The land hoarding and land inspector dilemma in China: An evolutionary game theoretic perspective

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Abstract:

China has experienced considerable economic growth since 1978, which was accompanied by unprecedented growth in urbanization and, more recently, by associated rising urban housing and land banking issues. One such issue is that of land hoarding - where real estate developers purchase land to hold unused in the rising market for a future lucrative sale, often several years later. This practice is outlawed in China, where land use is controlled by increasingly strengthened Government policies and inspectors.

Despite this, land hoarding continues apace, with the main culprits being the developers and inspectors working subversively. This resembles a game between two players - the inspector and the developer - which provides the setting for this paper in developing an evolutionary game theory model to provide insights into dealing with the dilemmas faced by the players. The logic and dilemma of land banking strategy and illegal land banking issues are analysed, along with the land inspector's role from a game theory perspective by determining the replication dynamic mechanism and evolutionary stable strategies under the various conditions that the players face. The major factors influencing the actions of land inspectors, on the other hand, are the costs of inspection, no matter if it is strict or indolent, conflict costs, and income and penalties from corruption. From this, it is shown that, when the net loss for corruption (income from corruption minus the penalties for corruption and cost of strict inspections) is less than the cost of strict inspections, the final evolutionary stable strategy of the inspectors is to carry out indolent inspections. Then, whether penalising developers for hoarding is severe or not, the evolutionary strategy for the developer is to hoard. The implications for land use control mechanisms and associated developer-inspector actions and counteractions are then examined in the light of the model's properties.

Keywords: land hoarding; China; strategies; evolutionary game theory

1 Introduction

China has experienced considerable economic growth since 1978, accompanied by unprecedented growth in urbanization. Land reform began in 1988 with the Chinese government approving legislation by which "the right to use land may be transferred in accordance with law" (Wu, 2001). In the early 1990s, China experienced phenomenal and speculative land development across the country (Wong and Zhao, 1999). For quite a long time since then, China's urban land system has been considered as state-owned and territorial, yet fragmented. The local governments have been made the 'real landlords', so as to assert full regulatory control over land use and transactions in order to secure rent revenues (Ding, 2004; Hsing, 2006).

Land use rights are therefore remarkably important to developers and they have to apply to, and obtain approval from, the government authorities (Bao *et al*., 2012). Land acquisition with land leasing strengthens fiscal conditions for local governments, promotes economic and industrial development, and encourages urban encroachment into rural areas (Hui and Bao, 2013). In this context, the land rush tide is consuming large expanses of arable land across China, resulting in developers forming strategies for the advance acquisition and holding of land before development – a process known as 'land banking' (Tu *et al*., 2008).

The effect of such considerations is that many Chinese developers would rather leave land already earmarked for residential purposes undeveloped for many years in anticipation of increased future housing prices (Liu and Ren, 2008; Wang, 2008; Zhang *et al*., 2009). As a result of hoarding land in this way, many land sites are left idle for speculative land banking purposes, leaving a large quantity of land resources either unoccupied or wasted. Government regulations exist to control land hoarding. These are policed by government employed land inspectors. However, while it is reasonable to assume that real estate developers will, in pursuit of economic interests, hoard land to obtain business opportunities, the extent to which inspectors are necessarily immune from similar considerations is less certain. Under the land inspection system, it is still possible for developers to pursue illegal land hoarding. Consequently, disputes over land often occur between inspectors, whose job is to minimise land hoarding, and developers, who want more land banking. How such issues are resolved, and the complex supervision and anti-supervision relationships involved between land inspectors and developers, is not clear. Also, there is always information asymmetry between the land inspector and the land inspection institution in monitoring land hoarding. With this information asymmetry and other interest-driven issues, land inspectors often encounter moral hazards and corruption risks in the course of their work, which in turn lead to looser regulation and supervision (Wang *et al*., 2008).

The developers and inspectors, therefore, both face dilemmas. For the developer, this is whether to indulge in illegal land hoarding that may or may not be detected by the inspector, while the dilemma for the inspector is whether to search too deeply for evidence of hoarding in response to some financial inducement from the developer. This clearly resembles a game between two players - the inspector and the developer - and provides the setting for this paper in developing an evolutionary game theory model to provide insights into dealing with the dilemmas involved. The aim is to analyse the logic and dilemma of land banking strategy and illegal land hoarding issues, as well as the land inspector's role from a game theoretic perspective.

The paper is organised as follows. First, is a literature review covering land hoarding and its control measures in several countries worldwide and China in particular. Then evolutionary game theory framework is introduced in terms of the land developer and inspector players, and the assumptions made and payoff functions involved. Next, the replication dynamic mechanism, and the evolutionary stable strategies, are determined under the various conditions that the players may face. Finally, the implications for a land use control mechanism and associated developer-inspector actions and counteractions are examined in the light of the model's properties.

2 Literature review

2.1 Land hoarding worldwide

Generally considered to be first initiated in The Netherlands in the 1890s, land banking has been growing ever since in other Western countries such as Sweden (from 1904), Canada (from 1950s), France (from 1958) and the USA (from 1970s), often through the government's purchase of unwanted land for planned future development, or as a land market intervention for urban growth management and urban planning implementation (Bao *et al*., 2012). Land hoarding, speculatively retaining land that would otherwise be sold (in anticipation of a price at a later date in excess of some threshold relative to its current risk-free market value), is a phenomenon reported in many countries. The most recent of these include the U.S., U.K., Australia, Switzerland, Uruguay, Costa Rica, Cambodia, Nigeria, Lesotho, Namibia and other African nations. In fact, a form of land hoarding in the U.S. is reported as far back as its Civil War, when most moneyed Virginians ('Eastern elite') were intent on making themselves even more so through the practice (James, 2010; Morgenstern, 2010).

Most countries exercise no control at all. Where control does exist, it is often in the form of *land taxation*. This occurs in most U.S. cities for example in the form of a property tax, which has been shown empirically to decrease land retention (Adelaja et al., 2010). Similarly, a recurrent property tax is applied supplementing an urban land tax in Namibia (Norregaard, 2013). An alternative used in parts of Africa are *investment rules for land*, but these are emerging only very slowly and without and firm commitment from the governments involved (Wohlmuth, 2012). *Re-zoning land areas* for development has also been tried in Sydney, Australia, but with little success in restricting land hoarding (Recsei, 2013)

Other reported control methods include a *land-value tax* (LVT). As Vincent (2012) explains, the U.S. property tax generally taxes buildings much higher than land, which has a corrosive effect on investment, construction and rehabilitation of existing structures. As a result, many old industrial and commercial properties that might have been warehoused or mothballed while waiting for a new use are demolished, so that the (often absentee) owner can avoid taxes. The effect is the degeneration of the districts involved. The opposite occurs in cities that use LVT. In one example of Clairton, Pennsylvania, the adoption of the LVT system tripled the vacant properties' contribution to the city budget, kick starting their sales/development, with the additional benefit of providing "resources to pay for the education of Clairton's children and liberate working and middle-class families from the bonds of labour and capital taxation".

Another case of relevance described by Monk et al., (2013), is Switzerland, where land hoarding is perceived as a major problem (Weber, 2010). Here, one mechanism to try and avoid land hoarding has been the development of *Land Improvement (LI) Syndicates* of land owners. These are land management tools typically in the form of public corporations, supervised by local authorities that aim to establish coordination between spatial planning and land management issues in order to avoid land hoarding (Weber, 2010). All landowners affected by spatial and land development projects are members and have the right to vote within the decision process, with decisions taken on a majority basis. Together, landowners seek to reorganise the land property to allow valuable development of the land, to equip their properties accordingly and to update the building rights according to the chosen development project (Weber, 2010).

Yet another recorded approach might be termed *the deal*. Vaughan (2012) describes the case of Osa Forest Products (OFP), for example, the second major stakeholder involved in the history of the Costa Rican Corcovado National Park (CNP). Between 1971-1973, charges of tax evasion, land-hoarding, repressive actions against settlers, corruption and other activities were levelled against OFP by congressmen from Costa Rica's national legislature and OFP quickly became an example of "land-hoarding" levelled at foreigners and their companies who neither used land, nor permitted nationals to use it. In September of 1975, Eventually, President Oduber began negotiations with OFP to exchange lands controlled by the Costa Rican government and OFP. Specifically the Costa Rican government wanted OFP lands in the CB for CNP, while OFP wanted public lands located in the center of the Osa Peninsula. After extensive negotiations, an agreement was reached for the land exchange in October 1975.

The remaining cases concern recommendations made that have yet to be implemented. De Shutter (2011), for example, advocate taxing land in discouraging speculative land hoarding by foreign investors in poor countries generally. Similarly, the Teilee (2010) recommends land use planning and taxes on unused land in Cambodia. Aliyu et al (2011), on the other hand, find a common procedure for land acquisition in Nigeria to be through "purchase from hoarders" and recommend an "enforcing penalty for none development of allocated plots". Colenut et al (2012), noting the prevalence of land hoarding in the UK, blame lack of regulation as a major cause, with decisions about the environment, being "financialised" – and "pawns in a system of finance and speculation" and that "what is needed is planning, regulation, and intervention for the common good". In Lesotho, where the traditional land tenure system vests all land with the king, "… a clandestine land market has developed and land hoarding and speculation are on the increase …[what is needed is] firstly and foremost the formulation of a land policy" (Daemane et al, 2012).

2.2 Land hoarding in China

Land banking in China started in the 1990s and is now widely practiced in over 1600 cities or counties, across both the public and private sectors (Bao *et al*., 2012). Private sector land banking research in China is concerned with the behaviour of developers when making decisions on the quantity of land involved as determined by their business strategies, where holding costs and anticipated earnings are traded off against each other (Hui and Bao, 2013; Zhang *et al*., 2011).

Hoarding land in this way over a period of time is clearly inefficient, and its control is exercised through the *Land Use Master Plan* (tudiliyong zongti guihua) and the *Annual Land Use Plan* (niandu tudi liyong jihua), which regulate the quota of planned farmland development for construction use. However, local governments are also involved, for example the Beijing state and municipal governments have, since 2003, introduced several strict land policies requiring local governments to better control their granting of land permissions against land hoarding and real estate speculators (Zhao, 2011).

However, the legal requirements relating to land use in China are often ignored. In 2004, for example, the Ministry of Land and Resources inspected all the economic development areas in the country and found 6866 economic development areas to have been created through illegal land conversion (Hui and Bao, 2013). As a result, the CPC Central Committee and the State Council established the State Land Inspection System in 2006 (The State Council Information Office, 2007) in order to reduce illegal land hoarding, strengthen land management and improve the land law enforcement supervision system. This system is intended to provide strict arable land protection, efficiently enforce state macroeconomic regulations, and promote unified land administration laws and regulations nationwide.

Nevertheless, by 2008, the situation was still not satisfactorily resolved, resulting in the release of the State Council's *Circular on Promoting the Economical and Intensive Utilization of Land*, requiring that

> ... when the land is idle for more than 1 year and less than 2 years, 20 percent of the lease fees for land use may be collected as an idle land fee. A duty shall be imposed on value increment of idle land plots, especially idle real estate, strengthening supervision and inspection and completely fulfilling the responsibility for economical and intensive land use. A dynamic monitoring system of the market for land shall be established and the monitoring of all kinds of land change shall be strengthened. Increasing construction land at the expense of cultivated land and illegal land use shall be the focal point of monitoring, the results of which shall be open to the public. Supervision of economical and intensive land use shall be strengthened. The Ministry of Land and Resources shall collaborate with the Ministry of Supervision to evolve improved law enforcement and land use inspection.

This was followed later that year by the *Opinion of the General Office of the State Council on Further Strengthening the Supervision Work and Earnestly Carrying out the Inspection*, which provided advice on how to strengthen supervision work and inspections. The *Circular on Further Strengthening the Management of Income and Expenditure of the Land Transfer*, released in 2009, required those involved to “Strengthen the supervision, and strictly enforce the responsibility system concerning the management of income and expenditure of land transfer”. Under the guidance of this series of policies, the Bureau of State Land Supervision conducted several supervision-related exercises from 2008, including exercises designed “To maintain economic growth”, “To carry out routine supervision in 26 cities and 13 counties”, and “To carry out inspections of new construction land in 172 cities”.

At the same time, the Ministry of Land Resources established nine land supervision bureaux to perform supervision duties on behalf of the Chief National Land Inspector and to help in the direct supervision of developers' land use (State Land Supervision, 2009). Today, China's state land inspection institution has one State Land Inspector-General, held concurrently by the Minister of Land and Resources; one Deputy State Land Inspector-General, held concurrently by one vice Minister of Land and Resources; and one full-time Deputy State Land Inspector-General (at vice-ministerial level). There is one Director-General and two Deputy Director-Generals in the State Land Inspector-General Office. In addition, each state land inspection bureau has one Director-General, two Deputy Director-Generals and several Commissioners.

However despite this strengthening of the land use supervision process, there are still problems. According to data released by the Ministry of Land and Resources in August 2010, there were 1457 parcels of idle land across the country, with a total area and total contract price of approximately 10000ha and 25.6 billion yuan respectively. The survey identified idle land throughout the country, with Guangdong (324 cases), Beijing (160 cases), Chongqing (151 cases), Hainan (141 cases) and Jiangsu and accounting for 25% of the total area. Of these cases, 31% had been idle for longer than 5 years, with some cases being even up to 20 years (Jiang *et al*., 2013).

The choice of a land hoarding strategy by developers in China is a natural result in considering the cost-benefit of government supervision. For example, developer China Resources purchased a 6401 m^2 tract of land for 5067 yuan/m^2 in 2005, with agreed start and completion times of 5 December 2005 and 30 June 30 2007 respectively. However, it did not commence construction until July 2011, leaving the land idle for 6 years. During this time, the price of housing in nearby Fuli city had risen to 38000 yuan/m^2 - an appreciation of more than 400% in value after allowing for all the development costs involved (Chinese Times, 2011).

Expropriated land hoarding in China occurs with both real estate and industrial development (Wu *et al*., 2014) and is related to land purchase and the development situation, so the gap between the growth rate of the areas of land acquisition and development largely reflects the extent of land-banking taking place. In general, the greater the gap is, the more land is being hoarded (Bao and Zhuang, 2012a).

<Insert Table 1 here>

Table 1 shows the dynamical changes in land purchase and development by China's real estate developers in 2003-2010, with the smallest gap occurring between 2006 and 2009. The reason appears to be that, after the establishment of the State Land Supervision System in 2006, developers assumed that land supervision would be stricter so the development was gradually reduced. As a result, the inspectors became more indolent in their assessments. Upon realising this, the developers increased their hoarding so that it once again became a serious problem until the national policy and supervision measures were strengthened by the 2008-2009 *Circulars* and *Opinions*. With this increase in supervision strictness, developer hoarding gradually reduced from 2008, reaching a minimum in 2009. This is clear evidence of the dynamics of developer-inspector strategic decision making. The increase in the gap since 2009 suggests that inspectors have returned to less strict behaviours or attitudes.

Real estate is one of the most important industries in terms of China's land resources, characterized by the ‘scarcity’ providing its basis. However, the industry is also notorious for its imperfect and lagging legal environment that has caused its commodity trading to suffer from serious information asymmetry concerning land transactions (Wu *et al*., 2005). This has further accelerated market failure, including "astronomical land prices" and "disorderly skyrocketing of housing price", as well as land hoarding. These issues have attracted significant scholarly attention, most of which has been from the perspective of government regulation. Bai (2008), for example, considers it an imperative for the government to regulate the real estate industry, both directly by controlling both price and land resources and indirectly through the adjustment of interest rates and tax regulations to ensure the stable development of the market. Chen (2008), on the other hand, believes that the government should establish a sound real estate market information collection and release system in order to strengthen the laws and regulations needed to improve the industry.

In theory, the government will intervene if the market fails. However, it is difficult for the local government to initiate regulations to reduce land hoarding as it gains enormous socioeconomic benefits from developers (Zhuang, 2010). This increases the likelihood of a conspiracy emerging between the government and the developers, making it necessary to better understand the dynamics of the interrelationships and the processes involved that culminate in a land hoarding decision being made. With boundedly rational developers, the decision to hoard land or not involves a process of trial and error in the form of an evolutionary process of learning, imitation and improvement. The same applies to the local government. Both government and land inspectors are faced with a similarly evolutionary process in deciding whether to opt for land use control or land supervision. Moreover, the situation is dynamic for, as the history of land hoarding in China indicates, the actions of the developers are followed by counteractions from the government, which are in turn followed by the countercounteractions of the developers, etc. Over time this series of actions or considerations may possibly lead to a stable state, or equilibrium, where neither party can benefit by any further action. This being the case, the issue to be addressed is how to engineer an equilibrium such as this that provides maximal benefit to the community and hence is the research question underlying land hoarding strategy and land inspector’s role.

3 Evolutionary game theory framework of the land hoarding decision between developers and land inspectors

Evolutionary game theory (EGT) provides a useful approach in this context by defining a framework of contests, strategies, and analytic models into which Darwinian competition can be modelled (Maynard-Smith and Price, 1973). EGT is based on the bounded rationality hypothesis. It takes a group as the research object to analyse its dynamical evolution processes, and then explain why and how the group reaches its currently evolved state. EGT differs from classical game theory by focusing more on the dynamics of strategy change as influenced partly by the quality of the various competing strategies, and partly by the effect of the frequency with which those various competing strategies are found in the population (Easley and Kleinberg, 2010).

When land inspectors and developers make decisions concerning land hoarding, the game process is uncertain, boundedly rational and dynamically evolving (Shen and Jiang, 2002; Bao and Zhuang, 2012b). Generally, the strategy space of land hoarding between land developers and inspectors comprises the hoard/not to hoard land and strict/indolent inspection decisions respectively.

3.1 Assumptions of the model

In order to simplify the analysis, two basic assumptions are made.

1. Two players. Although real estate developers and land inspectors make decisions as groups in the game, it is assumed that the game is played by two individual players, termed here *the developer* and *the inspector*.
2. Near-sightedness. When one player changes its strategy, the other player is assumed to take the present distribution strategy as the known condition, and then change its strategy to adjust to the new environment. However, this assumption ignores the strategy space and change in payoff functions caused by several individuals changing their strategies, which means the payment strategy will not change with the individual strategies.

3.2 Model analysis of payoff function and impact factors

In order to simulate the behaviour and stakes of the inspector and developer in the land supervision process, the payoff function and impact factors of the two players are analysed first.

3.2.1 Payoff function of the inspector, $U_1=R_1-C_1$

Land inspectors are national civil servants in China, and their salaries are linked to their post and rank. This basic salary is denoted by R_{11}. If an inspector is found to be indolent and corrupt, then its income becomes $R_{12.}$ If the inspector aspires to work hard, and engage in strict supervision, it will involve a significant cost, in both effort and time, to achieve. This cost is denoted as C_{11}. The process of supervising developers is prone to trigger contradictions and conflicts, as developer's land hoarding often relates to local governments, meaning that strict supervision of these developers can offend the local governments. This may lead to the loss of social relations, or even loss of relatives' economic and social interests, a conflict cost denoted by C_{12}. When the inspector is penalized for corruption, the penalization is C_{13}, while the penalty for indolent inspections is C_{14}. Hence, $C_{13}+C_{14}-R_{12}$ is the net loss in pay when the inspector is indolent and is penalized for corruption.

3.2.2. Payoff function of developers, $U_2=R_2-C_2$

The income of the developer mainly refers to the hoarding income R_{21}. C_2 refers to the cost of land purchases and land holding. The sum of these two types of cost is denoted by C_{21}. With a strict inspector who detects and penalises the hoarding developer, the land idle cost is C_{22} (Lou and Den, 2007).

The payoff function of a hoarding developer is $U_2=R_{21}-C_{21}-C_{22}$ while under inspection and $U_2=R_{21}-C_{21}$ when not under inspection. When the developer does not hoard, the payoff function is $U_2=0$, $U_1=R_{11}-C_{11}-C_{12}$ with a strict inspector and $U_1=R_{11}-(C_{13}+C_{14}-R_{12})$ with an indolent inspector. The payoff function is $U_1=R_{11}-C_{11}$ and $U_1=R_{11}-C_{14}$. In the actual situation, $R_{11}>0$ $C_{11}>0$; $R_{11}-C_{11}>0$; $C_{12}>0$; $R_{12} \geq 0$; $C_{13} \geq 0$; $R_{21}>0$; and $R_{21}-C_{21}>0$ which means that hoarding produces benefits. Table 2 provides the payoff matrix of the developer and the inspector.

<Insert Table 2 here>

<Insert Table 3 here>

For the convenience of calculation and without loss of generality, we make $R_{11}-(C_{11}+C_{12})=R_1$, $R_{21}-C_{21}-C_{22}=R_2$, $R_{11}-C_{11}=R_3$, $R_4=0$, $R_{11}-(C_{13}+C_{14}-R_{12})=R_5$, $R_{21}-C_{21}=R_6$, $R_{11}-C_{14}=R_7$ and $R_8=0$. This allows Table 2 to be simplified to Table 3.

4 Game theory framework between developers and inspectors - replication dynamic mechanism and evolutionary stable strategies

Assume partners are assigned randomly between the group of inspectors and the group of developers. If the proportion of strict inspectors is *x*, then the indolent inspectors account for 1-*x*. Also, assuming that the proportion of hoarding developers is *y*, the proportion of non-hoarders is 1-*y*. The replication dynamics equation of the inspectors is therefore:

$$F(x) = \frac{dx}{dt} = x(u_{11} - \overline{u_1}) = x(1-x)(u_{11} - u_{12})$$

$= x(1-x)[(R1-R3-R5+R7)y+(R3-R7)]$

$= x(1-x)[(C_{13}-R_{12}-C_{12})y+(-C_{11})]$ (Equation 1)

while the replication dynamics equation of the developers is:

$$G(y) = \frac{dy}{dt} = y(u_{21} - \overline{u_2}) = y(1-y)(u_{21} - u_{22})$$

$= y(1-y)[(R2-R4-R6+R8)x+(R6-R8)]$

$= y(1-y) [(-C_{22})x+(R_{21}-C_{21})]$ (Equation 2)

4.1. If the inspector is indolent and corrupt (R_{12}>0 and its penalty is C_{13}+ C_{14})

4.3.1 When the net loss of an indolent and corrupt inspector is less than the costs incurred by a strict inspector ($C_{13}+C_{14}-R_{12} < C_{11}+C_{12}$), then:

For the inspector, $(C_{13}+C_{14}-R_{12})<(C_{11}+C_{12})$, as $C_{11}>0$ when $C_{13}-R_{12}>C_{12}$, namely $C_{12}<(C_{13}-R_{12})<(C_{11}+C_{12})$. Then, when *y* is bounded at (0,1), the value of $(C_{13}-R_{12}-C_{12})y+(-C_{11})$ is always less than zero. In which case, $F'(0)<0, F'(1)>0, x=0$ is the evolutionary stable strategy (ESS).

For the developer, there are two possibilities.

Scenario 1: when $(C_{13}+C_{14}-R_{12})<(C_{11}+C_{12})$ and $(R_{21}-C_{21}-C_{22})<0$, if $x=(R_{21}-C_{21})/C_{22}$ (since $C_{22}>0$ and $R_{21}>C_{21}$, the value of $(R_{21}-C_{21})/C_{22}$ is within the range of (0,1)), then no matter what is the value of *y*, G(*y*) will always be zero. When $x>(R_{21}-C_{21})/C_{22}$ and $G'(0)<0$, $G'(1)>0$, then *y*=0 will be the ESS. When $x<(R_{21}-C_{21})/C_{22}$ and $G'(0)>0, G'(1)<0$, then *y*=1 will be the ESS. Now let $x_0=(R_{21}-C_{21})/C_{22}$, $y_0=C_{11}/(C_{13}-R_{12}-C_{12})$. Fig. 1 shows the replicated dynamic relationship of proportional change that the different percentage of members in the group of inspectors and the group of developers will adopt the respective strategies of inspecting strictly and hoarding. This indicates the ESS of the game to be *x*=0, *y*=1.

<Insert Figure 1 here>

The inspector's loss due to corruption is less than the cost of inspecting strictly. Under these circumstances, the ratio of strict inspectors will gradually reduce to zero. There are two practical reasons for this. First, inspection costs are high, as enforcing the law is difficult due to the risk of damaging social relations and individual interests and associated conflict costs. The second reason is that the supervision of land inspectors is inadequate to stop corruption.

When the penalties for corruption are less than the benefits of not being corrupt, the inspectors are generally not willing to try their best to monitor the developers' behaviour. For the developers, once their hoarding is detected by the inspectors, the penalty involved will increase the cost. However, since the cost of inspection is greater than the cost of corruption, there is less prospect of a strict inspection. In addition, a developer can obtain substantial gains by hoarding, which is easily imitated by other developers. Thus, the ratio of the developers choosing the hoarding strategy will gradually increase to unity.

Scenario 2: when (C_{13}+C_{14}-R_{12}) <(C_{11}+C_{12}) and (R_{21}-C_{21}-C_{22})>0, (-C_{22})x+(R_2-C_{21}) is always greater than zero, then $G^{'}\left(0\right)>0$, $G^{'}\left(1\right)<0$ and y=1 is ESS. Let x_0=(R_{21}-C_{21})/C_{22}, y_0=C_{11}/(C_{13}-R_{12}-C_{12}). Fig. 2 shows the equivalent replicated dynamic relationship of proportional change to Fig. 1. In this case, the ESS of the game is x=0, y=1.

<Insert Figure 2 here>

Again, the inspector's loss due to corruption is less than the cost of inspecting strictly. With R_{21}-C_{21}-C_{22}>0, the inadequate penalty for hoarding makes the value of the payoff function still greater than zero. Under these circumstances, therefore, the rational inspector's best strategy is to make indolent inspections, which encourages the developer to adopt a hoarding strategy - leading to a game strategy of hoarding developers and indolent inspectors.

For both scenarios, therefore, where the net loss of corruption is less than the cost of strict inspection, the evolutionary strategies for the developer and inspector are hoarding and indolence respectively, whether the penalty for the developer is severe or not. The reason is that, once the net loss of corruption is less than the cost of inspecting strictly, the inspectors will have incentives for corruption. This means that when the inspectors are not in the game, then, no matter how severe the penalty for hoarding is, the developer will choose the hoarding strategy, which will eventually result in hoarding by all the developers.

4.3.2 When the net loss caused by inspector corruption (C_{13}+C_{14}-R_{12}) is greater than the cost of strict inspection (C_{11}+C_{12}).

From equations 1 and 2, this can be expressed as a two-dimensional dynamic autonomy system (not containing time t) where

$$\begin{cases} F(x)=\dot{x}=x(1-x)[(C_{13}-R_{12}-C_{12})y+(-C_{11})] \\ G(y)=\dot{y}=y(1-y)[(-C_{22})x+(R_{21}-C_{21})] \end{cases} \qquad \text{(Equation 3)}$$

According to the two-dimensional differential theorem, the equilibrium point of the system is（0,0）、(0,1) 、(1,0) 、(1,1) and (x_0,y_0). x_0=(R_{21}-C_{21})/C_{22}, y_0= C_{11}/(C_{13}-R_{12}-C_{12}).

To solve the partial derivative of F(x), G(y) with respect to x and y respectively, we use the Jacobean matrix of equation 3:

$$J = \begin{bmatrix} \partial \dot{x} / \partial x & \partial \dot{x} / \partial y \\ \partial \dot{y} / \partial x & \partial \dot{y} / \partial y \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \qquad \text{(Equation 4)}$$

The determinant of J is $\det J = a_{11}a_{22} - a_{12}a_{21}$ and its trace is $trJ = a_{11} + a_{22}$. Table 4 provides the local stability analysis of the equilibrium point of the game between the inspector and developer.

<Insert Table 4 here>

This shows that there is no ESS at the five local equilibrium points. In other words, when the net loss from corruption (C_{13}+C_{14}-R_1) is greater than the cost of inspecting strictly (C_{11}+C_{12}), and the benefit of hoarding for the developer (R_{21}-C_{21}>0) is greater than zero, it is a dynamic process, meaning that there is no stable strategy for the two players. Therefore, the optimal strategy for the inspector is a mixed one, namely a stochastic dynamic monitoring strategy.

When x_0=(R_{21}-C_{21})/C_{22} y=0, y_0= C_{11}/(C_{13}-R_{12}-C_{12}), x=0, then clearly the ratio of inspectors monitoring hoarding behaviour depends on the ratio of hoarding developers, and *vice versa*. Thus (R_{21}-C_{21})/C_{22}, C_{11}/(C_{13}-R_{12}-C_{12}) is the dynamic scale of the two players.

In order for the inspector to gain maximum profit, the probability it will adopt is:

$$x = \begin{cases} 0 & ; 0 \le y < C_{11} / (C_{13} - R_{12} - C_{12}) \\ \text{Any value in } (0,1); & y = C_{11} / (C_{13} - R_{12} - C_{12}) \\ 1; & C_{11} / (C_{13} - R_{12} - C_{12}) < y \le 1 \end{cases}$$

(Equation 5)

while, for the developer to gain maximum profit, the probability is:

$$y=\begin{cases} 0 & (R_{21}-C_{21})/C_{22}\le x\le 1 \\ 0-1 & \mathrm{x}=(R_{21}-C_{21})/C_{22} \\ 1 & 0\le x<(R_{21}-C_{21})/C_{22} \end{cases}$$

(Equation 6)

According to the above analysis, therefore, the strategies adopted by the inspector and developer are counterbalanced. Combining equations 5 and 6 gives Fig. 3, where the thick solid line and thick dashed line represent the probability of inspecting strictly and hoarding for the inspector and developer respectively.

<Insert Figure 3 here>

In Fig. 3, the intersection of the thick solid line and the thick dashed line $p((R_{21}-C_{21})/C_{22},C_{11}/(C_{13}-R_{12}-C_{12}))$ represents an exactly balanced game. That is to say, $\mathrm{y}=C_{11}/(C_{13}-R_{12}-C_{12})$ is the critical point where the inspector should inspect the land banking behaviour. On the other hand, $\mathrm{x}=(R_{21}-C_{21})/C_{22}$ is the critical point where the developer should hoard. The probability balanced game between the inspector and developer is:

$$[(x,1-x),(y,1-y)]=[\left(\frac{R_{21}-C_{21}}{C_{22}},\ \frac{C_{22}+C_{21}-R_{21}}{C_{22}}\right),\left(\frac{C_{11}}{C_{13}-R_{12}-C_{12}},\ \frac{C_{13}-R_{12}-C_{12}-C_{11}}{C_{13}-R_{12}-C_{12}}\right)]$$

This implies that, to maintain the dynamic balance of *x*, *y*: if *x* (the probability of inspecting strictly) is reduced, then the developer's penalty (C_{22}) for hoarding must be increased to compensate. Similarly, if the benefit of hoarding (R_{21}) is reduced, the total cost of land purchases and land holding (C_{21}) must be increased. On the other hand, if *y* (the probability of hoarding) is reduced, the cost of corruption (C_{13}) must be increased to support the strictness of the inspectors. Meanwhile, the inspectors should be offered help in their work to reduce the cost of being strict (C_{11}). In addition, reducing the conflict cost (C_{12}) would help support the inspector’s work (Wu et al 2005). This is in agreement with the actions reported earlier by the State Council through its *Circular of the State Council on Promoting the Economical and Intensive Utilization of Land* and its *Opinion of the General Office of the State Council on Further Strengthening the Supervision Work and Earnestly Carrying out the Inspection.*

In actual land use and land control activities, the developers and land inspectors would adopt mixed strategies according to the policy changes of the other side. That is, the developers restrain their hoarding behaviour when the inspectors are being strict, while the inspectors adjust the strictness of their inspections according to the hoarding dynamics involved. This again aligns well with the real world dynamics reported earlier.

4.2. If the inspector is indolent with no corruption ($R_{12}=0;C_{13}=0$), its loss may be the penalty for its indolence ($C_{14}\geq 0$).

The replicated dynamic equation for F(*x*), G(*y*) will be:

$$F(x)= x(1-x)[(C_{13}-R_{12}-C_{12})y+(-C_{11})]=x(1-x)[(- C_{12})y+(-C_{11})]$$

$$G(y)=y(1-y) [(-C_{22})x+(R_{21}-C_{21})]$$

This can be demonstrated from two distinct conditions:

(1) Assuming that the cost of indolent inspections without corruption (C_{14}) is less than the cost of strict inspections ($C_{11}+C_{12}$) then, according to the above analysis, when the salaries of the inspectors are the same, and the cost of indolent inspections is less than strict inspections, boundedly rational inspectors will choose to make indolent inspections. As more and more inspectors make indolent inspections, the developers will choose to hoard regardless of the penalty involved and all will eventually hoard. Thus, the optimal strategic choice is to hoard land and carry out indolent inspections.

(2) Assuming that the cost of indolent but incorrupt inspections (C_{14}) is greater than the cost of strict inspections ($C_{11}+C_{12}$), then boundedly rational inspectors will choose the same strategy: to inspect strictly. However, the proportion of land hoarded by the developers depends on the penalisation and revenue implications of hoarding. There is no stable strategy in this situation.

4.3 A two-pronged approach for land use control and developer-inspector situations

The target of land use control is for developers not to hoard land. The role of the land inspectors is to provide the necessary supervision by carrying out the required checks. The evolutionary game model between boundedly rational maximising inspector and developer players captures the situation well in terms of both ESS and the evolutionary trend of the two groups in different non-cooperative situations. It also clearly demonstrates the heavy reliance on the somewhat fragile impartiality of the inspectors. To make the inspection more effective, a two-pronged approach has the potential for promoting the interaction between developers and inspectors, as well as for formulating sanctions of developer hoarding while strengthening the strictness of the inspector.

(1) *Controlling developer hoarding.* China has a number of relatively strict idle land control measures, including those contained in *Measures for Disposing Idle Land* released in 1999, *Circular on Strengthening Idle Land Disposal* released in 2007, *Circular on Promoting the Economical and Intensive Utilisation of Land* released in 2008 and *Measures for Disposing Idle Land* released in 2012. These policies are detailed and strict, in accord with China's current social and economic development, and play a role in deterring hoarding proclivity by gradually strengthening the penalisation of exposed hoarder developers. The application of the evolutionary game model developed here indicates the need for strengthened control in the future. Two obvious possibilities are apparent.

a. *Intensified penalisation of hoarders*. This obviates the need for ruthlessly strict inspectors - allowing a fairer, more circumspect, approach to appraisals that can take a variety of ameliorating issues into consideration. This also involves improving China's land management law to clearly define what constitutes hoarding activity and to provide a strong and practicable deterrent system. At the same time, increasing the idle cost C_{22} to make hoarding uneconomical will also help prevent hoarding by developers.

b. *Strengthened investment control of developers.* Most often, developers need a great deal of money to purchase land, so that controlling access to capital provides some insight into its likely use in land hoarding. Currently, the financial institutions are the main source of capital for developers. The government can pressure these financial institutions to strengthen the supervision of the developers' monetary affairs, such as by regulating the use of special funds and adjusting the lending rates and loan terms of known hoarding enterprises to limit their cash flow and increase the holding cost C_{21}.

(2) *Inspection, constraints and guidance of land inspectors.* As stated earlier, land hoarding is still occurring in China. It is argued here that the reason for the poor performance of policies relating to idle land includes the lack of supervision of, and constraints on, the inspectors. For long-term reform, building a healthy land market involves not only guiding the main market players, the developers, but also having an effective means of regulation. However, as with land inspectors, the performance of the regulators also needs to be managed for similar reasons (such as the time honoured 'passing the buck to the collective'). Currently, the opportunities for this are very limited. Nevertheless, the government can help by furthering the supervision and performance evaluation of land inspectors. Four immediate possibilities arise.

a. *Increase the land inspectors' performance by improving the performance evaluation mechanism*. This should follow the criteria of justice, equity and transparency, provide incentives for those who do well and penalise those who fall short of targets.

b. *Reduce the difficulty and cost of the inspection work.* The government should offer help for inspectors to reduce the difficulty and cost for their work (C_{11}).

This could include using advanced technology to establish a dynamic monitoring system to help the inspection work.

c. *Protect the interests of land inspectors.* For example, the inspectors' social relations as well as their individual interests will be complicated when they work in a place that has long been adverse to inspection work. An inter-regional post rotation system is suggested to reduce conflict costs C_{12}.

d. *Intensify the penalisation of land inspector corruption cases.* The government should improve the land management law, by clearly defining what constitutes corruption. This should be followed by the formulation of a practical and enforceable penalisation system with increased penalties for acts of corruption, to increase the cost of corruption C_{13}. Action on this has already commenced with the General Office of State Land Inspector's *Specification on the Inspection Work of Land Inspectors (trial edition)* in 2009, which provides useful support in regulating the work of the inspectors.

5 Conclusion

Land hoarding is a common activity in many parts of the world and, outside the planned economies, mainly just tolerated or countered in some way by such gentle methods as fiscal policies, investment rules, democratically ruled groups of stakeholders, etc. The situation in China is unique and straightforwardly interventionist, with its illegalisation of land hoarding and policing by a virtually unaccountable inspectorate. This lends itself to treatment as a game between acquisitive hoarders and indolent inclined inspectors, in which the land hoarding strategy of real estate developers is influenced by a variety of issues including land values, holding costs, idle costs and the actions of the land inspectors and other developers. Analysed in this way, it is shown that, when hoarding produces a greater net profit than other uses of the land, boundedly rational developers have no choice but to hoard and *vice versa*. The major factors influencing the actions of land inspectors, on the other hand, are the costs of inspection, no matter if it is strict or indolent, conflict costs, and income and penalties from corruption. It is shown that, when the net loss for corruption (income from corruption minus the penalties for corruption and cost of strict inspections) is less than the cost of strict inspections, the final evolutionary stable strategy of the inspectors is to carry out indolent inspections. Then, whether penalising developers for hoarding is severe or not, the evolutionary strategy for the developer is to hoard.

From the conditions examined here, the need for strict inspections is clearly critical in controlling land-hoarding activities. It is therefore vital to ensure that land inspectors perform to a satisfactory level. In China, land inspectors are civil servants, and their recruitment, assessment, appointment and transfer align with the relevant provisions of the civil service. At present, it is difficult to mandate the performance appraisal of civil servants. In addition, the work of land inspectors is both difficult to carry out strictly and difficult to evaluate externally, creating a tempting situation for those inspectors faced with the opportunity of generating additional income from (illegal) inducements to work in a more indolent way. At present, the land supervision bureau mainly offers honorary titles, in an attempt to inspire the inspectors' performance, such as "The outstanding achievement observation point (unit) and individual", "Good execution team", "Advanced unit of performance management", "Advanced worker", "Advanced office", "Excellent information officer", "Best advocate", "Outstanding communist party member", "Outstanding party worker", "Advanced grass-roots party organization", "Best inspector team" and "Sharp eyes". It is believed that these honorary titles do inspire the land inspectors' performance to a limited extent, but that the endemic nature of the land hoarding/corruption problem in China has led many in the industry to the view that there is a need to dramatically improve the evaluation of inspector performance and the associated rewards and penalties. In doing this, it is suggested that the government should reasonably guide the market behaviour of the main players, as well as the constraints on the behaviour of "regulators" such as local governments and land supervision institutions. Meanwhile, this paper provides a two-pronged approach to helping in land use control and supervision through deterring land hoarding by manipulating the ESS resulting from the actions and counteractions of developers and inspectors.

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