies of firms) are convex in the entire consumption space (as illustrated in Figure 1.1). This drawback was pointed out, for example, by Malinvaud (1972, p. 22) and Hildenbrand (1974, pp. 83–4).

4. Recall that in a finite economy, nonconvexity of preferences will cause possible nonexistence of competitive equilibria.
5. For a mathematical justification of this *density approach* (or *continuous population approach*), see Asami, Fujita, and Smith (1987) and Papageorgiou and Pines (1987). In essence, we regard this density model as a mathematical device for approximating the solutions of appropriately defined discrete population models, when the number of individuals is sufficiently large. Berliant (1984, 1985a, b), Berliant and Dunz (1987), and Berliant and ten Raa (1987) have proposed an alternative approach, called the *discrete population approach*, in which each consumer is assumed to occupy a subset of two-dimensional Euclidean space. Although the latter approach is theoretically more satisfactory, it involves enormous mathematical complexity. We will compare the two approaches in our planned second book.
6. Pedagogically, of course, it is preferable to study static theory before introducing complications due to time. Moreover, when a city is growing relatively slowly, static theory can effectively describe the equilibrium spatial configuration of the city at each point in time.

PART I

Basic theory

CHAPTER 2

Locational choice of the household

2.1 Introduction

Any household that moves to a city and has to choose a residence is faced with a complex set of decisions. We can view this situation as a trade-off problem, in which there are three basic factors: accessibility, space, and environmental amenities.

Accessibility includes both pecuniary and time costs associated with getting to and from work, visiting relatives and friends, shopping, and other such activities. The space factor consists of the need for some land as well as the size and quality of the house itself. Finally, environmental amenities include natural features such as hills and scenic views as well as neighborhood characteristics ranging from quality of schools and safety to racial composition.

In making a residential choice a household must weigh all three factors appropriately, yet also meet budget and time constraints. For example, a location with good accessibility usually commands a high price for space. So the household may have to sacrifice space for accessibility. Accessible locations, however, are typically lacking in environmental quality. Thus, the household also confronts a choice between accessibility and environment.

Even though in actual practice all three factors are important for making a residential choice, when constructing theory it is difficult to treat all factors at once. Following the time-honored wisdom of theory building, we shall begin by studying a pure case and expand the framework later on. Part I examines the trade-off between accessibility and space in residential choice. Part II introduces environmental factors.

2.2 Basic model of residential choice

The development of our understanding of residential land use begins with the basic model, which focuses on the trade-off between accessibility and