

Proceedings of the 2011 Land Policy Conference



Balance Sheet and Cash Flow Effects

	Own	Rent	
	\$1,000,000	\$0	Building
	\$0	\$100,000	Cost
	\$120,000	\$0	Rent Saved
	\$0	\$100,000	Bond Income

Balance Sheet

EWR	Newark Liberty Int
FLL	Fort Lauderdale
HNL	Honolulu Int
IAD	Washington
IAH	Houston
IND	Indianapolis
JAX	Jacksonville
JFK	New York
LAX	Los Angeles
LGA	New York

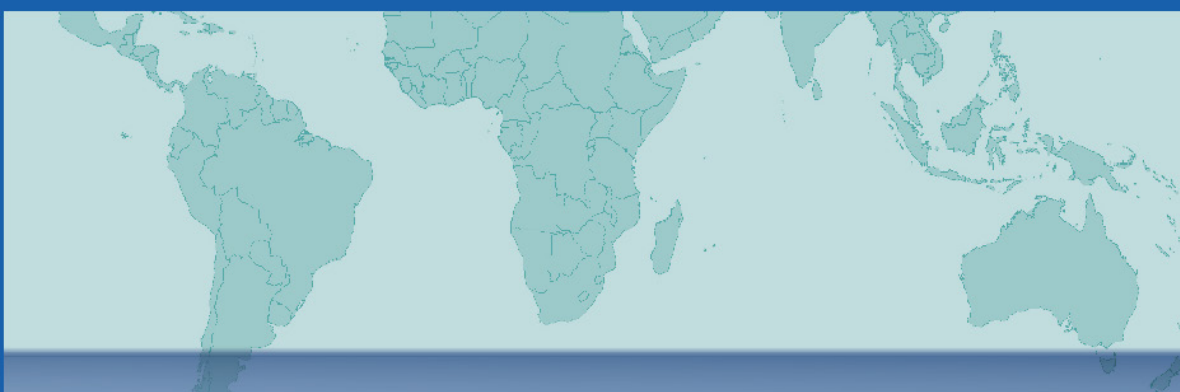
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Grazing

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VALUE CAPTURE and LAND POLICIES



Edited by Gregory K. Ingram and Yu-Hung Hong

Value Capture and Land Policies

Edited by

Gregory K. Ingram and Yu-Hung Hong

L LINCOLN INSTITUTE
OF LAND POLICY
CAMBRIDGE, MASSACHUSETTS

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Library of Congress Cataloging-in-Publication Data

Value capture and land policies /
edited by Gregory K. Ingram and Yu-Hung Hong.
p. cm.

Includes bibliographical references and index.

ISBN 978-1-55844-227-6

1. Public lands—Valuation. 2. Real estate development—
Finance. 3. Land use, Urban. 4. Public investments.

I. Ingram, Gregory K. II. Hong, Yu-Hung.

HD216.V33 2012


333.10973—dc23

2012008363

Designed by Vern Associates

Composed in Sabon by Achorn International in Bolton, Massachusetts.

Printed and bound by Puritan Press Inc., in Hollis, New Hampshire.

 The paper is Rolland Enviro100, an acid-free, 100 percent PCW recycled sheet.

MANUFACTURED IN THE UNITED STATES OF AMERICA

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Collecting Land Value Through Public Land Leasing

John E. Anderson

Governments around the world capture a portion of land value increases for the purpose of funding public infrastructure improvements. The usual justification is that public infrastructure improvements increase the value of property under the government's jurisdiction, so it is reasonable to capture part of that increase from the landowner in order to pay for the infrastructure. This is done in a variety of ways. In the West, where fee simple property ownership is pervasive, local governments typically use property taxes as the primary and general means of value capture. Musgrave and Musgrave (1989) provide background on the property tax as a form of wealth tax (taxing the stock of wealth rather than the flow of income) that captures a portion of the increased value for use by local governments. George ([1879] 1929) presented a well-known proposal to fund all government functions with a variant of the property tax: a single tax on land. His proposal was to leave private ownership in place, but to tax away the rent earned on the land, which would essentially capture all its value, in order to finance the public sector. Stiglitz (1977) has shown that in a local public goods economy, if the level of public expenditure is fixed and the population is variable, the optimal population that will maximize consumption per capita is that population where total land rents equal total expenditures on public goods. This result is called the Henry George Theorem.

Thanks are due to James Wen, Yu-Hung Hong, Greg Ingram, and participants in the Lincoln Institute of Land Policy conference Prospects for Land Value Capture, Cambridge, MA, 23–24 May 2011, for their helpful comments and suggestions.

Under a traditional property tax system, the tax base is the combined market value of the land and any improvements to it. As the property value rises due to the provision of local public goods or infrastructure improvements, the local government collects increased property taxes (unless there is a state or local limitation on the amount of taxes that can be collected). The property tax revenue stream is used to pay for infrastructure improvements and other public goods provided by the local government. The property owner benefits from the infrastructure improvements and pays for those improvements over time via property taxes. This is known as the benefits view of the property tax.

Under a private leasehold regime, the landowner transfers both the right to enjoy those benefits and the property tax cost of the benefits to the lessee. The lease contract price implicitly incorporates both the value of the benefits and the cost. Whether the property tax can be fully passed on to the lessee, of course, depends on the market conditions—that is, the usual elasticities of demand and supply as they affect the ultimate incidence. Under a public leasehold regime, the landowner is the government. As in private leasehold, both the right to enjoy the benefits of public improvements and the cost of those benefits is passed on to the lessee, presumably as part of the lease rate charged by the government. This approach accords well with the common practice in former and existing commonwealth countries, where the legal liability for the property tax is assigned to the occupant of the land (the lessee), not the owner. In that way, the lessee is thought to pay the price of the public goods and infrastructure benefits provided by the government. As the first section of the appendix illustrates, an equivalence can be established between a tax on the value of property (a stock measure) and the annual net rental income (a flow measure), making it straightforward to tax either property value or net rental income. According to the capital tax view of the property tax, the incidence of the average property tax rate applied across jurisdictions (as distinct from local variations around the national average) shows up in a reduced rate of return on all capital, which clearly falls on capital owners. In a leasehold regime, the capital owners are the lessees who build structures on the leased land.

Whether the land and improvements are taxed at the same rate, as is traditionally the case with a property tax, or they are taxed at different rates, as is the practice with a split-rate or graded tax system, it is the combined tax on the two components that is captured, in part. In more limited and specific applications, the state government may permit a local government to create tax increment financing (TIF) districts as a means to capture value. This economic development financing tool captures a portion of the increased property value resulting from economic development projects and uses the captured value to pay off bonds issued to finance the development projects. Also, it is not uncommon in the West for a government to form a partnership with a private developer for the economic development and operation of an airport, seaport, or other such facility that includes a ground lease for public land.

In China, where land ownership is retained by the state, local governments finance the provision of public goods and the expansion of urban infrastructure

by leasing government-owned land to developers or acting as developers themselves. In this way, local governments generate a revenue stream that is used to pay for infrastructure projects. The revenue generated is extra-budgetary. As public leasehold is practiced in China, there is usually no direct link between the lease required for a given plot of land and the infrastructure provided for that plot (e.g., streets, water, lighting, curbs, and gutters), as might be the case in a TIF district or a public-private partnership project in the West.¹

With a ground lease, the government leases the land to a developer for eventual development typically involving the erection of a building that will generate a stream of rent over time. In theory, when the lease ends, the land and any improvements to it revert to the government, unless the lease is renewed. In practice, however, most public leasehold systems permit lessees to renew their lease contracts. Ground leases typically have long terms (more than 50 years) with multiple renewal options. Furthermore, ground leases usually include specifications for the type and form of improvements that are permitted. In this way, the government can potentially control land use. Experience in Hong Kong and elsewhere, however, indicates that land use control results from a combination of land use regulations and lease restrictions, which may be in conflict over time, as land use rules may change more frequently than lease terms in a dynamic land market.

This chapter focuses on collecting land value through public land leasing, with special reference to the case of China. This is an interesting case because a constitutional amendment in 1988 permitting transferable land use rights, coupled with the institution of long-term leases for land, has produced a thriving real estate market in China's major cities. Local governments are using land lease revenue, now their major source of extra-budget revenue, to fund urban infrastructure improvements. In addition, there is growing interest in China in the potential implementation of an ad valorem property tax system as a means to fund local public goods. The natural question that arises is whether a property tax funding mechanism is compatible with a leasehold land tenure regime. Furthermore, given the presence of long-term leases in China, this chapter explores the rationale for long terms and considers how the lease term may affect the government's objective to capture land value.

Rationales for Leasehold Systems: Western Examples —————

There are multiple policy rationalizations for creating a system of government ownership of land coupled with leasehold tenure. In this section, we consider

1. For more on financing urban infrastructure development in China, see Anderson (2009a, 2009b). For more on property taxation in China, see Anderson (2010a, 2010b). For background on the general issue of land leasing in China, see Bourassa and Hong (2003) and Deng (2002). Hui et al. (2004) provide background on land value capture in Hong Kong and Singapore.

several examples of leasehold tenure systems in Western countries and their stated rationales.

In theory, the primary reason for a leasehold regime is that the government can retain ownership of the land and thus options for further land use opportunities in the future. In practice, however, the government may face substantial political challenges as it attempts to reclaim leasehold rights at the termination of leases. This obstacle may account for the fact that leases under such a system are generally renewed.

Mattsson (2003) presents two primary reasons why some Swedish municipalities have adopted a leasehold regime. First, the cities can encourage development of land without requiring developers to incur the cost of site acquisition up front. According to Mattsson, this is intended to facilitate the provision of affordable housing. A corresponding benefit is that public leasehold enables cities to retain control of land use by incorporating land use restrictions into the lease terms. Second, Swedish cities have a fiscal reason for using public leasehold. With long-term leases, Mattsson argues, cities can benefit from the appreciation in land values when they reclaim the land at the end of the leases, and they have the option to resell it at a higher price. (This is called an option value approach, discussed later in this chapter.) In the meantime, the ground rents charged can be raised as well. In this way, Mattsson argues, developers do not capture the land value increments created by public infrastructure investments.

The problem with Mattsson's analysis is that the policy objectives of generating lease revenue and providing affordable housing are incompatible. If a city chooses one objective, that choice precludes achieving the other. Not only is the other objective precluded, but focusing on one policy area also has a negative effect on the other. Choosing to maximize lease revenue makes affordable housing more difficult to provide, and choosing to provide below-market-rate leases to facilitate affordable housing works against generating maximum lease revenue. Cities must pick one policy objective and act accordingly, living with the consequences of that choice.

In Sweden municipal governments can lease the right to use land to a private individual for an indefinite period of time, and the lease involves the payment of an annual ground rent. This mechanism is implemented via a form of land tenure called site leasehold. According to Mattsson (2003, 90), "The primary purpose of site leasehold is to keep the value of land in public hands. It must be emphasized that the main objective is not to produce an immediate financial return for municipalities, but to capture increasing land values through periodic increases in ground rents. The calculation of ground rent, therefore, is critical to the success or failure of this endeavor."

The main purpose of site leasehold in Sweden, according to Mattsson, is twofold: the state retains the appreciation of land values and is able to subsidize housing costs through artificially low ground rents. The site leasehold mechanism is not primarily used to control urban growth and land use. Mattsson further indicates that enabling legislation does not specify how ground rents are to be

computed. As a result, there is a wide variation in the valuation methods used by Swedish municipalities. Furthermore, on the interconnection of lease payments and taxes, Mattsson says that in Sweden site leaseholds are treated the same as freeholds for purposes of taxation. The tax base and the tax rate for both land and buildings are determined in the same way. Site lessees pay property taxes based on the value of both. The only concession for site lessees is that they can deduct the ground rent from their taxable income. This tax treatment is identical to that of a property owner who can deduct interest payments on loans taken out to finance land purchase.

Capozza and Sick (1991) provide examples of leasehold regimes in the United States and Canada. In Canada, private homes are built on leased land inside national parks. It is also common for Native American tribes in the United States and Canada to lease lots to homeowners. In the United States, some homes in cities such as Baltimore and Syracuse are built on ground leases. Furthermore, in both the United States and Canada, petroleum companies routinely lease land in order to obtain mineral rights. Capozza and Sick explain the rationale for leasehold regimes as follows: "Presumably there are good reasons why these asset owners do not sell their properties outright. These institutions may want to maintain long-term environmental control of the property, or the property may represent an important legacy or heritage. Income tax may be a factor for private individuals and corporations" (209).

Why Ground Leases? _____

Dale-Johnson (2001, 451) says, "It is well known that the property rights associated with ground leases yield the owner of those rights less value than fee simple ownership." Ground leases create a form of inefficiency in that they alter the capital intensity of land development. The usual economic model of land development with private land ownership assumes that the owner will attempt to maximize the value of the property by choosing the optimal amount of capital to apply to the land in the development process. A ground lease with finite term T , however, ensures that the developer will underbuild, applying less capital per acre of land than would be optimal in an infinite-horizon model. A developer who buys the land and owns it, builds on the land and earns an infinite stream of rent, whereas a ground lessee earns a finite stream of rent, and any value left in the building asset is forgone at the end of the lease. So why do ground leases exist when it is more efficient to have a land market based on fee simple ownership?

Assuming that the local government owning the land has no particular expertise in real estate development, it would be more efficient to sell the land rather than lease it. One possible reason for using ground leases is that developers are liquidity constrained, and ground leases are a means of providing development financing. Another possibility is that the government is required to retain ownership. Ground leases are then a second-best means by which to mimic a land market. In China both of these reasons are relevant. While on the face of it, leases

are necessary due to the socialist context of land ownership by the government, it is also true that capital markets are underdeveloped and real estate developers may face extreme liquidity constraints.

Another view of the advantage of a leasehold regime is that ground leases provide maximum flexibility for both parties involved. In an option value view, leases are seen as maximizing the opportunities for both parties in the lease transaction. The lease mechanism can be viewed as providing a put option for the lessee and a call option for the government.² From the government's point of view, in particular, the lease mechanism may be an effective means of hedging risk in the land market.

Land Leasing as a Means of Value Capture —————

Hong (2003) identifies four ways that a public leasehold system may capture a portion of land value: (1) initial public auction or tender; (2) collection of an annual land rent; (3) altered terms of the lease at a time of lease modification; and (4) new terms at the time of lease renewal. Hong (1996) has also chronicled the premier example of land leasing as a means of value capture—Hong Kong. He found that the Hong Kong government captured 39 percent of the land value increments realized over the period 1970–1991 on parcels that were leased in the 1970s. He indicates that this percentage is relatively large given the fact that his research uncovered no situation where more than 50 percent of land value increments were captured using property taxes or other instruments. He also suggests two criteria to be used to evaluate the success of a land value capture mechanism under a public leasehold regime: (1) percentage of land value capture; and (2) percentage of public infrastructure investment financed by way of value capture.

Dale-Johnson (2001, 456) notes that there is substantial variation in the contractual forms of ground leases around the world. In the People's Republic of China, in particular, he says, "significant lump sum fees equivalent to the discounted value of the leasehold interest are paid upfront and periodic fees are low, *rather like property taxes*" (emphasis added). The Chinese requirement of up-front lease payment reflects both the local government's need for funding at the outset of a project in order to put infrastructure into place and the lack of mature capital markets in which governments can borrow for such projects. It also reflects the desire of the Chinese central government to cool down the hot real estate market that in recent years has shown signs of being a bubble.

Elementary Mechanics of Ground Leases —————

Ground leases are long-term contracts by which the government (the lessor) leases the land to a developer (the lessee) for a fixed term of T years. The developer de-

2. I am indebted to discussions with Perry Shapiro for this insight.

velops the land and shares the net revenue proceeds of the development with the lessor according to the terms of the lease contract. This sharing occurs by way of the pricing of the contract. The property rights associated with a ground lease yield the lessee less value than would be the case under fee simple ownership, of course. At the end of the lease, the lessee has no option to redevelop, and any improvements made to the land by the lessee revert to the lessor and therefore have zero residual value to the lessee.

Grenadier (2005, 1173–1174) begins his analysis of real estate leases this way: “A real estate lease is simply the sale of the use of space for a specified period of time. The tenant receives the benefit of using the space and the landlord receives the value of lease payments.” In equilibrium, the value of the stream of lease payments must equal the value of the use of space. Grenadier shows that leases are simply contingent claims on asset values.

Smith (1979) provides an option portfolio interpretation of leasing that is insightful. He shows that the price of a T -year lease for an asset includes the value of a European call option on the asset with expiration date T years in the future. (A European call option allows the leaseholder to exercise the option to buy the asset only at time T , whereas an American call option would allow purchase at any time until T .) The market price of an asset being purchased with fee simple ownership will exceed the lease price for a fixed term of T years. When the asset is leased, the option to re-lease and potentially redevelop at time T is retained and has value. Dale-Johnson (2001, 451) puts it succinctly: “Ground leased property trades at a discount relative to the fee interest.” That discount is a result of both the value of the redevelopment option and the zero residual value of improvements at the end of the lease. Capozza and Sick (1991) demonstrate that the size of the discount can be substantial and is primarily due to the forgone development option.

Dale-Johnson (2001) characterizes the optimal ground lease contract in the following way: In a perfect world, the landowner would negotiate a ground lease yielding a rental stream of revenue consistent with the value of the land in its highest and best use. That would be the first-best optimum. But there are a number of potential reasons why the lessee’s incentives may differ from the lessor’s over time. Chief among them is the possibility that the highest and best use of the land may change during the lease term. Dale-Johnson also explores various second-best alternative lease contracts.

VALUATION OF A SIMPLE LEASE

Suppose that a Chinese municipality decides to lease a plot of land with a simple fixed-term lease. The municipality requires a fixed lease payment $f(t) = f$ in each period t for a total of T years. The present discounted value of the stream of lease payments is then

$$(1) \quad V(T) = \int_0^T f e^{-rt} dt,$$

where f = periodic lease payment;
 r = discount rate; and
 T = fixed term of the lease.

Solving equation (1) gives the value of the lease:

$$(2) \quad V(T) = \left(\frac{f}{r}\right) [1 - e^{-rT}].$$

Hence, the value of the lease is the capitalized value of the annual payment stream, f , as if it were a perpetuity, given by the term f/r , scaled down by the second term in brackets, which accounts for the finite lease term, T .

To understand the use of equation (2), consider a lease in which the discount rate, r , is 0.03; the term of the lease, T , is 70 years (the lease term for residential property in China); and the annual lease payment, f , is 1. The value of the lease, V , is then 29.25. So for each yuan of annual lease payment, the value of the lease is 29.25 yuan. Obviously, the present discounted value of the lease payment stream is less than the nominal value of the payments ($fT = 70$). In fact, if the discount rate was higher, say 0.05, the value of the stream of lease payments would fall to 19.40.

As the first section of the appendix demonstrates, if an ad valorem tax is introduced, a property tax of rate τ applied to the perpetuity value of a leased asset is equivalent to a tax on the perpetual income stream of that asset of τ/r . Furthermore, the effect of an ad valorem tax on the value of a finite-year lease of term T is equivalent to an increase in the discount rate used to compute the present value of the stream of lease payments, from r to $(r + \tau)$.

It is also essential to consider two fundamental questions regarding lease terms: (1) what determines the annual lease payment, f ; and (2) what determines the choice of lease contract length, T ? Local governments in China do not appear to be using optimal policies in the choice of either lease parameter. Central-government regulations fix T based on the land classification. Local government officials determine f by way of auctions, tenders, or negotiations with developers. Consequently, the value of leases is not being optimized, and local governments are not capturing the full potential of the leasing mechanism for providing infrastructure financing.

The third section of the appendix provides a mathematical explanation of the determination of the optimal lease length, T , for both a single-rotation lease (one-time development) and a multiple-rotation lease (repeated lease terms for redevelopment). This model takes into account both the revenue stream generated by the lease and the residual value of the capital applied to the land. In China the developer builds a structure on the land, but at the end of the lease whatever value remains in that structure reverts to the municipality. Hence, the residual value matters. Of course, it also has implications for the property value assessment over the life of the lease and the subsequent amount of revenue derived. As the end of the lease approaches, the value of the improvements declines,

perhaps approaching zero if the lessee believes the lease will not be renewed and the improvements will be confiscated when it ends. Revenue from a property tax based on that declining value also will decline.

For a single-rotation lease, the optimal ending time is shown to be that time T when the marginal benefit of extending the lease for one more period (the rate of growth of the residual value of the property) equals the marginal cost of extending it (the opportunity cost of capital minus the lease revenue earned as a fraction of the residual value). See equation (A3) in the appendix. In the multiple-rotation case, where there is a series of leases, each of length T , it can be shown that there will be a shorter lease period for each rotation than there would be in the single-rotation case. See equation (A11) in the appendix.

BELOW-MARKET LEASE RATES

Chinese municipalities lease land at below-market rates, for several policy reasons discussed later in this chapter. This practice results in a reduced revenue stream when compared to leasing at market value. For example, suppose that the annual market lease rate is f_m for each period and the corresponding value of the market value lease is V_m . When compared to the market value lease, the below-market value lease involves lost revenue in the amount given by the expression

$$(3) \quad V_m(T) - V(T) = ((f_m - f)) / r [1 - e^{-rT}].$$

Leasing below the market rate scales down the lease value in a linear fashion. For example, if the municipality is leasing the land for one-tenth of its market value rate, $f = 0.1f_m$, the municipality is forgoing nine-tenths of the lease value.

Below-market value leases may be a primary economic development tool used by Chinese municipalities. Evidence presented in Tao et al. (2010) indicates that this is likely to be true, although the precise extent of the underpricing of leases is not clear. Chinese cities may be willing to grant leases at below-market rates in order to stimulate economic development, which in turn generates value-added tax (VAT) and other tax revenue.

TERM STRUCTURE OF LEASES

The choice of lease term, T , must also be considered. In China leases are for 40, 50, or 70 years, depending on the land use—commercial, industrial, and residential, respectively. Whether these lease terms are rational in an economic sense or can be justified on the basis of an economic policy objective is unclear. In a market leasing context, we would expect to find a term structure of leases, with lease prices a function of T . In China there is no term variation permitted within each property class. No research on the topic of lease terms in China is available.

Not only does the choice of these two parameters, lease time and price, affect the amount of revenue generated by the lease, but the choice of these parameters and other features of the lease contract can affect the value of the asset being leased. Miceli, Sirmans, and Turnbull (2001) show that the design of a lease

contract, in terms of its legal characteristics, directly affects the value of the leased asset. They also show that an efficiently designed lease requires specific elements of both property and contract law. Consequently, in common law countries lease law involves both specialties.

Grenadier's (2005) commercial real estate lease model provides closed-form solutions for equilibrium land values, building values, and lease term structure. In that model, the slope of the term structure of T (a plot of the equilibrium rent as a function of lease term) depends on the degree of competition among property developers. For an industry with just $n = 4$ competitors, the term structure of lease rates rises over the first 30 years or so, then holds steady into the future. With $n = 20$ competitors, Grenadier's model generates a term structure of rents that falls over time. For a given lease term T , the more competitors there are in the industry, the lower the equilibrium lease rent is. Long-term lease rates are structured to leave both landlords and tenants indifferent toward two alternatives: (1) signing a long-term lease; or (2) rolling over a series of short-term leases. If there are only a few competitors in the industry, there is a weak supply response to increased rents. That permits short-term rents to rise with demand. In the case of an intermediate number of competitors, the expected short-term rents can rise, but competition produces increased supply. With more competition in the industry, expected short-term lease rates cannot rise very much because rent increases are accompanied by increased construction.

The literature also provides empirical evidence linking lease terms and asset prices. For example, Janssen (2003) has demonstrated that when Swedish local governments lease land to developers for income-producing urban apartment buildings, rather than selling the land with freehold tenure, there is a statistically significant negative impact on the price of the buildings. His evidence indicates that the market in Stockholm is quite systematic in influencing pricing in this way. We would expect that the fewer land rights the government retains and the more likely it is that the lease will be renewed, the smaller the land lease price discount will be.

OPTION VALUE

The option to redevelop property is valuable to the government, but retaining that option also affects the market value of the lease. If it is considered likely that the government will not renew the lease at its termination, the price of the lease will be lower due to the lack of continuation, upgrade potential, or redevelopment possibilities. The government gets to keep the option, but it pays a price for that privilege. According to Capozza and Sick (1991, 209), "The price to be paid for retaining this control can be high." They cite examples from Vancouver, British Columbia, where single-family dwellings on land leased for 80 to 90 years sell at a discount of 20 to 40 percent compared to similar homes on land owned fee simple. The option to upgrade or redevelop is a real option, created by real estate investment opportunities.

Deciding whether it is economically sensible for the government to retain that option involves a comparison of the expected value of the option and the forgone capital that could have been obtained in selling the land and retaining no future option. The Chinese government retains the option for all of the land it leases, but in doing so it bears all of the risk. Capozza and Sick (1991) rightly identify risk as a major component of the pricing of real options, noting that an implemented development project subjects the owner to downside risk if the project fails. In contrast, the owner of an option to adopt the project in the future is insulated from that risk because he can choose not to exercise the option.

Dale-Johnson (2001) models long-term leases with a focus on the redevelopment option and contract incentives. His simulations suggest that three lease contract innovations can substantially improve the performance of long-term ground leases, making them perform more like fee simple ownership: (1) sharing the residual value of improvements when the lease ends; (2) including a lease extension clause that is triggered by redevelopment; and (3) incorporating a lease rate escalation clause. Long-term ground lease contracts with these features provide lessees with incentives to behave more like fee simple owners and provide a reasonable second-best alternative to fee simple ownership. Application of these private leasehold innovations to the public leasehold context, however, may involve high transaction costs for the state due to a potentially large number of leases. To the extent that some aspects of these innovations can be incorporated into public leases, however, the public leasehold regime can be made to operate more efficiently.

Land Use and Leases in China

As a reference point, it is useful to consider the usual terms of ground leases in the West. Dale-Johnson (2001) characterizes ground leases in North America, in particular, as having the following structure: Land is leased by its owner to a tenant for a long period of time, typically at least 50 years. The 50-year term consists of an initial subterm of 10 to 20 years, with options for two or three additional 10-year renewal periods. In total, the lease may be as long as 99 years. Any lease in excess of 99 years is considered a sale for tax purposes. The landowner usually stipulates or agrees to a plan for the particular type of development to be implemented on the land. In some cases, the ground lease is said to be “participating,” in which case the landowner retains a contingent interest in the property and receives a benefit from the development if it goes well. The rent paid under the terms of the lease is typically tied to the revenue or sales of the development that is using the land. This linkage ensures that there is a match between the rental income stream and the performance of the development. The base-level rent may be adjusted every 10 years, or a participation clause in the contract may allow the rental rate to increase on specified dates if the gross income from the property is rising.

Table 6.1
Land Lease Features in China

Lease term	70 years for residential land leases; 50 years for industrial; 40 years for commercial
Right of renewal	Lessee may negotiate with local government to renew lease.
Ownership of leasehold improvements	Lessee owns all leasehold improvements during term of lease. When lease expires, improvements will revert back to government if lease is not renewed.
Lease payments	Lessee makes several up-front payments, including land premium and community and urban infrastructure fees. Other fees may include urban renewal fee, as required. Lessee also pays annual land use fee (sometimes called tax).
Using lease conditions to control land use	Lessee usually has list of separate land use conditions; enforcement of conditions is lax. A certain portion of the land must be developed within two years. Some local governments may charge vacant land fee if land is not developed after two-year limit expires.
Additional requirements for redevelopment	N/A
Transferability of land rights	Lessee can sell, mortgage, or transfer land rights.
Government's right to repossess land	Government can terminate lease and retake land for public purpose.
Public attitude toward public leasehold	In late 1980s, there was opposition to public leasehold, especially leasing public land to foreign investors. Leasing of public land is now generally accepted by public.

Source: Bourassa and Hong (2003, 21). Right-of-renewal information has been updated from that reported in Bourassa and Hong.

Land leases in China are quite different from most Western leases. Chinese land lease features are summarized in table 6.1, based on evidence presented in Bourassa and Hong (2003). In China the lessee is required to make several up-front payments, including the payment of a land premium and prepayment of all community and urban infrastructure fees. After that, the lessee must pay annual land use fees. During the ground lease, the lessee has the right to sell, mortgage, or transfer the land use rights conferred by the lease. At any point during the ground lease, the government can terminate the lease and retake the land for a public purpose. Compensation for the leasehold rights and land improvements taken is required, of course. But the methods used in the determination of appropriate compensation levels are unclear.³ At the end of the lease, the lessee may

3. Article 42 of the Property Rights Law of the People's Republic of China includes provisions regarding compensation for expropriated property, although there are no specific guidelines for determination of the amount of compensation (National People's Congress [2007]).

negotiate with the local government for a lease renewal. If there is no renewal, the land and improvements revert to the local government.

Nystrom (2007) indicates that because the leasing system is relatively new in China, complications related to lease renewal, lease modification, takings, and various remedies have not yet arisen and been resolved. Bourassa and Hong (2003) report that although there was initial skepticism and opposition to public leasehold in China during the late 1980s, especially leasing of public land to foreign investors, public leasehold is now generally accepted by the public and widely practiced by local governments. Indeed, in an earlier paper (Anderson 2011), I provide empirical evidence on the extent to which prefecture-level cities are deriving revenue from land leases. My analysis indicates that on average over the period 2004–2008, Chinese cities derived off-budget revenue from land leases equivalent to 49.53 percent of their entire budgetary revenue levels. The cities relying most heavily on land lease revenue generally earned at least twice as much from that source as from all budgetary sources combined.

The leasehold regime in China is complicated by the fact that the government retains control of the land in multiple ways. Deng (2003) makes the important observation that in the Chinese leasehold system, the government plays three simultaneous roles: landowner, provider of public goods, and owner of state-owned enterprises (SOEs). Furthermore, it is essential to recognize that local governments in China often act as real estate developers and economic development agencies. The combination of these roles provides local governments with many opportunities to implicitly price their services.

There is limited, though important, empirical evidence available on ground leases in China. Yao (2000) empirically examines the land lease market in rural China using data from three counties of Zhejiang Province. He identifies two factors that have increased the number of land leases in rural areas: (1) productive heterogeneity in the agricultural sector; and (2) a freer labor market. Tao et al. (2010) offer the most extensive empirical study to date on land leasing in Chinese cities. They provide evidence on how leasing behavior by prefecture-level cities affected their budgetary tax revenues from various sources (enterprise income tax, business tax, VAT, other taxes, and total local taxes). Data are from the period 1999–2003, and city tax revenue sources are regressed on measures of leasing activity, including the number of leases auctioned or negotiated. Their strongest evidence shows that the number of negotiated leases has a positive impact on tax revenue with a three-year lag (but not a one- or two-year lag). This evidence is consistent with their hypothesis that cities negotiate low lease prices for manufacturing uses in order to attract economic development projects, which in turn eventually generate added budgetary revenue from the business tax and VAT. They found that auctioned leases do not have any impact on tax revenue in the long run, although they do have a short-run positive impact. The reason for this difference is that auctioned leases result in market-oriented prices. The construction of new homes and commercial buildings, commonly associated with auctioned leases, generates immediate economic activity for a city, which

in turn generates business tax revenue. At the end of construction, however, the boom effect ends and the revenue impact dissipates. Because auctioned leases are generally for residential and commercial uses, they have little impact on VAT revenue.

In the Chinese context, the local government is the local monopoly developer. Hence, using the insights of Grenadier's (2005) model discussed earlier, we might expect that short-term lease rents would rise with the demand for sites. Yet given the large number of local governments engaged in land leasing and acting as local developers, there is actually a very large number of competitors that produce an increased supply of sites in the aggregate. In this circumstance, short-term lease rates are not expected to rise appreciably.

The Chinese lease terms of 40, 50, and 70 years are not necessarily optimal terms, as indicated earlier. Furthermore, the model for determining optimal lease length presented in the third section of the appendix, does not appear to work for ground leases in China. More generally, we might expect ground lease terms to approximately match the amortization life of the debt-financed structures placed on the land. Given the underdevelopment of the Chinese capital market and the alternative methods of finance often used, that is not necessarily the case in China. (Much Chinese development occurs without independent bank financing.)

Furthermore, leases in the West typically have intermediate renegotiation dates prior to the final expiration of the lease. That is not the case in China. Once a lease is granted, no renegotiation is possible until the lease ends. Hence, the local government is locked into the lease terms until the lease expires. In the case of rapidly rising land values, the government forgoes the opportunity to capture some of the appreciation, due to the way the lease contract is configured.

Integration of Property Taxation in the Chinese Context —————

How might an ad valorem property tax be integrated into the leasehold system in China? First, it is important to recognize that a number of taxes are already applied to real estate in China. Song and Feng (2010) report that China currently has 14 types of real estate taxes. Based on their 2008 data, the four most important taxes are the urban land use tax, which generates 1.51 percent of all tax revenue in China; the house property and urban real estate tax, 1.25 percent; the land appreciation tax, 0.99 percent; and the farmland occupation tax, 0.58 percent. All together these real estate taxes account for 4.33 percent of all tax revenue in China. Although they are not major revenue sources, their existence provides a useful starting point for the design of a property tax mechanism that might serve as the starting point for implementation of a market value property tax. The key to implementing such a tax is to develop methods of valuing both land and structures.

With regard to land leases in China, there are potentially several ways to implement a property tax. Deng (2003) identifies three major forms of payment currently associated with land leases in China: (1) a lump-sum premium for the

lease; (2) an urban infrastructure fee to support infrastructure in the whole community; and (3) a community infrastructure fee to support infrastructure in a particular neighborhood within the larger community. The lessee also pays a land use tax every year. Deng indicates that the land use tax is small in comparison to the other three payments. These forms of taxation within the context of a leasehold regime provide several potential bases for a property tax. A critical issue, however, is the fact that ground leases in China are not being priced at market rates. Hence, lease prices cannot be used for the purpose of property taxation if that taxation is to be based on the market value of the property—which it should be in order to have an appropriate property tax system. Site lessees in China could pay a property tax based on the combined value of the land and all improvements to it. That would require an assessment mechanism to estimate the market value of both components. Assessment methods for valuing land cannot simply rely on market comparisons of lease rates, however, because those rates do not accurately reflect market values. This is true despite the fact that government regulations require an increasing emphasis on auctioned leases. Hence, some type of income capitalization approach would have to be developed, with appropriate access to net income data, to accurately value leases. Whether the quality of data available to implement this valuation approach is superior to that available for a market comparison approach requires further research.

In a typical Western property tax system, the property owner has fee simple ownership. The local government taxes the value of the property each year in order to generate revenue to fund the provision of local public goods that benefit the property owner. A traditional property tax system has an ideal tax base that is the market value of the property, including the value of both the land and improvements. The tax paid, T , is the product of the nominal tax rate, t^n , and the assessed value, AV : $T = t^n AV$. The assessed value is the product of the assessment ratio, r , and the market value, MV : $AV = rMV$. From these definitions, it can be shown that the effective tax rate, t^e , is the product of the nominal tax rate and the assessment ratio: $t^e = T/MV = t^n r$. In practice, assessments often lag behind market values, especially when market values are rising quickly. This causes effective property tax rates to be lower than nominal tax rates. That may reduce the number of homeowner appeals of assessed values, thereby reducing the administrative costs of administering the property tax system.

Furthermore, in some government jurisdictions, the assessed value is defined as a fixed fraction ($r < 1$) of the market value.⁴ Regardless of the assessment ratio, r , however, the essential link is that assessed value is related to market value in a property tax system.

4. This is immaterial, however, since the effective tax rate is simply the product of the nominal tax rate and the assessment ratio. To the extent that an assessor undervalues properties, the local government unit can apply a higher nominal tax rate to achieve a given effective tax rate.

This method of implementing a property tax is not exclusive of other possibilities. The Swedish case of leasehold tenure cited by Mattsson (2003) is instructive as we consider the potential in China. Under the Swedish system, site leaseholds are treated the same as freeholds for purposes of taxation. The tax base and the tax rate for both land and buildings are determined in the same way. Site lessees pay property taxes based on the value of land and buildings. In principle, Chinese local governments could do the same, implementing a property tax on the combined value of the land and improvements. In China we know that the market value of the land is not fully reflected in the lease price. Hence, a mechanism is needed to produce the market value of leased land.

The challenge of integrating a property tax into the existing leasehold system in China requires the resolution of two issues: (1) pricing of the land lease and value capture implicit in that pricing mechanism; and (2) valuation of improvements and their taxation via a property tax mechanism.

Conclusions

The objective of this chapter was to answer two questions regarding land leases in China. First, would a property tax mechanism be compatible with the leasehold system in China? Second, what is the rationale for the long lease terms in China, and, more important, how do these terms affect government objectives to capture land value?

On the integration of a property tax mechanism into China's leasehold system, there is no particular technical conflict that would prevent this possibility. Although most Western countries apply property taxes in a fee simple land tenure setting, a number of other Western countries apply property taxes in the context of a ground leasehold regime. Sweden is one example, providing evidence that a property tax system can be implemented within a leasehold context. Doing so requires that accurate valuation methods be applied to both the land and improvements to it. Valuing improvements is not particularly different in China than in other places in the world. The key challenge is estimating market value for ground leases. In China present lease prices do not fully reflect land values and are therefore an inaccurate basis for property taxation. Lease prices are highly idiosyncratic, reflecting a number of local factors, including whether the leases are granted via tender or negotiation. The challenge of developing a property tax system in China is in developing accurate methods of estimating true market values for ground leases.

On the question of lease length and government objectives to capture land value, there may be a conflict, but not necessarily. The real issue involved here is the option value that the Chinese government retains as it leases land. The option to redevelop the land at the end of the current lease is valuable, but in retaining that option, the government is paying a substantial price in the form of forgone lease revenue. Hence, the government is trading lease revenue for future option value. That may or may not be a worthwhile trade. Ultimately, the gov-

ernment is bearing the risk itself rather than pricing that risk and requiring the lessee to bear part of it. Chinese ground leases could be modified to permit more flexibility in term length, offering several points during the contract at which extensions could be exercised and lease rates altered to match the gross revenue being generated by any development of the land. If the government wishes to capture a greater share of the land value increase over time, such lease contract innovations are essential. These innovations will, however, diminish the net return to developers and thereby alter the incentive to develop. This is an essential tension that cannot be avoided.

REFERENCES

- Anderson, J. E. 1986. Property taxes and the timing of urban land development. *Regional Science and Urban Economics* 16:483–492.
- . 2009a. The Chinese municipality land leasing problem. Paper presented at the All China Economics Conference, City University of Hong Kong (December).
- . 2009b. Financing urban development in China. *The Chinese Economy* 42:48–62.
- . 2010a. Housing, taxation, and urban development in China. Paper presented at the International Symposium on Urban Development and Land Economics, Peking University–Lincoln Institute Center for Urban Development and Land Policy, Beijing (9–10 July).
- . 2010b. The path to property taxation. In *China's local public finance in transition*, ed. J. Y. Man and Y.-H. Hong. Cambridge, MA: Lincoln Institute of Land Policy.
- . 2011. Land lease revenue and urban public finance: Evidence from Chinese cities. Paper presented at the International Symposium on China's Urban Development and Land Policy, Peking University–Lincoln Institute Center for Urban Development and Land Policy, Beijing (16–17 July).
- Bourassa, S. C., and Y.-H. Hong. 2003. *Leasing public land: Policy debates and international experiences*. Cambridge, MA: Lincoln Institute of Land Policy.
- Capozza, D., and G. Sick. 1991. Valuing long-term leases: The option to redevelop. *Journal of Real Estate Finance and Economics* 4:209–223.
- Dale-Johnson, D. 2001. Long-term ground leases, the redevelopment option and contract incentives. *Real Estate Economics* 29:451–484.
- Deng, F. 2003. Political economy of public land leasing in Beijing, China. In *Leasing public land: Policy debates and international experiences*, ed. S. C. Bourassa and Y.-H. Hong. Cambridge, MA: Lincoln Institute of Land Policy.
- George, H. (1879) 1929. *Progress and poverty*. New York: Robert Shalkenbach Foundation.
- Grenadier, S. R. 2005. An equilibrium analysis of real estate leases. *Journal of Business* 78(4):1173–1219.
- Hartman, R. 1976. The harvesting decision when a standing forest has value. *Economic Inquiry* 14:52–58.
- Hong, Y.-H. 1996. Can leasing public land be an alternative source of local public finance? Working Paper WP96YH2. Cambridge, MA: Lincoln Institute of Land Policy.

- . 2003. Policy dilemma of capturing land value under the Hong Kong public leasehold system. In *Leasing public land: Policy debates and international experiences*, ed. S. C. Bourassa and Y.-H. Hong. Cambridge, MA: Lincoln Institute of Land Policy.
- Hui, E. C.-M., V. S.-M. Ho, and D. K.-H. Ho. 2004. Land value capture mechanisms in Hong Kong and Singapore. *Journal of Property Investing and Finance* 22:76–100.
- Janssen, C. T. L. 2003. Estimating the effect of land leases on prices of inner-city apartment buildings. *Urban Studies* 40:2049–2066.
- Mattsson, H. 2003. Site leasehold in Sweden: A tool to capture land value. In *Leasing public land: Policy debates and international experiences*, ed. S. C. Bourassa and Y.-H. Hong. Cambridge, MA: Lincoln Institute of Land Policy.
- Miceli, T. J., C. F. Sirmans, and G. K. Turnbull. 2001. The property-contract boundary: An economic analysis of leases. *American Law and Economics Review* 3(1): 165–185.
- Musgrave, R. A., and P. B. Musgrave. 1989. *Public finance in theory and practice*. 5th ed. New York: McGraw-Hill.
- National People's Congress. 2007. *Property rights law of the People's Republic of China*. Adopted at the 5th Session of the 10th National People's Congress of the People's Republic of China (16 March). Unofficial English translation available at http://www.lehmanlaw.com/fileadmin/lehmanlaw_com/laws_regulations/Property_Rights_Law_of_the_PRC_LLX_03162007.pdf.
- Nystrom, S. L. 2007. Risk and time in a land lease economy. Paper presented at the 30th International Federation of Surveyors (Fédération Internationale des Géomètres, FIG) General Assembly, Hong Kong (13–17 May). http://www.fig.net/pub/fig2007/papers/ts_1c/ts01C_01_nystrom_1415.pdf.
- Smith, C. W. 1979. Applications of option pricing analysis. In *Handbook of financial economics*, ed. J. L. Bicksler. Amsterdam: North-Holland, Elsevier.
- Song, X., and C. Feng. 2010. Study on real estate taxation in China. Working Paper W042. Beijing: Peking University–Lincoln Institute Center for Urban Development and Land Policy.
- Stiglitz, J. E. 1977. The theory of local public goods. In *The economics of public services*, ed. M. S. Feldstein and R. P. Inman. London: Macmillan.
- Tao, R., F. Su, M. Liu, and G. Cao. 2010. Land leasing and local public finance in China's regional development: Evidence from prefecture-level cities. *Urban Studies* 47:2217–2236.
- Yao, Y. 2000. The development of the land lease market in rural China. *Land Economics* 76:252–266.

 APPENDIX: LEASE ANALYTICS

This appendix provides some basic equivalence results, various value expressions, and a model of optimal lease length in which residual value is taken into account.

Some Equivalence Results

The fundamental value of a property is given by the simple perpetuity formula

$$V = \frac{f}{r},$$

where f = annual rent; and
 r = discount rate.

Property tax rate τ applied to property value V would generate revenue τV .

Because $V = \frac{f}{r}$, this is equivalent to $\frac{\tau f}{r}$. Hence, property tax rate τ applied to property value V (a stock measure) is equivalent to a tax on the perpetual rental income stream f (a flow measure) at the rate $\frac{\tau}{r}$. Alternatively, tax rate τ applied to rental stream f is equivalent to property tax rate $r\tau$.

Now suppose that we have a finite lease contract that lasts from initial time t to terminal time T . The value of the stream of lease payments $f(t)$ over time is the sum of those payments, indicated by the expression

$$V(t, T) = \int_t^T f(u) e^{-r(u-t)} du.$$

If we were to apply tax rate τ to the value of the lease, it can be shown that the value would be reduced to

$$V(t, T) = \int_t^T f(u) e^{-(r+\tau)(u-t)} du.$$

The effect of the ad valorem tax would increase the discount rate from r to $(r + \tau)$.

Value Expressions

A landowner is assumed to use land prior to development for farming purposes, with no improvements applied to the land (i.e., no capital). The predevelopment (farm) net income stream is denoted $f(t)$, where t is time. Further, suppose that

the postdevelopment net income stream is $h(t, D)$, reflecting the fact that it may depend on the time at which development occurs, D .

The value of land currently in farming use with potential future developed use is the discounted present value of the farming income stream plus the future expected development income stream.

$$(A1) \quad V(t, D) = \int_t^D f(u) e^{-r(u-t)} du + \int_D^\infty h(u, D) e^{-r(u-t)} du.$$

Now suppose that there is a property tax system in which the property tax rate before development is τ_b and after development is τ_a . Anderson (1986) has demonstrated that the value of a property at time t that has already been developed at time D ($t > D$), denoted $V(t, D)$, can be solved recursively to obtain the value expression

$$(A2) \quad V(t, D) = \int_t^\infty h(u, D) e^{-(r+\tau_a)(u-t)} du.$$

In this case, the value of the property is simply the discounted present value of the developed net income stream, where the discount rate includes both the opportunity cost of capital, r , and the effective property tax rate that applies to a developed property, τ_a .

For a property not yet developed ($t < D$), the value of the property when it is developed, denoted $V(t, D)$, can be shown to be

$$(A3) \quad V(t, D) = \int_t^D f(u) e^{-(r+\tau_b)(u-t)} du + e^{-(r+\tau_b)(D-t)} \int_D^\infty h(u, D) e^{-(r+\tau_a)(u-D)} du.$$

In this case, the value of the property is the sum of the present values of the predevelopment (farm) income stream and the postdevelopment income stream. The present value of the farm income stream involves a discount rate that includes both the opportunity cost of capital, r , and the predevelopment effective property tax rate, τ_b . The income stream from the developed use of the property has the discount rate $(r + \tau_a)$, as discussed previously, and that discounted income stream must be converted into time t dollars using the exponential expression that multiplies the discounted income stream (the integral in the second term).

Residual Value and the Optimal Lease Length _____

Now suppose that the property not only generates lease income for the municipality, but also has value at the end of the lease term. We can denote the residual value (or, in a forestry context, the stumpage value) as $G(T)$. In this case, the

problem is analogous to the forest rotation problem with stumpage value, and we can adapt Hartman's (1976) model to the current application.

Because the municipality owns the property, it takes into account both the lease revenue stream and the residual value. Thus, the present discounted value of the property is

$$(A4) \quad V(T) = \int_0^T f e^{-rt} dt + e^{-rT} G(T).$$

Maximizing the value $V(T)$ with respect to time T yields the first-order condition

$$(A5) \quad V'(T) = e^{-rT} [f(T) + G'(T) - rG(T)] = 0.$$

By setting the term in brackets equal to zero, we can obtain the equivalent first-order condition

$$(A6) \quad \frac{G'(T)}{G(T)} = r - \frac{f(T)}{G(T)}.$$

This condition indicates that the optimal ending time of the lease is that time T when the marginal benefit of continuing the lease one more period (the rate of growth of the residual value of the property) equals the marginal cost of extending the lease one more period (the discount rate, or opportunity cost of capital, minus the lease revenue earned as a fraction of the residual value).

The second-order condition requires

$$(A7) \quad V''(T) = -r e^{-rT} [f(T) + G'(T) - rG(T)] + e^{-rT} [f'(T) + G''(T) - rG'(T)] < 0.$$

At the optimum, this condition reduces to

$$(A8) \quad f'(T) + G''(T) < rG'(T).$$

This requires that $f(T) + G'(T)$ intersect $rG(T)$ from above, as indicated in Hartman (1976).

If we now consider a sequence of leases of term T , the model can be modified by writing the value objective function as

$$(A9) \quad W(T) = \frac{V(T)}{[1 - e^{-rT}]},$$

where $V(T)$ is defined as above. Maximization of equation (A9) with respect to T yields the first-order condition

$$(A10) \quad W'(T) = \left[\frac{1}{1 - e^{-rT}} \right] \left[-re^{-rT}G(T) + e^{-rT}G'(T) + e^{-rT}f(T) \right] - \left[e^{-rT}G(T) + F(T) \right] \left[\frac{re^{-rT}}{[1 - e^{-rT}]^2} \right] = 0,$$

where

$$F(T) = \int_0^T f(u)e^{-ru} du.$$

This first-order condition can be simplified to

$$(A11) \quad \frac{G'(T)}{G(T)} = \left[1 + \frac{F(T)}{G(T)} \right] \delta^{-1} - \frac{f(T)}{G(T)}.$$

This expression is a clear adaptation of the previous first-order condition for the single-rotation problem. The term δ is the Faustman interest rate, which is the present value of a dollar of income after T years, or

$$\delta = \int_0^T e^{-ru} du = \frac{[1 - e^{-rT}]}{r}.$$

This condition requires that the optimal lease length is that T where the marginal benefit of extending the lease one more period (given by the rate of growth in the residual value) equals the marginal cost of extending the lease. Comparing the result of the multiple-rotation problem with that of the single-rotation problem, Hartman (1976) shows that there will be a shorter lease period in the multiple-rotation case (assuming that we have an interior solution to the problem).