*Environment and Planning B: Planning and Design* 2008, volume 35, pages 847 – 862

doi:10.1068/b34018

# A game-theoretic approach to urban land development in China

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Received 20 February 2007; in revised form 16 May 2007

**Abstract. The property rights approach to urban development has recently been proposed in the planning literature to explain how urban systems self-organize spatially and institutionally. The land-tenure system is one of the key factors affecting land use and thus urban development. It is not clear, however, how such a factor affects the process of urban development. This research aims to provide reasonable explanations as to how the land-tenure system in China in general affects urban development, by building game-theoretic models which include plans as a manifestation of information and property rights as a manifestation of land-use rights. Viewing regulated development as a collective good, the model is based on the prisoner's dilemma game, where the local government regulates and the developer makes development decisions. Preliminary results show that land rights in the transitional economy of China are of paramount importance and must be clearly specified in order to make the land development process efficient at reducing transaction costs.**

## 1 Introduction

Cities are collectives of irreversible land development actions. Land development is a complex process involving a multitude of activities conducted by numerous participants, including planners, architects, real estate investors, and regulators. The process is so complicated that no model can yet describe fully the behavior of the participants (Gore and Nicholson, 1991), although attempts have been made to model such behavior partially from, for example, the perspective of planning and information economics (Schaeffer and Hopkins, 1987).

Motivated by the notion of property rights, and viewing the land development process as the manipulation of property rights in order to acquire such rights in the public domain, Lai (2001) provided a conceptual model of land development as the underlying framework for understanding the process. Property rights are defined here in a broad sense, in that the basic observation about such rights is the impossibility of delineation of such rights in reality. Some property rights are, therefore, left in the public domain, from which developers are motivated to acquire them. This conceptual model provides significant insights into why and how developers proceed in land development, and why and how organizations evolve. The model is sufficiently robust and powerful that land development cases in different cultures, all things considered, can be explained under the common framework.

The motion of property rights can be traced back as early as Coase's (1960) notion of transaction cost, in that transactions of rights in land are costly, which in turn hampers efficient resource allocation. Following this tradition, Barzel (1999) went one step further by constructing a property rights approach to economic behavior and showing analytically that, during an exchange, buyers and sellers would change their behaviors in order to acquire the property rights left in the public domain. Recently, Webster and Lai (2003) applied such a notion to explain how cities self-organize themselves institutionally and what we can do about it. In addition, Lai (2006a) conducted computer simulations based on the property rights notion to explore how cities self-organize themselves spatially, and concluded that the resulting spatial pattern can be characterized by a power law, or fractal, distribution of land uses. Some might argue that the property rights to land and buildings in cities are well defined, but a close examination shows that the property rights structure in cities is extremely complex, and those rights left in the public domain are abundant, waiting for developers to acquire them. This is evidenced by any transaction of a parcel of land between the developer and the landowner. If there were no unallocated property rights, there would be no cost to make such a transaction possible, including contractual costs, inspecting attributes of the asset under consideration, insurance, and post-sale services.

The game-theoretic property rights approach to land development is distinct from previous attempts in that the land development process in the latter is depicted either as a phased, static process of maximization of utility (Henderson, 1980), or as a decision-making problem characterized by bounded rationality for the maximization of value (Mohamed, 2006). In our model the core element of property rights is explicitly considered as a substantive decision variable that the local government and the developer are concerned with, rather than as some abstracted notion of utility or value, as previous models aimed to explain. In addition, our model takes into account the dynamic interaction between the local government and the developer that the previous models seem to ignore.

Grounded on the premise that the property rights approach to land development is promising, the objectives of this research are twofold: (1) to understand how plans serve as information gathering processes and how the derived regulations affect land and urban development in China, and (2) to make recommendations as to how land-use plans in China should be made to improve urban development. The two research objectives are to be addressed both theoretically and empirically in the research through modeling within the Chinese socioeconomic contexts. The presumption of the research is that local governments, developers, and landowners acquire property rights over land in making land-use plans and regulations, developing land, and making use of land. The situation can be characterized by the prisoner's dilemma game, in which the local government makes the decisions with respect to regulations, whereas the developer makes the decisions regarding land development. Viewing the regulated development of the community as a collective good, the game-theoretic model captures in part, if not completely, the interaction between the local government and the developer in the land-use planning arena, which is well recognized as a game situation (eg Berke et al, 2006; Rudel, 1989).

The property rights approach to urban development has, on the one hand, recently been proposed in the planning literature, in that cities tend to self-organize themselves spatially and institutionally and that property rights acquisitions are a common phenomenon in such processes (Webster and Lai, 2003). On the other hand, the interaction between local governments and land developers can be depicted in terms of game theory (eg Knaap et al, 1998). In a game situation a local government makes land-use plans and regulations to enhance social welfare, according to which developers make investment decisions to maximize profits or property rights. Even though this view is challenged in the public choice literature, in that governments are seen as maximizing votes and their officials as maximizing personal welfare, land-use plans would affect directly or indirectly both of those behaviors, and would thus play a significant role in making their decisions. Such a game situation can best be modeled by an iterative prisoner's dilemma game, in which cooperation might emerge. Land-use plans and regulations can be viewed as land-price or land-use controls in the land market and, once imposed, actors in land transactions tend to acquire the property rights left in the public domain. Viewing urban development as collectives of land development activities, we argue that this simple, but powerful, theoretical exposition can link the microlevel (land development) to the macro-level spatial processes (urban development). Empirical hypotheses can be derived from such a formulation for testing in future case studies.

The land-tenure systems in China are peculiar, from a market economy point of view, in that landowners can only 'rent', but not 'own' the land for a specific period of time. We argue that this peculiarity does not render the Coase theorem on transaction cost useless, but, rather, it enhances the argument of the Coase theorem, in that landowners only own the 'rights' over the land (Coase, 1960). Manipulations of rights are thus the essential element in land development processes, regardless of the types of land tenure. Urban development processes are complex, and we are just beginning to understand how these processes work. If individual land development activities can be partially controlled through land-use plans and regulations, and we know how the latter affect the former, we might be in a better position to harness the complex urban development processes in China.

Section 2 briefly summarizes the transition of urban development and planning in China. Section 3 depicts the analytic methods of the research. Section 4 describes the conceptual basis for the research using a hypothetical example. Section 5 constructs a model of a generalized two-person nonzero sum game, based on the Chinese land development context. Section 6 provides an empirical account of the validity of the model, on the basis of a field survey conducted in Shanghai. Section 7 provides some discussion and points out future work. Section 8 concludes.

## 2 Transitional urban development and planning in China

Since economic reforms commenced in 1978, cities in China have experienced dramatic physical, economic, and institutional changes. The transition is mainly from a centrally planned economy to a market-led economy (Zhu, 1999; and Yeh, 1999). In the centrally planned economy, urban development in Chinese cities was constrained at a minimum and urban structure was confined according to central plans. These plans brought order to an otherwise chaotic situation in that the mobility of people and the construction of buildings were confined through restrictive institutions, such as household registration systems. This is evidenced by the limited expansion of urban areas from 1949 to 1977.

Planning systems reflect how the central government in China deals with urban development problems. The transition from the centrally planned economy to the market-led economy incurred reforms in many scopes, including land management, housing provision, and urban planning. In order to adapt to such a transition, the Chinese government adopted an incremental approach to economic reforms, including urban planning systems. The urban planning practice in post-1949 China can be broadly divided into four stages: (1) physical planning, focusing on industrial development in the 1950s; (2) turbulent urban planning during political turmoil (1960–78); (3) restoration of the urban planning system (1978–89); and the new urban planning system since the 1989 City Planning Act (1989 – present) (Yeh and Wu, 1998). A clear trend can be observed: that the urban planning system in China tends to respect urban market forces that previously were totally ignored or nonexistent. For example, land-use rights are delineated and stipulated in regulations that allow individuals to own, transfer, and exchange these rights.

The rights to land in China, albeit without ownership, were a necessary element in establishing the land market in cities and in making efficient use of urban land. The emergence of land rights has been a major cause of the booming of the real estate business, but because of the slow evolution of institutions, the change in measures of managing urban land has not caught up with the growing need for land in the Chinese urban areas. There is an urgent need for innovations in the taxation systems for managing real estate development in China (eg Hsue et al, 2005). The privatization and commodification of real estate, together with improved taxation systems and emerging property rights, have increased the bargaining power of developers in negotiating with local governments within a market-led economy and the modern urban planning systems derived from the 1989 City Planning Act. It is within such a land development context that the present paper intends to investigate how local governments and developers interact in a game situation in which plans, viewed as information gathering, and property rights, viewed as a manifestation of land-use rights, play a central role.

## 3 Analytic methods

Cities are the outcome of the individual spatial decisions that interact with each other. To understand how cities evolve it is fundamental to understand the land development behavior of individual agents *and* how they interact. The analytic methods for exploring empirically and theoretically land development activities and their interactions are depicted in this section. A hypothetical case study is given after this section as an example as to how land-use plans and regulations can be analyzed in the proposed method. A mathematical model is constructed in section 5, based on the conceptual framework described in this section.

The usual difficulties in modeling the land development process are that the process involves many participants with conflicting perspectives, and that it is almost impossible to characterize the behavior of the participants in a common framework. For example, the process can be described in terms of decision sequences, focusing on how decisions are made in the process, or as a production-based approach, which emphasizes how the final products are established (Gore and Nicholson, 1991). Given the idiosyncratic characteristics of the land development process depicted in different descriptive models, we argue that two elements pervade any type of land development process: information and property rights.

The land development process is usually divided into four phases: acquisition, approval, construction, and letting. In the first phase the developer must locate a parcel of land that might yield profit from the project. Once the land has been secured, the process enters into the second phase, in which the developer must apply for the necessary permits. Construction commences in the third phase. In the fourth phase the final output after construction is then sold or leased in the market in order to yield profit for the developer. As argued by Schaeffer and Hopkins (1987), in each phase planning, which yields information, is conducted with respect to environments, values, and related decisions. Plans are made and revised as sets of related, contingent decisions based upon the information gathered. As a result, the land development process is a sequential decision-making problem—the decisions made in each phase being contingent on those to be made in the future. To clarify the roles that information and property rights play in the land development process, we focus in this section on the first phase: land acquisition. The interpretation of the behavior in other phases can be made similarly.

Property rights play an important role in the land development process, so it is useful first to define property rights. Property rights are the powers to consume, obtain income from, and alienate the assets over which the owners have the rights (Barzel, 1999). Thus, the property rights over a parcel of land are the powers to use the land to make a profit through cultivating, improving, or exchanging it. According to Barzel (1999), in reality, property rights are impossible to delineate completely in any exchange. Thus, transaction costs arise due to incomplete information about attributes of assets. For example, in making investment decisions developers usually acquire information about the locational advantages of parcels of land with a certain amount of cost. This implies that some of the attributes of exchanged goods, unknown to either party involved in the exchange, are left in the public domain, and the exchanging parties are motivated to capture these attributes during the exchange.

This is particularly true in land transactions, regardless of the types of land tenure. More specifically, the property rights of a parcel of land can be divided into fixed legal rights and variable economic rights. Whereas fixed legal rights are those legally protected by the government, such as documented ownership of the land, variable economic rights are the attributes of the land affecting its valuation, such as its accessibility to transportation networks. Because the fixed legal property rights usually incur the fixed cost of land acquisition as indicated by land prices, we argue that it is the variable economic property rights that fundamentally affect how and why developers proceed in the land development process. If the economic property rights are not taken into account in the land development process, the developer will be indifferent with respect to two parcels of land with the same amount of fixed legal costs but different attributes. However, this is obviously not the case in reality, regardless of the types of land tenure. For example, given two development sites in two physically identical situations (such as either side of a road or adjacent to each other) with the sole difference that one is contaminated, the cost of purchasing the fixed legal rights to one land would be the same as that to the other, if the information of contamination is kept secret or unknown. Once the information of the attribute of contamination has been revealed—that is, once the variable economic property rights are made known—the net value of the site would be changed, with the uncontaminated site more likely to be purchased given a reasonable price and thus the net value is more sensitive to the variable economic property rights. In other words, we treat fixed economic property rights as those that are clearly delineated and documented, and thus are associated with fixed costs.

Consider a developer in the first phase of land acquisition, looking for an appropriate parcel of land for a certain type of development. The attributes of each parcel of land vary depending on its location, land price, geological conditions, access to public facilities and infrastructure, the socioeconomic conditions of the surrounding environment, landscape, amenities, and environmental considerations. No two parcels of land are identical, and methods used to measure these attributes are expensive and often imperfect in their results. As a result, complete information about land attributes is prohibitive in cost to obtain, which results in positive transaction costs. Put another way, both the exchanging parties will invest resources to measure the attributes of the land before deciding whether to proceed in the exchange. After the transaction cost expenditures have been disposed, the developer and the owner of the land will each obtain only a certain amount of the information about these attributes. The information is incomplete for both parties because information is asymmetric, or at least different, in that the complete measurement of all attributes of a parcel is prohibitively costly.

The incomplete information acquired by the exchanging parties implies that some attributes of the land under consideration are thus unspecified and left in the public domain as unallocated resources. For example, the owner might conceal a criminal problem in the community where the land is located, whereas a developer might be secretly informed of a public transit facility that will be constructed near the property, thereby increasing the value of the land. In deciding which parcel of land to acquire for development, we argue that the developer will secure the land from which he or she can maximize the value of property rights by capturing those left in the public domain.

Before effecting the exchange, the developer and the owner invest resources to gather information about the attributes of the land to reduce uncertainties and risks. This investment is the major source of the transaction cost. Thus, planning as information gathering occurs during each transaction. It is worth noting what information the exchanging parties should gather and how they should proceed in information gathering. According to Friend and Hickling (2005), Hopkins (1981), and Schaeffer and Hopkins (1987), the developer is faced with four types of uncertainties: uncertainty about the environment, uncertainty about values, uncertainty about related decisions, and uncertainty about the search for alternatives. In the land development context, before land acquisition, the developer is uncertain about whether the investment will yield net gains. These gains are dependent on the trends of the surrounding environment of the land, government policies concerning future community development, related development decisions of other developers and the government, and possible final outputs of built forms. All these types of information influence the profit-yielding attributes of the land under consideration.

As argued earlier, complete measurement of the attributes of the land is prohibitively expensive, since the measurement process incurs cost. Therefore, uncertainties cannot be eliminated completely, and the planning—that is, information gathering—that occurs requires the investment of resources. Planning produces additional information for the developer and landowner, of which the value is the discrepancy between the expected values of outcomes with and without that information. As a result, whether the developer should plan depends on whether the increase in the value of the information produced by planning exceeds the costs of conducting planning. In the land acquisition case, if planning with respect to the attributes of land at different locations results in an increase in the expected value of property rights captured from the public domain, which exceeds the cost of conducting the planning, then the planning is worthwhile and should be conducted by the land developer.

In deciding whether the developer should plan, the information with respect to the four types of uncertainty gathered through planning must be specified a priori. That is, the developer must determine beforehand what information to gather. It has been proven that the information must be payoff relevant and sufficiently accurate—that is, information affecting the expected gains in decision making (Lai, 2002). The proof is based on the notion of optimal information structures that would yield the highest expected utility, given a best action. These conditions provide a useful guideline for information gathering in reality. In the land development context, the developer should acquire the information that is related to the value of the property rights captured in the land exchange, and which accurately measures the attributes of the land and predicts possible consequences resulting from the exchange.

In short, the seemingly idiosyncratic process of land development can indeed be described as a sequence of property-rights-capturing activities. By completing the contractual exchange, the developer captures the property rights, in terms of land attributes that are not fully delineated and left in the public domain. The transaction costs incurred in the exchange result mainly from information gathering or planning concerning the measurement of these attributes or the reduction of uncertainties. Since that measurement is costly, not all planning activities yield benefits; benefits are dependent on whether the information gathered exceeds the cost of conducting the planning. Since uncertainty cannot be eliminated completely, it follows that some property rights are always left in the public domain, and the capturing of these rights will always occur in any land development process, regardless of how much is invested in planning.

## 4 Effects of land control of land-use plans and regulations: an example

As a concrete example of how the property rights approach to land development can be used to interpret developers' behavior in response to changes in land policy, such as land-use planning and regulating, we consider a city with various land uses that are subject to public land controls. We suppose initially that all land uses are legally permissible and that the land prices are determined through the market mechanism. In this hypothetical example, imposing a land-control policy, such as land-use planning and regulating, that would limit all land uses to a single particular use—for example, residential—would be similar to placing price controls on the land market. How would the developer react to such a land-control policy?

Referring to figure 1, the initial demand and supply curves for land are shown as D and S. Viewing land as an intermediate, not the final, good of the land development process, the developer is on the demand side and the landowner is on the supply side. The market clearing price for land is $P^*$ with the associated amount of land exchanged as $Q^*$. We assume that a new land-control policy of land-use planning is initiated, which limits all land uses to residential, indirectly imposing a price limit of $P_c$ on the land. The demand shifts from $Q^*$ up to $Q_0$, and the supply shifts from $Q^*$ down to $Q_1$. However, the developer is willing to pay up to $P_1$ to secure the land, and there seems to be a shortage of $Q_0 - Q_1$ amount of land in the marketplace. The difference in the amount between $P_1 Q_1$, the consumers' willingness to pay for the total amount of transacted land, and $P_c Q_1$, the amount consumers actually pay for the transacted land, is dissipated in the public domain without identified recipients.

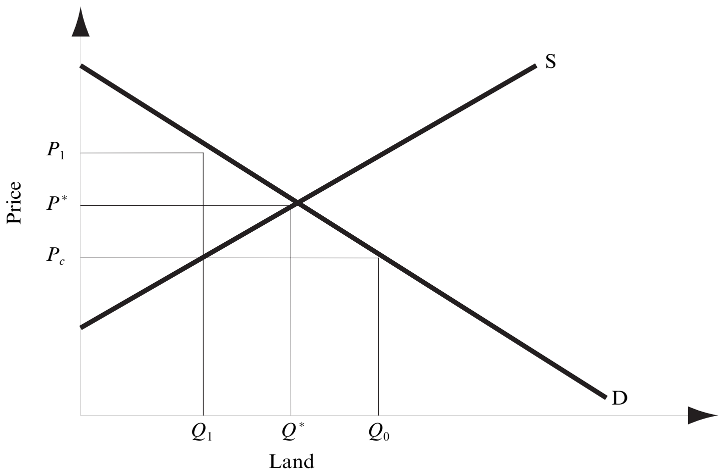


**Figure 1.** Effects of land control as an indirect price control.

The implication is that the developer is willing to pay that amount to purchase government-issued bounds in order to acquire additional land. As argued by Barzel (1999, pages 16 – 32), the rationing of any type for a good with a limited supply—for example, by waiting or queuing—is not caused by a 'shortage' of the supply of the particular good as traditionally conceived by economists. Instead, the shortage of the particular good in the market is a result of the consumers' maximization principle of capturing dissipated property rights, because, given that queuing is the only margin of the competition and that price control results in a price of willingness to pay that is higher than the controlled price, consumers would be willing to invest in waiting time, as manifested in the dissipated property rights, to acquire more resources. The same argument was applied to gas station owners' reactions toward the oil crises during the 1970s. Other behavioral predictions can be derived in response to the land-control policy, similarly to the above analysis using the property rights approach.

## 5 The model

In this research we will focus on the interaction between a local government and a developer in making plans, setting regulations, and making development decisions as a starting point. More complicated situations can be developed in the future, based on the simplified model. Knaap et al (1998) constructed a game-theoretic model to examine the logic and effects of land-use planning. Their model provides useful insights into how plans can affect the behaviors of local governments and developers in a game situation, and suggests hypotheses for empirical tests. In their model perfect rationality is assumed, in that both the local government and the developer behave in order to maximize the value of the objective functions. Though powerful in the logic of the model, perfect rationality is far from reality. In this research we assume that the local government and the developer behave according to bounded rationality. That is, neither the local government nor the developer is rational in the classic economics sense. An iterative prisoner's dilemma game can be used to model the interaction more realistically. In the game situation the local government and the developer are the two players of the prisoner's dilemma game with property rights in land as the payoffs, as shown in table 1.

**Table 1.** Payoff table, where the local government and the developer are the two players of the prisoner's dilemma game.

| | | Developer | |
|---|---|---|---|
| | | cooperate | defect |
| Local government | cooperate | R, R | S, T |
| | defect | T, S | P, P |

Here, T > R > P > S, which are payoffs measured in terms of property rights in land. The local government could either regulate (cooperate) or not regulate (defect) the uses of a piece of land, whereas the developer could either invest (cooperate) or not invest (defect). The Nash equilibrium for the game is for the local government not to regulate, and for the developer not to invest. However, it will increase the benefits of both if the local government regulates and the developer invests. If the two players iteratively play the game indefinitely, cooperation might emerge, so the outcome would be for the local government to regulate, and for the developer to invest (Axelrod, 1984). It would be interesting to examine what would happen in the situation in which either the local government or the developer plans for their moves, or in which both plan for their moves. In the iterated prisoner's dilemma game, no player has perfect foresight as to how the other player would behave, thus bounded rationality is assumed. In addition, we intend to treat rights in land explicitly as the inputs in the payoff table in the land development game situation.

The formulation above can be represented as a generalized two-person, nonzero sum game as elaborated in the following. Let

$$\mathbf{U}_{\mathrm{A}} = \begin{matrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{m1} & \cdots & a_{mn} \end{matrix}, \tag{1}$$

where $\mathbf{U}_{\mathrm{A}}$ is the payoff matrix for player A; $a_{ij}$ represents player A's payoff when player A adopts strategy $i$ and player B adopts strategy $j$; $i = 1, 2, 3, ..., m$; $j = 1, 2, 3, ..., n$;

$$\mathbf{U}_{\mathrm{B}} = \begin{matrix} b_{11} & \cdots & b_{1n} \\ \vdots & \ddots & \vdots \\ b_{m1} & \cdots & b_{mn} \end{matrix}, \tag{2}$$

where $\mathbf{U}_{\mathrm{B}}$ is the payoff matrix for player B; and $b_{ij}$ represents player B's payoff when player A adopts strategy $i$ and player B adopts strategy $j$.

Given the two players, strategies, and payoffs, the generalized two-person, nonzero sum game, of which the prisoner's dilemma game is a special case, can be formulated as shown in table 2.

Given the payoff table for the generalized two-person, nonzero sum game (table 2), we are now in a position to define the variables and parameters of the model in the context of urban development in China. Consider the most simplified situation, in which player A is the local government and player B is the developer. The symbols and the associated meanings are defined as follows:

$U_{\mathrm{g}}$ is the payoff function of property rights acquired by the local government;
$U_{\mathrm{d}}$ is the payoff function of property rights acquired by the developer;
$B_{\mathrm{g}}$ is the revenue of property rights received by the local government;
$B_{\mathrm{d}}$ is the revenue of property rights received by the developer;
$C_{\mathrm{g}}$ is the cost of property rights acquisition by the local government;
$C_{\mathrm{d}}$ is the cost of property rights acquisition by the developer;
$\delta$ is the parameter of risk incurred to the developer in the development process;
$\beta_{\mathrm{g}}$ is the positive externalities incurred by the local government imposing regulations;
$\beta_{\mathrm{d}}$ is the positive externalities incurred by the developer in making development decisions;
$\mathrm{I}_{\mathrm{g}}$ is the amount of information gathered by the local government as a function of planning investments $p_{\mathrm{g}}$;
$\mathrm{I}_{\mathrm{d}}$ is the amount of information gathered by the developer as a function of planning investments $p_{\mathrm{d}}$;

**Table 2.** The payoff table for the generalized two-person, nonzero sum game.

| | | Player B | | | | |
|---|---|---|---|---|---|---|
| | | $y_1$ | $y_2$ | $y_3$ | $\cdots$ | $y_n$ |
| Player A | $x_1$ | $a_{11}, b_{11}$ | $a_{12}, b_{12}$ | $a_{13}, b_{13}$ | $\cdots$ | $a_{1n}, b_{1n}$ |
| | $x_2$ | $a_{21}, b_{21}$ | $a_{22}, b_{22}$ | $a_{23}, b_{23}$ | $\cdots$ | $a_{2n}, b_{2n}$ |
| | | | | | $\cdots$ | |
| | $x_m$ | $a_{m1}, b_{m1}$ | $a_{m2}, b_{m2}$ | $a_{m3}, b_{m3}$ | $\cdots$ | $a_{mn}, b_{mn}$ |

| | |
|---|---|
| $\mathrm{R_g}(\boldsymbol{x})$ | is the total amount of property rights acquired by the local development; |
| $\mathrm{R_d}(\boldsymbol{x})$ | is the total amount of property rights acquired by the developer; |
| $\boldsymbol{x} = [x_1, x_2, ..., x_k]$ | is a vector of attributes associated with land under development consideration; and |
| $\varepsilon$ | is a random variable associated with property rights to indicate nondelineation of these rights. |

The following assumptions are made in constructing the interactive model for land development:

*Assumption 1:* The utility and cost functions associated with regulation and development decisions are linear, meaning that both the local government and the developer are risk neutral.

*Assumption 2:* The information gathering functions, $\mathrm{I_g}$ and $\mathrm{I_d}$, symbolize the amount of information gathered by the local government and the developer, respectively, and their values range from 0 to 1 and are independent. In addition, they are functions of planning investment, $p_\mathrm{g}$ and $p_d$, where $p_\mathrm{g}$ and $p_\mathrm{d}$ also range from 0 to 1.

*Assumption 3:* $\delta$ is the level of risk faced by the developer in the development process under time pressure. If its value is unity, there is no risk in investment. In order to fit the model to the Chinese urban development context, we set the range of its value from 0 to 2.

*Assumption 4:* $\beta_\mathrm{g}$ and $\beta_\mathrm{d}$ are the positive externalities, or the property rights left in the public domain owing to a land exchange, associated with the regulation and development decision made by the local government and the developer, respectively. In the model we assume that only the local government and the developer benefit from all positive externalities, and therefore, $[\beta_\mathrm{g}/(\beta_\mathrm{g}+\beta_\mathrm{d})]+[\beta_\mathrm{d}/(\beta_\mathrm{g}+\beta_\mathrm{d})] = 1$.

*Assumption 5:* Because property rights associated with the attributes of land under consideration are a bundle of two types of rights—for example, ownership by the state and lease to individuals—in China, these rights are functions of land attribute vector $\boldsymbol{x} = [x_1, x_2, ..., x_k]$, where $x_i$, $i = 1, 2, ..., k$, can be thought of as any attribute characterizing the land under consideration, such as area, geology, and accessibility.

*Assumption 6:* $\mathrm{R_g}(\boldsymbol{x})$ and $\mathrm{R_d}(\boldsymbol{x})$ are the property rights functions that transform land attributes into the overall property rights owned by the local government and the developer, respectively. In particular, $\mathrm{R}(\boldsymbol{x}) = \mathrm{R}[\mathrm{r}_1(x_1, x_2, ..., x_k), \mathrm{r}_2(x_1, x_2, ..., x_k), \varepsilon]$, where $\mathrm{r}_1$ and $\mathrm{r}_2$ are the transformation functions of rights to own and lease, respectively. In the Chinese context, except for the state, rights to own do not exist in general. Note that $\varepsilon$ symbolizes that property rights cannot be completely delineated.

*Assumption 7:* $B_\mathrm{g}$ and $B_\mathrm{d}$ are the revenues of property rights acquired by the local government and the developer, respectively, and

$$B_\mathrm{g} = \mathrm{I_g}(p_\mathrm{g})\mathrm{R_g}(\boldsymbol{x}) + \beta_\mathrm{g}, \qquad B_\mathrm{d} = \mathrm{I_d}(p_\mathrm{d})\mathrm{R_d}(\boldsymbol{x}) + \beta_\mathrm{d}. \tag{3}$$

In addition, the overall utilities for the local government and the developer are given in equation (4):

$$U_\mathrm{g} = B_\mathrm{g} - C_\mathrm{g}, \qquad U_\mathrm{d} = B_\mathrm{d} - \delta C_\mathrm{d}. \tag{4}$$

Given the general model, the definitions of mathematical symbols, and the assumptions, we can construct a model of the generalized two-person nonzero sum game specifically for the interaction between the local government and a developer in China, as follows:

$$U_g = I_g(p_g)R_g(\boldsymbol{x}) + \beta_g - C_g, \qquad U_d = I_d(p_d)R_d(\boldsymbol{x}) + \beta_d - \delta C_d. \tag{5}$$

Note that

$$\boldsymbol{B}_g = [b_{ij}^g], \qquad i = 1, ..., m; \quad j = 1, ..., n,$$

where $b_{ij}^g$ stands for the revenue derived from the property rights acquired by the local government when the local government adopts strategy $i$ and the developer adopts strategy $j$;

$$\boldsymbol{B}_d = [b_{ij}^d], \qquad i = 1, ..., m; \quad j = 1, ..., n,$$

where $b_{ij}^d$ symbolizes the revenue derived from the property rights acquired by the developer when the local government adopts strategy $i$ and the developer adopts strategy $j$;

$$\boldsymbol{C}_g = [c_{ij}^g], \qquad i = 1, ..., m; \quad j = 1, ..., n,$$

where $c_{ij}^g$ represents the cost derived from acquiring property rights by the local government when the local government adopts strategy $i$ and the developer adopts strategy $j$; and

$$\boldsymbol{C}_d = [c_{ij}^d], \qquad i = 1, ..., m; \quad j = 1, ..., n,$$

where $c_{ij}^d$ symbolizes the cost derived from acquiring property rights by the developer when the local government adopts strategy $i$ and the developer adopts strategy $j$.

To render the model a concrete example, consider the local government making a regulatory decision between zoning and a development permit, and the developer making a development decision between commercial and residential uses. The numerical assumptions, in the Chinese urban development context, are:

(1) Regardless of whether the developer makes commercial or residential land-use decisions, the costs of acquiring property rights for the local development under a development permit and zoning are $C_g^1$ and $C_g^2$, respectively.

(2) If the local government adopts a development permit, the costs of acquiring property rights for the developer making residential and commercial land-use decisions are $C_d^1$ and $C_d^2$, respectively. Under zoning, the costs of acquiring property rights for the developer making residential and commercial land-use decisions become $C_d^3$ and $C_d^4$, respectively.

(3) The total amount of property rights left in the public domain is $\beta$, from which the developer would obtain 80% and the local government would obtain 20% under the permit system. Under the zoning system, the developer and the local government would obtain the same percentage of 50% each.

(4) Regardless of which regulatory system is adopted, the local government could obtain 70% of the perfect information through planning—that is, $I_g = 0.7$—and the developer would obtain 60% and 80% of the perfect information—that is, $I_d = 0.8$ and 0.6—through planning for residential and commercial developments, respectively.

(5) The value of development risk $\delta$ varies in different combinations of the local government's and the developer's regulatory and development decisions. Under the permit system, $\delta$-values for residential and commercial land uses are 1.3 and 1.8, respectively. Under the zoning system, $\delta$-values for residential and commercial land uses are 1.0 and 1.4, respectively.

Given the above assumptions, the payoff table for the numerical example is as shown in table 3.

**Table 3.** Payoff table for the numerical example. See text for details.

| Local government | Developer | |
|---|---|---|
| | residential | commercial |
| Permit system | $[0.7\mathrm{R}_\mathrm{g}(\boldsymbol{x}) + 0.2\beta - C_\mathrm{g}^1,$ $0.6\mathrm{R}_\mathrm{d}(\boldsymbol{x}) + 0.8\beta - 1.3C_\mathrm{d}^1$ | $[0.7\mathrm{R}_\mathrm{g}(\boldsymbol{x}) + 0.2\beta - C_\mathrm{g}^1,$ $0.8\mathrm{R}_\mathrm{d}(\boldsymbol{x}) + 0.8\beta - 1.8C_\mathrm{d}^2]$ |
| Zoning system | $[0.7\mathrm{R}_\mathrm{g}(\boldsymbol{x}) + 0.5\beta - C_\mathrm{g}^2,$ $0.6\mathrm{R}_\mathrm{d}(\boldsymbol{x}) + 0.5\beta - 1.0C_\mathrm{d}^3$ | $[0.7\mathrm{R}_\mathrm{g}(\boldsymbol{x}) + 0.5\beta - C_\mathrm{g}^2,$ $0.8\mathrm{R}_\mathrm{d}(\boldsymbol{x}) + 0.5\beta - 1.4C_\mathrm{d}^4]$ |

There might or might not be an equilibrium in this game situation, depending on the numerical values of the remaining variables. If an equilibrium does not exist pure strategies may be replaced by probabilistic strategies. We let the probability that the local government will adopt the permit system be $p$, and the probability that the local government will adopt the zoning system be $1-p$. We let the probability that the developer will make a decision of residential use be $q$, and the probability that the developer will make a decision of commercial use be $1-q$. We then denote the expected payoff for the local government as $U_\mathrm{g}^\mathrm{E}$, and we have

$$U_\mathrm{g}^\mathrm{E} = p\{q[0.7\mathrm{R}_\mathrm{g}(\boldsymbol{x}) + 0.2\beta - C_\mathrm{g}^1] + (1-q)[0.7\mathrm{R}_\mathrm{g}(\boldsymbol{x}) + 0.2\beta - C_\mathrm{g}^1]\} + (1-p)\{q[0.7\mathrm{R}_\mathrm{g}(\boldsymbol{x}) + 0.5\beta - C_\mathrm{g}^2] + (1-q)[0.7\mathrm{R}_\mathrm{g}(\boldsymbol{x}) + 0.5\beta - C_\mathrm{g}^2]\}\,. \quad (6)$$

To solve for the maximum value of the expected payoff for the local government, we take the first-order derivative of equation (6) with respect to $p$, and we have

$$\frac{\mathrm{d}U_\mathrm{g}^\mathrm{E}}{\mathrm{d}p} = \{q[0.7\mathrm{R}_\mathrm{g}(\boldsymbol{x}) + 0.2\beta - C_\mathrm{g}^1] + (1-q)[0.7\mathrm{R}_\mathrm{g}(\boldsymbol{x}) + 0.2\beta - C_\mathrm{g}^1]\} - \{q[0.7\mathrm{R}_\mathrm{g}(\boldsymbol{x}) + 0.5\beta - C_\mathrm{g}^2] + (1-q)[0.7\mathrm{R}_\mathrm{g}(\boldsymbol{x}) + 0.5\beta - C_\mathrm{g}^2]\} = 0\,. \quad (7)$$

Substituting $\mathrm{R}_\mathrm{g}(\boldsymbol{x})$, $\beta$, $C_\mathrm{g}^1$, and $C_\mathrm{g}^2$ with numerical values, we can solve for the probability $q$ that will lead to the maximum expected payoff for the developer. In order to solve for $q$, which will lead to the maximum expected payoff for the local government, we write down the expected payoff for the developer as $U_\mathrm{d}^\mathrm{E}$:

$$U_\mathrm{d}^\mathrm{E} = p\{q[0.6\mathrm{R}_\mathrm{d}(\boldsymbol{x}) + 0.8\beta - 1.3C_\mathrm{d}^1] + (1-q)[0.8\mathrm{R}_\mathrm{d}(\boldsymbol{x}) + 0.8\beta - 1.8C_\mathrm{d}^2]\} + (1-p)\{q[0.6\mathrm{R}_\mathrm{d}(\boldsymbol{x}) + 0.5\beta - 1.0C_\mathrm{d}^3] + (1-q)[0.8\mathrm{R}_\mathrm{d}(\boldsymbol{x}) + 0.5\beta - 1.4C_\mathrm{d}^4]\}. \quad (8)$$

Taking the first-order derivative of equation (6) with respect to $q$, we have

$$\frac{\mathrm{d}U_\mathrm{d}^\mathrm{E}}{\mathrm{d}q} = \{p[0.6\mathrm{R}_\mathrm{d}(\boldsymbol{x}) + 0.8\beta - 1.3C_\mathrm{d}^1] + (1-p)[0.6\mathrm{R}_\mathrm{d}(\boldsymbol{x}) + 0.5\beta - 1.0C_\mathrm{g}^3]\} - \{p[0.8\mathrm{R}_\mathrm{d}(\boldsymbol{x}) + 0.8\beta - 1.8C_\mathrm{d}^2] + (1-p)[0.8\mathrm{R}_\mathrm{d}(\boldsymbol{x}) + 0.5\beta - 1.4C_\mathrm{d}^4]\} = 0. \quad (9)$$

Substituting $\mathrm{R}_\mathrm{d}$, $\beta$, $C_\mathrm{d}^1$, $C_\mathrm{d}^1$, $C_\mathrm{d}^1$, and $C_\mathrm{d}^1$, with numerical values, we can solve for the probability $p$ for the local government that would lead to the maximum payoff in this game. The numerical example simply depicts how the model can be used in reality to derive regulatory strategies by the local government, given that the values of the parameters are provided using real data.

A special note must be given to the situation in which the game is a two-person iterated prisoner's dilemma. When the payoff table is arranged as shown in the beginning of the section, the best strategy for both the local government and the developer is ‘tit for tat’, in which each of the two players cooperates initially and then reacts by following the other player’s action in the ensuing rounds (Chiu and Lai, forthcoming). Under the tit-for-tat strategy, cooperation would emerge eventually that yields the best outcome for both players (Axelrod, 1984). In the land development context, the local government and the developer would cooperate in making regulatory and development decisions that benefit both parties.

## 6 Empirical validation for the model

A field survey was conducted in Shanghai in order to verify the implications of the model. In short, the model captures well the essence of the behavioral interaction between the local government and the developer, in that most scholars interviewed acknowledge the role played by the variables included in the model, namely development and regulatory decisions. For example, almost all interviewees noted that planning as information gathering and the regulations thus derived serve as an important element in guiding the individual cases of land development. The developer does indeed have bargaining power with the local government in acquiring land, pursuing planning permits, and initiating construction, but the premise is, as indicated by an interviewee, that the developer must have sufficient capital. With a transition from a centrally planned economy to a market-led economy, the legal restriction imposed by the local government has been significantly alleviated. As the interviewee commented, the developer is free to make development decisions regarding various land uses as long as he or she reaches a financial investment threshold and abides by the planning laws, mimicking a permit system. However, Shanghai is also one of the first cities in China to experiment with the zoning system to control land uses. Therefore, the example of the game situation fits well in part, if not completely, the development situation in Shanghai, in which the local government has the right to regulate, either through zoning or permit, and the developer acts accordingly. In addition, property rights, in particular rights to land in terms of use, are indeed an essential element in the land development process in Shanghai. As noted by an interviewee, even with governmental intervention the bargaining process between the developer and the landowner is quite common with respect to compensation of rights in land. The local government has the authority to relinquish rights in land use to the developer through land management institutes, and the developer in turn can apply for planning and construction permits from the local government. The notion of property rights embedded in the payoff table built for the model is indeed a proper determinant that dictates the behavior both of the local government and of the developer.

Compared with the real development situations in Shanghai, the model is apparently too simplistic in that the land development process actually involves not only the local government and the developer, but also the landlord. Under the transitional economy, in which the local government’s authority of initiating large-scale projects is scrutinized by the citizens through more empowered rights to participate in influencing these projects, the landlord retains most rights in land use, which increases the transaction costs of land development. As a result, without the endorsement of the local government, the developer has to negotiate with the landlord in order to compensate for the removal of current residents in a land development project. In addition, the term ‘local government’ actually represents a complex collective of agents whose authorities are differentiated. For example, the application of a land development project has to be dealt with by the planning, land management, and construction departments, in order to receive development permits. The negotiation among these departments, the developer, and the landlord is so complex that the behavioral interaction of these agents is beyond what the model can depict. However, the field survey confirms that the model can indeed serve as a theoretical foundation from which insights can be gained into how plans can affect urban development in China.

## 7 Discussion

Attributes of land are a central element of the property rights approach to land development. They are a function of interrelated decisions made by infrastructure providers, developers, landowners, and households. Therefore, the attributes associated with a parcel of land vary depending on the mutual adjustments among the participants of the land development process. For example, infrastructure providers, usually government, can affect the attributes of a parcel of land by constructing sewers and water mains near the site. Forecasting and planning for the interrelated development decisions in the dynamic context by a developer can yield benefits in terms of captured property rights.

Planning is interpreted as a tool for coordinating decisions in order to reduce transaction costs (Alexander, 1992). One of the major functions of firms is to serve a similar purpose, because organizations are another form of decision coordination. The property rights approach can be used to enhance our understanding about organizations by viewing skills, equipment, and labor as assets over which some decision makers have rights. Most land development behavior is conducted through organizations. It is then possible to incorporate planning into organizational behavioral theory based on the property rights approach, so that planning behavior can be understood more fully in the context of the land development process. For example, the interactions of members in an organization can be considered as property rights maximization processes, in which people tend to acquire such rights left in the public domain in the form of skills, equipment, and labor.

As depicted in the hypothetical example, given the theoretical framework of the property rights approach to land development, we can anticipate behavioral reactions of developers in response to changes in land-use planning policy, and make predictions about how such a policy would affect urban development in different social and political settings. The theoretical basis for linking the microlevel to macrolevel urban spatial processes is provided (Webster and Lai, 2003), in that cities are viewed as self-organizing systems spatially and institutionally, and that property rights acquisition is a fundamental phenomenon within such spatial processes. The theoretical framework proposed here as regards a property rights approach to land development can readily be translated into a systemic view of self-organizing spatial processes of urban development.

The model we have constructed is targeted at the land development process in the Chinese context. In particular, we divide the rights to land into 'ownership' and 'lease', in order to reflect the peculiar land-tenure system in China. There might be two possible solutions for this generalized two-person nonzero sum model: equilibrium and probabilistic solutions. The equilibrium solution is a situation in which the local government and the developer make their respective regulation and development decisions to maximize their own revenues derived from captured property rights, whereas the probabilistic solution is an unstable situation in which the players apply stochastic decisions in the hope of maximizing their expected payoff in the long run. There is a special situation in which the payoff table forms a two-person iterated prisoner's dilemma, in which an equilibrium suboptimal solution exists, but in which cooperation would emerge such that an ideal solution which maximizes the total payoff would exist. Conditions can be specified by solving the model as to which of the three solutions prevail. Hypotheses can be derived for empirical tests, as to what level of planning investment should be made and whether commitment between the local government and the developer is needed in order to reach the ideal solution. Implications can be drawn in the future from such empirical tests, as to how land-use plans could affect urban development in China and how we can make these plans to improve such development in China.

## 8 Conclusions

We have proposed a conceptual framework of land development behavior based on the property rights approach, in which information and property rights are two fundamental elements. The approach is so powerful that land development of the private sector of urban areas can be interpreted as a sequence of development decisions for capturing property rights left in the public domain through the acquisition, approval, construction, and letting phases, regardless of the lengths of land-tenure systems in China. We have shown a hypothetical case in which the rationing of land due to a price-control policy is not caused by a 'shortage' of land in the market, but by the developer's capturing of dissipated property rights that resulted from that policy. We also outlined a game-theoretic approach to depict the interaction between the local government and the developer through the generalized two-person nonzero sum game, incorporating property rights into the dynamic model as measured by the payoffs in the game. The validity of the explanation power of the model is partially confirmed in a field survey in Shanghai, in that it captures the essence of the land development process in China. Insights into how land-tenure systems and land-use plans in China would affect urban development, and how such plans should be made to improve urban development in China, can be derived from such a research framework. Preliminary results show that, regardless of the peculiar land-tenure system in China, the model captures well real land development cases in Chinese urban areas, at least in Shanghai. Whether pure strategies or mixed strategies would be adopted depends on the distribution of the property rights in table 3. The implication is that the land-tenure system in China must clearly specify the rights over land, whether ownership or lease, and should be enforced by laws in order for the land development process to be efficient—that is, by reducing the transaction cost of land exchange. In the transitional, rapidly growing economy in China, which has triggered the decentralization of rights in land, plans thus made affect significantly land development in the Chinese urban areas. A transition is needed in China from plans that focus on physical improvement through the design approach to those that emphasize distribution of rights through the strategic approach, in order to improve the urban development process (Lai, 2006b).

It is well recognized that land-use planning can be viewed as a game situation (Berke et al, 2006; Rudel, 1989). The prisoner's dilemma game is particularly useful to model how cooperation emerges (Axelrod, 1984; 1997)—cooperation that the local government and the developer must face in pursuing collaboratively collective goods of community development. The game-theoretic land development model captures in part, if not fully, the interaction between the two parties. The potential of the property-rights-based interpretation of land development is depicted by the proposed model and the case study. They show that, given the idiosyncratic characteristics and institutional variations of land development across different cultures, the notion of property rights can capture well the land development process, all things considered. Much work remains to be done before we can fully understand the land development process. For example, the proposed model could be linked to one that incorporates the interaction between the developer and the landowner. However, the proposed model provides a promising approach to understanding, and a starting point to explore, how urban change occurs and what we can do about it.

**Acknowledgements.** This research is funded by the Lincoln Institute of Land Policy, USA (contract number: E10C018SL033105).

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