HOUSING MARKET BEHAVIOR WITH RESTRICTIVE LAND SUPPLY

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Submitted to the Department of
Urban Studies and Planning in Partial
Fulfillment of the Requirements for the
Degree of

Doctor of Philosophy
in Urban and Regional Studies

at the

Massachusetts Institute of Technology

October 1993

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Abstract

This thesis examines, both theoretically and empirically, the effects of land supply restriction on housing price and housing production. The analysis is conducted in the context of a closed city, where any increase in population must be accommodated within the market.

The theoretical part of the analysis extends the urban spatial theory by including natural and contrived land supply restrictions in a range of monocentric models. It reveals that a restriction on land supply increases housing prices by suppressing household space consumption rather than by reducing housing production. In equilibrium, housing densities and prices will be sufficiently high to ensure that enough housing units will be produced to accommodate the population. The analysis also identifies for the first time that the impact on the housing market of a temporary restriction on land use can be very different from that of a permanent reduction in land supply.

Incorporating the insights yielded from theoretical analysis, an improved stock-flow model is developed in which land supply is explicitly included in housing price and production functions. Empirical tests based on data from Hong Kong have confirmed the above relations between land and housing. Specifically, restrictive land supply is found to raise expected price appreciation but have no direct effect on the production of new housing units. The analysis also shows that the market response to changes in land supply is rational and can be understood in the framework of the perfect-foresight model of urban growth. Given the planned change of government in Hong Kong in 1997, this study provides a background to evaluate and predict the likely consequences of changes in land policy.

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Acknowledgements

I would like to thank my thesis supervisor, William C. Wheaton, for his guidance throughout the development of this work. I benefited at every step during this research from his knowledge, experience and insightful suggestions. Many thanks are due to Jerome Rothenberg and Karl E. Case for serving on my thesis committee and for their many invaluable comments.

I am grateful to Bertrand M. Renaud of the World Bank for initiating the thesis topic to investigate the effects of government land sale on the housing market in Hong Kong, for his many comments on this work, and for his help in developing my interest in this field. I would like to thank Ronnie Chen and his colleagues at Hanglong Investment Ltd. of Hong Kong for their help in obtaining related data, and the Rating and Valuation Department and the Lands and Building Department of Hong Kong for providing data for this research.

I acknowledge my special gratitude to Lloyd Rodwin, whose encouragement and recommendation led to my enrollment in the Ph.D. program at M.I.T. Lloyd has overseen my development ever since and has made many comments on this dissertation. I would like to express my deepest appreciation to Karen R. Polenske, my academic advisor, for her guidance throughout my Ph.D. study. Karen has been a special friend who not only enhanced my academic achievement but enriched all aspects of my life. I would like to thank other faculty members and friends in the School of Architecture and Planning at M.I.T. and the Joint Center for Housing Studies at Harvard University, especially William C. Apgar, Jr., Lawrence Bacow, Denise DiPasquale, Reinhard K. Goethert, Langley C. Keyes, Jr., Nancy McArdle, and Rena Sivitanidou for their help and encouragement at various stages during my graduate study. I gratefully acknowledge my appreciation to Mrs. Robert B. Newman for her friendship, encouragement and hospitality.

I would specially like to thank the Ministry of Education of China for the scholarship that enabled me to pursue graduate study in the United States. I am grateful for the World Bank Graduate Scholarship which supported me during the first few years of my enrollment in the Ph.D. program. Also, I thank the Joint Center for Housing Studies of Harvard University for its generosity throughout this work.

Finally, I am grateful to my husband, Xing Chen, whose unfailing help and support enabled me to complete my degree. I would like to dedicate this dissertation to my parents Zhixiang Yuan and Wangchong Peng, and to my daughter Sway P. Chen.

October 1993

Ruijue Peng
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Chapter I

Introduction

The relationship between housing and land is what distinguishes housing commodities from other goods and services in the economy. Empirical evidence to date has conclusively established that a shortage of land supply raises housing prices. Although a number of markets suffer from land shortage, there has still been no systematic economic analysis on the effects that a restricted land supply can have on the housing market. The objective of this dissertation is to investigate the behavior of the housing market with a land shortage to understand how a land supply restriction is translated into higher housing prices and to what extent the aggregate housing demand and supply are affected by the land supply.

An excellent example of a housing market subjected to a strong land supply restriction is Hong Kong. As a city state, its boundary is fixed. The city is known for its crowded living conditions and skyrocketing housing prices. More than half of the total housing stock is small flats with less than 50 square meters (556 square feet), and 85% of the stock is less than 75 square meters. Combined with an average household size of 4.3, the crowding is obvious. The price for a typical 50 square meter flat was around HK$390,000 (about US$50,700) in 1986, 6.3 times the median
household income in that year. Given that a price-income ratio of 3 is generally considered to be the threshold for affordability, housing in Hong Kong is obviously very expensive. In addition to the natural restriction, the land supply in Hong Kong is also subject to contrived restrictions. Due to its colonial past, the government of Hong Kong owns practically all the land in the territory. As a consequence the government has special powers in regulating land use: it determines when and how much new land will be put on the market for various uses. These natural and contrived restrictions on land supply make Hong Kong a good case for studying housing market behavior under conditions of restrictive land supply.

In Hong Kong, the influence of land supply on housing is obvious. Figure 1.1 shows the annual sale of land for private housing during the period 1964-1990. The variation in housing prices during the corresponding period is shown in Figure 1.2. A clear correlation can be observed: a decrease in land sales increases housing prices in the subsequent year, while an increase in land sales leads to reduced housing prices. An argument often used to explain such a negative correlation between housing prices and the supply of new land is that reducing land sales prevents developers from getting the land they need, which in turn reduces the production of housing and pushes up the price of housing. An empirical analysis of Hong Kong, presented later in this dissertation, shows, however, that a reduction in land sale does

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1 Housing price is estimated based on the average price for Type B units (40 - 59 square meters) derived from the Property Review of Hong Kong's Rating and Valuation Department. Median household income is estimated based on the income distribution of households in the 1986 Bi-Census.
Figure 1.1

Land Sales for Private Housing

Thousands of Square Meters


Figure 1.2

Percentage Change in Real Housing Prices

not reduce the production of new units but instead raises housing prices significantly. Therefore, the increase in housing prices is not a result of a housing shortage. This apparent discrepancy has raised an important question in the economics of housing. How is this housing market affected by land supply?

This dissertation presents a formal analysis of the operation of the housing market under a condition of restrictive land supply within the context of a general market equilibrium. The analysis consists of two parts. The first part extends the urban spatial theory by including land supply restrictions in a range of monocentric city models. The analysis shows that in a closed city where population increase must be accommodated within the market, a land supply restriction suppresses household space consumption and increases the willingness of each household to pay for space. Due to the unique nature of land, higher housing output can be brought forth through greater intensity of land use, i.e., higher density, as long as prices are high. Because the demand for housing, especially for housing units, is inelastic relative to other demands, in market equilibrium the production of housing will not be reduced but the density and prices will be higher.

The theoretical model also shows that in a housing market with perfect foresight, the effects of temporary controls on land use can be very different from those of a permanent reduction of land supply. The key element of a perfect-foresight model is the anticipation of future market conditions, thus allowing for calculation of housing prices or the present value of all the expected future rents. For a given set of expected market conditions, there exists a unique development pattern in which land
use is efficient and the prices are maximized in all locations. When the land use deviates from the efficient pattern but there is no change in the aggregate land supply, housing prices decrease everywhere. When the disturbance results in a reduction in total land supply, i.e., the restriction is permanent, then prices increase in all locations. This difference has never been distinguished before.

Incorporating the insights from this theoretical modeling, the second part of the dissertation develops a macroeconometric model for empirical analysis, in which the flow of land supply is included as a variable in both the housing demand and supply. When applied to the housing market of Hong Kong, the model helped to empirically identify the channel through which land supply affects the housing market. Specifically, restrictive land supply is found to raise the expected price appreciation but has no direct effect on the production of new housing units, a result consistent with the theoretical analysis. This demonstrates that land supply is not a determinant of housing supply, and that it affects the housing market through housing demand rather than housing supply.

The empirical results also suggest that changes in land supply were perceived by the market as permanent in Hong Kong. The result is understandable considering the government's monopoly control over land supply. Because there was no consistent long-term policy on land, the market uses land sales as an indicator of the government's land policy. A reduction in new land for housing is regarded as showing that the government intends either to restrict land use in the near future or to reduce the share of land for housing. Since only events in the foreseeable future are
meaningful to the market, even a delay of land use for a finite but sustained period is equivalent to a theoretically "permanent" land reduction. Therefore, the reaction of the housing market is rational.

Including this introduction, the thesis consists of seven chapters. Chapter II begins by reviewing the land system of Hong Kong. Because of the colonial history, the government of Hong Kong owns all the land in the territory and leases land to private developers. A direct consequence of this system is the government’s monopoly control over land supply. Evidence suggests that the government’s policy on land supply is greatly influenced by factors other than market forces.

Chapter III reviews the existing theoretical and empirical literature on related subjects. Contemporary urban spatial theory is largely built upon a family of so-called monocentric city models. In a typical monocentric city model, the supply of land is regarded as elastic. Any increase in the demand for land for a particular use can bring forth additional supplies by outbidding other uses. While land use control is considered in some recent efforts at modeling, it is analyzed in the context of an open city with fixed lot size. An analysis of a closed city with a restrictive land supply is not yet available.

Most empirical evidence on the impact of supply restriction is derived from partial equilibrium analysis. By using hedonic price equation and micro data sets, the objective is to identify the implicit price attributable to supply restriction rather than to explain the operation of the market. Macroeconomic housing research on market operation, on the other hand, uses a stock-flow model. To date, no stock-flow based
analysis has been able to handle the connections between the housing market and the land market. Existing econometric estimations based on the stock-flow model often include land prices as factor costs in housing production. It is assumed that high land prices reduce the profitability of construction and therefore the output of production. This assumption, however, is conceptually misleading. Economic theory has long suggested that land prices are largely determined by demand factors. High housing prices cause high land prices, not vice versa. From the review of the literature it is obvious that existing theory and empirical research are unable to explain a housing market like that of Hong Kong.

Chapter IV presents theoretical modeling of urban growth with restricted land supply in the context of a closed city. Starting with a static monocentric city model, the impact of a natural restriction on urban density and land prices is first examined. Since the population is exogenous, a greater intensity of site use must be allowed. As a result, a fixed city boundary restricts only space consumption rather than the number of households. As space consumption is restricted, the marginal substitution rate of land is higher, and so are the bids on rent for land.

The contrived supply restriction is then examined in the framework of the dynamic monocentric model. Assuming that the market is operated under perfect foresight and that supply restriction is presented as an unexpected event, the model shows that only future density is affected. While the built urban structure is unchanged, future rents for existing structures must adjust. Hence prices in the entire city are affected. In particular, this analysis identifies for the first time that the
effects on prices of a temporary growth control can be very different from the effects resulting from a permanent control.

Chapter V presents an empirical analysis of the housing market in Hong Kong. The housing market in Hong Kong provides a good case study for two reasons. First, it is a closed city with a severe natural restriction on its land supply. Second, the supply of new land is under the monopoly control of its government. Because the flow of land supply is exogenously determined and can be easily quantified, it is possible to trace its consequence. In addition to the restrictive land supply, the housing market in Hong Kong also has a huge public sector. The impact of public housing has been significant.

Incorporating the uniqueness of the housing market in Hong Kong, an econometric model is developed for empirical analysis. The model is a variation on the stock-flow approach but contains several innovative features built upon insights gained from the theoretical modeling. First, the quantity of new land supply is included in the demand equation. The assumption is that the amount of the supply of new land affects the expected price appreciation. Second, land price is excluded from the production function of new units whereas the quantity of land supply is included. The purpose is to test whether land has any separate effect on housing production when the effect of prices is controlled. Finally, the model concentrates on the private sector and includes the public sector via the effect of stock.

Following a discussion of the data series, estimated results are presented along with an analysis of their implication. As summarized above, restrictive land supply is
found to raise expected price appreciation but have no direct effect on the production of new housing units. Income elasticity is higher while price elasticities of demand and supply are within the range of other estimates. Overall the results are consistent with urban spatial theory.

To test the robustness of the empirical model, Chapter VI presents forecasts based on various assumptions about future policy on land supply. In the light of the return of Hong Kong to China in 1997, understanding how the market can be influenced by different land policy is of particular importance. With everything being equal, the forecasts show that a restrictive policy on land supply lifts housing prices and spurs the production of private housing units, whereas a "pro-growth" policy lowers housing prices and dampens housing production. But the change in housing production then sends a secondary signal to the market by changing total housing stock, which can also be important in determining future prices and production.

Chapter VII concludes the dissertation by summarizing the major results and their implications.
Chapter II

Background: Hong Kong's Contrived Land Supply

As mentioned in Chapter I, the supply of land in Hong Kong suffers not only from natural limitations but also from contrived restrictions. To understand the capacity of the government of Hong Kong to regulate land use, one has to know about its land tenure system. This chapter reviews briefly Hong Kong's land tenure system and its implications for the practice of controlling land supply.

II.1 The Land Tenure System and Land Supply

The territory of Hong Kong consists of three parts: Hong Kong Island, Kowloon Peninsula, and the New Territories. In the last century, the British government seized the freehold of Hong Kong Island and Kowloon Peninsula and a 99-year leasehold over the New Territories from the Chinese government. Since then, the Hong Kong government, acting on behalf of the British government, has maintained a policy of retaining the freehold of the ceded territories and a 99-year leasehold over the New Territories.

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2 For a detailed introduction to the land tenure system see Hadland (1978), Bristow (1984), and Leung (1986).
reversionary interest in the leased territories. Therefore, all land sold by the government is subject to a lease term.

The length of a land lease depends on the vintage of the land lease and on the location of the given land parcel. Lands on the Island leased in the 19th century generally carry a 999-year lease. All privately-held lands in the New Territories were leased for a period of 99 years, beginning on July 1, 1898. Most other lands carry a 75-year lease, which may be renewed for another 75 years upon payment of a premium.

To obtain a lease term, the grantee pays a lump sum premium and an annual rent. The annual rent is normally a nominal sum and bears little or no relationship to the actual value of the land. Even for sites selling for hundreds of millions of Hong Kong dollars, the annual rent is merely HK$1,000 (about US$130) per lease. The rent requirement is primarily a legal symbol to maintain the lessor and lessee relationship. As the amounts of rent are negligible, in practice the premium paid for a piece of land represents the aggregate of its annual rental values for the term of the lease. Given the usual length of the lease, the market premium attached to any given land lease approximates the respective land value. In 1990, the average premium for all types of land sold on Hong Kong Island through auction or tender deal was about HK$41,906 per square meter, which approximates US$490 per square foot. Most of the leases are transferable and the land market is in fact a market of land leases.

There are three main methods of land disposal in Hong Kong. They are
public auction, tender sale, and private treaty. The government's basic policy is to sell leases to the highest bidder at public auction. All land available to the general public for ordinary use is sold in this way. The government announces the land sales twice a year for both auction and tender sales and publishes the general and special conditions, including restrictions on users and other development conditions. The auction procedures are very similar to those in the private sector. Auction sales are generally subject to reserve prices and the land is withdrawn if the reserve is not reached.

Where the specified use has a limited market and the sale is unlikely to attract general interest, or where the government wishes to examine in advance detailed proposals for the development of a particular lot, or to scrutinize the background and capability of the developer to ensure that the development meets with all government requires, tender sales are usually adopted.

Land for special uses such as public housing, public utilities, schools, churches, temples, clinics, welfare, and certain other purposes is usually granted by private treaty and, in such cases, the premium charged varies from nothing for non-profit-making groups up to the full market value for public utilities.

The share of each means of disposal fluctuates greatly from year to year. In

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3 In addition to the three methods of disposal, until 1981 there was a tendering system in force involving letters A and B. Since 1960, when land was required within an area covered by an approved layout plan, the policy was to give the lessee the opportunity to surrender the land in exchange for the right to be granted government land at some future date. From time to time the government would put up lands in the New Territories for those who held a Letter A or B.
In 1988, auction or tender sales accounted for 63% of the total land released by the government. In 1989, only 21% of the land was sold through auction or tender deal but this figure increased to 54% in 1990.

Because revenue from taxation in Hong Kong is relatively small, land sales are a major source of government income. From 1977 to 1985, on average, land sales contributed nearly 20% of revenue. People in Hong Kong often complain the amount of revenue the government receives from land sales. But the government has insisted that land sales as a contributor to revenue and the demand for funds for the public works program are equally significant. The government’s ability to finance the development of new towns and the provision of infrastructure largely depends upon the land sale revenue.

In 1977, a Special Committee on Land Supply was set up to review requirements for land and make recommendations to the government on matters relating to land disposal. Under its recommendations, annual land sales increased rapidly from 0.686 km² in 1979, to 0.957 km² in 1980 and a record high of 2.166 km² in 1981 (see Figure 2.1). Subsequently, the property market experienced the longest and most severe recession in two decades. The market started to turn down in 1982 and did not pick up until 1985. As Figure 2.2 shows, real housing prices declined at a rate of nearly 20% in 1982 and 1983. A similar decline was observed for commercial and retail property prices. Facing such a market downturn, land sales were reduced from the 1981 level. Yet they were maintained at a level around 1 km² during the period 1982 to 1984. The Special Committee on Land Supply was
Figure 2.1
Total Land Sales in Hong Kong
Thousands of Square Meters

- Excluding Other Uses
- Total

- other uses include public utilities, institution, and other nonindustrial, nonresidential and noncommercial uses.

Figure 2.2
Percentage Change in Property Prices

Real Price Change

- Private Housing
- Office
- Retail
dissolved in 1985. In the same year the *Sino-British Joint Declaration* was ratified and become effective. The administration of land supply entered a new phase.

### II.2. The Sino-British Agreement and its Impact on Land Supply

In the early 1980s, there was great uncertainty about Hong Kong’s future because the New Territories Lease would expire in 1997. After three years of prolonged negotiation, the Chinese and British governments reached an agreement in 1984. The British government announced that it would give up the sovereignty of Hong Kong in 1997. The Chinese government also made clear that the social and economic structure of Hong Kong, including ownership of land and other forms of property, would remain unchanged for at least 50 years after 1997. The two governments concluded the *Sino-British Joint Declaration*. A special agreement on land was signed as a part of the *Joint Declaration*. According to the agreement, land sales by the present government during transition period are restricted to 0.5 km\(^2\) per annum; proceeds from land sales, after deducting for the cost of site formation, will be distributed on a 50/50 basis to the future government.

In 1985, a Joint Land Commission was formed to monitor the exercising of the agreement and the adequacy of the 0.5 km\(^2\) land sales limit. In that year, 2.217 km\(^2\) of land was released, setting a new record (Figure 2.1), with the bulk of it leased in the first half of the year. This extraordinary increase in land sales has been called an attempt by the present government to circumvent the 0.5 km\(^2\) land sales limit (Li,
1989). However, because most of the increase in land sales was for "other uses," such as public utilities and institutional use, it did not cause another dip in the property market.

Since 1986 land sales have been determined by the Joint Land Commission. For each of the four years 1986 to 1990, the amount of land approved by the Joint Land Commission and actually disposed of exceeded 0.5 km² (Figure 2.1). Obviously the land sale limit prescribed by the Joint Declaration was not rigid. Nevertheless, the limit has remained as a guideline. Unless other circumstances arise, such as the need to use land for schools and container terminals, the Joint Land Commission would probably not deviate too much from it. As Figure 2.1 shows, excluding land for "other uses," the sale limit has generally been enforced.

While the Joint Declaration limits the total amount of land to be disposed of each year, it does not place any limits on the type of land to be sold. The present government thus has the freedom to adjust land supply among various uses. As with land for private housing, annual sales have stayed above 0.1 km², which is relatively high compared with historical trends (Figure 1.1).

II.3. Issues to be Studied

Given this background, there is little question that the quantity of and the procedures for land sales are greatly influenced by non-market forces. However, it is not the intention of this study to speculate on the reasons why certain amounts of land
were delivered or why particular means of disposal were adopted, although this would be an interesting study in its own right. The purpose of this dissertation is to understand the subsequent consequences of a given pattern of land supply rather than the supply itself.

In the light of the change of government in 1997, such a study is of particular importance. Although the basic social and economic structure of Hong Kong is very likely to remain the same after 1997, the future government has no reason to maintain the present guidelines for land sales. In this regard, this study provides a background to understand the likely consequences of the changes in land policy.
Chapter III

Review of the Literature

Land and housing are the two major subjects in urban economics. There is abundant theoretical and empirical literature on these two subjects. By reviewing the existing literature, the purpose of this chapter is to identify the extent to which the relation between land and housing has been inadequately addressed, and to lay out the foundation for and the approach to subsequent analysis.

III.1. Monocentric Models of Land Use

Modern urban land use theory represents a distinct and unique branch of microeconomics, as it extends traditional economic theories of consumer and producer behavior to incorporate space consumption and location preference. The family of so-called monocentric city models forms the core of the theory. The concept of the monocentric city has its historical origins in the work of von Thunen in the last century. However, it did not attract the widespread attention of economists until the middle of this century. Since the late 1950s, increasing urban problems have helped to focus the attention of urban and regional economists on the work of von Thunen.
Following the pioneering work of Isard (1956), Beckmann (1957) and Wingo (1961), Alonso (1964) succeeded in generalizing von Thunen’s concept to an urban context. Since then, urban economics has advanced rapidly and inspired a great deal of theoretical and empirical work. Prominent works in this area include those of Muth (1969), Mills (1972), Wheaton (1974), Henderson (1977), Kanemoto (1980), and Miyao (1981), to name a few.4

Basic to the monocentric city model is the trade-off between accessibility and space. The model rests on a set of assumptions about the spatial character of the urban area: 1. The city is monocentric; that is, it has a single center called the central business district (CBD), where all job opportunities are located; 2. Households can commute to the CBD along a direct line from their place of residence and it is the only type of travel in the city (travel within the CBD is ignored); 3. The land is a featureless plain. In this context, the only spatial characteristic of each residential location that matters to households is the distance from the CBD.

In the simplest monocentric model, households are identical. Each has a common utility function, \( u = u(x,q) \), in which \( x \) and \( q \) enter as positive arguments. Each household earns an income, \( y \), which can be spent on space or land, \( q \), other goods including food, clothing, and housing, \( x \), and the cost of commuting the distance to work \( k(z) \). The price of land per unit is \( R(z) \), which depends on location and is to be determined in equilibrium. The cost of commuting is exogenous, as is

4 For an early history of urban economic theory, see Alonso (1964, Ch.1). For recent development in urban economic theory see the survey articles by Wheaton (1979) and Fujita (1986).
the unitary price of \( x \). At a particular distance, \( z \), the residential choice of the household can be expressed as

\[
\max \ u = u(x,q), \quad \text{subject to} \quad Y = x + R(z)q + k(z).
\]

Individual equilibrium is determined by solving this optimization problem. The market equilibrium is then determined by adding two more equilibrium conditions. Land rent at the urban edge equals its "opportunity cost" such as agriculture rent; and the total number of households needed to fill the space from the city center to the urban border just equals the population to be housed. At general market equilibrium, households must live at different distances to work, and yet be equally satisfied. In his original work, Alonso developed a parallel approach which was conceptually richer and led to the same equilibrium for land use. A relatively detailed review of this alternative approach is presented below.

Adopting the perspective of supply, Alonso suggested that land use emerges from a competitive auction. Land is assumed to be owned by absentee landlords (farmers, for instance), who auction their land only to those consumers offering the highest return per unit of land. The process of rent maximization is not unrestricted, however, and must be constrained by several equilibrium conditions. The first of these is that, if all consumers possess the same tastes and income, they must all enjoy the same level of utility, regardless of where they locate. This constraint is expressed by

\[
u = u(x,q).
\]

(3.1)

In addition, the land rent \( R \) that landlords extract must be in accord with
each consumer’s budget constraints. Given income $y$ and the travel costs of living at distance $z$, $k(z)$, this expressed by

$$R(y) = \frac{y - x - k(z)}{q}. \quad (3.2)$$

With the consumer indifferent ($u$ fixed), the process of the land auction ensures that, unless consumers collude, each must gradually offer the maximum land rent to be assured of a location. A consumer’s "bid rent" is thus defined as the maximum amount of rent owners can charge for land, given a level of indifference among consumers. This is determined by maximizing express (3.2), with respect to $q$ and $x$, subject to the constraint (3.1). This process yields two first-order conditions: the constraint (3.1) and the marginal requirement

$$\frac{\delta u/\delta q}{\delta u/\delta x} = R(z). \quad (3.3)$$

Given the structure of $k(z)$, the two equations 3.1 and 3.3 are solved for $x$ and $q$ as functions of $y$, $z$, and $u$. The consumer’s bid rent is the value of $R$, obtained by inserting the solution value for $x$ and $q$ into equation 3.2. These three solution functions are represented by

$$q = q(z, u, y),$$
$$x = x(z, u, y),$$
$$R = R(z, u, y). \quad (3.4)$$

Since land owners seek the highest income, they will rent their land to urban households only if the urban households are willing to match or exceed the rent that the owners can earn from other uses. The boundary of the city ($b$) is thus the point where urban bids equal rents for alternative uses which are often assumed to be uniform at $S$. 

21
\( R(b,u,y) = S. \) \hspace{1cm} (3.5)

Finally, the land area from the city center out to this boundary must be just sufficient to accommodate the land demands of urban households. For a circular city, this is expressed by

\[ 2\pi \int_{b}^{z} q/\text{d}z = N. \] \hspace{1cm} (3.6)

To obtain the equilibrium rent and density profiles, the simultaneous solution of (3.5) and (3.6) for \( m \) and \( u \) is required. Once these values are known, they can be inserted into expression (3.4) to obtain the equilibrium values of \( q \) and \( R \).

The equilibrium solution obtained by the above method represents the so-called closed-city model, in which the population is exogenous whereas the level of utility is endogenously determined within the system. It is sometimes argued that mobility between cities may be sufficient to make these assumptions unwarranted. The alternative is called the open-city model. In an open-city model, the utility level is taken as exogenous. Equilibrium conditions, equations 3.5 and 3.6, are used sequentially to determine first the population and then the size of city that sustains this level of utility.

The principal conclusions of the monocentric model are straightforward. Whether a city is closed or open, the equilibrium rent gradient must decline so that the increased commuting cost is balanced against the savings on land expenditure. Moreover, as long as land, \( q \), and other goods, \( x \), are "normal" and have positive income effects, the density gradient also declines with commuting distance so that living away from the center will be compensated for by the ability to rent larger lots.
of land.

A comparative static analysis of the model yields insightful theorems regarding the growth and change in urban spatial structure [Wheaton (1974)]. With respect to the closed-city model, all else being equal, a larger population results in higher density and higher land rent at all locations. The city size is larger but the utility level is lower. An increase in transportation costs or a decrease in household income leads to more steeply sloped rent and density gradients, smaller city size, and lower level of utility. Conversely, a decrease in transportation costs or an increase in household income leads to flatter sloped rent and density gradients, a larger city size, and a higher level of utility.

III.2. Monocentric Model of Urban Housing

While Alonso was expanding the Von Thunen model to consider land consumption by households, Muth (1968) and, later, Mills (1972) were trying to expand it to incorporate housing. The result is a model that sheds considerable light on housing price, though in retrospect it appears mathematically equivalent to Alonso’s model.

In the Muth-Mills variation, consumer utility depends on the consumption of an aggregate commodity called "housing," h, and other goods, x. In addition to commuting cost, consumers face a unit price for x and a price, P(z) for housing. Housing is produced from capital inputs, c, and land q. The price of the former is
exogenous and equal to \( r \), whereas land rent, \( R(z) \), will be determined, like the price of housing, endogenously to vary over space. Given the budget constraint (equation 3.7), households maximize their utility (equation 3.8), which results in the marginal condition of equation 3.9. Producers, on the other hand, maximize profits from the production function shown in equation 3.10 which results in the marginal conditions of equations 3.11 and 3.12.

\[
y = x + P(z)h + k(z) \tag{3.7}
\]

\[
u = u(x, h) \tag{3.8}
\]

\[
\frac{\partial u}{\partial h} = P(z) \frac{\partial u}{\partial x} \tag{3.9}
\]

\[
h = f(c, q) \tag{3.10}
\]

\[
P(z)\delta f/\delta c = r \tag{3.11}
\]

\[
P(z)\delta f/\delta q = R(z) \tag{3.12}
\]

Given the price of housing at any location \( z \), the equations above are solved for \( x, h, c, q \), and land rent, \( R(z) \). The rent for housing is determined by a locational marginal condition, in which increases in commuting cost are balanced against savings for housing expenditure rather than land as in the Alonso model.

\[
h \cdot \delta f/\delta q + \delta k/\delta z = 0 \tag{3.13}
\]

The solution to differential equation 3.13 provides the price gradient of housing once a constant of integration is obtained. Both this constant and the size of the city are determined by the same equilibrium conditions used by Alonso: equations 3.5 and 3.6.

As Wheaton (1979) pointed out, the Mills-Muth approach is effectively no
different, mathematically, from Alonso’s. Equations 3.7 to 3.13 are actually
equivalent to a reduced form model in which consumers directly select land
consumption and housing capital from the composite utility function:

\[ u[x, f(c,q)] \].

Since households consume \( c \) in any amount, anywhere, at any time, it is equivalent to
food and clothing and behaves just as \( x \) does. Housing capital is mainly an appendage
that does not really change the model’s mathematical character.

However, there is one important difference between the Alonso model and the
Mills-Muth model. In Alonso’s model, the direct household preference for land
determines bid rents for land and residential density; in the Muth-Mills model,
consumers have no direct preference for land. It is the household demand for housing
together with the technical characteristics of a production function for housing that
determines the residential density and land rents. Because costs for housing capital
are spatially constant, housing prices and land prices must bear the same spatial
characteristics.

III.3. Dynamic Models of Urban Growth

During the last two decades, there has been a growing awareness that the long-
run equilibrium portrayed by above static model is never, in fact, achieved. As
Solow (1973) pointed out, buildings and streets are among the most durable objects
people make, and it is very expensive to move or even to remove them. Existing
patterns of location must therefore be determined in large part by decisions that were made under conditions that ruled long ago. It seems far-fetched to expect that what now exists will bear much relation to what would now be an equilibrium.

Recognizing this weakness, two groups of dynamic monocentric models have been developed since late 1970s. In both groups of models, housing capital is durable and the spatial development of cities occurs incrementally over time so that the process of growth can be examined.

The first group of dynamic models assumes that the development of each period is done with myopic foresight, and is therefore determined exclusively by market conditions at the time of development. Examples of this group are the works of Harrison and Kain (1974), Anas (1978), Brueckner (1980), Wheaton (1982b). In the Anas model, capital is completely durable. With population growth, new construction always occurs at the fringe of the city. With market parameters constant, but population growing, Anas demonstrates that residential density increases with commuting distance, an outcome which is just the opposite of the static result. Only with a sufficient increase in income over time may residential density decrease with greater commuting distance. Harrison and Kain reached similar conclusions. The Wheaton model advanced the Anas model by assuming durable but replaceable capital. In each period, new construction can take place in two patterns: new development at the urban fringe or the replacement of the existing city. At any period of time, there are three possible uses or bids for any site in an urban growing model: old rental, new development, and alternative or agricultural rent. New
construction will take place at the urban fringe as long as the rent from new use exceeds the alternative land rent. But if the rent from the new use minus the expenses associated with the replacement exceeds the gross rents from the old use, redevelopment will take place. Through computer simulation, Wheaton demonstrated that urban development occurs in an outward manner initially. The replacement of urban capital will happen only when the passage of time has rendered existing uses substantially "out of touch" with current market conditions. Once this happens, it always occurs at the most central locations (where the urban capital is the oldest), and the density of replacement will be much higher than the existing use. The result, after many years of urban land use, is composed of high-density (redeveloped) land in the center and a relatively flat density gradient from there outward, the result most close to the static model.

A central criticism of the myopic growth model is that urban development rarely occurs with myopic foresight. The existence of an active, speculative market in urban land suggests that the anticipation of future events is certainly part of the development process. To capture the effects of expectation on the pattern of development, Arnott (1980), Brueckner (1980), Wheaton (1982a), and Braid (1988) each developed a model of urban growth under the assumption of perfect foresight.

The key element of perfect foresight models is the present value calculation of bid rents from a particular development. These rent payments will vary through the future, depending on such market parameters as income, transportation costs, and population. By comparing the present value bid rents for all periods, each developer
determines a development strategy at some initial period: when to develop his land and how dense the development should be. Each parcel of land is then developed at that period for which the present value bid rents are the highest. At equilibrium, the present value of land rents is maximized at all localities. Since the knowledge of the future is perfect, it will never be in the interest of any developer to deviate from this chosen strategy. In effect, the actual course of events in the future depends on present behavior. A perfect foresight growth model thus involves a simultaneous determination of the land market in all periods.

After comparing urban growth under the two different assumptions of foresight, Wheaton (1982b) concluded that the outcome of urban growth under perfect foresight is not that different from growth under myopic foresight. In both cases, the general observation holds that the primary determinant of urban spatial structure is urban history—not the equilibrium character of the current market. This is important because it suggests that future changes affect only future development and do little to alter the existing landscape. As to how the future affects the pattern of development, the two models are different. For instance, in the absence of changes in income and transportation costs, the myopic model predicts rising density in distance with population growth. Under perfect foresight this does not hold. Density generally decreases with distance unless population growth is extremely slow and discount rate is very low. Another feature of the perfect foresight model is the spatial ordering of development. Under certain market conditions, urban spatial development can occur from outside inward, a pattern of development that approximates the speculative
holding of land and illustrates that such withholding can be efficient.

So far, there has been little empirical evidence as to whether development in the real world tends to accurately predict the future, or myopically ignore it. Nevertheless, perfect foresight models are regarded as intellectually more interesting and have inspired some important theoretical work. While few observers would contend that truly long-run changes are anticipated, the present value calculations substantially diminish the importance of such knowledge. Moreover, by maximizing present value land rents, the perfect foresight model explains how land rents are capitalized into land prices in accordance with finance theory, a feature which is absent in both the static model and the myopic foresight model.

III.4 Theories of Urban Land Use with Restrictive Land Supply

Land supply in most monocentric models is purely economic. The decision on whether to supply land for urban use is based upon a comparison between returns to land for urban uses and other uses. As long as urban bids are higher than opportunity land rents, land is rendered to urban use. In the case of urban growth under perfect foresight, land supply is really a decision on when to develop land or when to convert land from rural to urban use. This decision again is based entirely upon an economic consideration: to maximize the present value of bid rents.

\footnote{For instance, Capozza and Helsley analyzed land prices and expected growth in the framework of the perfect foresight model in 1989 and advanced this analysis into urban growth under uncertainty in 1990.}
In reality, the economics of land supply is often subject to restrictions. They can be restricted either by a city’s physical siting or by constitutional factors. A number of cities, such as Hong Kong and Singapore, confront both physical and contrived supply restrictions. While there have been a few previous attempts in the literature to model an urban spatial structure in a situation of restrictive land supply, these studies were generally limited to either static equilibrium or partial market equilibrium.

The first and only attempt to deal with a natural supply restriction can be traced back to the work of Mills (1972), in which an area’s topography was considered in a static model. A city whose employment center is located at the coastline of a lake or ocean will have a less circular structure as opposed to a standard circular monocentric city. In this case, the equilibrium condition of equation 3.6 has to be rewritten according to the city’s circumference,

\[ \alpha 2\pi \int \frac{b}{z} q dz = N \]

where \( \alpha \) can be 3/4 (such as Boston), 1/2 (Chicago) or even only 1/8 (Bombay). All else being equal, the city with the smallest circular circumference (smallest \( \alpha \)) will have the most distant city edges. Based on comparative static analysis, this suggests that such a city will have higher housing and land rents in all locations.

The main reason that natural constraints have not been a concern to economists is the unique nature of land as a production factor. Although there is no question that total land is fixed and therefore in inelastic supply, other production factors can be substituted for it. As suggested in the Muth-Mills monocentric model of housing, the
demand for land is actually a demand for improvements to the land. Whereas pure land cannot be produced, improvements can be made by employing labor, material and capital equipment. In theory, an increase in the value of improvements can always induce an additional supply of improvements when the quantity of sites remains fixed.6

Unlike natural restrictions, contrived supply restrictions have received more attention in the literature. There have been several attempts to model land use regulations or growth controls. Cooley and La Civita (1982) analyze the growth-control problem as a choice of optimal city size in a static model. Sheppard (1988) studies the effect of restricting land area available to various classes of consumers in a static multi-class city. In a dynamic two-period model, Frankena and Scheffman (1981) analyzed the imposition of minimum lot size restrictions for new arrivals, where the restrictions are imposed by incumbent landowners in an attempt to force new residents to pay more than their share of the costs of a property-tax-financed public service.

In addition to spatial models of land use regulations, there are a number of non-spatial models of zoning, in which the bid rent and the consumer’s preference for location play no significant role. Pogodzinski and Sass (1990) conducted a review of formal economic models of zoning, including both spatial and non-spatial. Their

6 The degree of capital-land substitution attracted a considerable empirical research efforts in the late 1970s. A summary of the empirical results can be found in the study conducted by McDonald (1981). The range of estimates was 0.36 to 1.13, with most of the estimates below 1. McDonald argued that all estimates were probably biased downward by errors in the measurement of land values.
review shows that the theoretical literature presents many contradictory conclusions about the implications of zoning for welfare and land and housing prices. These conclusions differ partly because of different assumptions and different model structures. The main structure difference is whether one or several jurisdictions are modeled and whether the model is spatial. Zoning models also differ in their use of endogenous or exogenous variables, and their main assumptions on producers and consumers. Pogodzinski and Sass's chief criticism of these models is that none of them take into account all of the important factors, so that one gets only a partial view of the effects and efficiency of land use controls.

Recent progress in modeling supply restrictions is represented by two similar but independent papers by Brueckner (1990) and Turnbull (1991). The Brueckner model focuses on the effects of population externality on land development timing and the Turnbull model analyzes the effects of a minimum lot size restriction on the growth path of a city. Both models are built in the same context of a dynamic open city.

In the Brueckner model, the market is operating with perfect foresight, land consumption is fixed at unity, the level of utility is exogenously fixed, and population is endogenously determined. The time path of urban land rents in the model in part reflects the presence of a negative population externality (a large population lowers the city's quality of life and reduces the rent that urban land commands). After deriving the optimal date of rural-urban conversion (the date that maximizes land value), the analysis considers the effect of an unanticipated growth control regulation,
which delays conversion at each location. The model’s population externality is the key factor in the analysis. Given the externality, a slowing of population growth due to the control raises the land rent in urban use at every date and location as consumers pay a premium to live in a smaller city. For land that is already developed, imposition of the control raises all future rents and therefore increases the value of land. The control’s impact on the value of undeveloped land is, however, not straightforward. The impact is the net effect of two changes: first, the control delays the date at which urban rents can be earned, which lowers value; second, the control raises urban rents by lowering the city’s population growth path, which raises value. Once the impacts of an arbitrary growth control law are understood, the analysis then focus on the form of the efficient control. Given that the utility is exogenous, efficient control is characterized as maximizing the total value of land in the community. Based on a specific utility function, Brueckner computed both the efficient and equilibrium growth path and illustrated that while mild controls are likely to be welfare-improving (i.e., they raise total land value), a strength control may be worse than no control from a welfare point of view.

It is important to realize that, because an open-city model is used in the analysis, population pressure and the resulting excess demand for housing play no role in determining the market impact of growth controls. Consumers denied residence by the presence of the control simply relocate to other communities. Since population pressure can actually be a very important factor, particularly at the metropolitan level, the model is applicable only to situations in which households are perfectly mobile.
In his paper, Brueckner suggested a closed-city model of growth controls as a future research topic, but he argued that controls may not be politically viable in such a setting, because the control cannot improve the city’s quality of life when the population is exogenous.

**III.5. Empirical Studies of Supply Restrictions**

While the theoretical literature offers few consistent explanations of supply restrictions, there is a considerable empirical literature documenting the effects of supply restriction. The evidence to date conclusively establishes that supply restrictions raise property prices. Two types of restrictions have been studied. One is natural restrictions; the other is the degree of zoning restrictiveness.

The relevant literature on natural restrictions is composed of three inter-urban comparisons. In an empirical study of density gradients, Muth (1969) employed a dummy explanatory variable to indicate whether or not the city is bounded by an ocean or lake. Ozanne and Thibodeau (1983) did the same in their analysis of metropolitan housing price differences and found that the dummy variable is significant in explaining the variation of rental prices but insignificant in explaining the variation in housing prices. Rose (1989) quantitatively measured the supply of land and found that inter-urban land price variations of 30% to 60% may be due to natural (water) restrictions on the supply of land.

The study on restrictions imposed by zoning ordinances started with the
monopoly zoning hypothesis advanced by White (1975). According to the hypothesis, when homeowner desire to increase the value of their homes through restrictive zoning, the fraction of urban area land controlled by the local government determines the extent to which they can achieve this. Hamilton (1978) tested the hypothesis and suggested that inter-urban price variation of as much as 50% may be due to government restrictions of land supply. Fischel (1980) qualified the hypothesis but presented additional evidence that cast some doubt on its ability to explain inter-urban housing price variations. Since then, a considerable number of papers have provided empirical evidence on the positive impact of zoning ordinances on housing prices. [see Elliot (1981); Schwartz et al. (1981); Dowall and Landis (1982); Katz and Rosen (1987); and Pollakowski and Wachter (1990)].

Two explanations for the positive impact of zoning on housing prices have been offered in the literature. First, at the local level, particularly from the community point of view, zoning creates an amenity by preserving a community’s "quality of life," whose value is then capitalized into housing prices. Second, at the metropolitan level where households are less mobile, zoning is thought to create excess demand by restricting the supply of housing in the face of population pressure. A typical example of this group of literature is Frech and Lafferty’s (1984) analysis of the effect the California Coastal Commission had on the price of single-family housing. They found the commission’s action to protect the coast raised the prices of homes in one region at least $528; for some homes the price rise was estimated to be $2,690 (in 1984 dollars). The price rise occurred as far as 13 miles inland. While
the price rise for houses within 0.5 miles of the coast was attributable to an amenity effect, as Frech and Lafferty concluded, most of the price rise was due to the reduction in residential land, i.e., a scarcity effect, because for houses from 0.5 miles inland to 13 miles inland the amenity effects were virtually absent.

With almost no exceptions, the studies named above have all employed a hedonic equation and micro data sets to estimate the effects of supply restriction. The major contribution of this portion of the literature is that it isolates the price change attributable to various factors so that the implicit prices of non-market goods can be determined. However, like all economic research, this approach is not without limitation. One difficulty relates to the effects of general market equilibrium. When the changes in housing prices that result from zoning ordinance are substantial, many homeowners will move and these movements will alter the hedonic price structure itself.

III.6. Macroeconomic Model of Housing Demand and Supply

Macroeconomic housing research has tended to be a separate branch of the literature in housing. This group of studies is mainly built upon the so-called stock-flow model. Using aggregate time series data, the primary objective is to forecast the level of housing prices and new housing construction. Basic to the stock-flow model are two equations: housing demand and housing supply. The demand for housing is assumed to depend on the price level of housing, the "asset cost" of financing that
price, and exogenous variables, such as demographic characteristics and permanent income. In the short run, the housing stock is fixed. Housing prices adjust to equate demand to the existing stock. The supply of housing, on the other hand, consists of new construction and the existing stock after depreciation. New construction, in turn, is always assumed to depend on housing price and construction costs that include factor costs and interest rates [Fair (1972)].

To date, no macro-economic housing research has made the connection between the housing market and the land market. This deficiency is often attributed to the lack of suitable data on the land market. However, even if data are available, very little theory explains how to incorporate land variables into the framework of the stock-flow model. A common practice is to include land prices as a cost variable in estimating new construction. It is expected that an increase in land prices will reduce the profitability of construction and thus reduce the supply of new housing. One criticism of such an approach is that land prices are determined by housing prices, not vice versa. Of course, to individual builder the price of land is a cost; as with building components, he has to pay the going competitive market rate to obtain it. But the "individual" view that land prices should be controlled because they are "bad" puts the cart before the horse (Harvey, 1987). From the market point of view, it is the demand for houses that determines the price of residential land. Therefore, the inclusion of land prices as factor costs can be conceptually misleading.

In many respects, it is the relationship between housing and land that distinguishes the production of housing services from other goods and services in the
economy. The understanding of this relationship is hindered by the separation of empirical research and theoretical work. Despite much cogent discussion of residential land use in urban spatial theory, the theory and macroeconomic housing research have been independent of each other.

Dipasquale and Wheaton (1990) recently attempted to incorporate urban spatial theory into a stock-flow model. Their central argument is that high housing prices are not necessarily associated with high levels of construction. According to the urban spatial theory, the larger the city, the higher the overall housing price. But, if a large city grows less rapidly than a small one, then the large city will have high housing prices but little new construction whereas the small city may have lower housing prices but significant new construction. Thus it is the increase in and not the level of housing prices that brings forth new construction. To capture such effects, lagged total stock is included in their estimation of new construction on the U.S. housing market. As expected, the coefficient for this variable was found to be negative.

Although they have offered no satisfactory explanation for the relationship between land and housing, stock-flow analyses nevertheless have greatly improved the understanding about the operation of the housing market. Meanwhile, the explanatory power of the stock-flow model itself has been improved because of the more careful and realistic considerations of the housing market. For instance, the "asset cost," used to be measured by mortgage interest rate only; it is now recognized to be affected by expected future capital gains and tax savings as well [Kearl (1979), Schwa
The traditional stock-flow model assumed that prices adjust to equate the demand for housing with the supply and that the market then clears quickly at any time. A number of researchers have raised doubts about such instant adjustments and have suggested that it may actually take some time for the market to clear. Whitehead (1974), Hadjimatheou (1976), and Artis et al. (1975) each incorporated the partial adjustment principle in modeling housing demand on the U.K. housing market. Dipasquale and Wheaton (1990) did the same in modeling housing demand on the U.S. housing market. All these studies found the speed of adjustment coefficient to be statistically significant.  

A final point about macroeconomic housing research is that most of the studies have used data from the U.S., Canada, or West European countries. Hence many of the findings of these empirical models are applicable only to the institutional context of these countries. The characteristics of other housing markets have remained unexplored. In particular, very little consideration has been given to how to incorporate the public sector and various public policies which are more common in developing countries.

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7 Despite this statistical significance, Deaton and Mueibauer (1980) argued that the partial adjustment principle is highly unsatisfactory for use in modeling durable purchases. A major problem with the principle in the context of modeling housing is that over time, the speed of adjustment "coefficient" will have the nature of a variable rather than a parameter; if demand adjusts gradually, the speed of such an adjustment is unlikely to be independent of economic influences.
Chapter IV

Modeling Urban Growth with Restrictive Land Supply

This chapter examines urban growth under conditions of restrictive land supply within the framework of the monocentric model. The focus of the analysis is the effects of supply restrictions in the context of a closed city. As Brueckner (1990) pointed out, any growth control (or supply restriction) in such a setting creates a scarcity effect rather than an amenity effect. While it is not difficult to imagine that restricting land supply will pack the population into a smaller area, how exactly the market responds to the restriction has never been explicitly explored. The purpose of this chapter is to offer a formal theoretical analysis.

Starting with a simple static model, the chapter first examines the long-run equilibrium land use with an absolute physical constraint. A dynamic model with perfect foresight is then established to assess the dynamics of land use with both natural constraints and contrived regulations. Unlike natural constraints, regulations can restrict land use in two different ways. They can either force land use at certain periods below its optimal level or can preempt land for all future development. In both cases, the regulation is exogenously determined. Such restrictions are not fashioned without real grounds. As described in Chapters I and II, the ultimate
The purpose of the analysis is to understand the housing market of Hong Kong, where land supply is subject to both natural impediments and a monopoly control by the government.

**IV.1. Static Monocentric Model With a Fixed Boundary**

Building upon the simplest version of the monocentric model (described in detail on pages 19-22), N identical workers are assumed to be employed at a central site of production. Each worker earns an income, \( y \), which is spent on space or land, \( q \), other goods, \( x \), and the cost of commuting the distance \( z \) to work, \( k(z) \). The price per unit of land, \( R = R(z) \), is determined in the market equilibrium and is a function of distance \( z \) from CBD. The cost of commuting is exogenous, as is the price of \( x \). Each worker’s household is assumed to have a common utility function in which \( x \) and \( q \) enter as positive arguments.

Following Alonso’s rent-maximizing approach, the territory is assumed to be owned by absentee landlords who auction land to those consumers offering the highest return per unit of land. As described in Chapter III, this process of rent maximization must be constrained by several equilibrium conditions. First, each household must enjoy the same level of utility, regardless of where they locate (equation 4.1). Second, the land price (\( R \)) that landlords extract must be in accord with each consumer’s budget constraints (equation 4.2). The result of the constrained rent maximization is the marginal efficiency condition (equation 4.3).
\[ u^* = u(q, x) \]  \hspace{1cm} (4.1)

\[ R = \frac{y - k(z) - x}{q} \]  \hspace{1cm} (4.2)

\[ \frac{\partial u}{\partial q} + \frac{\partial u}{\partial x} = R = \frac{y - k(z) - x(u, q)}{q} \]  \hspace{1cm} (4.3)

Given the structure of \( k(z) \), the two equations 4.1 and 4.3 are solved for \( q \) and \( x \) as functions of \( y, z, \) and \( u \). The household's bid price is the (maximum) value of \( R \), obtained by inserting the solution value for \( x \) and \( q \) into (4.2). These three solution functions are represented by

\[ q = q(z, u, y), \]
\[ x = x(z, u, y), \]
\[ R = R(z, u, y). \]  \hspace{1cm} (4.4)

Finally, the land demand of urban households has to be accommodated within the territory. For a linear city, this is expressed by

\[ \int_0^b \frac{dz}{q} = N. \]

The difference between a nonrestrictive model and a restrictive model is whether the city size is expandable. In a traditional nonrestrictive model, the city is assumed to be surrounded by an endless rural areas. Since urban residents compete with farmers for land, the outer boundary of the city (\( b \)) is the point where urban bid rents equal rural rents \( [R(b) = A] \). Given that rural rents \( (A) \) are exogenous, the
boundary is determined simultaneously with utility, land rent and density profiles. A greater population or higher income expands the city as the urban householder’s willingness to pay for land at the boundary leads him to out bid the rural users. Conversely, higher rural land rents or higher travel costs shrink the city boundary.

Instead of being surrounded by endless rural areas with which the city can always compete for land, a restrictive model assumes that the city is located on a territory surrounded by water or some other barrier. Once the city boundary (b) reaches the edge of the territory (m), the barrier makes further expansion impossible. To determine whether m is restrictive, the optimal city boundary, denoted as b*, has to be calculated as if there is no constraint. If b* is less than m, the land beyond the city boundary will be left for agricultural use or simply vacant in which case the land rent at the city boundary will be zero. If b* is greater than m, the city boundary b is no longer endogenous but fixed at m. While the city boundary is exogenous, the rent at the city boundary has to be endogenously determined. Equations 4.5 and 4.6 depict these equilibrium conditions.

\[
N = \begin{cases} 
\int_0^b \frac{dz}{q} & \text{for } b^* \leq m, \\
\int_0^m \frac{dz}{q} & \text{for } b^* > m. 
\end{cases} \tag{4.5}
\]

\[
R(b) = \begin{cases} 
A & \text{for } b^* \leq m, \\
R(m) = \frac{y - k(z_m) - x(u, q_m)}{q_m} & \text{for } b^* > m. 
\end{cases} \tag{4.6}
\]

With equations 4.1 to 4.6, the model has a unique set of solutions for the level
of utility $U$, rent $(R)$ and density $(q)$ gradient for any given set of $Y$, $k$, $N$, and $m$.

At this solution, the urban system shows no propensity to change.

Figure 4.1 illustrates the general features of such a long-term market equilibrium. Both the population density and the land rent decrease with the distance, $z$. When the city boundary is within the territory boundary, the market behaves as if there is no supply restriction. When the market requires more land than the territory can offer, the population is then forced to live with a higher density, resulting in higher rents everywhere in the territory.

Figure 4.1
Static Equilibrium of Density and Rent
Optimal Land Use and Public Ownership

Equilibrium land use describes the situation in which equality between demand and supply for land is achieved everywhere. However, the fact that an urban land market is in equilibrium does not necessarily imply that the resulting spatial structure is desirable. In the literature, it is common to define optimal allocations of land and to examine the relationships between equilibrium and optimal land use. Exactly what optimal land use is, of course, depends on how the objective function is specified. A number of authors have shown the equivalence between equilibrium land use and optimal land use in one way or another. While a comprehensive analysis of optimization problems for land use is beyond the scope of this study, it is necessary to point out that the market solution of equilibrium land use that results from the maximization of land rent (equation 4.2) is identical to the outcome that maximizes the utility for each individual household (equation 4.1). Both approaches lead to the same marginal conditions (equation 4.3). In the context of identical households, the maximization of rents is equivalent to maximizing aggregate utility.

The question of optimal land use can also be contemplated from the perspective of public ownership. As said before, this study is based on the situation

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8 In spaceless economics, it is common to maximize a Benthamite social welfare function, which is the sum of the utilities of individual households. However, Mirrlees (1972) discovered that this is not the most convenient approach to land use problems as the maximization of a Benthamite welfare function results in the assignment of different utility levels to identical households depending on their locations. A more convenient formulation of optimization problems for land use theory is the so called Herbert-Stevens model, in which the objective is to maximize the surplus subject to a set of pre-specified target utility levels for all household types. See Fujita (1990) for further discussion on this subject.
of Hong Kong. One of the unique characteristics of Hong Kong is its land tenure system. Because of the colonial history, the government of Hong Kong owns practically all of the land of the territory and leases land to private developers. Because the current government is financially self-reliant, its land tenure system is closer to a public ownership system. Given this background, it is natural to wonder whether equilibrium land use that has resulted from rent maximizing by absentee landlords is still applicable.

To reflect the situation of public ownership, the city residents are assumed to form a government, which rents the land for the city from a third party at $S$. The government in turn subleases to city residents at the competitively determined rent $R(z)$ at each location. The total differential land rent (TDR) from the city is defined as:

$$TDR = \int_0^b (R(z) - s) q(z) \, dz.$$  

Under public ownership, the government’s land rent revenue ultimately goes back to consumers. Thus rent maximization is not only efficient but also desirable. Assuming the government’s revenue from the land is evenly shared by city households, the share of each household is $TDR/N$ given that there are $N$ identical households. Then the income of each household is its nonland income $y^*$ plus a share of the differential rent $TDR/N$. Note that in a competitive market $TDR$ is unknown. Nevertheless, the rent maximization problem can be formulated as follows:
\[ \max R = \frac{y^* + TDR/N - k(z) - x}{q}, \text{ subject to } u^* = u(x, q). \]

In the context of restrictive land supply, the equilibrium conditions are:

\[
\begin{align*}
q &= q[z, u, (y^* + TDR/N)], \\
x &= x[z, u, (y^* + TDR/N)], \\
R &= R[z, u, (y^* + TDR/N)], \\
\int_0^m \frac{dz}{q} &= N, \\
b &= m.
\end{align*}
\]

Given the existence and uniqueness of the optimal land use in the previous analysis, it can be seen that there exists a unique equilibrium for the model under public ownership. Comparing equilibrium conditions for models under two different specifications of ownership, one can readily conclude that if TDR is the total differential rent at the solution of private ownership model (with income \(Y\)), then the solution of this model is the solution of the public ownership model (with income \(Y^* + TDR/N\)). In other words, the two types of models have an identical set of solutions.\(^9\)

**Comparative Static Analysis**

A comparative static analysis of the restrictive model yields some insight into the effect of a supply restriction. Suppose that the city's outer boundary changes from \(m_a\) to \(m_b\) such that \(m_a > m_b\). All else being equal, the same population has to be

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\(^9\) See Fujita (1989) for a detailed discussion.
accommodated on less land. Per capita consumption of space has to be reduced. Since utility is convexity, the marginal substitution rate for space must be higher when the consumption of space is forced below its optimal level. In other words, households are willing to pay more for the same amount of space. As a result, rents and density are higher at all locations and utility is lower. This effect of smaller territory is equivalent to a higher rural price when the city is surrounded by farms. In both cases, the city is smaller in size but rents and density are higher at every location.

The effects of a larger population are the same as those for a smaller city size. With the city boundary fixed, an increase in population reduces per capita land consumption so that new households can be accommodated. Intensified demand pushes rents up. With income unchanged, the level of utility must be depressed.

The effects of changing transportation costs or income are relatively complex. Suppose transportation cost increases but income remains the same; then net income decreases at all distances. As affordability decreases, lots in the suburbs are less advantageous compared with lots closer to the city center. Consequently, both the rent and the density gradients will be steeper with respect to distance. If transportation costs are high enough, the city boundary will shrink and land outside the boundary will be left vacant if there is no alternative use. In this case, the rent at the outer boundary and beyond will be zero \( R(b) = R(m) = 0 \).

On the other hand, higher income or lower transportation costs increase net income at all distances. In this situation, transport costs to city center become
relatively less important and the land in the center is less advantageous. Some households might like to move from the center to the suburbs to enjoy larger size lots. This tends to increase the rent and density in the suburbs. If the city boundary is not fixed, higher urban rents outbid alternative uses and the city expands to meet the demand. However, when the city is fixed, increased income can only cause higher rents and density in the suburbs. For the market in equilibrium, rents in the suburbs have to increase sufficiently to clear the demand. As a result, the rent and density gradients would be flatter. At the extreme, both rent and density gradients would be horizontal if transportation costs decline to zero.

It is important to realize that the equilibrium described above is a result of instant adjustment of all capital. In reality, existing density is more or less fixed. New construction represents only a small part of the total capital. Therefore, the explanatory power of the static model is limited to long term equilibrium where capital can be regarded as nondurable through deterioration and replacement.

IV.2. Dynamic Urban Growth with a Fixed Boundary

In the static model, land use at each location is simultaneously determined and therefore there is no sequential problem. In reality, most buildings and other constructions can last a long time and are expensive to remove. Hence the sequence of development is important. Particularly when the total land is fixed, current land use represents a sacrifice of land for the future. To reflect this mechanism of land
use, this section presents the dynamic version of the urban spatial model with the condition of limited land supply.

As described in Chapter III, existing literature on dynamic urban growth has been built on two different assumptions about market behavior: myopic foresight or perfect foresight. Since there is a fundamental conceptual difference between the two, it is necessary to elaborate a little bit on the assumption about participants' behavior before presenting the model.

If development decisions are made under myopic foresight, no prior estimates are made about the relevant future. As long as there is land available for development, limits on land supply will not be a concern. Urban development will keep going to accommodate the growth of the population at the demanded density as if there is no supply limitation. Such a development pattern will not change until the land runs out. After the city reaches the edge of the territory, the demand for space has to be met by increasing the density of new development. A replacement of urban capital will eventually occur as previous blind development becomes "out of touch" with market conditions under the supply constraint.

Defined in global terms, total land supply is fixed and no city can expand forever. But such a global limitation on land is meaningless to most cities because capital destructs long before land runs out. The limitation is worrisome only if the limitation is tangible. In Hong Kong, the natural restriction on the land supply has been a major public concern. Even in primary school days, residents of Hong Kong are taught about the scarcity of land. In such a context, it is very unlikely that the
supply constraint will be totally ignored in development decisions. To understand urban growth where such a supply restriction is part of the development process, the model presented below adapts the perfect foresight theory.

Specifically, the model is conceptualized as follows: first, capital is durable and development is irreversible; second, all participants have perfect knowledge of future income and population growth, changes in transportation costs, and total land available for development. The development of land, at any time, occurs in a manner which maximizes the return to the land from that point onward. This return, defined as the present value of anticipated cash flows of land rents from development, depends on when the land is developed and the density on which it is built. Given the knowledge of market conditions at all times, each developer chooses a particular combination of time and density so as to maximize his or her return. Thus, each point in the city will be developed at that time for which the present value bid is the highest.

To simplify calculations, the time horizon is divided into a set of discrete periods, the last of which continues indefinitely. Market conditions vary only between, not within, periods. Thus, if there are a total of n discrete development periods, the city must have n sections or zones over space. The first zone begins at city center 0 and ends at boundary $b_1$. The second begins at $b_1$ and ends at $b_2$, and the last one (zone n) begins at $b_{m-1}$ ends at m, which is fixed. The consumer’s utility varies between periods but must be constant over space within each period.
Figure 4.2 illustrates a simple case with four development periods. The development process is considered from two dimensions: space and time. For instance, in time period T1, only the area of zone 1 (from city center to b1) is developed for urban use. In time period T2, the city grows to b2 as the area of zone 2 (from b1 to b2) is also developed for urban use. In other words, all the sites within the area of zone 1 are developed in the same period T1. The density profile for this area is $q_1(z)$. Similarly, all the sites within zone 2 are developed in time period T2 with a density profile $q_2(z)$. Note that the space zone may not be associated with the time period in the same order. For instance, the space zone next to the urban center may not necessarily be the first one developed in the given time horizon, i.e., may
not necessarily be developed in the first period, T1. Under certain conditions, a reversed development pattern (from outside inward) is possible.\(^\text{10}\) Finally, the land price at each location is the present value at time zero of the land rents earned in all periods for that location. For a location in zone 4 which is not developed for urban use until T4, its price equals the present value of non-urban rents earned in T1, T2, and T3, and urban rent earned in T4.

Except that the total land is fixed, the model is otherwise the same as the Wheaton perfect foresight model (1982a). When land is unlimited, the present value bids for development in each period adjusts so that the amount of land allocated for development over time exactly meets the needs of the city’s growing population at the demanded density. Both the inter-period boundaries and the outer boundary of the city are endogenously determined. When the total land is fixed, inter-period boundaries are still endogenous but the outer boundary is exogenous. The development density in each period adjusts not only to accommodate the population growth during that period but also to insure that just sufficient land is left to accommodate future population growth so that land developed in all periods equals exactly the entire territory.

Similar to the definitions for the single period model, the rent that households are willing to pay in a period \(t\), at a given location \(z\), depends on their preference to

\(^{10}\) The necessary condition for a reverse, outside in development is that the present value bid in period \(i+1\) is steeper than in period \(i\). Wheaton (1982) has shown that this condition is achievable if the density in period \(i+1\) is sufficiently higher than that in period \(i\), or the interest rate is sufficiently low.
the consumption of land $q_i$ and other goods $x_t$, as well as the budget constraint, during that period.

\begin{align*}
  u_t &= (q_i, x_t), \\
  y_t &= k_t z + x_t + R_t q_i, \quad t = i, i+1, \ldots, n.
\end{align*} \tag{4.7} \tag{4.8}

where $q_i$ is defined as the lot size built in period $i$ at location $z$, $R_t$ as unit rent at location $z$ in period $t$; $y_t$ as household income in period $t$; $k_t$ as cost per unit of distance of commuting in period $t$; and $u_t$ as the level of residents' utility during period $t$. Inverting the utility function so that $x_t$ is on the left-hand side, and $u_t$ is contained as a right-hand argument, a single expression is obtained for unit rent offered in period $t$ at location $z$, given the market conditions $y_t$, $k_t$, and $u_t$:

\begin{align*}
  R_t &= \frac{y_t - k_t z - x_t (u_t, q_i)}{q_i} = R(y_t, k_t, z, u_t, q_i).
\end{align*} \tag{4.9}

From the developer's perspective, it is the present value of anticipated land rents that is essential. Each developer, therefore, selects a development strategy in terms of density and development time so as to maximize his return. For the development of a piece of land located at $z$, the decision can be represented by

\begin{align*}
  \max \ P = \sum_{t=1}^{n} D_t R_t(z, q_i, u_t, y_t, k_t) + \sum_{t=1}^{i-1} D_t A_t + C_t D_t \quad i = 1, 2, \ldots, n \\
  (q_i, i)
\end{align*} \tag{4.10}

where $A_t$ represents the land rent from an alternative use in period $t$, $C_t$ is construction cost at time $t$, and $D_t$ is the discount factor defined as:
Note that construction cost, $C_t$, changes over space only through the construction density. Unless it is defined otherwise, its value will not change the spatial characteristics of the model.

At equilibrium, utility has to be constant over space. This is insured by the assumption in which only one utility prevails during each period. Thus, the solution to the optimization problem in equation 4.10 is a set of $q_i$ which obey the condition that marginal profit equals marginal cost:

$$0 = \frac{\partial P}{\partial q_i} = \frac{1}{q_i} \sum D_t \left( R_t - \frac{\partial x_{e_i}}{\partial q_i} \right)_{u_t = cst.}$$  

(4.11)

Meanwhile, the maximization of $P$ is also restricted by several other equilibrium conditions. First, in a competitive market, an asset should be held until the marginal rate of net price appreciation equals the opportunity cost of time--normally the interest rate. In the perfect foresight model, this comparison occurs at the boundary between development in two adjacent periods. At such a point, the net present value of the two development strategies, or land price, is equal (equation 4.12).

$$P(b_i, q_i) = P(b_i, q_{i+1})$$

(4.12)

Second, new development in each period accommodates just the population

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11 See Wheaton (1982a) for a detailed discussion of this proposition.
increase during that period.

\[ \int_{b_{t-1}}^{b_t} \frac{dz}{q} = \Delta N_t \tag{4.13} \]

where \( i=1,2,\ldots,n \); and \( \sum_{i=1}^{n} \int_{b_{t-1}}^{b_t} dz = \left\{ \begin{array}{ll} b^* & (b^* < m) \\ m & (b^* \geq m) \end{array} \right. \)

where \( b^* \) is the optimal city boundary if land supply is unrestricted. When \( b^* \) is greater than \( m \), the edge of the territory, the supply restriction becomes effective. As the outer boundary of the last zone is explicitly defined as \( m \), equation 4.13 insures that land developed in all periods just equals the entire territory. For any given set of \( y_i, k_i, N_i, A_i, m \) and \( a \), the specifications of utility function, equilibrium solutions for utility, \( u_i \), density, \( q_{i(t)} \), interperiod boundary, \( b_i \), rent, \( R_{i(t)} \), and price, \( P(z) \), can be obtained based on equations 4.7-4.13.

**IV.3. Simulations of Perfect-Foresight Urban Growth with a Fixed Boundary**

To illustrate the key properties of the model discussed earlier, a perfect-foresight simulation is programmed using the Cobb-Douglas utility function. The Cobb-Douglas utility is given by

\[ u_t = x_t^a q_t^{1-a} \tag{4.14} \]

The unit rent \( R_i \) (equation 4.9) and \( P \) (equation 4.10) are then
\( R_t = \frac{y_t - k_t z}{q_i} - \left[ \frac{u_t}{q_i} \right]^{1/\alpha} \)  \hspace{1cm} (4.15)

\[
P = \sum_{t=1}^{T} D_t R_t + \sum_{t=1}^{T} D_t A_t - \left[ \frac{C_i}{q_i} \right] D_i \]
\[
= \frac{1}{q_i} \left[ (AP)_i - (BP)_i z - (CP)_i q_i^{1-1/\alpha} \right] + (SP)_i \]  \hspace{1cm} (4.16)

Where the parameters are defined by

\[
(AP)_i = \sum_{t=1}^{T} D_t y_t - D_t c_t
\]
\[
(BP)_i = \sum_{t=1}^{T} D_t k_t
\]
\[
(CP)_i = \sum_{t=1}^{T} D_t u_t^{1/\alpha}
\]
\[
(SP)_i = \sum_{t=1}^{T} D_t A_t
\]  \hspace{1cm} (4.17)

Here, consumer spending on other goods, \( x_t \), is replaced by utility, \( u_t \), which is a constant over the entire territory in each period. The construction cost is assumed to be proportional to the construction density, \( 1/q_i \), with a proportional constant \( c_t \). The parameters \((AP)_i\), \((BP)_i\), \((SP)_i\) are exogenous while \((CP)_i\) is endogenous.

The first order condition for maximizing the price (equation 4.11) leads to an expression of the lot size \( q_i \)

\[
q_i = \left( \frac{(AP)_i - (BP)_i z}{(CP)_i^{1/\alpha}} \right)^{\alpha-1}
\]  \hspace{1cm} (4.18)

Combining equation 4.18 and equation 4.13, one obtains
\[
(CP)_i = \alpha \left[ \frac{(BP)_i \Delta N_i}{(1 - \alpha) \left[ \left( (AP)_i - (BP)_i \beta \right)^{1 - \alpha} - \left( (AP)_i - (BP)_i \beta \right)^{1 - \alpha} \right]} \right]^{\frac{\alpha - 1}{\alpha}}
\]

(4.19)

In numerical solution to these equations, a set of trial solutions \{b_i\} is used to calculate \((CP)_i\) and \(q_i\). The land prices at the development boundaries are then compared to determine if equation 4.12 is satisfied. The process is iterated until the solution is approached.

Three simulations were run in which the outer boundary of the city varied so that the effect of land supply restriction could be examined. All simulations used the same set of market conditions except that the city territory is different. The first simulation, which served as the base case, assumed a fixed city boundary of 25 miles. The city boundary would be as twice as large if the land supply was unrestricted. This fixed boundary ensured that the effects of supply restriction would be observed. The second simulation used a reduced and fixed city boundary of 16 miles to illustrate the effects of a highly restrictive land supply on land price and development density. The third simulation used a city boundary of 90 miles which is larger than the optimal city size; the market was therefore unrestricted.

A summary of the parameters used in the simulations is shown in Table 4.1. For simplicity, ten time periods are used. Each period accommodates 1,000 households. Household income at the beginning period is $24,000 and increases at a rate of 8%. Annual travel costs are $100 per mile with a growth rate of 6%. The annual opportunity rent of land, i.e., agricultural rent, is $300,000 per mile. This
rent unit is due to the linear city assumption.

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*Table 4.1: Simulation Parameters*

\[ u = q^{1-\alpha} e^x \quad \text{where} \quad \alpha = 0.85 \quad r = 6\% \]

Figures 4.3 and 4.4 present land price and density profiles with a fixed city boundary of 25 miles. It should be clear that the land price presented here is the present value of rents at time zero. As shown, the model yields a continuous and declining land price gradient. The density profile, however, is "sawtooth" shaped. At each inter-period boundary the density jumps discretely while within each period it decreases smoothly with \( z \). On average, the density profile shows a slow decline with distance \( z \).

It is important to distinguish the "real" and "artificial" aspects of this density profile. The declining density within each period is simply an extension of the static model. As distance increases, the present value of rents must decrease by the same (or less) amount that the present value of travel costs increases. In the static model,
Figure 4.3
Equilibrium Land Price as a Function of the Distance from CBD with a Fixed City Boundary of 25 miles ($z=25$) and 10 Discrete Development Periods.

Figure 4.4
Equilibrium Density as a Function of the Distance from CBD with a Fixed City Boundary of 25 miles ($z=25$) and 10 Discrete Development Periods.
this implies that land consumption is based upon an income-compensation demand curve. Because of utility convexity, land consumption will always increase as land prices fall with distance. Density therefore decreases as rent falls. The discrete jump of density at boundaries, on the other hand, is an artifact that results from the use of finite and discrete development periods. The cause of the jumps can be easily understood. In a competitive market, the present value of land rents has to be continuous for adjacent locations, even when they are developed in two different periods. This requires that density at the later-developed side of the inter-period boundary be higher so that higher rents can be collected to compensate for its later development. If the model uses a large number of "short" development periods, the forces that cause discrete density jumps at inter-period boundaries will spread out more evenly, resulting in more but smaller jumps. In reality, development is a continuous process in time and these jumps do not actually occur. However, the factors that raise density for later developed locations and thus ensure price competitiveness do still exist. The assumption of finite and discrete development periods dramatizes these effects. The actual density profile should be approximately the envelope of the simulated profiles, which can either decrease or increase with \( z \), depending on market conditions.

Figures 4.5 and 4.6 show price and density profiles with a smaller city boundary of \( m=16 \) miles. Significant price increases can be observed at all locations. The price gradient is continuous and declines with distance as before. But the density shows an overall increase with greater distance. The increasing density reflects the
Figure 4.5
Equilibrium Land Price as a Function of the Distance from CBD
with a Fixed City Boundary of 16 miles (z=16)
and 10 Discrete Development Periods.

Figure 4.6
Equilibrium Density as a Function of the Distance from CBD
with a Fixed City Boundary of 16 miles (z=16)
and 10 Discrete Development Periods.
fact that travel costs are less important. As the city size shrinks, there are shorter
distance to travel. Density decreases less within each period whereas a larger "jump"
in density at the inter-period boundaries is required to compensate for later
development at the same distance. This case illustrates that density can either
increase with z or decrease with z in a perfect foresight dynamic model depending on
thetightness of the land supply and other market parameters, a property which is
totally absent in the static model.

For purposes of comparison, Figures 4.7 and 4.8 present simulation results
with no supply constraint. For the market parameters given in Table 4.1, the model
determines the optimal city size of 64 miles while the territory is 90 miles. As the
city spreads out, price and density are lower everywhere. Both price and density
appear with a declining gradient, a result which is closer to the static model.

Figure 4.9 compares the calculated utility path for three simulations. Utility is
lower in all periods when land is restricted. The more severe the restriction, the
lower the utility. Thus there is no question that land constraint lowers the quality life
in a given city. However, under perfect foresight, the negative impact of land
constraint is shared in all periods.
Figure 4.7
Equilibrium Land Price as a Function of the Distance from CBD with Unrestricted Land Supply and 10 Discrete Development Periods.

Figure 4.8
Equilibrium Density as a Function of the Distance from CBD with a Fixed City Boundary ($z=25$) and Unexpected Supply Restrictions in Periods 5, 6, and 7.
VI.4. Perfect Foresight Urban Growth with a Fixed Boundary and an Unexpected Temporary Disturbance in Land Supply

This section and the next section illustrate how urban spatial structure changes when the land supply is also subject to contrived restrictions. The difference between a natural constraint and a contrived restriction is that the former is preexistent and is known to the market whereas the latter is imposed by constitutional regulation and is therefore not known in advance. Two types of land use regulation are considered. In both cases, the basic structure of the dynamic model presented above is unchanged. Growth control is treated as additional constraints to the model.
The first type of land use regulation is conceptualized as follows: starting at some period, an unexpected regulation is set up to limit the amount of land use for the next several periods. The existing outer boundary of the city is unchanged, and land use in post-regulation periods will still be determined by market forces. While all participants have perfect foresight about future market conditions and a perfect knowledge of aggregate land supply, this regulation is not known in advance. Thus the allocation of land follows the market solution until the regulation is suddenly imposed. Once it is imposed, all participants become fully aware of how many future periods will be regulated and how much land will be set up for each regulated period. In effect, the regulation becomes part of the later development process.

For those periods under land use regulation, their boundaries are exogenously determined. Hence, in addition to the equilibrium conditions of equations 4.12 and 4.13, the maximization of land price (equation 4.10) is subject to one more constraint for each regulated period. The constraint can be expressed as:

\[ \int_{b_{i-1}}^{b_i} dz = L_i \]

(4.20)

where \( L_i \) is given. The value of this constraint depends on how many periods are regulated. It is assumed that regulated land use for a particular period \( L_i \) is always less than the market solution for that period. This assumption is necessary because, if the regulated amount of land is greater than the market solution, excess land will be held vacant for future use and the regulation will have no effect.

Without a change in market conditions, the same population increase has to be
accommodated with less land in those periods under regulation. Based on the analysis for the single period model, it is not difficult to conclude that rents and density will be higher in these periods. However, in the context of durable capital, new development in each period represents only a part of the city's capital (with the exception of the first period). Thus the key issue here is the previous development. Because development is irreversible, the density of existing residence cannot be changed. But with the market in equilibrium, utility has to be constant over space. Thus it follows that rents for existing residences must adjust so that new households are as well off as existing households. In other words, a supply restriction on new development affects not just the rents for new development but the rents for the entire city.

One direct consequence of such a disturbance is the discontinuous land prices. Because the density of existing development is fixed whereas rents must adjust, the condition of equal prices at inter-period boundaries for developed land is no longer guaranteed. Price jumps at these boundaries are unavoidable. For those areas developed under the regulations, prices are also discontinuous. This is because in each period the regulation forces a delay in development at some locations. Since these locations would otherwise be developed earlier, the prices must be lower when they are forced to be developed later. Only for those areas developed in the post-regulation periods is price continuous over space.

Another consequence is the occurrence of vacant lots. As regulated periods are forced to use less land, there will be more land left for post-regulation periods.
With the population increase unchanged, both rents and density tend to be lower in subsequent periods, and the utility level tends to be higher. But, with the market in equilibrium, only one utility prevails in each period. For those who live in the previously developed small lots to enjoy the same level of utility as their descendants, their rent payments must be sufficiently low. If the difference between the two periods is significant, it is possible that even a zero rent for an existing residence is not enough to offset the disadvantage of high density. Of course, rents cannot be negative. Under these circumstances, people will leave old densely developed areas for the sake of more space consumption and the new development will have to accommodate more than just the population increase in the corresponding period. This movement tends to increase the density of new development and push rents up for the entire city. As the density of new development increases, some households move back to their previous residences. Such movement between old residences and new development will continue until every household achieves the same level of utility and no lots yield a negative rent. Thus, in the presence of a contrived supply restriction, vacancy is required for the market in equilibrium.

A ten-period simulation was programmed to incorporate the land use regulation as discussed above. The simulation used the same market parameters as in the first case in the previous section, the case with a fixed city boundary of 25 miles, so that results can be compared. The first four periods were developed as if there was no regulation. It then followed a three-period of regulated land use. Specifically, land use in the 5th, 6th and 7th periods was respectively forced to be
less than the market solution. Land use in post regulation periods is again market
determined.

Figures 4.10 and 4.11 present price and density profiles with three regulated
periods as described above. It can be seen that density increases during regulated
periods and decreases in post-regulation periods. For the periods prior to regulation,
density is unchanged. Discrete price jumps can be observed at inter-period
boundaries of early development and for developments during regulated periods.
However, the most important result here is that land prices are lower at all locations
compared with the prices without the disturbance. This result is expected. Because
the total land is unchanged, a reduction of land use in one period increases the
amount of land available for future use. While land rents are higher in the periods
with less land, they must be lower in the future when there is more land. However,
the discounted present value of land rents overall must be lower compared with the
situation without regulation, because the regulated land use deviates from the market
solution in which land price has been maximized. The only changed condition from
the previous market solution (price maximization) is that vacancy is allowed when
land use is subject to contrived restrictions. The occurrence of vacancy is exact an
indication of inefficient land use. It reduces land prices because an over supply will
reduce future land rents.

Figure 4.12 shows the utility path under regulation. There clearly exists a
tradeoff between regulated periods and future periods. Utility is lower during the
periods under regulation but higher in post-regulation periods. Despite the tradeoff,
Figure 4.10
Equilibrium Land Price as a Function of the Distance from CBD with a Fixed City Boundary (z=25) and Unexpected Supply Restrictions in Periods 5, 6 and 7

Figure 4.11
Equilibrium Density as a Function of the Distance from CBD with a Fixed City Boundary (z=25) and Unexpected Supply Restrictions in Periods 5, 6 and 7
the present value of utility is lower when land is kept over for future use. Thus, the city’s overall quality of life is worse in the presence of such a disturbance.

VI.5. Perfect Foresight Urban Growth with a Fixed Boundary and an Unexpected Permanent Change in Land Supply

While the regulation discussed above represents a temporary disturbance to the market, the following section considers a situation in which a regulation preempts land for urban use. Like the first regulation, it is an unexpected event. But instead of the changing land use for some periods, the regulation in this case is to change total land supply.
The model is conceptualized as follows: starting at some period, a regulation is set up to reduce (or to increase) the total land available for urban development. Since the regulation was unknown in advance, land development was initially based on an understanding that there was a certain amount of land available. Once the regulation is imposed, all participants realize that the land available for urban use is actually less (or more) than they originally thought. Development afterwards will therefore adjust to the new city boundary.

In the case of land reduction, the adjustment process is less complicated. Once the reduction in the total land supply is known to the market, each developer revises his development strategy in terms of development time and density based on his new knowledge of the city boundary. To accommodate the same population increase, each period in the future uses less land and the density has to be higher. Because of the durability of capital, the density of previous development is fixed. Given the higher density in later developments, there is no incentive for people to move out of the old residences. Because there is no vacancy in the early development, new households can only be accommodated by new development. Thus, there will be no household movement between old and new developments. Only the rents adjust so that the utility in each period is constant over space.

The simulation results for a permanent reduction in total land are presented in Figures 4.13 and 4.14. Again, the simulation is based on the same market parameters as used in the first simulation in section IV.3. Land reduction occurs at the 6th period. Prior to the land reduction, development was based on a city boundary of 25
Figure 4.13
Equilibrium Land Price as a Function of the Distance from CBD
with a Fixed City Boundary ($z=25$) and
an Unexpected Permanent Reduction in Land Supply

Figure 4.14
Equilibrium Density as a Function of the Distance from CBD
with a Fixed City Boundary ($z=25$) and
an Unexpected Permanent Reduction in Land Supply
miles. Density is therefore the same as in the base case. After the reduction in available land, density is higher. Discrete price jumps can be observed at inter-period boundaries in the areas developed earlier. As explained previously, this discrete pattern of land price is a result of changing rents for fixed lots. However, the most important result is that land prices are higher at all locations. While this result is similar to the static model which also predicates higher land prices with a smaller city boundary, there is an important difference between the two. In a static model, higher land prices are a result of smaller lot size at all locations. Here, the density of existing development is fixed. Higher land prices resulted from higher future land rents.

If the regulation is to increase total land supply, then the results are just the opposite. Figures 4.15 and 4.16 present the simulation results for an unexpected permanent increase in land supply. It is clear that an increase in total land supply causes lower land prices everywhere. Existing density is unchanged but the density of new development is lower. Note that in this case vacancy is also likely to occur. If land increase is significant, households will be moving out from their existing small lots. As before, this movement tends to increase the density of new development and increase land rents for both existing and new development, which in turn brings some households back to their existing residences. The household movement will continue until the market is in equilibrium, in which case utility must be constant over space and no lots yields negative land rents.
Figure 4.15
Equilibrium Land Price as a Function of the Distance from CBD
with a Fixed City Boundary ($z=25$) and
an Unexpected Permanent Increase in Land Supply

Figure 4.16
Equilibrium Density as a Function of the Distance from CBD
with a Fixed City Boundary ($z=25$) and
an Unexpected Permanent Increase in Land Supply
Finally, Figure 4.17 compares the utility path that results from two different permanent changes in land supply. As expected, the increase in total land supply increases utility whereas a reduced land supply decreases utility.

Figure 4.17
Utility Path with a Fixed City Boundary and a Permanent Change in Land Supply

In conclusion, the effects of a temporary land use regulation can be very different from those of a permanent growth control. Without changing the total land, a temporary regulation can only cause a decrease in land prices at all locations. On the other hand, a permanent reduction in land supply increases land prices at all locations and a permanent increase in land supply decreases land prices at all locations.
However, it is important to understand that these results are based on some extreme assumptions about expectation. While expectation of future development is important, real expectation does not project to infinite as has been assumed in the perfect foresight model. Because in reality capital is not going to last forever, anything beyond the duration of capital will not be relevant. In that situation, capital will be replaced. The static model discussed earlier will then prevail. Thus, the perfect foresight model must be understood as a relative concept. It is applicable only to a finite time duration when capital is durable, and when return of investment is relevant to the market. If a regulation restricts current land use and preserves land for fifty years, consumers would not view such a scheme as a temporary disturbance to the market. Rather it would be viewed as a "permanent" reduction of total land in the spectrum of their expectation.
Chapter V

Housing Market Behavior with
Restrictive Land Supply

The theoretical modeling in the previous chapter offered some important insights into the effects of restrictions on land supply. In a closed city where population increase must be accommodated within the city, any restriction in land supply, whether due to a natural or a contrived restriction, suppresses space consumption. As space consumption is suppressed, household willingness to pay for space increases. The higher bid rents then lead to a higher intensity of land use which ensures that all households are accommodated. From a dynamic perspective, an unexpected supply restriction changes the future density. While the existing lot size is fixed, future rents for existing lots must adjust in the presence of such a restriction. In a rational market, higher future rents are capitalized into a higher land price. The analysis also shows that the effects of a temporary land use regulation can be very different from those of a permanent growth control. A temporary regulation always decreases prices whereas a permanent growth control increases prices.

Using data from Hong Kong, this chapter provides empirical evidence on the
extent to which the development in the real world can be explained by the urban spatial theory. As discussed earlier, land supply in Hong Kong is subject to not only physical restrictions but also absolute control by the government. The housing market in Hong Kong therefore provides a good case for empirical analysis.

The chapter consists of four sections. Section 1 reviews briefly the historical trends of government involvement in the Hong Kong housing market. Section 2 outlines the macroeconomic model of the housing market. Section 3 describes data sources and, finally, section 4 presents the results of the analysis.

V.1. Public Housing and its Impact

The government of Hong Kong not only has a powerful control over land supply, but also has played an active role in the residential market. In 1954, the government started to produce resettlement units to clear squatters and to free valuable land. Since then, more and more public housing has been built. By the end of the 1980s, Hong Kong had the second largest public housing sector in the capitalist world (after Singapore). The public sector accounted for nearly half of the total housing stock. Table 5.1 presents some summary statistics to highlight the impact of public housing program.

Before going further into this discussion, it is necessary to clarify the concept of household described here. According to the U.S. census, a "household" comprises all persons, related or unrelated, who occupy a separate living quarter, i.e., a housing
unit. In effect, the number of households is equivalent to the number of occupied housing units. In Hong Kong, the Statistical Department uses a different definition. Persons who share the same housing unit may not be counted as being in the same household. An additional criterion is employed in determining a separate household: whether or not they eat together.

Table 5.1: Summary Statistics of Housing Development in Hong Kong

<table>
<thead>
<tr>
<th>Population per Occupied Housing Stock</th>
<th>1965</th>
<th>1980</th>
<th>1990</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stock-based Households</td>
<td>5.3%</td>
<td>5.5%</td>
<td>4.9%</td>
</tr>
<tr>
<td>Public Housing Stock</td>
<td>5.9%</td>
<td>6.5%</td>
<td>5.0%</td>
</tr>
<tr>
<td>Private Housing Stock</td>
<td>4.7%</td>
<td>4.6%</td>
<td>4.8%</td>
</tr>
<tr>
<td>Average Annual Growth Rate in</td>
<td>1965-90</td>
<td>1965-80</td>
<td>1981-90</td>
</tr>
<tr>
<td>Population</td>
<td>1.9%</td>
<td>2.3%</td>
<td>1.4%</td>
</tr>
<tr>
<td>Stock-based Households</td>
<td>5.3%</td>
<td>5.5%</td>
<td>4.9%</td>
</tr>
<tr>
<td>Public Housing Stock</td>
<td>5.9%</td>
<td>6.5%</td>
<td>5.0%</td>
</tr>
<tr>
<td>Private Housing Stock</td>
<td>4.7%</td>
<td>4.6%</td>
<td>4.8%</td>
</tr>
<tr>
<td>Average Annual Land Sale for Private Housing (in Square Meters)</td>
<td>83,554</td>
<td>47,905</td>
<td>144,156</td>
</tr>
</tbody>
</table>

Under this definition, a household is a group of individuals who live in the
same housing unit and eat together. For example, a grown child who lives with his parents but prepares his own meal will be counted as a separate household, whereas a live-in housekeeper who shares her meal with her employer will be counted as part of the same household. The underlying assumption is that persons who share the same household meal are more likely to belong to the same family. The difference between the two definitions -- from the U.S. and Hong Kong -- is that the former measures households that have actually formed whereas the latter measures the potential households (or family) which are likely to form as individual households. Obviously, there are always more potential households than occupied housing units. To avoid confusion, this study uses "actual household" to refer to the U.S. definition, and "potential household" or "family" to refer to the household definition employed by the census of Hong Kong.

One of the most extraordinary changes in Hong Kong over the last three decades was a rapid decline in the size of the actual household. In 1965, the number of people per occupied housing unit (excluding institutional housing) was 8.4. That ratio dropped to 5.3 in 1980, and to 4.3 in 1990. A closer examination shows that the decline in the actual household size was a combined result of these factors: an ever-smaller potential household size, a reduction of the amount of doubling up, and a decrease in crowded temporary housing structures. As Figure 5.1 shows, in 1966, half of the potential households comprised 5 persons or more. Twenty-five years later, this group accounted for only one quarter of potential households whereas the
Figure 5.1
Potential Households by Size

Thousands

<table>
<thead>
<tr>
<th>Year</th>
<th>8 or more</th>
<th>7 persons</th>
<th>6 persons</th>
<th>5 persons</th>
<th>4 persons</th>
<th>3 persons</th>
<th>2 persons</th>
<th>1 person</th>
</tr>
</thead>
<tbody>
<tr>
<td>1966</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1971</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1976</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1981</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1986</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1991</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Census and Statistics Department

Figure 5.2
Doubling-Up in Private Housing Blocks

Thousands

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of Units</th>
<th>Number of Households</th>
</tr>
</thead>
<tbody>
<tr>
<td>1971</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td>1976</td>
<td>400</td>
<td>400</td>
</tr>
<tr>
<td>1981</td>
<td>600</td>
<td>600</td>
</tr>
<tr>
<td>1986</td>
<td>800</td>
<td>800</td>
</tr>
<tr>
<td>1991</td>
<td>1000</td>
<td>1000</td>
</tr>
</tbody>
</table>

Number of Units | Number of Households

* Private housing blocks accounted for 79% of permanent housing stock in the private sector in 1971, and 84% in 1991

82
group with three persons or less represented half of the total potential households. Meanwhile, the degree of doubling up dropped greatly. In private housing blocks (multi-unit housing structures), where doubling up is most common, one unit used to house 1.67 families (potential households) in 1971 and accommodated only 1.13 in 1991 (Figure 5.2). Also, the number of temporary structures decreased greatly over the last ten years. As Figure 5.3 shows, nearly 120,000 families lived in temporary units in 1981; this number was reduced by half to 60,000 in 1991.

Figure 5.3
Temporary Units and Housed Households

12 The shrinking size of the potential household reflects the change in family structure. For instance, traditional extended families (with three or four generations living together) are much less common than twenty-five years ago. It is common today to see parents separating themselves financially from their married children, even though they may still live in the same unit. At the same time, grown children moving out is more common. Other factors that contribute to the smaller size of potential households include the declining birth and marriage rates, and the increase in the divorce rate.
All these changes are directly linked to a rapid rate of actual household formation. Without any increase in the formation of actual households, a decline in family size would only intensify the degree of doubling up, which obviously was not the case. As Table 5.1 shows, actual household formation increased at an average annual rate of 5.3%, whereas the population growth was less then 2% throughout the period. The fact that household formation grew at a much faster rate than the population reinforces the importance of changes in household structures and living arrangements. In fact, nearly two thirds of actual household formation during that period must be attributed to the shrinking family size and the decrease in subdivided units and temporary structures.

One of the oldest assertions in the field of housing economics is that actual household formation is closely related to new construction. A major factor that made such rapid formation of actual households possible was the government’s efforts to provide public housing. During the period 1965-1980, additional housing units were added at a rate of 6.5% per year in the public sector. The massive production in the public sector effectively released the pressure on the private housing sector. Starting from the early 1980s, when the pressure on the private housing sector was less intense, the public housing policy shifted from massive production to a more quality-oriented but more limited public housing program. The annual growth rate of the public housing stock has slowed down to 4.9%. In comparison, the private sector has kept to a relatively stable growth rate throughout the period. Additional private housing units were added at a rate of 4.6% in 1965-1980 and were kept at a rate of
4.8% in 1981-1990. Evidently, without an aggressive public housing program, the change in actual household size would be much less dramatic.

The government’s efforts on public housing were also reflected in the land sales for private housing. During the period 1965-1980 with rapid expansion in the public sector, the average annual land sale for the development of private housing was 0.048 km\(^2\). In the 1980s, corresponding to less aggressive public housing construction, land sale for private housing was increased to 0.144 km\(^2\) per year. The increase in land sales signifies the government’s attempt to make the private sector a more important housing supplier. This again points to the fact that land sales are closely related to other policy considerations.

V.2 Macroeconometric Model

The housing market of Hong Kong is unique in its natural impediments to land supply as well as the contrived supply restrictions. In addition, it has a very large public housing sector. Given this background, it is clear that existing macroeconomic housing models are not readily applicable. Thus it is a challenge to this study to formulate an empirical model with these characteristics reasonably incorporated.

The housing market model outlined below is a variation on the traditional stock-flow model and contains two sets of equations. One system of equations estimates the demand for housing stock and the other estimates the supply of housing stock.
Many studies of housing market separate rental housing and owner-occupied housing. But data limitations preclude such a segmented approach as consistent measures of the two segments are not available. In Hong Kong, the housing market is almost entirely one of small flats in high-rise or multi-unit buildings. In 1989, about 85% of the units in the private sector were flats of less than 70 square meters and 93% were smaller than 160 square meters. While these flats are mainly for owner-occupancy, they are also purchased for investment or speculation purposes. Pure residential rental properties are rare in the private sector. The private rental market consists mainly of small landlords who own one or two flats. Many tenants are potential owner-occupants and vice versa. The housing market is somewhat similar to the condominium market in the U.S.

Therefore the model is for the entire Hong Kong housing market. The underlying assumption is that there is no essential difference between rental housing and owner-occupied housing structures. As Pozdena (1988) argued, in the absence of legal restrictions on doing so, a given unit of housing can be used to supply housing services either to a tenant or to an owner-occupant. Thus, the services provided by a structure are the same whether it is rented or occupied by the owner. Since a housing unit currently rented can be offered for sale to owner occupants and provide the same

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13 The segmented approach was first taken in H. Rosen and K. Rosen (1980) and has been followed up in a number of other studies.

14 Property Review 1990, Rating and Valuation Department, Hong Kong.

15 In 1990, the overall owner occupancy rate in Hong Kong was 43%. Most rental units were in the public sector and accounted for 38% of the total housing stock. Thus the owner occupancy rate in the private sector was more than 60%.
services, the currently rented housing and the currently owner-occupied housing are competitive substitutes for one another.

The fact that the two modes of tenure, rental or ownership, are competitive substitutes, has important implications for the equilibrium price of housing. Specifically, the rental price and the user cost of housing perceived by the owner occupant for the same housing services must be very similar for households on the margin; if they are not, households might switch to the other form of tenancy. Also, if reasonably vigorous competition occurs among landlords for tenants, the observed rental prices will be equal to the landlord’s user costs. Thus, for the housing market as a whole in equilibrium, the owner-occupant user cost and the landlord user cost must both be equal to the rental price on the margin. If this were not so, there would be a migration of households between the two modes of tenancy or a migration of households among different rental units in order to seek out more economical housing alternatives.\textsuperscript{16}

The argument of competitive substitutes, however, is not applicable to public and private housing. While public and private housing stock bear the same function in terms of providing housing services, the costs of housing services in the public sector are below market value because of government subsidy. As public sector rental prices do not correspond to market clearing rental prices, households in the public sector are not operating at margin. For the same quality of housing service,

\textsuperscript{16} Much of the discussion on competitive substitutions and equilibrium housing prices is drawn from Pozdena (1988).
households will prefer public housing over private housing. In fact, there has been a long waiting list for public housing in Hong Kong ever since the public housing program started in the 1950s.

Because of the excess demand for public housing, changes in public sector rents have little impact on the private housing market. Higher rents shorten the waiting list, whereas lower rents lengthen the waiting list. The number of households that remain on the private market will not change unless public sector rents begin to match market rents. In this regard, the major influence of the public sector is that its quantity determines how many households will remain in the market. The model thus concentrates on the private sector and includes the public sector only via the effect of housing stock instead of through relative price.

Housing Demand

Aggregate housing demand is the quantity of housing desired by all households. The primary exogenous factors determining the aggregate demand for housing include household wealth (or permanent income), size of the population, demographic characteristics of the population, and size of the public housing sector. The endogenous factors that determine demand include the costs of housing, household formation, and housing price. The methods employed to estimate these endogenous factors are discussed below.

Housing Costs: As stated above, for the market in equilibrium, the owner-occupant user cost and the landlord user cost both must be equal to the rental price on
the margin. Thus the issue to be clarified here is how the equilibrium rental price is determined. A major feature that differentiates housing from most other consumption goods is the durability of housing assets which can produce a flow of services many years into the future. While rental price is the cost for housing services over a period of time, the price of a housing unit reflects the costs of the housing service flow produced by the structure. Unless the housing unit deteriorates or is physically altered, this housing service flow is perpetual. In a perfect financial market, the price of housing assets must be equal to the discounted present value of rental income for the housing services. In other words, the rent for housing services of a given housing stock depends upon the price of the housing stock and the opportunity costs of capital. Because mortgage payments are not tax-deductible in Hong Kong, the opportunity cost of capital is simply the difference between the real interest rate and the expected appreciation in housing price. Thus equilibrium rental price can be expressed as:

$$ R = P^* (i - EP) $$

(5.1)

where $P$ is the equilibrium price for housing stock, $i$ is prevailing market interest rate, and $EP$ is expected price appreciation.

**Expected Price Appreciation:** Modeling how consumers form expected appreciation in housing price is an important aspect of this study. Existing aggregate housing models have employed two alternative approaches. The first approach assumes that expectations are developed based on some pattern of current or past behavior in the market. While such "adaptive" or "backward-looking" expectations models are frequently criticized as being ad hoc, evidence from consumer surveys
indicates that consumers often operate in this manner [Case and Shiller (1988)]. The alternative approach assumes that consumers are perfectly informed about the operation of the market and that expectation formation is rational. Being rational does not mean that consumers can perfectly predict unforeseen changes or shocks to the market--only that once such shocks occur, informed consumers are able to correctly predict how the market will respond. Thus, with rational expectations, consumers will constantly adjust their expectations about the future path of prices according to the best available information on exogenous change [Sheffin (1983)].

In reality, "adaptive" and "rational" are not mutually exclusive. Real expected appreciation formation is probably both "adaptive" and "rational." In this study, expected price appreciation is assumed to be a result of two considerations. First, consumers will look back at recent price appreciation trends to speculate about future price appreciation. Second, consumers will look at the conditions of recent land sales to adjust their expectations for future price appreciation. As stated above, the sale of new land is exogenously determined by the government. While consumers are not able to predict land sales, if they are rational, they are able to predict the market effects of a given land sale and capitalize the effects into their bid price for housing. This modeling strategy is a direct application of the urban spatial theory. As stated earlier, an unexpected restriction on the supply of land changes land price by changing future land rents. Incorporating expected price appreciation with equation 5.1, the equilibrium housing cost can be expressed as a function of equilibrium price of housing assets (P), real interest rate (i), recent price appreciation (PA), and
quantity of land sale (LS).

\[ R = F(P, i, PA, LS) \]  \hspace{1cm} (5.2)

where PA is average price appreciation in the last three periods.

Household Formation: The number of households is of fundamental importance to housing demand. For the market as a whole, household formation is parallel to aggregate housing demand. The basic set of factors underlying the number and composition of households is a combination of sociological and economic forces. Trends in fertility rates and mortality rates over time determine the population's age distribution. This age distribution is itself an important influence on the size and number of households formed. Since household formation tends to be associated with reaching adulthood, all else being equal, a greater proportion of young adults in the population increases the number of households. Several other factors are likely to have an effect on household formation: income level by age group, female labor force participation rate, marriage and divorce rate, and the availability of public housing. Most importantly, the choice of individuals and families to actually form an independent household is largely dependent on the cost of housing [Smith, et.al. (1984), Borsch-Supan (1986)]. Higher housing cost, whether due to higher prices for housing assets or higher opportunity costs of capital, discourages household formation. Agreement is now widespread that in the short run the number of separate households and the number of available dwellings are likely to be simultaneously determined.

However, a major difficulty associated with all econometric models of the
housing market is that the simultaneous determination of housing price and household formation is not allowed. Despite the fact that housing systems and demographic change are inexorably linked, existing housing market analyses typically treat demographic influence as exogenous instead of trying to model these interactions. A common practice is the use of population as a proxy for demographic change. A number of studies also use a term specified as the "pure demographically induced" rate of household formation. This term accounts for changes in the age/sex distribution of the population, on the assumption of headship rates stable at a certain value [Buckley and Ermisch (1982), DiPasquale and Wheaton (1990), Park, et.al. (1992)]. Given that household formation in Hong Kong is far more rapid than population growth, demographic change alone is not enough to explain the change in housing demand. The modeling exercise explored an alternative methodology by using "potential households." The variable is estimated by multiplying the number of occupied housing units by the ratio of doubling-up plus the number of households in temporary structures. In effect, "potential households" consist of those who consider themselves as separate units even though they actually share one housing unit with others, and those who live in temporary structures.

The difference between "pure demographically induced," "actual," and "potential households" measures the extent to which changes in income, prices, and other economic variables influence household formation. While "pure demographically induced households" are completely exogenous to the housing system, "actual households" are completely endogenous. The "potential households"
capture the effect of both demographic factors and other social economic factors on household formation. The advantage of using "potential households" is that it eliminates the simultaneity problem, yet nevertheless allows for the joint estimation of household formation and housing prices.

Note that the discrepancy between "potential households" and "actual households" is significant only in the private sector. In the public sector, the difference is negligible. According to the census, the ratio of potential households to occupied units in the public sector was 1.01 in 1971, 1.01 in 1981, and 1.008 in 1991. Obviously, doubling up is not common in public housing. Also, due to the excess demand, vacancy in the public sector is trivial. Therefore, the number of households who lived in public housing is basically equivalent to the number of housing units in the public sector.

Determinations of Housing Prices: The specification of the housing demand equation includes housing cost variables, household wealth, and "potential households." The public housing sector is also explicitly incorporated into the model for estimation. As shown, equation 5.3 provides for an interaction between the number of households and the other demand variables:

\[(H - STKp)[\beta_0 + \beta_1 P + \beta_2 Y + \beta_3(i-P)A + \beta_4 LS] = TSTK - STKp \tag{5.3}\]

where \(\beta_0\) is a constant and \(\beta_1\) to \(\beta_4\) are a set of coefficients, \(H\) represents total "potential households," \(P\) is housing price, \(Y\) is permanent income, \(i\) is interest rate, \(PA\) is the average price appreciation over the last three periods, \(LS\) is amount of current or recent residential land sales, \(TSTK\) is total housing stock, and \(STKp\)
represents public housing stock.

The expression implies that the demand for housing observed in the market is actually the demand of those who are not able to obtain housing in the public sector. The right-hand side of equation 5.3 is the existing private housing stock in the market. The first bracket on the left-hand side, \((H-STKp)\), is the "potential households" in the private market. The term in the second bracket on the left-hand side is the fraction of "potential households" that actually formed individual households. It is this fraction that varies with the exogenous and endogenous market conditions. Without subtracting public stock, the model can be interpreted as total demand equal to total existing housing stock. As stated above, the public sector influences the market mainly through the quantity of its supply. In general, it increases the fraction of potential households that actually forms individual households. If the supply of public housing follows a pattern similar to that of private housing, however, its effects on the parameters in the demand equation 5.3 cannot be easily predicted. For example, if the supply of public housing follows a pattern similar to that of private housing, the coefficients for the market parameters determined with and without subtracting the public housing would not be very different.

The expected sign of \(\beta_1\) is negative, because the demand for housing should decline as the price of housing rises. Similarly, as the opportunity cost of housing rises, the demand for housing should decrease, and hence, \(\beta_3\) should be negative. The sign of coefficient for permanent income (\(\beta_2\)) is expected to be positive, as the
demand for housing increases along with rises in household permanent income.

Solving equation 5.3 for the market clearing housing price yields equation 5.4:

\[ P = \frac{1}{\beta_1} \left[ \frac{STK_v}{(H-STK_p)} - \beta_0 - \beta_2 Y - \beta_3 (i-PA) - \beta_4 LS \right] \]  

(5.4)

where STK_v is the private housing stock (STK_v=TSTK-STK_p).

**Gradual Adjustment:** The traditional stock-flow model assumes that housing prices adjust instantly to equate the demand for housing with the existing stock. As reviewed earlier, a number of empirical analyses suggest that housing prices may adjust only gradually in response to shocks. To test the graduate price adjustment hypothesis, a graduate price adjustment as presented by equation 5.5 is incorporated into the basic stock flow model. It is assumed that the current period price, at any time, depends on both the unobserved current period equilibrium price and the actual price observed in the previous period.

\[ P_t = \tau P^*_t + (1-\tau)P_{t-1} \]  

(5.5)

where \( P_t \) is the price realized in current period \( t \), \( P^*_t \) is the equilibrium price in current period \( t \), \( \tau \) is the rate at which \( P_t \) converges to \( P^*_t \), and \( P_{t-1} \) is the price observed in the previous period \( t-1 \).

Combining equation 5.4 with the graduate adjustment equation 5.5, the complete price specification for estimation is presented below.

\[ P = \frac{\tau}{\beta_1} \left[ \frac{STK_v}{(H-STK_p)} - \beta_0 - \beta_2 Y - \beta_3 (i-\Delta P/P) - \beta_4 LS \right] + (1-\tau)P_{t-1}. \]

\[ = q_0 + q_1 \frac{STK_v}{(H-STK_p)} + q_2 Y + q_3 (i-PA) + q_4 LS + q_5 P_{t-1}. \]  

(5.6)

where \( q_0 \) is a constant and \( q_1 \) to \( q_5 \) are a set of coefficients.
Housing Supply

In equilibrium the demand for housing is equal to the amount of existing stock. The housing stock at any given time is a function of the housing stock in the previous time period adjusted for additions to the stock through new completions, subdivision and conversion, or demolition. Though housing market theory suggests that inventory losses and conversion are endogenously determined, data limitations preclude their inclusion in an aggregate model as consistent measures of inventory loss and conversion are not available. Previous studies of the U.S. housing market suggest that net annual inventory loss is between 0.3% to 0.5% of the total stock [Kain and Apgar (1985)]. Based on changes in housing stock from 1988 to 1989, estimated net annual inventory loss in Hong Kong was 0.39%. Assuming a net inventory loss of 0.4% per year, equation 5.7 depicts the basic stock adjustment function:

\[ TSTK = 0.996 \times TSTK_{t-1} + S_p + S_v \] (5.7)

where TSTK is total housing stock, \( S_p \) is the number of new housing units completed in the public sector, and \( S_v \) is the number of new housing units completed in the private sector.

Because housing supply in the public sector is determined by the government rather than by market forces, it is assumed to be exogenous. The focus of interest is the supply of new housing units in the private sector. In the present context, it is fundamental to determine how new housing supply will respond to market signals, as this in turn will generate secondary signals which will have an impact on demand.

The decision to supply new housing units is based on the expected profitability
of housing construction given the price of housing and the relative costs of construction. Because of the long duration of construction, especially the construction of high-rise buildings, current housing completion must be a result of decisions made in previous periods. Thus the volume of new housing completion can be generally expressed as a function of lagged housing price, lagged construction cost factors, and the expectation of price increase upon completion. The following explains how cost factors and expectation are actually presented.

Cost Factors: There are four major factors of production engaged in the housing construction process: land, labor, material and capital. Existing econometric models of the housing market often include costs for all these factors: cost indexes of labor and material, interest rates or the costs of capital, and land prices. As criticized, land prices are determined by housing prices, not vice versa. In a competitive market, land prices represent only the residual of housing prices and other capital costs. Therefore, housing prices are used in the model instead of land prices.

Land Supply: Understanding the relationship between land and housing

\[ C = aP + b, \]
where \( C \) represents construction costs, \( a \) is a coefficient, \( P \) is housing price, and \( b \) is a constant. The land price (LP) can be expressed as
\[ LP = P - C = -b + (1-a)P. \]
(5.8)
This expression shows that if land prices are regressed against housing prices, a negative constant and a positive coefficient on housing prices are expected and the magnitude of the coefficient will be less than 1.
production is another important aspect of this study. Land is a unique production factor. Because intensive use is possible, higher housing prices can induce additional housing output without increase the input of land. In this regard, housing production responds mainly to housing prices. This in fact is the fundamental assumption upon which the urban theory discussed earlier is built. In a closed city, supply restriction increases land prices and density but does not reduce the number of households. To obtain empirical evidence on this issue the amount of land sale is included in the housing production function. This modeling strategy intends to capture the direct effect of land on housing production by controlling the effect of housing prices.

**Expectation**: In considering the supply side expectation, the question arises again: Is the market rational or myopic? If builders are fully informed, their expected price increase upon completion will be the actual price increase. While the rational expectation may be unrealistic, empirical results suggest that it is a better alternative than myopic expectation. Thus the model includes current price change to reflect actual price change perceived by speculative builders.

In addition, existing housing studies have suggested that builders are likely to be cognizant of economic and demographic trends that will affect the demand for their product. Thus measures of economic and demographic growth, such as change in real GDP, are likely to serve as signals for builders to construct new housing and so will be included in the estimated equation.

**Housing Completion**: Based on the considerations discussed above, the housing completion equation will thus be of a form of equation 5.9:
\[ Sv = a_0 + a_1 P_{t-1} + a_2 \Delta P + a_3 C_{t-1} + a_4 i_{t-1} + a_5 LS_{t-1} + a_6 \Delta GDP_{t-1} \]  
(5.9)

where \( a_0 \) is a constant, \( a_1 \) to \( a_4 \) are a set of coefficients, \( P \) is real housing price, \( \Delta P = (P_t - P_{t-1}) \) is the change in real housing price, \( C \) is construction cost index of labor and materials, \( i \) is real interest rate, \( LS \) quantity of land sale, and \( \Delta GDP \) is change in real GDP.

All else are being equal, any increase in housing prices or in price appreciation increases the profitability of housing construction. The expected signs of \( a_1 \) and \( a_2 \) should be positive. Conversely, any increase in construction costs or interest rate decreases the profitability of construction; hence the expected signs of \( a_3 \) and \( a_4 \) are negative. If the volume of land sales has a binding effect on construction, a negative sign on \( a_5 \) is expected. Finally, since economic growth signals increases in housing demand, coefficient \( a_6 \) on the change in real GDP should be positive.

**Gradual Adjustment:** As with the price equation, a gradual adjustment is tested for the supply of new housing units. Given that the housing stock in Hong Kong consists mainly of high-rise buildings, a longer construction cycle is expected. The response of housing completion to a change in profitability is more likely to be subject to lengthy lags than that in other housing markets. The gradual construction adjustment process is specified by equation 5.10.

\[ Sv_t = \tau Sv^*_t + (1-\tau)Sv_{t-1} \]  
(5.10)

where \( Sv_t \) is private housing completion in the current period \( t \), \( Sv^*_t \) is the equilibrium level of completion in period \( t \), \( \tau \) is the rate at which \( Sv_t \) converges to \( Sv^*_t \), and \( Sv_{t-1} \) is the level of housing completion in previous period \( t-1 \). At any point, the level of
actual new completion depends on both the unobserved current period equilibrium level of completion and the actual completion observed in the previous period.

Combining equation 5.9 with gradual adjustment obtains the estimated equation 5.11:

$$S_{t} = j_{0} + j_{1}P_{t-1} + j_{2}ΔP + j_{3}C_{t-1} + j_{4}L_{t-1} + j_{5}GDP_{t-1} + j_{6}S_{t-1}$$ (5.11)

where $j_0$ is a constant and $j_1$ to $j_7$ is a set of coefficients.

**V.3. Data Series**

In any econometric application, obtaining reliable data is no less important than formulating reasonable models. It is fortunate that the Rating and Valuation Department of Hong Kong produces statistics about every private housing transaction and the Buildings and Lands Department keeps detailed records of land sales. These two departments provided most of the important data for this analysis. These data are described here.

**Housing Price:** Empirical estimates of the parameters of the aggregate housing model require estimates of the market price of housing of constant quality. The price series used for estimation in this study was derived from the housing price index produced by the Rating and Valuation Department. The index is designed to measure price changes with quality kept constant. Prices of transactions scrutinized by the department for stamp duty purposes are all included for the production of indexes. The index measures price changes by referring to the factor of price divided by the assessment value of the subject properties based on floor areas, location and other
qualitative aspects.

However, the index was not produced in this form until 1979. Thus consistent housing price index series are not available for early periods. While the department has been helpful in providing some rough estimates, it is necessary to note that data for the early periods may be less reliable. Prior to 1979, a crude index was developed by using average prices of typical small flats (40 to 70 square meters).

**Housing Stock and Housing Completion:** Data on both housing stock and annual housing completion in the private sector were obtained from various issues of the Property Review produced by the Rating and Valuation Department. Note that estimates reported in the Review cover only "urban housing" and it was not until 1981 that the entire territory was considered to be an "urban area." Since this is likely to cause underestimates of stock and completion for the early period, estimates before 1981 have been adjusted according to annual estimates of housing units published in various issues of Economic Background by the Hong Kong government.

The public housing stock series was estimated based on two sources. For the early period 1965-1980, estimates were based on the working paper by Castells (1986) on public housing and economic development in Hong Kong. More recent data were derived from various issues of the Hong Kong Housing Authority Annual Report. Public housing includes units provided through the following programs: public rental units, housing authority home ownership scheme, and urban improvement scheme.

**Potential Households:** The number of "potential" households in the private
sector is estimated based on occupied housing stock and the ratio of census estimated households to occupied permanent stock. The ratio was derived from the census (every 10 years) and bi-census (every five years) and was interpolated between these years by averaging. Annual estimates of "potential" households are obtained by multiplying this ratio by the number of occupied private housing units. In the public sector, there is almost no difference between "potential" and "actual" households. Since vacancy and doubling-up are negligible in public housing, the number of households is equivalent to the number of housing units.

Construction Costs: A single cost index of labor and materials is available from the Architectural Services Department from 1970 onwards. For 1965-1969, rough estimates were derived based on aggregate construction costs of labor and materials in the private housing sector, weighted by completed floor areas.

Land Sales and Land Prices: Data on annual land sales are derived from auction and tender sale records of various years provided by the Buildings and Lands Department. Land supply was the total square meters of land sold through auction or tender deal for residential development or residential and commercial combined development during the calendar year.

Annual average land price was calculated based on realized premium and the series is not location-adjusted. Land price varied significantly by location. Locations on Hong Kong Island are usually sold at higher prices than those in the New Territories. Since the late 1970s, more and more of the lots put on sale were located in the New Territories. Therefore, the average land price is biased downwards. To
capture the location variation, a land price index was constructed based on the
average land price on Hong Kong Island. While this series is less biased, it is still
not truly location-adjusted.

Consumer Price Index and Interest Rate: In order to account for changes in
the relative prices of other goods and services, the housing prices, construction costs,
and household permanent income series in this study were all expressed in inflation-
adjusted terms, using all the items of the consumer price index (CPI). Similarly, the
interest rate series was reduced by the inflation rate as given by the CPI index. Two
series of interest rates were employed during the estimation. Short-term deposit rates
were used to indicate opportunity costs of capital in the estimation of housing
demand, and the best lending rates were used as costs of construction finance in the
estimation of housing supply. Both rates were obtained from the Statistical
Department of Hong Kong.

IV.4. Results of Empirical Analysis

Housing Price

As described above, the factors related to the demand for housing stock are
used to estimate housing prices through equation 5.6. In order to determine the
validity of this model, a set of variations on the model were used in the regression.
As Table 5.2 shows, the first case omitted both the land sales and the lagged price in
equation 5.6, while the second case omitted only the land sales. A comparison
between Case 1 and Case 2 shows that the values of both the R-square and the
Table 5.2: Estimates of Housing Demand

<table>
<thead>
<tr>
<th>Independent Variable</th>
<th>Case 1</th>
<th>Case 2</th>
<th>Case 3</th>
<th>Case 4</th>
<th>Case 5</th>
<th>Case 6</th>
<th>Case 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>30.82</td>
<td>-23.99</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.39)</td>
<td>(-0.39)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Income</td>
<td>1871.76</td>
<td>778.99</td>
<td>782.50</td>
<td>676.97</td>
<td>787.27</td>
<td>904.99</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(7.95)</td>
<td>(2.64)</td>
<td>(2.62)</td>
<td>(2.62)</td>
<td>(3.60)</td>
<td>(3.05)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(-0.77)</td>
<td>(-1.31)</td>
<td>(-1.17)</td>
<td>(-1.90)</td>
<td>(-2.49)</td>
<td>(-1.72)</td>
<td>(-2.53)</td>
</tr>
<tr>
<td>i − PA</td>
<td>-0.90</td>
<td>-0.50</td>
<td>-0.49</td>
<td>-0.47</td>
<td>-0.34</td>
<td>-0.34</td>
<td>-0.35</td>
</tr>
<tr>
<td></td>
<td>(-3.87)</td>
<td>(-2.68)</td>
<td>(-2.56)</td>
<td>(-2.99)</td>
<td>(-2.51)</td>
<td>(-1.67)</td>
<td>(-2.62)</td>
</tr>
<tr>
<td>Price (−1)</td>
<td>0.60</td>
<td>0.56</td>
<td>0.82</td>
<td>0.76</td>
<td>0.62</td>
<td></td>
<td>0.76</td>
</tr>
<tr>
<td></td>
<td>(4.17)</td>
<td>(3.49)</td>
<td>(5.62)</td>
<td>(7.01)</td>
<td>(4.52)</td>
<td></td>
<td>(7.12)</td>
</tr>
<tr>
<td>Land Supply</td>
<td>2.39E−05</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td></td>
<td>(0.70)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Land Supply (−1)</td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>-8.5E−05</td>
<td></td>
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<tr>
<td></td>
<td>(-2.82)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land Supply (−2)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>-9.6E−05</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>(-4.55)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land Supply (−3)</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>-5.7E−05</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(-1.99)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R−square</td>
<td>0.84</td>
<td>0.92</td>
<td>0.92</td>
<td>0.95</td>
<td>0.97</td>
<td>0.93</td>
<td>0.97</td>
</tr>
<tr>
<td>Durbin−Watson</td>
<td>0.75</td>
<td>1.15</td>
<td>1.05</td>
<td>1.59</td>
<td>2.04</td>
<td>1.39</td>
<td>2.09</td>
</tr>
<tr>
<td>Price Elasticity</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-0.80</td>
<td>-0.96</td>
<td>-</td>
<td>-0.98</td>
</tr>
<tr>
<td>Income Elasticity</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2.23</td>
<td>2.39</td>
<td>-</td>
<td>2.45</td>
</tr>
</tbody>
</table>
Durbin-Waston statistic increased with the addition of the lagged price. Thus the hypothesis of a graduate price adjustment cannot be rejected.

Cases 3 to 6 in Table 5.2 examine the effect of land sales. The inclusion of current land sales (Case 3) obviously does not improve the statistical significance, but the lagged land sale does. As shown, coefficients on the one-, two-, or three-year lagged land sales are statistically more significant than those for current land sales. With the two-year lagged land sales the statistical significance is highest at the 97% confidence level. The result shows that the expectation adjustment occurs only after the exogenous shock. With respect to current land sales, there apparently is not enough time for consumers to adjust their expectations. While there is a delay in the effects of land sales being capitalized into housing prices, such a delay should not last long. According to the estimated results, the impact of land sales on prices reaches the market in approximately two years.

The results in Table 5.2 show that household wealth, or permanent income, has a significant and positive effect on housing price. The cost of capital has a significant but negative effect. The ratio of housing stock per potential household, as expected, has a negative effect on housing price. It should be noted that the lagged housing price is also highly significant. Not only is the estimated coefficient itself statistically significant, the addition of the lagged price improves the goodness of fit of the model. The estimated value of $\tau$ suggests that prices move to approximately 24% of their long-run equilibrium value in the first year following a shock, which is similar to the result estimated for the U.S. housing market.
The significant effect of land sales on housing prices has some important implications for land policy in Hong Kong. First, the housing market is restricted by the amount of land for sale. If this were not so, land sales would have little effect on housing prices. Second, based on the theoretical analysis in the previous chapter, the consistently negative coefficients on land sales suggest that the restriction on land sales is perceived by the market as a "permanent" reduction in land supply rather than a temporary disturbance. This perception is understandable. Because of the government's monopoly control over land supply, a reduction in the flow of land supply is regarded as an indicator of the government's intention to restrict land use in the near future. Since only events in a reasonable time frame are meaningful to the market, a delay in land use for even a finite period in the foreseeable future can be equivalent to a theoretically "permanent" land reduction. Therefore, the reaction of the housing market is rational.

Finally, Case 7 of Table 5.2 presents estimates based on alternative specifications on households and housing stock. Instead of focusing on the private sector, this model specification estimates aggregate housing demand without subtracting public stock on both sides of the equation. Compared with Case 5, it can be seen that except an increase in the absolute value of the coefficient on the ratio of housing stock and potential households, as it should be, the general property of estimated results does not change. This result indicates that the supply of public housing in Hong Kong has followed a path similar to the market trend. As shown in Figure 5.4, the pattern of changes in housing stock in the public sector indeed
appeared to follow that for the private sector except for a few short periods.

Figure 5.4
Change in Housing Stock

![Change in Housing Stock graph]

Note: stock change roughly equals to new completion minus demolition.

After comparing the econometric results of the various specifications, Case 5 of Table 5.2 was chosen as the preferred specification for housing price. As presented in equation 5.12, all the coefficients were statistically significant and appeared with the expected signs.

\[ P = 787.27Y - 31.63STK/H - 0.34(i-\Delta P/P) - 8.5\times10^{-5}\text{Land}_{-2} + 0.76P_{-1} \]  

\begin{align*} 
(3.60) & \quad (2.49) & \quad (2.51) & \quad (4.55) & \quad (7.01) 
\end{align*}
**Housing Completion**

Using the same method as that used for housing price analysis, the model for housing completion, equation 5.11, is evaluated. Estimates for housing completion are presented in Table 5.3. As expected, both housing price and expected price change appeared consistently with positive coefficients, and real interest rate appeared consistently with negative coefficients. However, as was true for many studies of housing supply, the coefficient for the construction cost index was found to be troublesome. The expected sign of the coefficient is negative, since higher construction cost reduces the profitability of the construction. In reality, however, this effect may be small. On the other hand, both the housing price and construction cost increase with time. Unless we can separate out the effects such as inflationary components in the housing price and construction cost, the impact of higher real construction cost can be overwhelmed by other effects. Since the coefficient for construction costs consistently had a wrong sign, the variable was excluded from the rest of the estimates.

The most important result of this analysis is that the number of new completions is generally not affected by the supply of new land, as shown in Cases 4, 5 and 6 of Table 5.3. Because housing completion is a result of construction activities started in previous periods, current land sales should have no effect on the current level of completion. The binding effect, if any, is expected to result from previous land sales. As Case 4 shows, the coefficient on one-year lagged land sales is statistically insignificant, as are the coefficients on two-year lagged and three-year...
Table 5.3: Estimates of Private Housing Supply

Dependent Variable = Private Housing Completion

<table>
<thead>
<tr>
<th>Independent Variable</th>
<th>Case 1</th>
<th>Case 2</th>
<th>Case 3</th>
<th>Case 4</th>
<th>Case 5</th>
<th>Case 6</th>
<th>Case 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>-2911.44</td>
<td>12422.10</td>
<td>3767.65</td>
<td>5136.43</td>
<td>3856.63</td>
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<td>4038.99</td>
</tr>
<tr>
<td></td>
<td>(-0.24)</td>
<td>(3.36)</td>
<td>(1.19)</td>
<td>(1.53)</td>
<td>(1.16)</td>
<td>(1.15)</td>
<td>(1.49)</td>
</tr>
<tr>
<td>Real Housing Price (-1)</td>
<td>45.63</td>
<td>146.78</td>
<td>53.88</td>
<td>10.32</td>
<td>49.05</td>
<td>97.31</td>
<td>79.93</td>
</tr>
<tr>
<td></td>
<td>(0.53)</td>
<td>(3.33)</td>
<td>(1.47)</td>
<td>(0.20)</td>
<td>(1.13)</td>
<td>(2.65)</td>
<td>(2.16)</td>
</tr>
<tr>
<td>Change in Real Price</td>
<td>163.87</td>
<td>191.45</td>
<td>175.10</td>
<td>231.88</td>
<td>192.01</td>
<td>223.82</td>
<td>185.84</td>
</tr>
<tr>
<td></td>
<td>(1.38)</td>
<td>(1.62)</td>
<td>(2.09)</td>
<td>(2.39)</td>
<td>(1.67)</td>
<td>(2.72)</td>
<td>(2.45)</td>
</tr>
<tr>
<td>Real Interest Rate (-1)</td>
<td>-420.17</td>
<td>-332.31</td>
<td>-646.38</td>
<td>-756.35</td>
<td>-626.45</td>
<td>-667.50</td>
<td>-582.42</td>
</tr>
<tr>
<td></td>
<td>(-1.00)</td>
<td>(-0.78)</td>
<td>(-2.11)</td>
<td>(-2.37)</td>
<td>(-1.92)</td>
<td>(-2.20)</td>
<td>(-2.17)</td>
</tr>
<tr>
<td>Construction Cost Index (-1)</td>
<td>349.159</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1.34)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Completion (-1)</td>
<td>0.68</td>
<td>0.68</td>
<td>0.67</td>
<td>0.53</td>
<td>0.48</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(4.74)</td>
<td>(4.79)</td>
<td>(4.49)</td>
<td>(3.74)</td>
<td>(3.53)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land Supply (-1)</td>
<td>0.02</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1.03)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land Supply (-2)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4.1E-03</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(0.22)</td>
<td></td>
</tr>
<tr>
<td>Land Supply (-3)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.0E-03</td>
<td></td>
</tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(0.16)</td>
<td></td>
</tr>
<tr>
<td>Change in Real GDP (-1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.21</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(1.39)</td>
</tr>
<tr>
<td>R-square</td>
<td>0.44</td>
<td>0.39</td>
<td>0.72</td>
<td>0.73</td>
<td>0.72</td>
<td>0.78</td>
<td>0.81</td>
</tr>
<tr>
<td>Durbin–Watson</td>
<td>0.81</td>
<td>0.68</td>
<td>1.55</td>
<td>1.54</td>
<td>1.55</td>
<td>1.27</td>
<td>1.54</td>
</tr>
<tr>
<td>Price Elasticity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.11</td>
</tr>
</tbody>
</table>
lagged land sales (Cases 5 and 6). Therefore, the amount of land sales has very little effect on the production of new housing units. The result leads to an important understanding of the ways in which land sale restrictions affect the housing market. Apparently, the negative effect of land sales on housing prices is independent of housing completion. It can be concluded that a shortage of land increases housing prices, but the increase is not caused by a housing shortage. Because it is not uncommon for people to think that restrictions on land supply cause housing shortages, the result is of great educational importance. Of course, one factor behind this result is Hong Kong’s flexible building regulation.\(^{18}\)

A second result of the analysis is that a gradual construction adjustment greatly improves the explanatory power of the model. As Cases 2 and 3 show, the addition of lagged completion increases R-square from 0.39 to 0.72. Without this variable, the model appeared with a very large intercept, implying that a significant amount of housing completion cannot be explained. This intercept is reduced by almost three quarters with the addition of the gradual adjustment term in Case 3.

Finally, like many aggregate housing models, the leading indicator of market activities is found to improve the fit of the model. As presented in Case 7, although the coefficient on lagged change in real GDP is not significant, the addition of this variable improves R-square, and increases the significance of the overall estimates. Also, it reduces the magnitude of the coefficient on lagged completion. As a result, the housing completion rate adjusts to equilibrium level at a more reasonable rate of

\(^{18}\) See Bristow (1984).
52% in the first year following a change in profitability. The preferred specification is presented below:

\[ S = 4038.99 + 79.93P + 185.84\Delta P - 582.42i + 0.21\Delta GDP_{-1} + 0.48S_{-1} \]

(4.13)  \( (1.49) \)  \( (2.16) \)  \( (2.45) \)  \( (-2.17) \)  \( (1.39) \)  \( (3.53) \)

Estimated R-square based on the preferred specification is 0.81.

**Elasticities of Demand and Supply**\(^{19}\)

The price elasticity of housing demand is an important determinant of the volatility of housing prices in a given market. Hong Kong is often mentioned as a city with volatile housing prices. The estimated price elasticity of demand based on the preferred specification (Case 5 in Table 5.2) was -0.97, which is elastic when considering the aggregated demand for housing units discussed here.

Table 5.4 presents some available estimates for different countries. The purpose of including this table is to provide a comparison with a range of estimates obtained in other studies. However, it is important to note that estimated elasticities are not strictly comparable across studies. With respect to price, demand for housing services such as space is generally more elastic than that for housing units. Estimates based on aggregated data are generally less elastic than estimates based on household observations. Moreover, all the estimates presented in Table 5.4 are demand elasticities for owner-occupied housing whereas elasticities in this study measure

---

\(^{19}\) price elasticity of housing demand \( \beta_1P(H/STK) = [(1-q_1)/q_1](P*H/STK) \);
income elasticity of housing demand \( \beta_2Y(H/STK) = -(q_2/q_1)(Y*H/STK) \);
price elasticity of housing supply \( (a_1+a_2)P/Sv = [(j_1+j_2)/(1-j_3)]P/Sv \);
where \( P, H, STK, \) and \( Sv \) are the values of the sample mean.
overall housing demand. The demand for owner-occupied housing is a decision on whether to own or rent, but the aggregate demand for housing measures the decision on whether to form a separate household. All else are being equal, aggregate housing demand is expected to be less elastic than the demand for owner-occupied housing because it is a decision with fewer alternatives.

Table 5.4: Estimates of Price and Income Elasticity of the Demand for Housing and Price Elasticity of Supply of New Housing Units

<table>
<thead>
<tr>
<th>Study</th>
<th>Sample and Dependent Variable</th>
<th>Price Elasticity of Demand</th>
<th>Income Elasticity of Demand</th>
<th>Price Elasticity of Supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>H. Rose 1979</td>
<td>US Housing Services</td>
<td>-0.67</td>
<td>0.35</td>
<td></td>
</tr>
<tr>
<td>MacRae &amp; Turner 1981</td>
<td>US Housing Services</td>
<td>-0.89</td>
<td>0.26</td>
<td></td>
</tr>
<tr>
<td>Diposqal1e &amp; Wheaton 1991</td>
<td>US Housing Units</td>
<td>-0.1 to 0.19</td>
<td>0.3 to 0.7</td>
<td>1.0 to 1.2</td>
</tr>
<tr>
<td>Park, et al. 1992</td>
<td>CANADA Housing Units</td>
<td>-0.77</td>
<td>0.3</td>
<td>0.51</td>
</tr>
<tr>
<td>Horioka 1988</td>
<td>JAPAN Housing Services</td>
<td>-0.8</td>
<td>1.4</td>
<td></td>
</tr>
</tbody>
</table>

Despite all the considerations mentioned above, there is some professional consensus that, in aggregate, housing demand is rather inelastic with respect to price [Quigley (1979)]. The price elasticity of demand in Hong Kong is in the upper range of other findings, even though it is in regard to aggregate demand for housing units.
This is understandable considering the phenomenal doubling up in Hong Kong.
Under such a situation, lower housing prices will bring forth more independent
households. But one must be aware that the elasticity of housing demand is not
constant. As the actual household size getting smaller, aggregate housing demand
tends to be less and less elastic to housing prices. For instance, estimated price
elasticity of demand for housing units in the U.S. housing market is only in the range
of -0.1 to -0.19, meaning the number of households is insensitive to the changes in
housing prices. This inelastic housing demand in the U.S. is directly related to its
small household size, which is 2.6 on average.

Demand for housing with respect to permanent income is found to be highly
elastic in Hong Kong. The estimate of income elasticity based on the preferred
specification in this study (Case 5 in Table 5.2) was 2.39. It is important to note that
the elasticity estimated here measures the income elasticity of aggregate demand for
housing units, or income elasticity of household formation. The estimates presented
in Table 5.4 are not directly comparable. Nevertheless, they provide an informative
reference for understanding a housing market with significant land restrictions. For
instance, income elasticity in Japan is found to be 1.4 but in the U.S. it is in the
range of 0.3 to 0.7. The difference in income elasticity between Japan and the U.S.
has been noticed by several authors [Horioka (1988), Renaud (1991)]. An
explanation based on the income growth stage has been proposed. In this explanation,
Japan’s relatively high income elasticity was linked to its position on the income
growth path behind the U.S. during the postwar period. Since housing is an essential
consumption in any society, a less developed economy may have a higher income
elasticity of housing demand. While this explanation contains part of the reason for
Japan’s high income elasticity as compared to that in the U.S., it cannot explain
estimates based on other less developed countries. For instance, studies of the
housing markets of Colombia and Korea found that both markets have an income
elasticity of housing demand less than 1 [Ingram (1984)], as compared to Japan’s 1.4.
These countries have not advanced further than Japan on the income growth path.
The high income elasticity of Hong Kong, however, is understandable when one
considers how crowded it is. Given the considerable rate of doubling up, the desire
to form a separate household must be greatly intensified when one’s income increases.
While there is no apparent explanation for the discrepancy in income elasticities
across countries, restrictive land supply must be an important factor.

Finally, price elasticity of supply for new units, calculated based on the
preferred specification (Case 7 in Table 5.3), was 1.11. This is well within the range
of other estimates. As shown in Table 4.2, the estimated elasticity of new housing
units with respect to price based on U.S. data was in the range of 1.0-1.2, and the
estimate based on the Canadian data was 0.51.

Land Price

As suggested earlier, land prices are essentially the residual of housing prices
and other construction costs. To validate this relationship, Table 5.5 presents
estimates of land prices as a dependent variable of housing prices.\textsuperscript{20} The results are as expected. The constant is consistently negative. The coefficient of housing prices is highly significant and is less than 1. In addition, the change in housing prices also had a significant coefficient. Land sales show little correlation with land prices. This finding agrees with the basic assumption of land economic theory: land is valuable simply because the commodity produced on it is in demand. Therefore, land prices must depend only on the prices of that commodity. The computation of R-square suggests that 73\% to 81\% of the movement in land prices can be explained by housing prices alone.

<table>
<thead>
<tr>
<th>Table 5.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimates of Residential Land Price</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dependent Variable = Auction Price for Private Residential Land</th>
</tr>
</thead>
<tbody>
<tr>
<td>Independent Variable</td>
</tr>
<tr>
<td>----------------------</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Housing Price</td>
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<tr>
<td></td>
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<tr>
<td>Housing Price Change</td>
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<tr>
<td></td>
</tr>
<tr>
<td>Housing Price Change</td>
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<tr>
<td></td>
</tr>
<tr>
<td>Land Supply</td>
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<tr>
<td></td>
</tr>
<tr>
<td>Land Supply (-1)</td>
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<tr>
<td></td>
</tr>
<tr>
<td>Land Supply (-2)</td>
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<tr>
<td></td>
</tr>
<tr>
<td>R-square</td>
</tr>
<tr>
<td>Durbin–Watson</td>
</tr>
</tbody>
</table>

\textsuperscript{20} See footnote 17 on a general relation between land prices and housing prices.

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Chapter VI

Forecasts

In order to test the robustness of the empirical model and to understand how different policies on land supply affect the housing market, this chapter presents a forecasting exercise for the housing market in Hong Kong for the period 1991-2005. The forecasts are generated by using empirically estimated functions of housing price (equation 5.12), housing completion (equation 5.13), and the stock adjustment function (equation 5.7). It is important to note that the forecast is an academic exercise rather than a real economic forecast. Since the purpose of the forecast is mainly educational, the assumptions about future growth are developed to illustrate the qualitative rather than the quantitative features of the market.

VI.1 Assumptions

In order to evaluate the effects of different land supply policies, a base case of the future housing market is first produced. This base case assumes that the economy and land supply over the next fifteen years will follow the current course of development. With all market conditions unchanged but the land supply varied, the exercise presents comparisons on housing prices and housing completions under
different schemes of land supply.

In addition to the base case, three types of land supply variations are examined. The first type of variation depicts a situation of long-term change in land supply, in which the effects of both a restrictive land supply policy and a pro-growth land supply policy from 1997 onwards are evaluated. The second type of variation demonstrates a short-term change in land supply. In this case, changes in land supply is assumed to take place in 1992-1995 and to return to the base case level afterwards. The last variation illustrates the impact created by a cyclical land supply, in which land supply is characterized as restrictive in one period and pro-growth in another period. All the land supply scenarios are developed without prior market knowledge. Therefore the market responds to a change in land supply according to only two factors: current market conditions and recent history. The behavior of a market with perfect foresight has been clearly described in Chapter IV and will not be repeated here.

Major assumptions used to produce forecasts are discussed below.

**Land Supply:** The average annual land supply of 125,000 m² in 1985-1990 is used as a benchmark. In the base case, land supply is assumed to be kept at this level throughout the period. A restrictive policy is to cut land supply to zero whereas a pro-growth policy is to double the level of annual land supply, to 250,000 m².

**Public Housing Growth:** The growth of public housing stock is assumed to be stable and moderate. This assumption of moderate growth of public housing is based on a consideration of future demographic trends. As described earlier, shrinking
household size has been the most significant change in demography in the last 25 years. While a further decline in household size is expected, the decline will be much less rapid because the average actual household size has been reduced from 8.4 in 1965 to 4.3 in 1990. Corresponding to this fact, the public housing program is expected to focus more on the maintenance of existing stock than on massive production of new units. Therefore, additional public housing units are assumed to be added at an annual rate of 2.5% instead of the 4.9% of the past decade.

**Economic Conditions:** Total private consumption, which is the average household’s permanent income, grows at a rate of 3.5% after inflation. This rate is approximately the average of 1989 and 1990. Real GDP grows at 3%, which is also the average rate for 1989 and 1990. Population growth is assumed to stay at the current rate of 1.3% until 2005. Given the expected slower reduction in household size, the potential household size is assumed to decline to 2.8 by 2005. The decline in potential household size, together with the 1.3% rate of population growth will lead the number of potential households to grow at an annual rate of 2.6%. Finally, inflation will stay at the 1990 rate of 7% and the bank lending rate at 9%.

VI. Results

*Long-Term Change in Land Supply*

Figures 6.1 and 6.2 present three paths for housing price and private housing completion under different scenarios of land supply. As shown, if land supply is kept
at the current level throughout the period, both housing price and housing completion in the private sector appear to have steady growth. Real housing prices rise at an average annual rate of 2.3%. The level of private housing completion increases at an average annual rate of 1.6%. With such an increase in the rate of housing completion, the private housing stock expands at an average rate of 3% per year. Together with a moderate annual growth of the public sector at 2.5%, this growth profile will keep the total housing stock growing at a pace just slightly higher than that of potential households. It should be noted that the growth during the first few years of the forecast is less steady. The housing completion increases at a high rate during 1991-1992 and then decreases during 1993-1995. This fluctuation results from conditions in the market prior to 1991. Because of the lagged response of housing completion, the increase in housing starts during 1989-1990 increases the housing completion during 1991-1992. This high level of completion suppresses housing prices and reduces housing completion for the following years. The effects last for five to six years until a steady growth is reached.

As shown in Figures 6.1 and 6.2, when the government adopts a restrictive policy and provides no land from 1997 onwards, the market witnesses a large increase in housing prices. Real price escalates at a rate of 9.4% between 1998 and 1999. As prices shoot up, housing completions increase despite the reduction in land supply. The increase in completions in turn affects housing prices by adding housing stock so that the appreciation in housing prices flattens out gradually. By the year 2005, the real price is about 25% higher than the price for the base case.
Figure 6.1
Real Housing Prices Under Three Different Conditions

Figure 6.2
Housing Completion Under Three Different Conditions
The situation is just the opposite if the government adopts a pro-growth policy and doubles the land supply from 1997 onwards. As shown, the price declines as the land supply increases. The decline in price also drags down the housing completion. However, such a decline does not last long. As the growth of total housing stock slows down due to fewer new completions, the increasing demand for housing prevents prices from sliding further, which in turn leads to a positive increase in housing completions.

*Short-Term Change in Land Supply*

In this case, the change in land supply is assumed to take place during the period from 1992 to 1995. As before, there are two ways the land supply can change. One reduces land supply to zero (a restrictive policy) and the other increases land supply from 125,000 m$^2$ to 250,000 m$^2$ per year (a pro-growth policy). After 1995, the land supply is back to the level of 125,000 m$^2$.

Forecasts of housing price and housing completion are presented in Figures 6.3 and 6.4. Although the land reduction lasts for only three years, the market has no prior knowledge of this duration, and reacts as if it is a permanent reduction. As shown, prices increase as land supply drops. When land supply is restored to the normal level, prices drop gradually towards the base case. On the other hand, the level of housing completion also increases as housing prices rise. But when housing prices fall, the completions eventually fall too, even to a level below the baseline case. When the government increases the land supply, then the reverse occurs.
Figure 6.3
Real Housing Prices Under Three Different Conditions

Figure 6.4
Housing Completions Under Three Different Conditions
What is interesting to note here is that at certain times after a restrictive policy is adopted, a lower level of housing price is observed as compared to the base case. A pro-growth policy, on the other hand, can result in a higher price than the baseline case. As Figure 6.3 shows, the prices under the two different policies eventually cross each other. The same situation can be found for housing completions. The reason for this result is in the total housing production. When land supply is reduced, the housing price increases, leading to a higher level of housing production. After the disturbance is over, the market moves back towards the baseline. The excess housing produced during the disturbance will then reduce the prices and the completions for certain future periods. Similarly, when land supply is increased, fewer units are produced. When the market moves back to normal, a shortage of housing occurs that eventually pushes up housing prices and completions. This result reinforces the importance of the secondary effect.

**Cyclical Land Supply**

Figures 6.5 and 6.6 show how the market responds when the land supply is cyclical. In this case, land supply follows a pattern of zero supply and a double supply every three years. For instance, for 1991-1993 land supply was zero, but for the period 1994-1996 the supply is 250,000 m² per year. Every time the land supply decreases, the price increases. Every time the land supply increases, the price decreases. As a result, great fluctuations in housing prices are observed. The fluctuation in prices also leads to a volatile housing supply.
Figure 6.5
Real Housing Prices Under Two Different Conditions

Figure 6.6
Housing Completions Under Two Different Conditions
Summary

The forecasting exercise offered an important lesson. First, suppressing the land supply does not suppress housing production but instead increases housing prices. As prices increase, even more housing can be produced. On the other hand, a pro-growth policy which increases land supply decreases housing prices, which at least temporarily reduces housing production. Second, although housing production is not directly affected by land supply, its response to housing prices sends a secondary signal to the market which can be important in determining future price and completion. Finally, the housing market in Hong Kong can be greatly influenced by the government’s policy on land supply.
Chapter VII

Conclusion

This dissertation offered a formal analysis of the effects of land supply restriction on housing prices and housing production in the context of general market equilibrium. In doing so, it has made three contributions to housing research. These are theoretical, empirical and policy oriented.

Theoretically, it represents a first attempt to model natural and contrived land supply restrictions in a closed city where population increase must be accommodated within the market. The theoretical analysis yielded a number of important results. First, in a closed city restrictions in land supply significantly affect the housing market and the welfare of the population. The major effect of a restrictive supply is to increase housing price. Second, the supply restriction increases housing prices by suppressing consumer space consumption rather than by reducing the production of housing units. Reductions in land supply, whether they are due to natural or contrived restrictions, suppress space consumption and increase the willingness of households to pay for space. The higher bids on land then lead to a higher intensity of land use so that all households are accommodated. From a dynamic perspective, supply restriction increases future density and therefore increases future rents. In a rational market, higher future rents are capitalized into higher housing prices. Third,
in a market with perfect foresight, the effects of a temporary control on land use can be very different from those of a permanent reduction of in the land supply. The key element of a perfect-foresight model is the anticipation of future market conditions, thus allowing for calculation of housing prices or the present value of all expected future rents. For a given set of future market conditions, there exists a unique development pattern in which land use is efficient and the prices are maximized at all locations. If a contrived supply restriction causes land use to deviate from the efficient pattern but does not change the aggregate land supply, housing prices decrease everywhere. If the disturbance results in a reduction in total land supply, i.e., the contrived restriction is permanent, prices then increase at all locations. This difference has never been distinguished before.

Empirically, the dissertation makes a connection between housing and land supply, which has been absent in the existing macroeconomic housing research. The econometric model developed in this study extends the conventional stock-flow approach by explicitly including land supply in the housing price and production functions. When applied to the housing market of Hong Kong, the model helps to empirically identify the channel through which land supply affects the housing market. To be specific, a restrictive land supply is found to raise expected price appreciation but to have no direct effect on the production of new housing units, a result consistent with the urban spatial theory developed above. In addition, the analysis revealed that changes in land supply were perceived by the market as permanent in Hong Kong. This market response is rational given the Hong Kong government’s monopoly control
over land supply. A reduction in land supply is the most accurate indicator of the
government's intention to restrict land use for the near future. Because only events in
a finite, foreseeable future period are meaningful to the market, a delay in using land
in the near future can be equivalent to a theoretically "permanent" land reduction.
This market response illustrates the need to apply the perfect-foresight model with
care. The key feature of a perfect-foresight model is to include the factor of
durability of housing stocks in order to better capture the market dynamics.
However, a theoretically "permanent" effect in the model should only be regarded as
temporally "finite" in a real market because both the durability of the housing stock
and the duration of the "foreseeable" future are finite.

Finally, the study has an important policy implication. In the light of the
change in government in Hong Kong in 1997, this study provides a theoretical
background and analytical method to understand the likely consequences of changes in
land supply policy. First, the market will most likely continue to respond to changes
in land supply as if such changes will remain unless the government's policy is clearly
stated. Second, because of the unique nature of land as a production factor, reducing
the land supply will not directly affect housing production. It will, however, raise
housing prices. When prices are higher, more housing units, not less, are likely to be
built in the short run. But a change in housing production then sends a secondary
signal to the market through changes in the housing stock which can also be important
in determining future prices and production.
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