

# Potential Housing Bubble with Chinese Characteristics: Analysis and Policy Design through an Operational Model

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## Abstract

This thesis analyzes the potential housing bubble in the Chinese urban housing market. Using an operational model built on system dynamics (SD), it explores the unique housing market structures, information flows, key agents and their decision-making processes, and the system constraints that may contribute to the bubble forming phenomenon.

Its SD models differ from intensive data-driven economic models. They are structural, operational, and focus on causal relationships. They can more easily accommodate non-market features and unique institutional components, where long-range historical data are not readily available. As the Chinese government heavily controls its housing markets, housing prices greatly depend on political decisions. The models incorporate the incentives and decisions of key agents in the market and have predictive power through simulation and scenario analysis. They can thus help decision-makers transform decisions, actively manage risks and opportunities, timely design and implement policies, and consequently change the system from within.

This thesis specifically discusses three Chinese-specific features:

1. Rising housing price and the cap rate change;
2. High vacancy rates caused by speculators purchasing multiple housing units as money-storage investments they are unwilling to rent;
3. Land financing schemes where local governments rely on income from land sales to support their budgets which leads them to use their monopolistic position to short-supply the land.

The research design starts from the DiPasquale-Wheaton model (D-W) which Western urban economics theory has validated for analyzing housing cycles. It operationalizes this by:

1. Converting the D-W to a basic SD model;
2. Augmenting this with additional generic features;
3. Incorporating unique Chinese market features to create China-specific models; and then
4. Creating an integrated overarching model for conducting a case study using historical data of Nanjing, China.

The result is one of the first operational models for the Chinese housing market that has the explanatory mechanisms and somehow overcomes the data availability issues. It provides an intuitive and transparent structure that we can easily modify to address complex issues.

The main findings are:

1. The Nanjing case study demonstrates “why and how” the interaction of certain market features can create a significant bubble in housing prices. In particular, it indicates that the land supply component plays a dominant, amplifying role in the system.
2. It shows that under certain policy interventions or crises, the potential bubble may burst and drop prices.
3. Understanding these conditions, policy makers can transform the decision-making processes of key market agents and move toward long-term sustainable development.
4. Although demand side policy interventions are less effective in controlling housing prices than supply side interventions, they are preferable for the social stability.

Thesis Supervisor: Richard de Neufville  
Professor of Engineering Systems  
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## 1 Introduction and Dissertation Overview

In the past decade, the world has witnessed a substantial boom – a golden era – in the Chinese real estate market, with the price of real estate – especially the price of housing – increasing at a rapid rate in major cities. The phenomenon of price escalation has become a popular research topic. In the Chinese market, major housing economic indicators such as housing price, land auction price, and price-to-rent ratio have reached at record highs, as shown in Figure 1-1.

These indicators, combined with frequent government interventions have many researchers believing that the current Chinese housing market should be considered a housing bubble (Wu, Gyourko, and Deng, 2012, 2016; Cao, Huang, and Lai, 2016; Glaeser et al., 2016; Zhao and Michael, 2016). During the last decade, the average housing price for major Chinese cities has grown at an annual rate of 17%, whereas the real GDP of these cities has only grown at a rate of 11% (Chen and Wen, 2017). Speculations of a potential housing bubble are pushed to the forefront of social, financial, and political debates. Such debates are often accompanied by the international criticism of bubble-bursting ghost cities in the third or fourth tier cities, thus forming the two extremes along the spectrum of the Chinese housing market.

Housing Price Index (2006Q1-2013Q4)

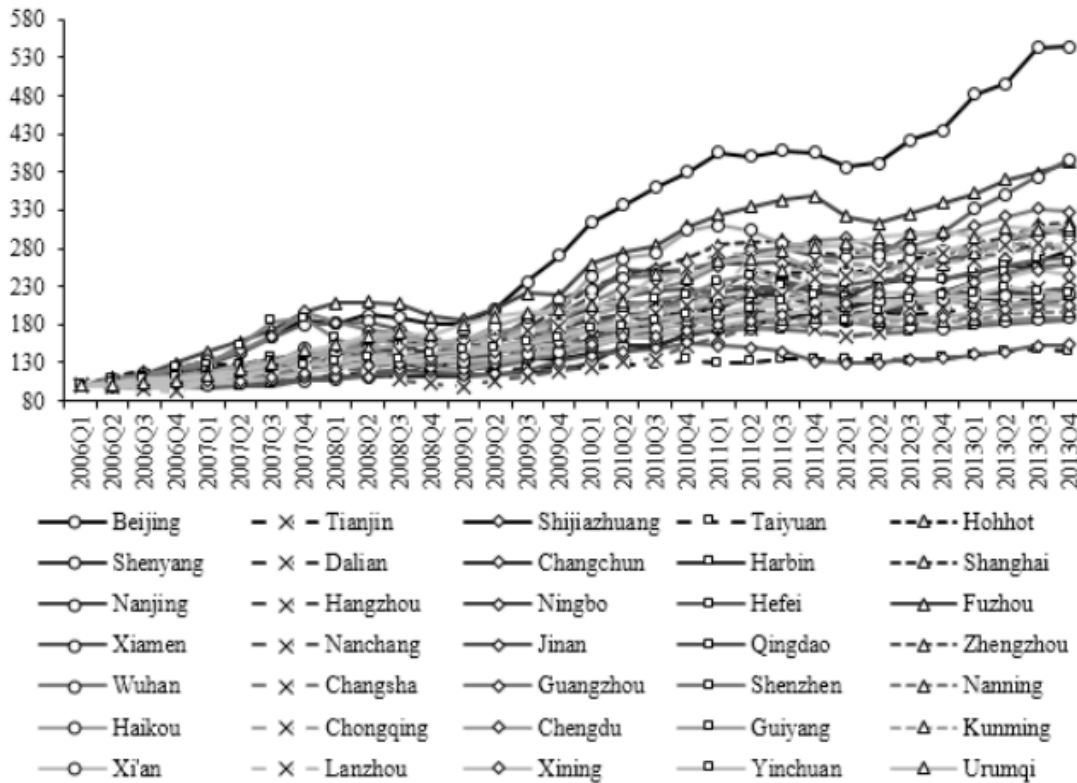


Figure 1-1 Hedonic housing price indices across 35 major Chinese cities (Zheng, Sun, and Kahn, 2016)

Research and news coverage in the Chinese housing related fields have focused primarily on the short-term month-to-month political, economic, and social effects while neglecting the long-term fundamentals. This coverage focuses narrowly on the ever-climbing housing prices, as well as the opportunities to invest and speculate, but not on analyzing the peculiar market mechanisms that are driving the prices. There are few evaluations of whether or not the price increases are sustainable for the long term, nor are there any substantial discussions of the consequences should prices fall.

Traditional urban economic models such as the pedagogically efficient DiPasquale-Wheaton (D-W) model are proven to be effective in understanding and analyzing conventional housing market cycles where a free-market economy dominates. However, it faces limitations when being applied to the fast developing Chinese markets

where political and other non-conventional characteristics play an important role. At the same time, operational models such as System Dynamics (SD) models have been used to analyze real estate markets over the past generation, yet the technique remains relatively unknown and little used in academia – and, more to the point, among practitioners and educators in the real estate community. The research topics that apply SD to real estate models are scattered around different areas of interests, and thus they do not provide a holistic view.

### **1.1 Motivating Case: The Potential Chinese Housing Bubble**

This section covers some important elements of the Chinese Urban housing market. It is important to note that while the Chinese housing bubble is the motivating case, the approach and analysis in this thesis is designed to be generalized and potentially applicable to other Southeast Asian countries where similar political schemes and market features exist.

The Chinese housing market is complex and the range of topics can be seemingly unrelated: There is rapid urban expansion due to rural-to-urban migration; historically high vacancy rate is caused by speculative investors facing limited capital investment channels; there is non-existence of a full housing cycle, or collapse of bubble in any asset category; local governments' expenditure budgets strongly depend on land sales; strong and frequent central government policy control causes uncertainty and leads to short-term housing euphoria; and lastly, there is short and limited data history to conduct a thorough research.

These features of the Chinese housing market are not normally found in more traditional Western economies and therefore have not been addressed by traditional Western housing models. Yet, these unique features have the potential to exert a substantial impact on the Chinese housing price. By acknowledging them, discussing them, understanding them, and eventually incorporating them into one systematic operational framework, one can explore the underlying relationships among them. This approach will help us to explore the conditions of bubble forming, bursting, and the extreme

volatilities in the market. One can also explore what strategies can be implemented to mitigate such conditions.

### 1.1.1 The Context of Chinese Housing Market

Among all characteristics, China's housing market in recent decades can be recognized or generalized by rapid urbanization, ever-growing housing prices, frequent government interventions, and another round of continuously-growing housing prices.

The constantly rising housing prices frequently take over the news headlines and lead to numerous debates in the real estate field. The stability of the real estate market, especially the housing market, has become an important topic for scholars, government policy makers, as well as investors around the world. This has been especially true ever since the subprime mortgage crisis that took place in the United States in 2007. In China, many believe that the current housing market boom is also in the process of forming the next real estate bubble. Jianlin Wang, China's former richest man and commercial real estate guru has claimed that the property market is definitely in a bubble, but it is controllable (by the government).<sup>1</sup> "*Big but doesn't Burst*" has since become an almost philosophical description of the potential housing "bubbles" with Chinese characteristics. It implies that the bubble can become bigger but the government will always have the ability, through political intervention, land supply, and monetary policy adjustment, to keep it under control.

Initially, the industry began to weaken at the time of the international Great Financial Crisis in 2009. At that time the Central Government introduced stimulus package<sup>2</sup> that, while successful in stemming the slowdown in the market, led to a new round of soaring housing prices. As shown in Figure 1-2, this occurred most notably in the so-called "first tier" cities (also known as "gateway" cities, including Beijing, Shanghai, Guangzhou,

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<sup>1</sup> "No Confidence in China Markets Inflates Housing Bubble", Bloomberg News, September 16, 2013. Web. Aug 9, 2016. See < <http://www.bloomberg.com/news/articles/2013-09-15/no-confidence-in-china-markets-inflates-housing-bubble>>.

<sup>2</sup> Matthews, Chris. "Why China's Stimulus Package Was a Big Mistake", Fortune International, Jan 15, 2016. Web. Jan 10, 2017. See < <http://fortune.com/2016/01/15/why-chinas-stimulus-package-was-a-big-mistake>>.

Shenzhen, and, depending on the source, also possibly including Tianjin, and/or Nanjing). This price surge has led to concerns about home affordability in some cities, as well as fears that the market might be exhibiting an even larger housing bubble. If this is true – if such bubble exists and should collapse, the result could wreak havoc in the financial system not only in China but internationally as well.

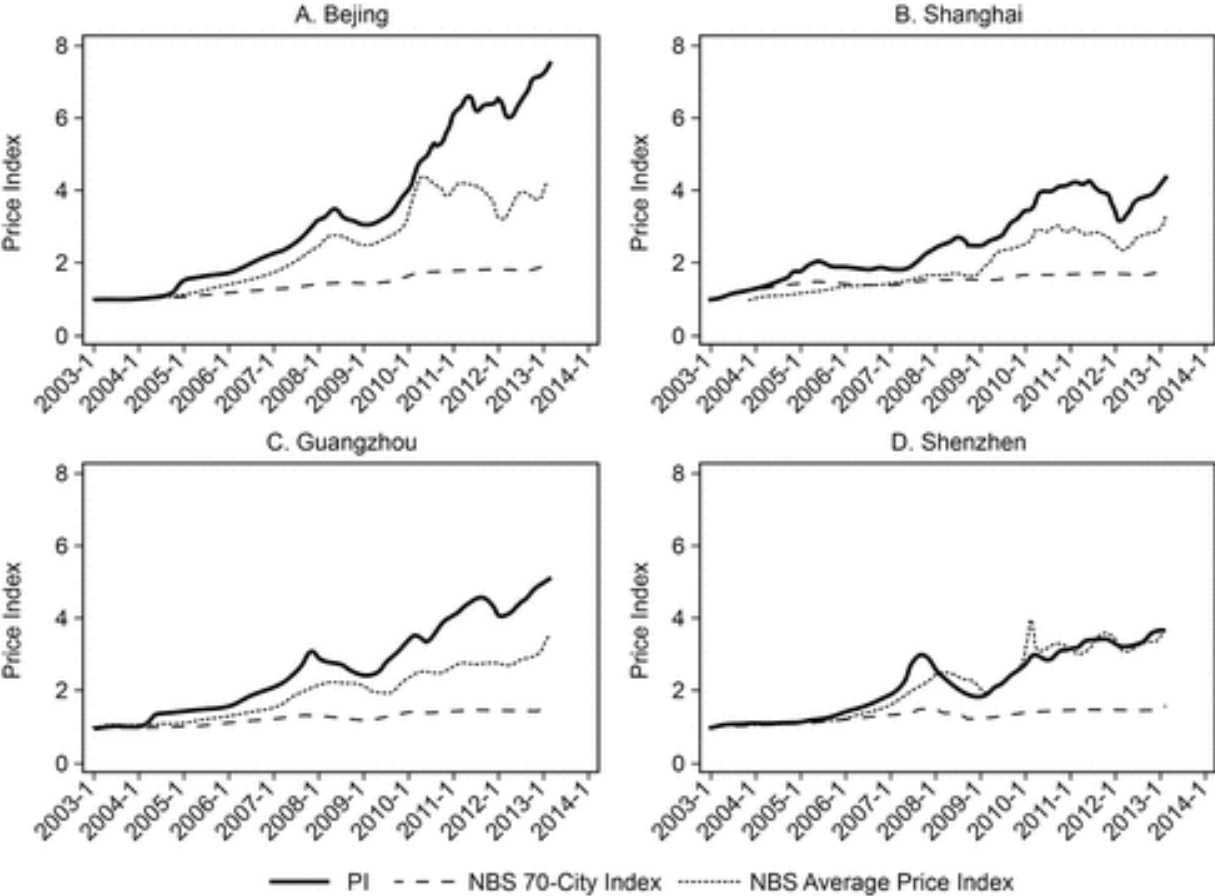


Figure 1-2 Price surge in major gateway cities after 2009 (Fang et al., 2016)

However, whether the housing bubble exists is debatable. There has not been a full housing cycle in the Chinese market yet, so how do we know that the current price escalation is not just the climbing phase of a normal market cycle, headed to reach the first market equilibrium. Many believe that the extra usage demand created by the needs of migrants proves that there is no risk of a bubble forming and the high cost of

housing reflects the proper market price.<sup>3</sup> The new rural to urban immigrants, to a certain extent, have guaranteed the demand of residential units. It is widely referred to as “usage demand” (‘gang xu’ in Mandarin) to distinguish from the investment and speculative demand of the middle and upper class. Real per capita incomes have been doubling roughly every seven years, and may continue to grow at very rapid rates. The result will be a tremendous increase in demand, not just in terms of the quantity but also the quality of urban housing, including renovation and reconstruction of the existing housing stock as well as the creation of new stock. These can serve an alternative explanation to the rapid housing price increase.

Indeed, China is one of fastest growing income countries and every year there are millions of rural to urban migrants. The past generation in China has also witnessed the greatest urbanization in world history to date. China’s cities grew by over 500 million people from 1980 to 2015, and this process continues. The current (2016) urbanization rate already reached 56.1% and may further increases to 60%, equivalent to 100 million migrant workers in 2020.<sup>4</sup> Another 250 million inhabitants may come into the urban population by the year 2030. This migration process is also happening at extreme rate, taking only 30 years, and is heavily guided and influenced by waves of government policy control. They claim that the rural to urban migrants should be considered as the driving force of housing demand in big cities.

In reality, the rural to urban migration is not a simple process due to the strict control of Hukou system.<sup>5</sup> Most of the migrants do not have the immediate right or the financial means to purchase housing units in the cities where they work. Regarding the supply-demand imbalance, researchers also contend that in the long run, due to birth control and the mandatory implementation of one child policy starting from the late 1970s, the buying power of the middle age and young generation will only decrease in the future.

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<sup>3</sup> Shepard, Wade. “Demand For Housing In China’s Heated Property Market Is Real”. Forbes Asia. 25 March 2016. Web. June 25, 2016. See <<http://www.forbes.com/sites/wadeshepard/2016/03/25/demand-for-housing-in-chinas-heated-property-market-is-real/#637a2ea810d5>>.

<sup>4</sup> “China’s urbanization rate at 56.1 pct”. Xinhuanet. April 19, 2016. Web. June 22, 2016. See [http://news.xinhuanet.com/english/2016-04/19/c\\_135294134.htm](http://news.xinhuanet.com/english/2016-04/19/c_135294134.htm).

<sup>5</sup> The “Hukou” system is a record system of household registration required by law in China to determine where citizens are allowed to live and profit the benefits from education and medical system.

To make things worse, the older generation who possess extra housing units will likely sell them off to the market in order to financially support their retirement.<sup>6</sup> Extra supply with decreasing demand will lead to a long-term downturn of housing price which can be one form of bubble bursting process.

It is impressive that Chinese cities have, for the most part, accommodated this unprecedented migrant demand in such short time frame. This has been done in part by flexibly adapting the policy framework governing the housing industry. Before 1994, constructing the housing units for urban working labor force was the solely responsibility of local governments and state-owned enterprises. As the economy boomed, it has become such financial burden that the government decided to use a three year period (1994-1997) to finish the transition of the central-planned housing system to commercial housing system.<sup>7</sup> From 1994-1998, the national policy has also encouraged a transition from the previous centrally-planned social housing system to a largely market-driven system based on the sale of long-term land leaseholds by local government authorities to private developers (Man, 2015). A constitutional amendment in 1988 permitted the private purchase of land use rights for leaseholds of 70 years for residential use, and 30 to 50 years for industrial and commercial use. From 1998, private developers started to produce most of the housing in China, largely units for owner-occupancy, as well as other types of buildings.<sup>8</sup>

Although such swift changes are happening within one generation, the effort of owning a housing unit has become a major financial burden for multiple generations within the family. In Chinese culture, owning a house is a prerequisite for entering into a marriage and a reflection of social status. Since obtaining bank loans becoming more and more

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<sup>6</sup> Ha, Jiming. "China's housing bubble is the biggest in the world", April 10, 2016. Web. Aug 13, 2016. See < <http://finance.sina.com.cn/china/gncj/2016-04-10/doc-ifxrcizu3909885.shtml>>.

<sup>7</sup> "Decision on Deepening on the Reform of Urban Housing System" The State Council of the People's Republic of China, National Development and Reform Commission, 43, (1994). 国务院, "关于深化城镇住房制度改革的决定", 国家发改委, [1994] 43 (1994).

<sup>8</sup> "Notification on Further Continuation of the Reform of Urban Housing System and Accelerating Housing Construction." The State Council of the People's Republic of China, National Development and Reform Commission, 23, (1998). 国务院, "关于进一步深化城镇住房制度改革加快住房建设的通知", 国家发改委, [1998] 23 (1998).

difficult, it is normal to have the grandparents and parents' generation provide the down payment or full amount for the young generation to afford housing units. It is reported that 90% of the families in China own their home and make the home ownership rates one of highest among all nations.<sup>9</sup>

One of the potential explanations for housing bubble is that the demand for purchasing housing units in some cities tends to include a large component that is driven by investors, using housing units as a means to store monetary wealth, not for the purpose of living in the units. Such demand is referred to as the “speculative” housing demand,<sup>10</sup> effectively using housing as an investment. The income disparity in China is significant. The percentage of the population in the middle and upper class is still small, but it is this percentage that owns most of the speculative housing units. For various reasons, many of such units are simply held vacant, not rented out. They are wasted in terms of actually providing housing to anybody.

The lack of efficient stock and bond markets significantly limits the investment vehicles for middle and upper class Chinese families. For most of these families, housing is their only investment channel. This is due, at least in part, to the fact that China is just beginning to develop the broadly diversified system of mature capital markets and the associated financial industry infrastructure that is necessary to provide rationally priced and transparent alternative investment opportunities of sufficient depth and scale to accommodate the population's rapidly accumulating private wealth.

The housing market is, for the most part, actively targeting such families – that is, those seeking investment opportunities – as they are the only ones that can afford to buy. In

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<sup>9</sup> Shepard, Wade, “How People in China Afford Their Outrageously Expensive Homes”, Forbes Asia. March 30, 2016. Web. Aug 12, 2016. See < <http://www.forbes.com/sites/wadeshepard/2016/03/30/how-people-in-china-afford-their-outrageously-expensive-homes/#44e29bbf4aa5>>.

<sup>10</sup> It is important to clarify that in the context of this thesis, “usage demand” refers to the ordinary buyers that aim to possess a housing unit for daily living purpose, while “speculative demand” or “speculative investors” refers to the housing investors who purchase the housing units and leave them vacant, not selling them or renting them out. They hold the units as a means of “money storage” and only sell them when the market peaks. They do not rent the houses out for the reason that the prices rise is always bigger than the rental income.



some first tier cities, the housing price has increased by almost 300-400% in less than 10 years' time. This substantial price jump has attracted most of the middle and upper class to invest heavily in residential properties for speculative purposes, driving the price higher. It is reported that the actual number of housing units that are held vacant by investors is well underestimated. According to the China Household Finance Survey (CHFS), conducted by a research team in Southwestern University of Finance and Economics, the vacancy rate has reached 22.4% in 2013.<sup>11</sup> There is no official statistical data of the vacancy rate collected by the Chinese government. But the large presence of vacant units can be roughly estimated by counting the “dark units” in the fully sold residential buildings at night, such as in Figure 1-3.



Figure 1-3 Vacant but owned units without lighting on at night time in city center of Dalian, China

(Image source: author)

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<sup>11</sup> Li, Gan (2015) Conference presentation at 2015 Asia Pacific Real Estate Research Symposium at Southwest University of Finance & Economics in Chengdu, China. He and his research team from Southwestern University of Finance & Economics Household Finance Survey in 2013 found a nationwide average vacancy rate over 22%, based on a survey of 28,000 households. Detailed description can be found at <[chfsdata.org](http://chfsdata.org)>.

Chinese cities have shown different trends in the housing market. It is believed that only the first and second tier cities in coastal region are seeing the bubble effect, where most of the upper and middle class live and can afford homes. By contrast, in some third to fourth tier cities, the trend is that there is an increasing severe of housing oversupply.<sup>12</sup> Many of the ghost cities such as Erdos have been constructed at a record pace to host a million people and then abandoned entirely, with significant decrease of labor force.<sup>13</sup>

One objective of this thesis is thus to provide insights ex ante to the housing bubble analysis in the Chinese market and find an operational framework to include the major Chinese market features. For example, we can provide insight into the effective of speculative demand on the Chinese housing market.

### 1.1.2 The Roles of Chinese Central and Local Governments

It has also become clear that the housing market is linked to the local governments' public finance system in a manner that is perverse and ultimately unsustainable. In China, the land market is detached from the housing market: the central government owns the urban land, while the consortium of the villages made of farmers own the rural land. The land cannot be freely traded or developed. The central government normally sets up the annual quota for the local governments as per how much land they can disburse every year through public auction for the purpose of housing development. Xiao (2014) has found that this top-down fashion has led to several critical problems: allocated amount of quota barely meets the demand, and the distribution of limited quota is not assigned according to actual demand.

Local governments obtain a crucial proportion of their revenue from the sale of land leaseholds, which are paid for entirely up front at the time of sale (rather than by annual leasehold payments). Further, the ability of local governments to sell land is effectively used as collateral for government debt. Yet, both the supply of and the demand for land

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<sup>12</sup> "Chinese Third and Fourth Tier Cities". BBC China. October 7, 2015. Web. December 20, 2016. See <[http://www.bbc.com/zhongwen/simp/press\\_review/2015/10/151007\\_press\\_review](http://www.bbc.com/zhongwen/simp/press_review/2015/10/151007_press_review)>.

<sup>13</sup> Day, Peter. "Ordos: The biggest ghost town in China." BBS Magazine. BBC News. March 17, 2012. Web. January 19, 2017. See <http://www.bbc.com/news/magazine-17390729>.

for leaseholds are not infinite, and the revenue produced by such sales is highly dependent on the prices the land leaseholds command in the marketplace. When local governments sell land leaseholds to developers, the land is generally supposed to be developed within two years. The obvious risk is that land development will be driven by local governments' need for revenue – including the need to service debts and invest in other infrastructure expenditures – rather than being driven by actual market demand for buildings, especially housing. This system is generally referred to or criticized as land financing scheme (Lu and Sun, 2013).

For example, in the land market of first tier cities such as Beijing and Shanghai, housing developers have already complained that the profit margin has been squeezed to nothing because the land supply is limited, which directly lead to the high land bidding prices. In other words, “the cost of flour is more expensive than the price of bread”.<sup>14</sup> As a result, the developers have to raise the housing price significantly to sell to the market in order to make a profit, which is considered to be the root of the potential housing bubble.

This potential bubble has also raised concerns of the Chinese Central government. As response, the government, in recent years, has implemented strict policies to micromanage the bubble. The government believes that it can guide the housing bubble to a soft-landing, when needed. However, other than minor short-term market reactions, the housing price has never dropped significantly.

Most of the Central government's policies have tried to target speculative demand. For example, in 2010 the government started to implement the “home purchase restrictions” law nationwide. This restriction law allows each family to purchase at most two units in the first and second tier cities. With the new purchase restriction law implemented, the demand triggered by such investment and speculation needs temporarily vanished and led to a significant short-term reduction in the housing demand (Sun et al., 2014).

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<sup>14</sup> Fung, Esther. “China's ‘Land Kings’ Return as Housing Prices Rise.” Wall Street Journal. June 19, 2016. Web. June 25, 2016. See < <http://www.wsj.com/articles/chinas-land-kings-return-as-housing-prices-rise-1466325638>>.

In addition to the implementation of the purchase restriction, there have been other monetary policy adjustments. For example, the Central government has been intervening the credit market by adjusting interest rates higher or lower, in order to manipulate market demand. The government also implemented a new resale tax, raising the residential unit resale tax from 1% to 20%, if the for-sale unit is not the primary residence.<sup>15</sup> There are also plans in place to implement property taxes<sup>16</sup> and inheritance taxes in order to further suppress the potential housing bubble.

However, how long such strong political interventions will last is unknown and thus creates uncertainty. There has been a trend of “gaming” in the housing supply market. Many housing developers appear to choose to gamble on the short duration of such national policy enforcement. They either behave as a land hoarder<sup>17</sup> and stop construction, or hold finished products from selling in the property market, which results in a decrease on the supply side. Also, housing development activity is considered the major force pushing the national economy and GDP growth. Suppressing the housing sector for long term will inevitably hurt the economy. It is even further noted that the construction sector keeps a large portion of the work force employed, thus contributing to social stability. When the housing sector was not performing in 2012, China’s GDP reported a declining growth rate as shown in Figure 1-4.

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<sup>15</sup> The details of resale property tax is written in Chinese. Online source:

<http://house.sina.com.cn/focus/ershoufangjiaoshui/> Access date: Dec 15, 2016.

<sup>16</sup> Li, Luodan. “Time for China to embrace property tax?” Chicago Policy Review. May 13, 2015. Web. Jan 19, 2017. See <http://chicagopolicyreview.org/2015/05/13/time-for-china-to-embrace-property-tax/>.

<sup>17</sup> “Developer’s land hoarding can last 20 years with land price increased by 100 times”. Report on the land hoarding behavior of Chinese developers. Fang.com cited Chinanews.com. September 28, 2015. Web. Jan 19, 2017. See <<http://fdc.fang.com/news/2015-09-28/17517152.htm>>.

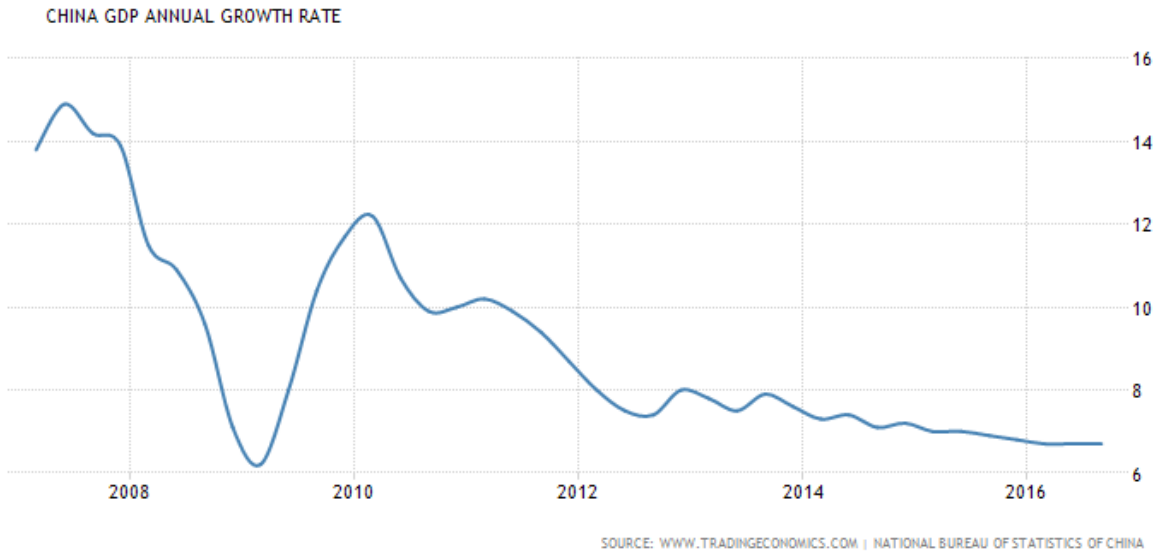


Figure 1-4 China GDP growth rate

(Note: the graph is generated by tradingeconomics.com with data from National Bureau of Statistics of China)

The Chinese government deserves credit at least for acknowledging potential bubbles and taking steps to rein them in. The frequent governmental interventions can be interpreted as a painful process that the government is going through, trying to come up with a better policy for the housing market. How effective each policy design is? What will be the market reaction to such design in the long run? The current issue is: given all the new policies that have come into place, the demand is still strong and the housing price is not dropping. Why they are not working? If this trend continues, would the market start to collapse and if so, what strategies can be used to lead to a “soft landing” and avoid immediate crash?

### 1.1.3 Unsustainable Chinese Housing Market Features

On the surface, we can observe two phenomena: on one end of the spectrum, the bubble-like housing price is increasing at an exponential rate that makes it unaffordable in gateway cities. By contrast, on the other end of the spectrum, there are ghost cities that few people are willing to reside in, leaving a large number of vacant units and

waves of defaults by developers and local governments on government debt. Both extremes trigger the discussions of sustainability.

The term “sustainability” in the Chinese urban housing market can be defined, or rather, challenged, in many aspects. The current housing trend in China is widely quoted as “unsustainable” and the causes are closely related to the market dynamics previously mentioned. This thesis will confine, define, and analyze the sustainability issues within the following scope:

1. The most obvious sustainability issue is the ever-increasing, bubble-like prices in major cities where job opportunities are present, yet working families cannot afford to purchase housing.
2. At the same time, speculative investors purchase multiple housing units as investment opportunities and leave them vacant. These investors are betting on an ever-rising housing market. It is almost similar to the recruitment process of Ponzi scheme where the payment of quick returns to the first round of housing investors rely on the continuous influx of money from later investors. If an avalanche event should happen and these vacant units are released all together to the housing market for sale, the market would inevitably collapse.
3. On the supply side, local governments rely on selling land to the housing developers in order to collect fees and meet their fiscal budgets. This mode of “land financing scheme”, which is covered in details in Chapter 6, will not last for long term because of the scarcity of land. The financial model of having annual fiscal budget relying on incremental land sales but not annual property tax revenue is not a sustainable mode.<sup>18</sup>

## 1.2 Research Objectives and Methodologies

Traditional urban economic models such as the D-W model and its stock-flow version are used to understand the equilibrium dynamics of the conventional markets where market economy dominates. However, classical econometric models face limitations

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<sup>18</sup> Property tax is not yet fully implemented in China.

when being applied to the Asian markets where political economy and other non-conventional institutional and behavioral characteristics play an important role. Alternatively, engineering methodology such as System Dynamics (SD) can help address these issues and provide a simulation tool especially useful in analyzing the impact various policies. Therefore, the goal of this effort to conduct an interdisciplinary research regarding the housing market across different theories, methodologies, and contexts by addressing the following major research question:

*How do we integrate the key components of Chinese housing market into one system framework in order to usefully and efficiently analyze the potential housing bubble ex ante, and identifying solutions that lead to sustainable development?*

In order to approach the question, a set of SD models are developed progressively at different research stages, to arrive at a final operational model of the Chinese housing market. Anchored on the traditional economic theories, the Chinese market features will be incorporated and connected with arrows as in the SD methods. The direction of the arrows will reflect a clear causal and quantifiable relationship. The model structure can be modified to include new features, assumptions, or decision rules to test the “what-if” scenarios. The model building process will also rely on the qualitative analysis of the Chinese market through field studies and online resources. Potentially sustainable policy designs will be tested and evaluated.

There are four progressive research stages to this thesis and they build upon each other step-by-step. These stages are:

1. Translate the traditional D-W model into a baseline SD model;
2. Complement and enhance the baseline model by expanding model boundaries and create a set of generic SD models to understand the housing market fundamentals and their assumptions;
3. Construct, improve, and validate another set of SD models that specifically incorporate the features that are unique to Chinese housing market;

4. Using simulation and Chinese data, identify and understand the potential bubble component in the housing price structure by comparing prices suggested by the simulations of overarching models created based on Stages 2 and 3.

Regarding Stages 1 and 2, this thesis contributes to both the theory and methodology by developing a novel housing system simulation model using the system dynamics technique, anchored on traditional urban economics theory. The proven D-W model provides the theoretical foundation for the SD model building process. The SD models in early stages enhance the flexibility and unleash the simulation power of D-W model by incorporating new components and modifying the assumptions of previous components to lead to new findings.

The models in Stage 3 take into consideration the important facets of Chinese market by incorporating special market features that do not exist in conventional Western housing market. These also incorporate the interactive decision-making process of key stakeholders (investors, developers, central and local governments) that reflect the larger political influence these institutions have in the Chinese economy. An additional benefit is, by having such system setup, should a 'beacon event' take place and is observed in the market, the model is able to follow the signal and trace back through the causal chain in the model and identify the possible root cause. Each of these new features will be added one at a time so that we can observe the effect of each component through the simulation result change comparing against the benchmark price, defined as the simulation results by using only the original D-W model structure applied with economic fundamentals. Economic fundamentals are macroeconomics parameters such as income, cap rate, household number, etc as done in Ahuja et al. (2010).

More importantly, in Stages 3 and 4, based on the simulation results of validated SD models, this thesis shows *ex ante* "why and how", under certain widely-prevailing circumstances, the housing market can demonstrate bubble-like unsustainable results. It also shows that with a better understanding of the cause and consequences of these



conditions, there are policy decisions that could induce a “soft-landing” and move toward more sustainable development. For example, the model provides policy insights into certain issues such as how local government can manage its annual land supply to micro-manage the housing prices, and why central government should set up policies to lower the speculative vacancy rate by forcing more vacant housing units to circulate into the usage housing market.

An additional benefit of this thesis is that it summarizes and introduces various phenomena such as speculative investment and land financing scheme. These concepts are widely talked about in the Chinese housing market, so much so that the average citizen has become familiar with these terms. By translating the Western economic theory into a more transparent SD model and further modifying it to fit the specific circumstances of the Chinese market, this thesis fosters communication between academic and quotidian society. In effect, it will enable the not so mathematical or tech-savvy investors or real estate developers to understand the escalating effect of bubble formation and potential collapse through the SD model.

### **1.3 Expected Outcomes**

The set of SD models developed in this research, at each stage, have different purposes and expected outcomes.

First, it directly translates a static analytical economic model into an engineering based operational SD model. The lens of analysis is shifted from the long-run equilibrium seeking behavior to short-run adjustments between equilibriums that are more sensitive to new policy design and implementation.

Secondly, more to the point, the visual clarity of SD method allows an “unpacking” of the causality links in the system, and a flexibility in adjusting the system assumptions, expanding the model boundaries, which facilitates the discovery and discussion of new model behaviors other than cyclic behavior.

Thirdly, and more specific to the situation in China, the newly integrated market features modify the basic SD model structure and provide constraints that have changed the model's behavior, providing potentially virtuous and vicious pricing spirals that can accelerate and rapidly burst when a market bubble presents. It imitates the bubble behavior than the long-run cyclical behavior of conventional housing markets in Western countries. Behind the special features were the behavior of the key market players and their interactive decision-making processes. Different combinations of decision-making processes, such as rational forward-looking versus myopic euphoria, independent versus collaborative efforts, or Ponzi-like recruitment process, will cause each SD model to program differently and thus lead to different system behavior.

Finally, the SD models help to conduct counterfactual analyses and demonstrate how the market would behave under different policy conditions, including differences in the timeframe at which various policies are implemented. The research focus shifts from ex post analysis to ex ante analysis. These also offer insight to alternative policies, such as evaluating between policies targeting the supply side or housing market vacancy rates, instead of focusing uniquely on suppressing demand. Such insights will help guide the central/local governments, or developers toward better policy designs. The SD models gain descriptive power by enabling a more realistic representation of the urban housing system in China.

#### **1.4 Thesis Outline**

The research framework of this thesis is conceptually innovative in the sense that it conducted interdisciplinary research across different phenomenon (market bubble vs market cycle), different theories and methodologies (economic theory vs system dynamics theory), and applied in different contexts (traditional Western market vs dynamic Chinese market).

Chapter 1 starts with introduction of various factors in the Chinese market. They are seemingly unrelated and spread among different aspects of housing market, while they

are all closely contributing to the constantly rising housing price. It identifies the research objectives and methodologies.

In Chapter 2, the literature review section covers three overlapping topics. They are phenomena, theories & methodologies, and context. The phenomenon aspect examines housing market cycles and bubbles. The theories and methodologies aspect examines the well-accepted urban economic theory as well as system dynamics techniques. Specifically, when combining both of these methodologies together, it is plausible to find a way to analyze housing market from the ex ante perspective. Finally, the context aspect adds special conditions, such as those unique conditions found in the Chinese housing market.

Chapter 3 lays out the research design of this thesis. The first step is to transform the analytical economic models to system dynamics model in order to switch the research platform. Anchored on the urban economics theory, the new SD platform with modifications, and with hypothetical data is used to unveil the power of such approach, and answer research hypotheses. The validation process of the model is discussed in detail. Lastly, the SD model will incorporate the non-market features and conduct scenario analysis to provide insights to policy design.

In Chapter 4, an initial SD model is created based on the traditional economic model (DW model). In Chapter 5 and 6, the original assumptions of the DW model setting are challenged through modification, such as adding delay mechanisms and the scarcity of land reserve component, internalizing cap rate, etc. A set of generic SD models are created and significant changes in the simulation results are observed.

In Chapters 7, 8, and 9, the contextual features of Chinese housing market are further discussed and integrated to the SD models. This provides the ability to conduct scenario analysis, compare the bubble scenario against traditional market cycles, and provide policy insights. These features include unsustainable demand growth, speculative investment, land financing scheme, etc.

Chapter 10 is a case study of Nanjing, China and we apply the real world data into the integrated model to partially validate the model with historical data. We also conduct future scenario analysis such as panic tests and see how the housing market responds to certain market condition changes.

Chapter 11 is the conclusion chapter.

## 2 Literature Review

*“Microeconomists still rarely cite macroeconomists, economists rarely cite psychologists, and academics rarely cite news media stories.”*

--- Robert J. Shiller (2003)

*“Asset price bubbles represent a challenge to researchers and policymakers because some fundamental questions have not been answered in a convincing manner: How does one define an asset price bubble in a practical way? How can we identify an asset price bubble? If a bubble could be identified and measured, how should a policy maker respond?”*

--- Randall S. Kroszner (2003)

### 2.1 The Organization of the Literature Review

As the title of this thesis suggests, even in its most concise form, the literature review section will cover the contents across three different areas:

1. Two Phenomenon: Housing Bubbles vs. Housing Cycles
2. Two Theories-Methodologies: Urban Economics vs. System Dynamics
3. Two Contexts: Chinese housing market vs. Western housing markets

The organization of the literature review session of thesis will be as shown in Figure 2-1. The table structure serves as a “mapping of the field” to address the interdisciplinary characteristics of this thesis. Each cell represents a specific field that will be covered in the literature review section, which can be either phenomenon, theory and methods, or contexts, or some overlapping aspect of each of these. The cells that are colored in green means that there exists rich literature, while the cells that are colored in yellow means that the existing literature is relatively weak, and the cell in red represents the goal of this thesis.

<b>Phenomenon, Theory and Methods, Contexts</b>	Bubbles / Market cycles (Phenomenon)	Western Housing markets (Contexts)	Urban/Housing Economics (Theory and Methods)	System Dynamics (Theory and Methods)	Chinese Housing markets (Contexts)
Bubbles / Market cycles (Phenomenon)	Bubble history, characteristics of bubbles, phases of bubbles, bubbles in other industries/sectors.				
Western Housing markets (Contexts)	Bubble studies apply to US, UK, HK, etc conventional market.	The general features of conventional housing market.			
Urban/Housing Economics (Theory and Methods)	Housing bubble studies using economic models.	Application of economic models in Western countries	A long stream of urban economics research with a focus on real estate cycles. (provide theory and model)		
System Dynamics (Theory and Methods)	(limited literature)	(limited literature)	New Model	Forrester, Sterman, model validation (provide theory and method)	
Chinese Housing markets (Contexts)	<b>GOAL</b>	Comparison between Western Housing market and Chinese Housing market	Econometric analysis of Chinese housing market (help with validation process)	SD literature written in Chinese on Chinese housing market (many issues)	Special features such as land financing scheme, speculative demand, etc (provide contexts)

Figure 2-1 Organization of literature review of thesis

**2.2 Asset Bubbles and Housing Bubbles**

**2.2.1 An Overview of Asset Bubble Research**

The concept of asset bubble is not new and there is a long stream of literature starting from the known events such as the 17<sup>th</sup> century Dutch tulip mania and the 18<sup>th</sup> century South Sea bubble. Kindleberger (1991) defined bubbles as “a sharp rise in price of an

asset or a range of assets in a continuous process, with the initial rise generating expectations of further rises and attracting new buyers (mainly speculators)”. In other words, the future price rise of the asset is not based on the intrinsic value of the asset that is driven by economic fundamentals, but by unrealistic expectations. In this thesis, economic fundamentals generally refer to the macroeconomics parameters in the market such as employment, income, investment, vacancy, etc. This is what differentiates bubbles from general market cycles and oscillations: Changes in price that cannot be explained by economic fundamentals.

The foremost characteristic of an asset bubble is its unpredictability. The research findings have reached the general consensus that bubbles are very difficult to identify *ex ante* (Kroszner, 2003). For one reason, in transitional economy such as in most developing countries, the bubble expansion phase can be camouflaged under alternative hypotheses such as the impact of changes in economy, the improvement in productivity, etc. This was especially obvious during the dot-com bubble in the US when the New Economy, driven by the internet industry, started to boom. Also, it is difficult to identify a bubble when simply applying the criteria that a bubble is when the market price is significantly higher than the equilibrium value of the asset. This is because one cannot determine what an asset price equilibrium value is, given the volatility (Trichet, 2003). On the other hand, recognizing the price differences *ex ante*, and treating the differences as a potential bubble component is undeniably useful for the warning mechanism.

Another characteristic of a bubble is the escalating speed with which the bubble both forms and bursts. Bubbles in various asset classes go through similar phases as covered in the anatomy of a typical crisis by Kindleberger and Aliber (2005). The speed of rising and collapsing are covered in phases like speculative manias, the expansion of credit, and euphoria. This stream of literature expands the discussion of bubble beyond the domain of classic economics and into the domain of behavior economy. It emphasizes that human behaviors such as herd mentality and euphoria contribute to the escalating speed of contagion. Visually it is shown in Figure 2-2, the “Phases of

Bubble” model invented by Dr.Jean-Paul Rodrigue. The key message in his model is that the rationality of the market is taken over by psychology, when expectations about future price rising becomes a “no brainer”.

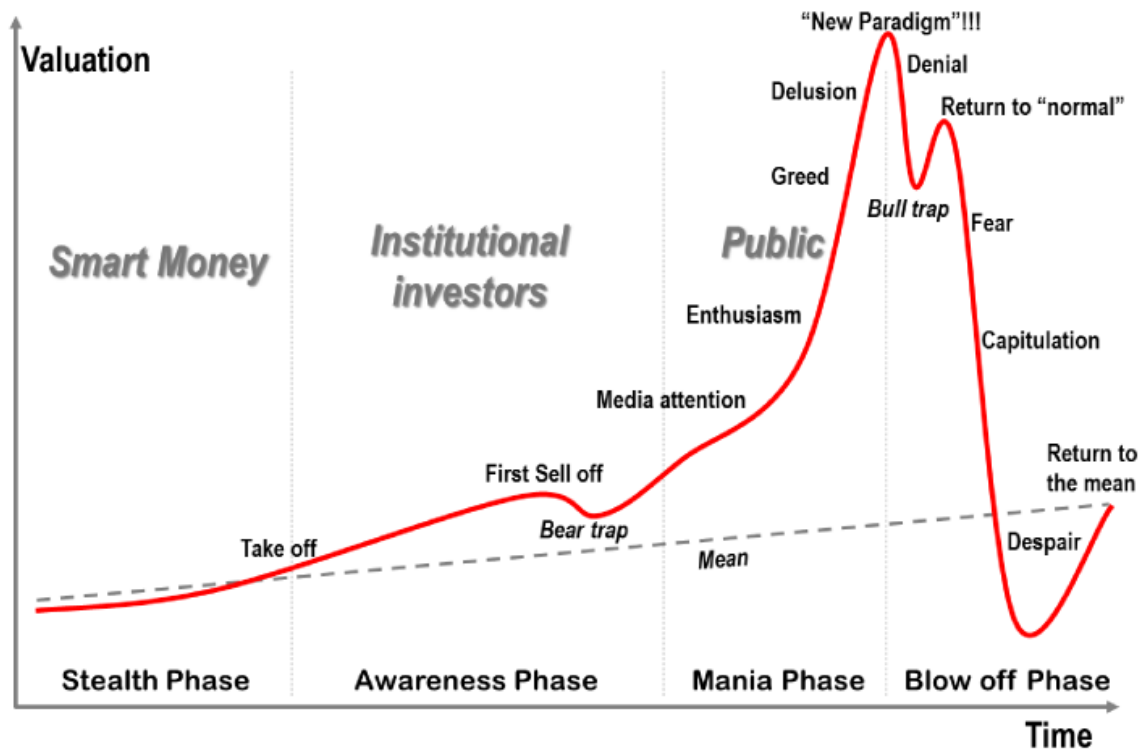


Figure 2-2 Phases of a bubble (Rodrique, 2008)<sup>19</sup>

Although bubbles are not easy to identify ex ante, lessons of each bubble collapse can be fully analyzed ex post and there are various factors that can be used to explain the ‘self-feeding mechanisms’ of the bubble, such as:

1. The speculative investment behavior;
2. The myopic investors;
3. Credit expansion;
4. Herd mentality; and
5. Ponzi finance and speculative finance.

<sup>19</sup> The detailed discussion of the phases of bubble, please see Dr.Jean-Pual Rodrigue’s personal homepage at Dept. of Global Studies & Geography. Hofstra University, New York, USA. See [https://people.hofstra.edu/geotrans/eng/ch7en/conc7en/stages\\_in\\_a\\_bubble.html](https://people.hofstra.edu/geotrans/eng/ch7en/conc7en/stages_in_a_bubble.html).



There are also long and rich ex post discussions of the preventative strategies against these feeding mechanisms with detailed discussions of the monetary policy and the role of government. These are mainly divided into two views: “Letting it burn out” or “government intervention”. In the first view, voices are against the government interventions. Kroszner (2003) pointed out that the policymakers should not respond to an apparent asset bubble without knowing sufficiently its condition because the response may result in more harm than good.

### 2.2.2 Economic Research of Housing Bubbles

In the domain of housing bubble research, there is sufficient economic literature that has been written based on the empirical facts in the post bubble periods for the mature market such as in the US and other Western countries (Case and Shiller, 1994; Case and Mayer, 1996; Baddeley, 2005; Glaeser et al., 2008; Mayer, 2011). In Asia, Japan has experienced the housing bubble in the late 1980s and early 1990s due to the loose monetary policy, self confidence, and land market structure (Dehesh and Pugh, 1999; Shiratsuka, 2005; Shimizu and Nishimura, 2007). In the 1990s, media coverage and political uncertainties are considered as the potential causes of the Hong Kong housing bubble (Bucchianeri, 2011). In the US, most recently, the loosening in terms and standards for mortgage credit has contributed to the housing bubble forming and collapse (Dokko et al., 2011; Jarsulic, 2012). In summary, there is no shortage of research into the past housing bubbles that have occurred in western, free-market economies.

In the case of China, however, the simple truth is that it has not witnessed a scenario of housing price collapse. Neither a bubble cycle, nor a full housing cycle, has happened since the privatization of the housing market in 1998. In other words, despite the short-term fluctuation, for more than two decades, the ever-rising Chinese housing price may be still in the process of forming the very first potential bubble.

Since the late 1990s, there have been continuous predictions or forecasts regarding the first Chinese housing bubble. In the late 1990's, it was claimed that the first-tier cities, such as Shanghai, were in the middle of the largest property collapse in the world, largely blamed on the unprecedented construction boom (Ramo,1998). The vacancy rate in Shanghai was high as 40% in 1997 but that didn't slow down the new construction and it was thus speculated that Shanghai was building a giant speculative property bubble (Haila,1999).

For the same time period, a counter argument has been made by Liu and Shen (2005) to voice that there was not a bubble in the housing market. They depicted a chart of theoretical mechanisms between housing prices and economic fundamentals and identified the key determinants for Chinese housing price change. Through econometric analysis, they concluded that the price change from 1986-2002 can be explained by the economic fundamentals that are listed in Figure 2-3 rather than a bubble.

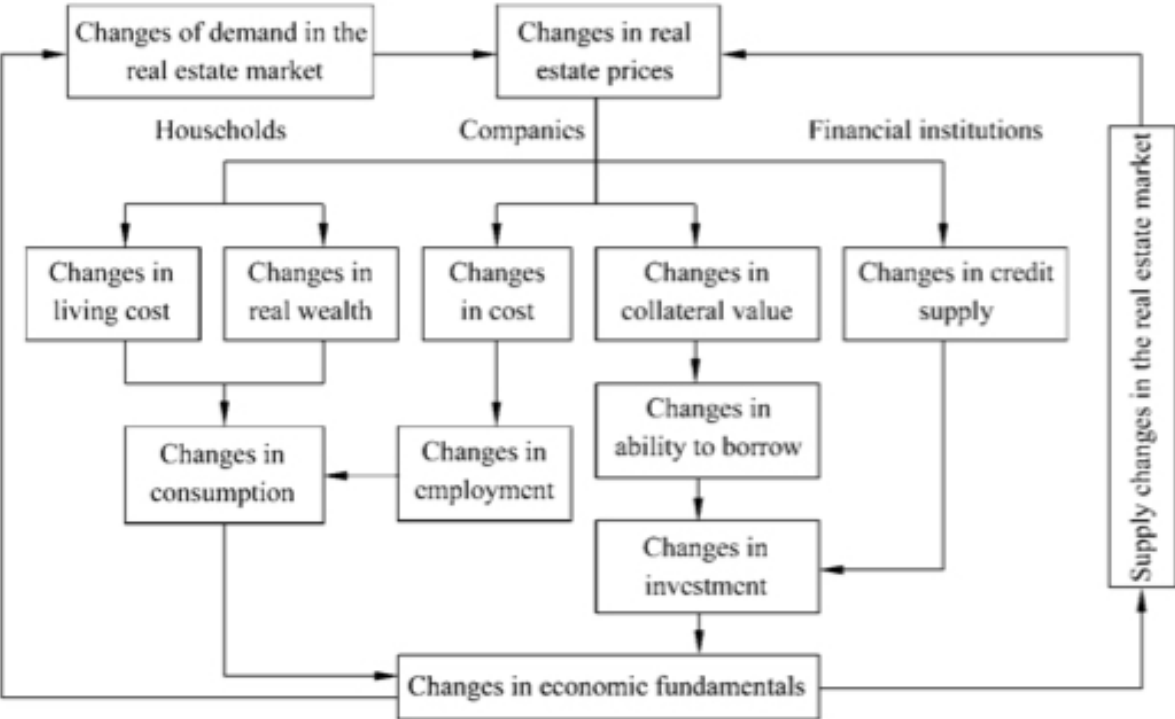


Figure 2-3 Theoretical mechanism between real estate prices and economic fundamentals (Liu and Shen, 2005)

Since the new millennium, some ex post economic research has been done to measure the potential size of the Chinese housing bubble (Liang, Gao, and He, 2006; Li, 2010) using macroeconomic parameters, but little work has been done to dig into the mechanisms that are driving the potential bubble. Generally, housing bubbles are believed to exist and it is found that the bubble is particularly huge in the cities along coastal areas and special economic zones (Dreger and Zhang, 2013). By using Hong Kong's housing bubble as benchmark, it is found that Shanghai has experienced a bubble in the scale of 22% price surge in 2003, while Beijing, the capital city of China, has shown no signs of bubble at the same year (Hui and Shen, 2003). Later, there were predictions that the housing price in Beijing reached the peak of bubble in 2007 while Shanghai reached its bubble peak in 2004 (Hou, 2010). Han, Liu, and Cao (2008) show that back from 2002-2006 the average price bubble, defined as the difference between market price and intrinsic value of housing, is about 22.5%.

However, according to the conservative numbers of Chinese Statistical Yearbooks, the housing price in Beijing, Shanghai and other major cities have more than tripled since these predictions have been made. The effort of predicting a bubble, and further quantifying a potential bubble ex ante<sup>20</sup>, through measuring the intrinsic price of housing using economic fundamentals, is obviously not convincing.

On the other hand, what is convincing and useful for this thesis is that there indeed exists a portion of price that these researchers can observe but cannot be explained by economic fundamentals. This portion of price can be attributed to a potential bubble component. We use the word "potential" here is because: (1) it is hard to quantify and make a firm claim ex ante; and (2) the forecast is always wrong. However, there should still be attempt made to try to explain ex ante why this observable potential bubble component exists.

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<sup>20</sup> We claim that it is "ex ante" is because all such economic measurement is done before a collapse of the bubble that actually takes place. They have assumed that the period covered in the research is a bubble period even before the bubble bursts.

There are many market features that may contribute to such phenomenon and speculative investment behavior in the market is in generally believed to be the foremost factor. However, there are also other Chinese specific features such as land financing scheme, herd behavior, stimulus package and credit expansion, government policy intervention, culture, etc.

A large amount of research has been done regarding speculation, widely considered as one of the major contributors towards bubbles either in the Chinese housing market or Chinese stock market (Han, Liu, and Cao, 2008; Jiang et al. 2010). The Chinese government has significant difficulty in channeling investment into productive resources instead of speculative assets. The real estate market and the stock markets in China are systematically negatively correlated. When the stock market crashed and was not performing for long term, the real estate market started to boom (Zhang and Fung, 2014). The “hot money” or speculative capital inflow was believed to be one of the major contributors in driving up both the housing price and stock price in China, although not at the same time (Guo and Huang, 2010). Economic studies have found that key monetary parameters such as mortgage rate, hot money supply are significant in interpreting housing prices while major economic parameters (or economic fundamentals) such as housing home income are not independently significant (Zhang, Hua, and Zhao, 2012).

There are also predictions that have been made regarding the post bubble period of Chinese housing market. There are cautious positive views toward the numerous housing price bubbles because of the frequent and powerful Chinese policy control assuming that the central government will save the market should there be a collapse (Barth, Lea, and Li, 2012). Even a burst of the housing price bubble should occur, the Chinese economy will not be so affected that lead to a crisis (Dreger and Zhang, 2013; Fang et al., 2015).

### 2.2.3 Is Chinese Housing Market a Ponzi Scheme?

Many online voices from real estate specialists claim that the current housing market is a Chinese government sponsored Ponzi scheme because the market is entirely propped up by loans.<sup>21</sup> Speculations of the timing of a Minsky moment (the moment that a sudden major collapse of asset values happens after a stage of Ponzi finance), of the housing market starts to surface.<sup>22</sup>

By definition, a bubble is not a Ponzi scheme. The definition of a Ponzi scheme is a financial fraud that pays abnormal high levels of short-term returns using money from new investors. Thus, by definition, it is definitely not right to claim that the Chinese government is running a Ponzi scheme because it is not a financial fraud: The underlying assets – the housing units – do exist and have intrinsic values. However, the housing units are believed to trade in high volumes at prices that are significantly above the intrinsic values. It shows more characteristics of a bubble<sup>23</sup> than a Ponzi scheme. There might also be other reasons where the investment value for certain investors is higher than the market value of the underlying assets, which can be observed in many other types of assets such as infrastructures (Zhang, 2008).

The most recent and infamous event is Madoff's Ponzi scheme, which exposed the myth of sophisticated investors (Pozza, Cox, and Morad, 2009; Smith, 2010). The foremost reason that makes the Chinese housing boom look like a Ponzi scheme is the herd mentality and recruitment process of the new investors coming into the market. Herd behavior is observed in the Chinese investors in both stock market and housing market (Xu, 2007). It is found that investors in Chinese residential housing markets tend to herd before the crisis, and there is no herding behavior during and after financial

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<sup>21</sup> He, Qinglian. "Chinese housing: Beauty contest or Ponzi scheme?", and also "China's Ponzi Real Estate Market". OC Housing News. October 9, 2016. Web. December 10, 2016. See <<http://ochousingnews.com/chinese-housing-beauty-contest-or-ponzi-scheme/>>.

<sup>22</sup> Durden, Tyler. "Beyond The Minsky Moment: China's Ponzi Schemes Are Now Investing In Other Ponzi Schemes". ZeroHedge. March 30, 2016. Web. December 6, 2016. See <<http://www.zerohedge.com/news/2016-05-30/chinas-ponzi-schemes-are-now-investing-other-ponzi-schemes>>.

<sup>23</sup> "Bubble vs. Ponzi Scheme". Diffen.com. Web. January 18, 2017. See [http://www.diffen.com/difference/Bubble\\_vs\\_Ponzi\\_Scheme](http://www.diffen.com/difference/Bubble_vs_Ponzi_Scheme).

crisis (Lan, 2014). In the bubble literature, Scheinkman and Xiong (2003) present an equilibrium model in which an asset buyer acquires an option to sell the asset to other more optimistic agents, which causes a significant bubble component when such belief mismatch is sufficient to generate a trade.

Owning a home is a prerequisite in Chinese culture before entering a marriage (Wu, Gyourko, and Deng, 2012). Given the large population base, it is almost guaranteed of rounds and rounds of new investors coming into the market. At the same time the current Chinese housing Ponzi-like finance is even more frenetic: the first round investors will have the ability to cash out, and then achieve higher leverage to buy in again and become the new investors, assuring a continuous Ponzi-like recruitment process.<sup>24</sup>

At the same time, the frequent government intervention in guiding or rather, misguiding the behavior of the housing purchasing does make it look similar to a dealer in a Ponzi scheme. In major cities like Shenzhen, the housing price have been increasing by 50% every year. When Chinese government pumped the stimulus package into the market (most of them flow into the real estate sector) and lowered the interest rate, it indeed looks like the government is luring in more new investors into the housing market, paying out huge return to the previous investors.

#### 2.2.4 The Necessity of Establishing a Real Estate System

A summary of the previous economic literature suggests the asset bubble is considered to have the following general characteristics:

1. It is difficult to identify ex ante.
2. It cannot be fully explained by macroeconomics based on market fundamentals.
3. It has the similar characteristics as a Ponzi scheme.

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<sup>24</sup> Durden, Tyler. "The Chinese Housing Ponzi Exposed: As We Sell Our First Apartments, We'll Have Cash Flow To Build The Next Stage". ZeroHedge. April 23, 2014. Web. January 18, 2017 See <<http://www.zerohedge.com/news/2014-04-23/chinese-housing-ponzi-exposedd-we-sell-our-first-apartments-we'll-have-cash-flow-bui>>.

4. Broader and diversified financial systems weather the post-bubble collapses better than narrow, less diversified systems and strong regulatory and supervisory institutions are always the best strategy of preventing bubbles (Hunter, 2005).

If we assume that the bubble exists, the literature has pointed out the difficulty of predicting the moment of collapse till ex post. However, that doesn't mean that work cannot be done ex ante, to analyze the mechanisms that may contribute to the bubble formation and collapse, and find appropriate policies to mitigate the impact should a market collapse happen.

The factors being discussed above are mostly factors in the asset market part of the housing market, such as speculative investment, credit expansion, Ponzi-like finance, herd behavior, etc. They may seem sufficient when being used to study the stock market. However, when analyzing the housing market, the impact of those factors and investment decisions of the relevant stakeholders will perpetuate into the actual physical property market. Property market is where land being purchased, construction happens, and new housing stock being delivered. The property market will in turn impact the asset market after certain construction time delay, which in fact change the subsequent asset market conditions. It is thus crucial to analyze the housing market as a complete system in order to understand the mechanisms underneath the bubble phenomenon.

In the scope of this thesis, we will treat the current housing price boom in China as a potential bubble, without excluding alternative hypotheses such as strong demand or its economy structure shift. It is thus necessary to apply validated economic models with the Chinese condition, and see whether the all of Chinese housing price can be explained by the economic fundamentals. If not, then what are the other features that may contribute to the bubble component beyond the traditional economic fundamentals. In other words, we can use the research that has been conducted to analyze market cycles as the starting point, or baseline, or benchmark, in order to analyze market bubble.

## 2.3 Research on Real Estate System and Cycles

### 2.3.1 Housing Cycles vs. Housing Bubbles

Urban economics is a branch of economic study that is related to wide range of important urban issues such as location theory, transportation, housing, firm site selection, employment, etc. The quantitative analysis began with Alonso's (1964) monocentric city model, and was further refined by Muth (1969) and Mills (1972). But this entire stream of literature is focused on the microeconomic analysis of property markets. The unit of analysis is the individual property or household, and the behavior of interests is Ricardian rent.

Instead of individual level, when the unit of analysis is aggregated at metropolitan, regional, or national level, the research is generally considered to be in the domain of macroeconomic analysis of property markets. Within this category, there is a substantial collection of literature focusing on the modeling of real estate markets and analyzing market cycles.

The key difference between a bubble and a market cycle is that the market cycles are market oscillation around the intrinsic value of the housing, and it is mainly caused by the interactions of economic fundamentals, whereas a bubble is driven by irrational self-feeding mechanisms that create value out of thin air. Market cycles can be explained by the macroeconomics factors along with certain investment behaviors. Quigley (1999) demonstrates that the real estate prices can be affected and predicted by economic fundamentals, but also raise the concerns regarding to whether the real estate bubble can be predicted the same way, as the bubble may change the economic fundamentals due to a situation of asymmetric information. However, that sheds the light on the possibility of using the existing model that have been applied and validated to study market cycles as the step stone to target the housing bubble.

In summary, housing cycles are distinguished from housing bubbles based on the following five characteristics:



1. Scale: intuitively cycles do not derail from the intrinsic value in large scale without correction.
2. Predictability: the market cycle can be predicted ex ante while a bubble cannot.
3. Steady-state: a housing cycle is fundamentally self-balances and oscillates around a steady-state (as shown in Figure 2-4), whereas a bubble is fundamentally self-reinforcing and feeds on itself.
4. Speed: cycles reduce speed when reaching the price peak, while bubbles escalate with exponential speed when reaching or departing from the price peak.
5. Feeding mechanisms: the mechanisms behind market cycles can be explained by economic fundamentals, and bubbles can be attributed to factors other than economic fundamentals.

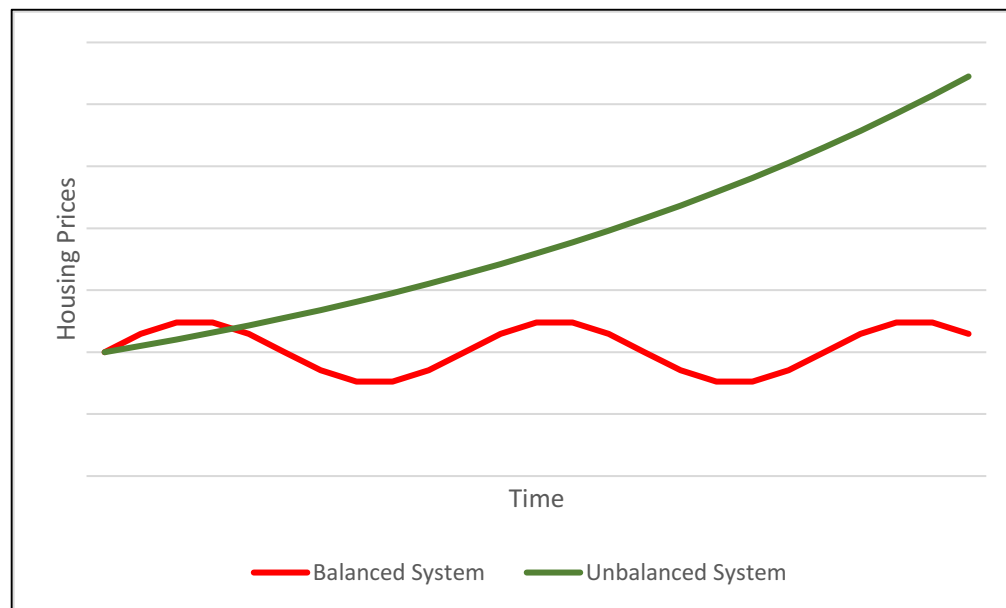


Figure 2-4 Balanced system (red) demonstrates market cycles; unbalanced system (green) demonstrates market bubble

### 2.3.2 Real Estate System and Market Cycles: Urban Economics Models

Though the antecedents go back at least to Hendershott and Ling (1984), much of the real estate cycle literature has been based on, or effectively reflects, a particularly

compelling and eloquent depiction of the inter-related markets for the usage of built space and for the ownership of property assets known as the “Four Quadrant Model” (4QM or D-W 4QM) proposed by DiPasquale and Wheaton (1992,1996). For future references, in the scope of this thesis, D-W model and 4QM have equal meanings.

Foremost, it is highly necessary to go through the details of the 4QM in Figure 2-5 as it is well tested and will serve as a foundation of the other derivative model building process. In the 4QM, the upper-right quadrant reflects the market for the usage of built space. The horizontal axis is the stock of built space (effectively, the occupied space, as the basic model does not consider vacancy), and the vertical axis is the annual net rental price. The line (function) in the upper-right quadrant,  $S = D (R, \text{Economy})$ , is the demand function of the space users, reflecting how much space would be occupied as a function of the rental price, which under usual microeconomic theory assumptions reflects the aggregate marginal benefit of space occupancy to the users. “S” is the quantity of stock demanded (occupied). The arguments of the demand function include “R,” the annual rental price, and “Economy,” the sources of need and preference for space usage. Although the basic 4QM represents rental property, the essence of the model can be applied to owner-occupied property as well if we think of the rent as “imputed rent” or the annual value of the service flow of the built space to its users.<sup>25</sup>

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<sup>25</sup> In the Exhibit the space market (market for the use of built space) is referred to as the “property market,” while the market for the ownership of the property asset is referred to as the “asset market.” In the case of owner-occupied properties, the two markets are tightly linked, though may still be usefully distinguished conceptually for analytical purposes. One may conceive of the owner-occupant as renting to and from himself.

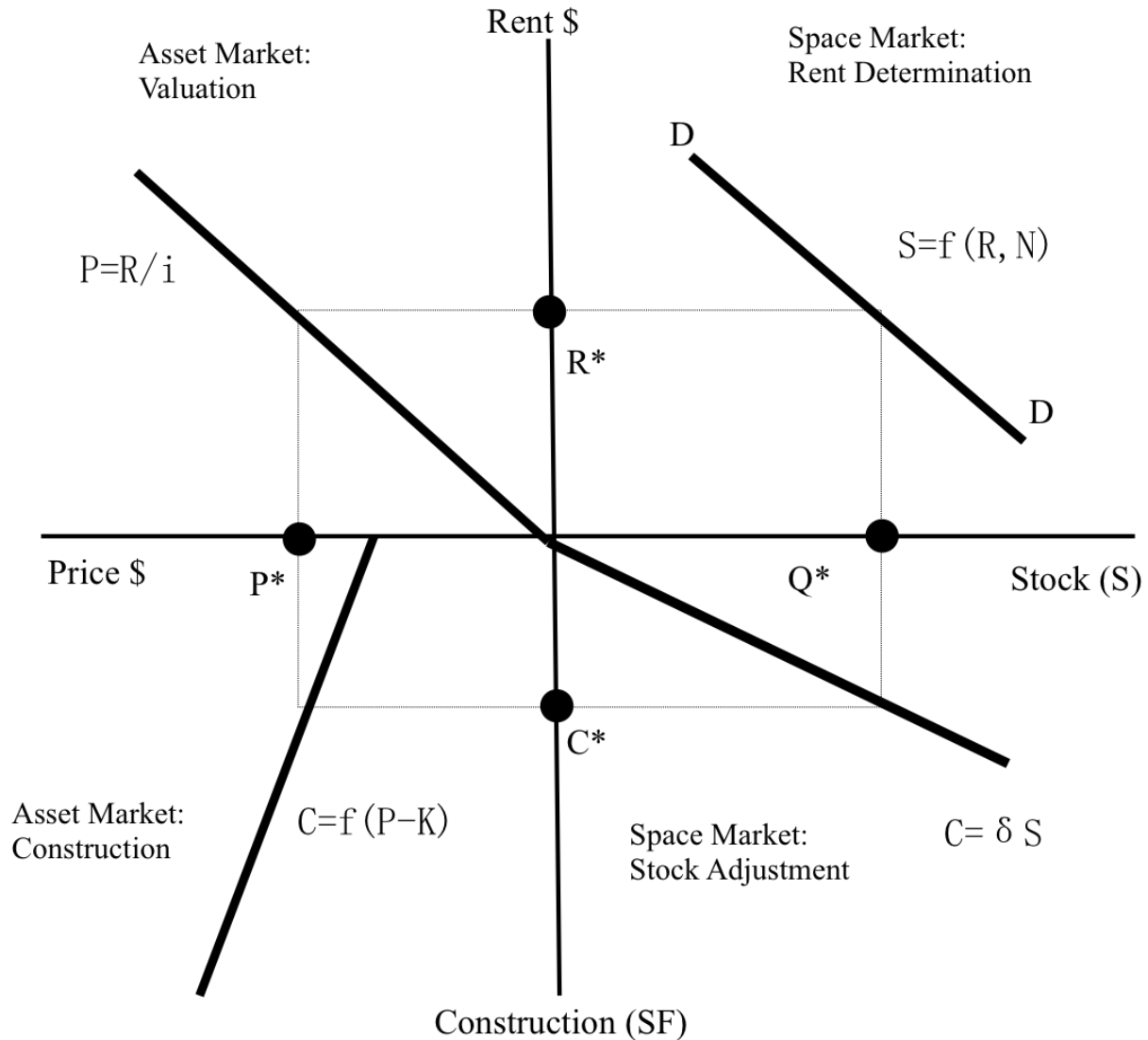


Figure 2-5 The DiPasquale-Wheaton 4Q Model (DiPasquale and Wheaton, 1992)

The upper-left quadrant then relates the rental price (“R”) in the space market on the vertical axis to the asset price (“P”) in the property asset market measured on the horizontal axis. (All the axes in the 4QM radiate out from the origin, hence, movement leftward on the left quadrants’ horizontal axis represent larger positive prices for the assets.) The function in the upper-left quadrant represents the rental income yield in the property asset market, that is, the ratio of property asset prices to annual rental income,  $P = R/i$ , where “i” is the yield rate per annum.

In the classical 4QM the yield, in effect, the pricing in the asset market, is taken to be entirely exogenous. More sophisticated models, either enhancements to the 4QM or stock-flow models, make the asset market yield a partly endogenous parameter. However, there is strong evidence that in fact asset market yields are largely exogenous to the real estate system specifically, coming substantially from the broader capital market, at least in terms of short to medium term changes in the yields, and at least in the United States. (See Geltner and Mei 1995, and Plazzi et al. 2010.)

The lower-left quadrant depicts the real estate development industry. The line in the lower-left quadrant represents the annual gross rate of new construction of built space in the market, as measured on the vertical axis (with the positive direction being downward on that axis, away from the origin). The construction function,  $P = f(C)$  (or its inverse,  $C = f^{-1}(P)$ ), relates the responsiveness of the development industry to pricing in the property asset market. This reflects building “replacement cost” (current costs of construction) and the price elasticity of supply (how much new space developers will build in response to an increase in property asset prices). In the traditional depiction this function includes a region on the asset price axis below (to the right of) which no development will take place, the asset price presumably being too low in that region to compensate for the cost of land and construction plus necessary developer profit. Thus, the development function intersects the horizontal price axis at a point to the left of the origin.

Finally, the lower-right quadrant in the 4QM relates the rate of new construction to the rate of demolition in the existing stock of buildings. The function in the lower-right quadrant,  $S = C/\delta$ , divides the annual construction rate by the annual demolition rate. For example, if  $1\text{M m}^2$  per year are built, but 5% of existing buildings are demolished each year reflecting depreciation and obsolescence, then the steady-state stock will be  $1\text{M}/0.05 = 20\text{M m}^2$ , with the  $1\text{M m}^2$  new construction each year exactly offsetting the  $0.05 \times 20\text{M} = 1\text{M m}^2$  of demolitions each year. It is this stock-adjustment function in the lower-right quadrant that completes the 4QM as a long-run steady-state model.

The culminating and key feature of the 4QM is the rectangle whose vertices just touch each of the four function lines in the four quadrants. This rectangle is the long-run equilibrium in the system. The vertical and horizontal sides of this rectangle represent the equilibrium within and between the space and asset markets in the upper two quadrants as mediated to a steady-state result by the development industry in the lower two quadrants (assuming the developers are the ones who demolish old buildings in the lower-right quadrant as well as build new ones in the lower-left quadrant). The model is simple and eloquent in its evocation of the overall system, the relationship between the two real estate markets and the development industry. It is a great pedagogical device.

However, it is crucial to recognize that the DiPasquale-Wheaton 4QM is a steady-state model. It represents a long-run equilibrium. It does not quantitatively depict dynamics – that is, how the system changes over time from one long-run equilibrium to the next. It is true that the model can be altered (or “tweaked”) to gain some insight about changes in the marketplace. A good example of this is described in Geltner et al. (2014) Chapter 2.<sup>26</sup> But this type of “tweaking” the 4QM is informal and vague in its positive implications. Colwell (2002) describes a series of elaborations of the original DiPasquale-Wheaton model (4QM) that can account directly and explicitly for the long-run equilibrium and address other simplifications in the simple model. But these enhancements undercut the eloquence and pedagogical value of the original model, and do not provide any explicit dynamics, tending to reinforce the model’s focus on long-run equilibrium rather than on transition paths toward such equilibria.

The urban economics literature has addressed this deficiency with a series of models that are essentially formal elaborations of the 4QM into systems of simultaneous linked

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<sup>26</sup> Consider a permanent upward shock in the demand function in the upper-right quadrant. *Ceteris paribus*, this will lead to an increase in rent and corresponding increase in asset price seen by dropping horizontal and vertical straight lines counterclockwise from upper-right through upper-left. But then when you try to follow this new rectangle continuing counterclockwise through the lower two quadrants you do not “meet up” on the right quadrants’ horizontal axis; the rectangle is not closed, indicating you do not have a long-run equilibrium. The fully closed and complete rectangle anchored on the new (higher) space usage demand function will result in a fallback in the rent and asset prices to levels ultimately below the initial myopic values first indicated, though above their pre-shock starting values, suggesting a type of cyclical or cobweb (“tatonnement”) process of market dynamics.

equations. These are referred to as “stock-flow models” based on the stock-flow theory of highly durable goods, and do indeed represent the dynamics of the market. These can be calibrated by econometric analysis of empirical data about rents and occupancy and construction, as observable in actual real estate markets. This stream of literature dates to at least to Rosen (1984). Wheaton, and Wheaton and Torto (1987, 1988, 1997, 1999) did most of the development, and Hendershott and co-authors (1995, 2002a, 2002b, 2010) provided substantial enhancements. Although first developed for office markets, these types of models can, in principle, be applied to any real estate market sector.<sup>27</sup>

### 2.3.3 Real Estate System and Market Cycles: System Dynamics Models

In parallel, another methodology that has been developed called System Dynamics (SD). It uses the same stock-flow simulation technique, applies to the same context, and shares the same research interests. However, there is very little interaction between the urban economics and system dynamics fields. It is as if the two fields coexist at the same time but in a parallel universe.

The stock-flow model structure mentioned in the economic literature is the foundation of System Dynamics. SD was developed by Jay Forrester from the Massachusetts Institute of Technology. In his book *Urban Dynamics* (1969), Forrester used the system dynamics technique to demonstrate that an urban area can be seen as a system of interacting industries, housing, and people.

The System Dynamics technique has been further developed and widely applied to analyze the behavior of real-world complex systems. It is accepted and used in the corporate world due to the actual performance improvement that the analysis brings (Forrester, 1993; Angerhofer and Angelides, 2000; Sterman, 2000; Santos, Belton, and Howick 2002; Akkermans and Dellaert, 2005). It is also used to design suitable policies

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<sup>27</sup> See Ibanez & Pennington-Cross (2013) for a review as well as a survey overview applying the modeling to 34 major metropolitan areas and four space market sectors in the United States. Stock-flow models have also been applied to London and a few other global cities that have substantial data on the space market and construction industry history.

with its power of scenario analysis through simulation. The ability to analyze various scenarios makes the model particularly useful for modeling the potential outcome of various potential policy choices (Sterman, 2001).

The behavior of system oscillation is one of the key research focuses in the SD field. And the fundamentals of the SD technique reside in the feedback structure from the complex system behavior, captured by the causal loop diagrams. Causal loop can be either balancing or reinforcing: balancing loops control the system behavior and bring it back to a stable stage, while reinforcing loops allow the system behavior to escalate. In that sense, it is not hard to notice that the stock-flow model developed by DiPasquale and Wheaton (1996), and advanced by Wheaton (1999) is fundamentally a balancing loop. That is the reason why the real estate market price in the 4QM model, although it oscillates, does not escalate beyond control and always returns to some level of equilibrium.

The core concept of the SD technique is that the model must mimic the structure of the real system well enough so that the model behaves the same way the real system would. In Wheaton's (1999) stock-flow model, the disturbance of the system is exogenous (such as a demand shift), but the oscillation (or market cycle) of the system is created endogenously due to the lags of delivering durable goods and the myopic investment behavior. The scale and speed of value deviation demonstrates a sine function shape. The stock-flow model developed based on 4QM theory succeeded in exploring the dynamic operation of urban housing market and explaining why different types of real estate assets can have different cyclical oscillation behavior.

In his book, the chapter of "Instability and Oscillation", Sterman (2000) attributed the origin of system oscillation to the stock management problem of the supply chain. The system induces a corrective action when there is a stock discrepancy. When delivering durable goods, due to the time delay, oscillation arises. He uses both the cases of "beer

game”<sup>28</sup> and “boom and bust in real estate market” to demonstrate the oscillation caused due to delay in the supply chain of the system.

In detail, Sterman (pp 698-706, 2000) independently proposed a case study using the system dynamic technique to explain the boom and bust of commercial real estate markets without using the 4QM. The model itself is driven by market expectation and the sole purpose is to explain the cyclical behavior by focusing on investors’ ignorance of ongoing construction in the pipeline. If we carefully study the causal loops in Sterman’s model which will be detailed in Chapter 4 of the thesis, it’s not hard to notice that the essence is still in the 4QM framework, except that the factors of expectation and time delay for adjustment are counted in. Both urban economic theories and system dynamics methodologies target similar issues and using stock-flow theory of highly durable goods as well as the myopic behavior of real estate developers to explain the housing market dynamics. This sets the example that in the real estate market research field, traditional urban economics models in the essence of stock-flow models, and the system dynamics models may have more commonalities than differences.

#### 2.3.4 From Urban Economics to System Dynamics: Interdisciplinary Research

Urban economic theory works in conventional markets but it is not yet proven to be applicable to unconventional markets such as in China. Either with the classic 4QM or the stock-flow model, they assume free and competitive markets. While it works well with traditional mature market such as in the US and Europe, the application to fast growing markets in most of Southeast Asian countries is debatable due to the complexity of government rules, land ownership, speculative behavior, and the dysfunctional the capital markets. The econometric models are generally data intensive, requiring long time series of historical data, which makes them difficult to apply in many emerging market situations where historical data is not available. This leads us to think that Systems Dynamics (SD) modeling might provide useful insight in that perspective.

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<sup>28</sup> Details see < <http://www.beergame.org>>.



The concept of building SD models based on existing proven economic theories is not new. Smith and van Ackere (2002) demonstrated how to embed a static economic model within a dynamic framework using the system dynamics methodology. They argued that the integrated version is likely to enhance both methodologies as it permits examination of a range of alternative scenarios. At the annual international conference of the System Dynamics Society, there are sessions demonstrating the efforts of system dynamists using the SD approach to analyze issues in the domains of macro, micro, and regional economics. Direct economics model translation into SD platform is mostly used for pedagogical purposes so that the students can understand the theory not only from the analytical level with mathematical equations, but also from the causal loop diagram and hands-on simulation practice. For example, existing economic models such as Harrod-Domar and Solow Models of Economic Growth are directly translated into the SD form (Kunte and Om, 2016).

The natural next step would be to build a SD model directly based on the stock-flow model of Wheaton, or the 4QM. Barlas et al. (2007) used the SD methods to study the price oscillation effect in Istanbul. Although they did not use the 4QM as the starting point to build the SD model, they indeed used the findings in Wheaton and DiPasquale (1996) as a reference mode to demonstrate that price oscillation found in the economics field can be introduced as mental model in the SD domain. Similar approach was found in Ozbas et al. (2014) in studying the endogenous dynamics of housing market cycles.

There are other works that have been done using SD technique to study certain aspects of the real estate market, such as mortgage markets, housing financing programs, housing affordability issues (Kummerow, 1999; Hu and Lo, 1992; Hwang, Park and Lee, 2009), or simulation methods comparable to SD (Malpezzi and Wachter, 2005). Chen (2005) used SD methods to analyze the relationship between speculative investment and the ever-increasing housing price in Shanghai. It is found that the price increase is largely due to the strong demand. Speculations contribute to the price jump but then the ultimate risk is transferred to the mortgage lenders, which are local banks. Should the market collapse, the local banks will be put in a disadvantaged position. However, these

studies tend to derail from the real estate economic fundamentals and only focus on certain aspect of temporary market phenomenon, represented by subjective causal loops.

Mashayekhi et al. (2009) were the first to establish the translation process and replicated the 4QM. They did not just stay satisfied after replicating Wheaton's 1999 simulation results; instead, they further modified the model by separating the observed "rent" from the rental market and the observed "price" from the owner-occupied market, and applied this to the analysis of Iranian housing market. They built the integrated SD models to simulate the interactions of rental and owner-occupied markets in Iran and found that an increase in durability of buildings in the owner-occupied market leads to more intensive price oscillations. They adopted the innovative approach of replicating an existing proven economic theory into a SD platform, and then modified the structure to apply to a new context. The essence of the model still remains in the same realm as in Wheaton (1999) by keeping exact equations.

Eskinasi (2012, 2014) adopted the same approach, starting from the direct replication of the 4QM. His research attempted to conduct hypothetical policy analysis of the Dutch market, and aimed to explain why, when housing prices in the Dutch market were increasing, new construction still remained low. Eskinasi took one more degree of freedom: the research has only kept the basic components of the 4QM in order to formulate the causal loops of the basic SD structure. He chose not to keep the major mathematical equations of the 4QM and thus generally neglected the discussion of the cyclical effects. He has modified and quantified the model structure exactly based on the empirical observation of the Dutch housing market to answer the research questions that is only concerning that specific market.

As a major literature review contribution, Eskinasi (2012, 2014) has also thoroughly reviewed the system dynamics literature written in English, with 154 entries in total related to terms of "urban", "house/housing", and "real estate". He broke it down into three categories:

1. Forrester and his urban concept;
2. Netherland policy school: focusing at Dutch housing policy models;
3. Housing markets and real estate dynamics school: focusing on institutional behavior and market cyclicity.

The interest of this thesis remains in the last category: market cyclicity. However, other than the limited SD work mentioned above, most of the SD research conducted in the domain of real estate market is not linked to the urban economic theories. It is mostly because the system dynamists are generalists who possess great skills of SD modeling but do not necessarily possess the specific knowledge of real estate market, despite the interdisciplinary characteristics of this type of research. It is also because the SD methodology offers the freedom for the generalists to build a SD model based on empirical observation and understanding of the market, thus do not need to tackle real estate market issues where often nonlinearity equations and data problems will hamper progress.

The freedom of building SD models sometimes results in issues, with over-complexity being one of them. For example, Hennekam and Sanders (2002) developed a network model to illustrate a large Dutch urban network of 40 interconnected urban sectors. The approach inevitably increased the complexity of the model structure by involving a large number of entities and relationships. To keep the model visually comprehensive, it will have to aggregate parameters, thus limiting the usefulness of the model. As a result, the accuracy will be reduced. This raised the concern, as in most SD models, how concise a model should be.

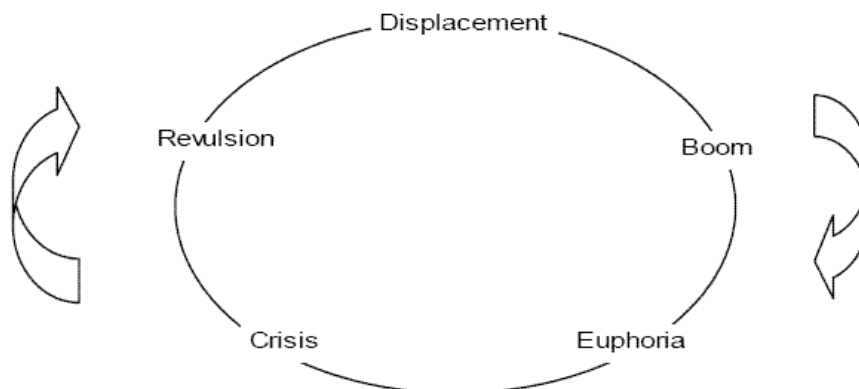
### 2.3.5 System Dynamics to Study Bubbles and Ponzi Scheme

On the other hand, bubble dynamics and their effects have been a topic of interest to system dynamics researchers. Compared to economic models, the system dynamics approach is valuable for analytically penetrating the casual structure of a complex system and effectively understanding complex issues such as bubble formation and collapse (Information Resource Management Association, 2014). Sterman (2000) has

demonstrated that the speculative bubbles using the essence of speculation by Mill (1884), as well as the oil crises of the 1970s, can both be modeled by the system dynamics feedback structure of the markets. Kurebayashi (2004) used a system dynamics model to analyze the bubble effects of the long distance telecom service industry in US market. Dwenger and Pavlov (2008) used an exchange rate model to demonstrate how speculators create price bubbles in the foreign exchange market.

Furthermore, the stages that described in the bubble economic literature can be modeled through SD technique. The famous Kindleberger-Minsky bubble model as in Figure 2-6 is in form of a simple reinforcing loop.

#### Anatomy of a bubble: the Kindleberger-Minsky model



Source: Kindleberger, SG Cross Asset Research

Figure 2-6 Anatomy of a bubble: the Kindleberger-Minsky model

Source: Kindleberger (2001), Société Générale Cross Asset Research<sup>29</sup>

Most relevant to this thesis, Mukerji and Saeed (2011) created a system dynamics model to study the 2008 subprime mortgage crisis in the US. They created a housing model and conducted experiments such as loosening of capital requirements of banks,

<sup>29</sup> See < <http://thefrugalplain.blogspot.com/2009/11/kindleberger-minsky-anatomy-of-bubble.html>> Access date: Jan 12, 2017.

influx of cheap money, lowering interest rates, and mortgage reform, to demonstrate the boom and bust of the housing market. Similar effort was recently made by the keynote of Greenwood Strategic Advisors AG in the 34<sup>th</sup> International Conference of the System Dynamics Society<sup>30</sup> by claiming the ability to explain housing bubbles in the US through their system dynamics model. It indeed demonstrates the ability of using SD approach to analyze housing bubbles, but the key drawback is that all these efforts are ex post after the economists and media have covered the details of the bubble busting story.

The recruitment process of Ponzi scheme is similar to the speculating behavior of a bubble. Both Ponzi scheme and bubble lead to a bust. In the System Dynamics field, there is only one article that mentioned the operation of a Ponzi and set up a ‘catastrophe archetypes’ of a system model to explore the catastrophic potentials of different types of the system (Mrotzek and Ossimitz, 2008). It sets up a pool of outsider investors for recruitment is limited and drains out through the recruitment process, when Ponzi scheme is doomed to collapse. But the simple model of recruitment process can be useful in forming the speculative investment model component for this thesis.

### 2.3.6 System Dynamics to Study Housing Market: Chinese Literature

As a literature review contribution, inspired by Eskinasi (2012, 2014), this thesis provides a list of literature in the housing dynamics domain written in Chinese. Indeed, there are a large number of works that have been done by Chinese scholars using SD methodology to analyze the Chinese housing market. However, this part of literature remains unknown to the international SD community. It is mostly because these academic works are written in Mandarin and published in lesser known Chinese journals. The Chinese academic work in SD can be generalized into three categories.

The first category can be generalized as “Case study of ABC city: a system dynamics approach”. It has become a routine in the Chinese SD literature to build system

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<sup>30</sup> The 34<sup>th</sup> International Conference of the System Dynamics Society is held in TU Delft, Netherlands, July 21 2016. See <<http://www.systemdynamics.org/conferences/2016/index.html>> The presentation was made by Greenwood Strategic Advisors AG from Switzerland as the final keynote of the conference. However, the details of the conference were not accessible online after the conference.

dynamics models based on a case study of a specific city. In recent years' publications, almost all major cities in China are covered. Shenzhen seems to be a good repeated candidate for SD case study due to the fact that it has the most liberal market and is subject to new policy interventions (Luo et al. 2004; Li, 2011; Geng and Li, 2011). Similar approach has also been used for case studies of other Chinese cities (Luo, He, and Niu, 2001; Hu and Shen, 2001; Zhu and Huang, 2003; Jin et al., 2004; Shang, 2006; Feng, 2008; Lou et al., 2010; Lu and Tan, 2010; Liu and Zhou, 2011; Chen and Liao 2012; Li and Hua 2012; Wu et al., 2013). The positive aspect is that these research works indeed recognized the complexity of the market as well as the unavailability of testing data.

The second category focuses on specific issues in China and normally present themselves as "XYZ issue: a system dynamics analysis". For example, regarding Chinese land market, Bai (2000) used Shenzhen as a case study to demonstrate the relationship among industrial land use, residential land use, natural resources, and economy growth. It is interesting as the Chinese government owns the land and there is the ratio between industrial and residential land use distribution every year and such ratio directly affects the housing prices. The relationship between affordable housing and commercial housing has also been a major researches topic (Liao, 2004; Fu, Chen, and Liang, 2008; Hu, 2011; Du, Yang, and Li, 2012; Li and Wang, 2012).

The third category targets the policy intervention and price change (Su, 2010; Qi and Zhang, 2011; Wan, 2013). It uses simulation to suggest that policy design can be improved to enable the government to micro-manage the housing price. Li (2011) criticized the current policy designs in China and advocated using SD simulation to help the government achieve better policy design, even without data support. Li and Zhang (2011) applied SD method to the Chinese land market research. They emphasized the importance of land price in affecting the housing price but also recognized the difficulty in conducting simulations due to data availability and constant governmental policy changes. This in turn leads to the possibility of combining SD methods and qualitative analysis, to conduct simulation based on hypothetical data instead of using real data.

One common claim made in this category is that the policy control cannot be possibly quantified in the Chinese case because of data availability, and also because the policy control is an intangible qualitative factor.

The literature written in Chinese language has provided rich empirical evidence in identifying city/region specific characteristics of housing market, listed policy interventions, and emphasized on the importance of land market. Unfortunately, due to language issues, the main empirical findings remain unknown to the international audience.

On the other hand, the process for model building and validation either do not exist or do not meet the international SD standard. The quality of the publications also remains debatable, as most of them are Master student's thesis with zero citations. The data and equations that have been used in the model are not disclosed along with the paper. The SD diagram only has causal loops and there are rarely any actual SD models shown.

#### **2.4 Potential Research Gap Identified by the Literature Review**

The ultimate goal of the thesis is to analyze the phenomenon of the potential Chinese housing bubble that is currently being widely discussed. But, the peculiar Chinese market features<sup>31</sup> underneath the housing market are not yet well documented qualitatively, integrated, and analyzed quantitatively. Researchers have mostly studied the housing bubble ex post using econometric methods, but the essence of the bubble forming and bursting mechanisms - causal structure and the interactive relationships among components in a housing system – is generally neglected. In terms of bubble prevention, a well understanding of such information is particularly crucial ex ante.

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<sup>31</sup> Just to note a few: (1) Speculative vacancy rate is considered to be high in China. The Chinese speculators tend to buy extra units of housing as money storage vehicles but the difference is that they do not rent them out and only leave it vacant; (2) Land financing scheme: Chinese local government rely on the sales of developable land to developers in order to meet their fiscal budget. Such Chinese specific mechanisms will be documented in later chapters.

Phenomenon, Theory and Methods, Contexts	Bubbles / Market cycles (Phenomenon)	Western Housing markets (Contexts)	Urban/Housing Economics (Theory and Methods)	System Dynamics (Theory and Methods)	Chinese Housing markets (Contexts)
Bubbles / Market cycles (Phenomenon)	Bubble history, characteristics of bubbles, phases of bubbles, bubbles in other industries/sectors.				
Western Housing markets (Contexts)	Bubble studies apply to US, UK, HK, etc conventional market.	The general features of conventional housing market.			
Urban/Housing Economics (Theory and Methods)	Housing bubble studies using economic models.	Application of economic models in Western countries	A long stream of urban economics research with a focus on real estate cycles. (provide theory and model)		
System Dynamics (Theory and Methods)	(limited literature)	(limited literature)	New Model	Forrester, Sterman, model validation (provide theory and method)	
Chinese Housing markets (Contexts)	<b>GOAL</b>	Comparison between Western Housing market and Chinese Housing market	Econometric analysis of Chinese housing market (help with validation process)	SD literature written in Chinese on Chinese housing market (many issues)	Special features such as land financing scheme, speculative demand, etc (provide contexts)

Figure 2-7 Mapping through the existing literature

While mapping through the existing literature as in Figure 2-7, we have identified three research gaps that are beneficial to the field of Chinese housing bubble research:

1. Develop an integrated model and strengthen the collaboration between urban economics models and system dynamics models;



2. Focus on ex ante study of potential bubbles instead of ex post study of collapsed bubbles;
3. Capture the difference between housing bubbles and housing cycles: using existing urban economic models (with economic fundamentals) as benchmark and capture the difference when non-market features are incorporated into the integrated model.

#### 2.4.1 Complement and Enhance Urban Economics with System Dynamics

The D-W model from urban economics is a powerful and practical tool that has been used successfully by sophisticated elements in the real estate investment industry in the U.S. and other mature markets. This economic model is generally taken as a “canonical” starting point for system dynamics models of urban real estate systems. The SD technique is consistent with traditional economic approaches towards modeling dynamic issues. The casual loops in SD include balancing loops and reinforcing loops. The balancing loops enable the system to be equilibrium seeking after an exogenous shock and to return to a stable state. In this sense, it confirms the economic notion of an equilibrium stage. The reinforcing loop, on the other hand, will allow the exogenous shock to be magnified and thus suggests the presence of an unstable equilibrium. The current China housing market has demonstrated both characteristics.

The objective of system dynamics models is not to negate or replace the urban economics stock-flow models, but to communicate with them, and further complement and extend them.

Urban economists have long noted that the econometric models (e.g. D-W model) of dynamic equilibrium stop short of being complete or ideal for some purposes. It has been noted that the econometric models become too complex or data-hungry if they try to include unique or special features, typically institutional characteristics, of particular markets (Wheaton, 1999; Smith and van Ackere, 2002; Eskinasi 2012). In general, the econometric models lack richness and flexibility in their ability to explicitly depict particular elements, causal flows, and actors’ behaviors which can be important not only in understanding system behavior but in analyzing policies and decisions. This includes

key elements in the system such as explicit consideration of the nature and role of land supply and land price. The elasticities and other sensitivity and adjustment parameters in the econometric models often lack much temporal richness, usually at most only a distinction between “short run” and “long run” elasticities, but without the degree of temporal nuance that would be most useful from a policy and decision perspective.<sup>32</sup> Finally, the econometric models can be difficult for non-specialists to visualize and grasp, making them challenging to communicate to decision makers and of limited use for pedagogical purposes to a non-specialized audience.

On the other hand, the SD model requires less data input but it relies heavily on the model structure validity, as well as the interactions and causal relationships of subcomponents. This makes it more appealing for analyzing the unique characteristics of the evolving Chinese housing market, where large files of empirical data do not exist. The limitation is that most SD models are built without urban economics theory to serve as the foundational cornerstone. The model structure tends to be subjective. The empirical testing also relies on large amount of subjectively selected parameters and data to mimic the actual trend. Few scholars have tried to integrate the system dynamics method and economic models.

As a result, in order to analyze the Chinese housing market, an integration of the SD technique from the engineering and traditional economic models may enhance both methodologies, as shown in Figure 2-8. The two methodologies do share some common ground: the stock and flow based system dynamics technique are inherently consistent with Wheaton’s stock-flow approach of the 4QM. Many of the limitations in the stock-flow models can be addressed by SD modeling, in particular in the case of the Chinese urban housing markets, at least to a degree that will prove useful for purposes of policy research and/or pedagogy for teaching young real estate entrepreneurs in China.

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<sup>32</sup> Use of Error Correction Models (VECs) as in Hendershott *et al.* (2002b) do provide interesting empirical calibration of adjustment times. But VEC models are data intensive, and SD models can bring explicit causal modeling with added depth and flexibility to enable representation of unique institutional frameworks in the market, while also still taking into consideration the findings from the stock-flow models.

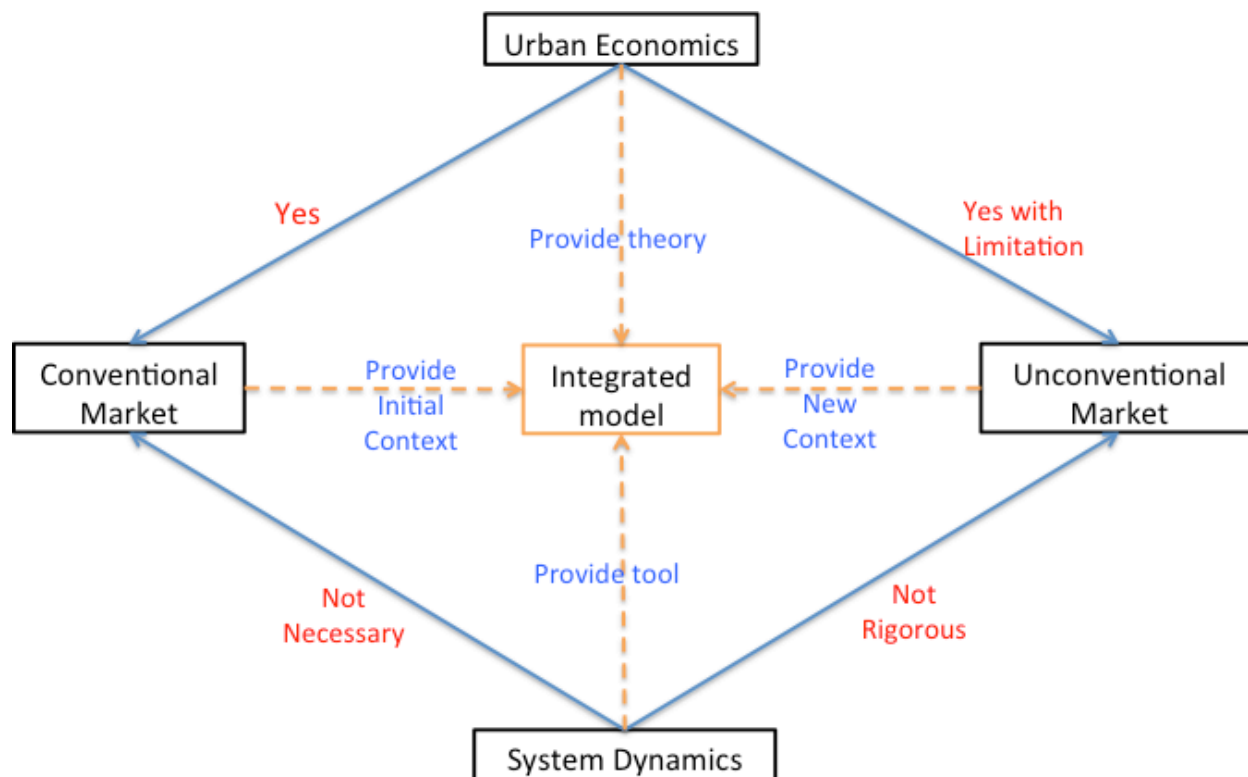


Figure 2-8 Application of an integrated model to the Chinese housing context

#### 2.4.2 Analyze the Housing Market Ex-Ante: Bubbles vs. Economic Fundamentals

Housing bubbles can be easily camouflaged to be a phase of housing cycles, but they are different from housing cycles. Housing bubbles are reinforcing mechanisms that are created from thin-air, while housing cycles are balancing mechanisms driven by economic fundamentals and oscillate around the steady-state. Here economic fundamentals are defined as a group of quantifiable macroeconomics parameters such as income, rent, vacancy, etc. There is a long stream of literature that has been written regarding housing cycles. Economic models have been applied and validated in the Western housing markets where market economy dominates. However, they face difficulty in identifying and analyzing bubbles from ex ante, especially without data

support. But, the theories and models can serve as the ideal cornerstone and starting point of this research.

Engineering methods such as System Dynamics (SD) are used to study exactly the same phenomenon of market cycles. In general, the SD model is more flexible and focuses on the causal structure of the system. It is less restrictive on following the economic theories, and relies less on intensive historical data analysis. For that reason, an SD model often sheds light on new policy design from ex ante. Instead of staying in the realm of equilibrium-seeking, SD models allow the system to be explosive, and has the flexibility to incorporate peculiar market mechanisms, making it ideal to analyze the housing bubbles.

This thesis needs to first to build a system dynamic model based on urban economics theory enhanced with decision-making process and apply it to the Chinese market in order to understand the market conditions and policy consequences. We introduce the features that are not part of the traditional economic fundamentals and peculiar to the Chinese market. The 4QM model itself is a constantly equilibrium-seeking balance loop. It would not allow the system behavior to spiral out of control. SD theory can be complementary to it in understanding the non-traditional market through an integrated analysis using both methodologies.

Then we will compare the simulation results of the enhanced model against the benchmark, which is the market oscillation results simulated uniquely by using 4QM and information of economic fundamentals. Provided that both models will go through the validation process, the difference of simulation results can be used to justify under what conditions may cause the market to form a bubble or to collapse. Further, it can help to design appropriate policies to lead to a soft landing and mitigate the damages of market collapse, should it happen. In the long run, it can test different policy designs to find the best strategy for long-term sustainable development.

A summary of research gaps is shown as in Figure 2-9.

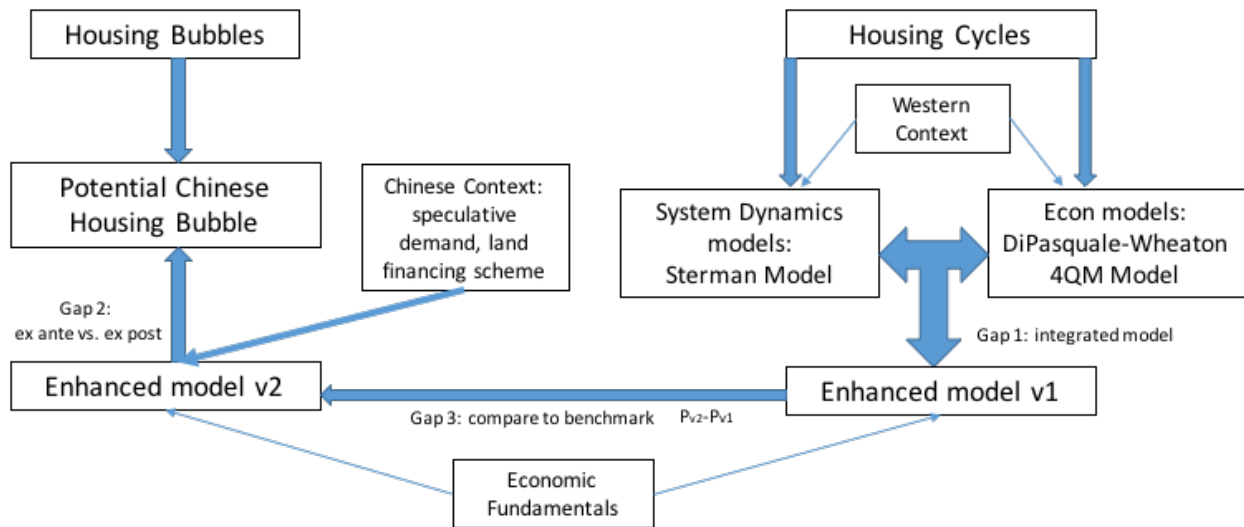


Figure 2-9 Research gaps identified in the literature review section

### 2.5 Research Questions and Hypotheses

The research questions of the thesis are:

1. Can SD methodology be used to complement and extend upon the findings of urban economics models?
2. Can certain features in the Chinese housing market lead to bubble results? If so, under what circumstances may it happen and what are the possible explanations?
3. What preventive or mitigation policies can be designed ex ante, in order to reach a short-term “soft landing” when facing a bubble phenomenon?
4. To what extent can Chinese housing prices be explained by using traditional urban economics model and parameters of economic fundamentals and is there a way to measure the bubble component in the housing price structure?

The research hypotheses of the thesis are:

1. Hypothesis 1: SD models have the flexibility of modifying D-W model assumptions and incorporating new components and lead to alternative research findings.
2. Hypothesis 2: in the context of Chinese housing market, certain features such as speculative investment and land financing scheme can form potential market bubble,

and, if not properly managed, can lead to unsustainable results, such as immediately market collapse.

3. Hypothesis 3: unsustainable results can be mitigated through proper policy design such as implementation of property tax or through management of land supply.
4. Hypothesis 4: Chinese housing price cannot be uniquely explained by economic fundamentals and there exists a measurable bubble component in the current housing price structure driven by certain market features.

### 3 Research Design

The research gaps identified in the literature review section lead to the concept that system dynamics has the potential to be used to both complement and extend the urban economic models to analyze the Chinese housing bubbles ex ante. Additionally, an SD-based model can be especially useful for the evaluation of potential policy designs.

Starting with what we know in the field of knowledge:

1. Traditional economic models such as D-W model and its stock-flow version are efficient in analyzing the housing market as a system and especially useful in explaining the housing market cycles in Western economy.
2. The SD model allows an “unpacking” of the causality links in the system, and a flexibility in modeling the system, which facilitates analysis of policy changes and testing of “what if” scenarios.
3. Economic models rely on historical data and provide analysis ex post, while SD models rely on model structure validity and conduct simulation ex ante using hypothetical data.
4. The current Chinese housing market shows the signs of an expanding housing bubble, but there are alternative hypotheses claiming that it might be just a climbing phase of market cycle.
5. Housing market cycles can normally be explained and predicted by the traditional economic fundamentals using the D-W model, but market bubble cannot be predicted and explained only with those economic fundamentals.
6. Chinese housing market includes unique institutional and political features that are quite different from the classical Western economic paradigm; these features are difficult to fully represent with traditional economic models.

The first task is to build a SD model to perfectly replicate the existing findings in the classic D-W stock-flow model to demonstrate that SD methodology has the same ability in conducting housing analysis. The next set of tasks extends the basic SD model into a

set of models to explore alternative assumptions, new components, the Chinese context. More specifically, the research design is conducted in the following five major steps:

1. *Platform Shift*: Replicate the D-W stock-flow model<sup>33</sup> using SD methodology
2. *Generic Model Modification*: Modify the assumptions and add new components to the SD model to demonstrate the power and flexibility of SD methodology when applied to research of housing market cycles.
3. *China-Specific Model Modification*: Modify the structure of the new SD model with the peculiar Chinese market features to resolve inconsistencies in our interpretation of evidence (e.g. constantly rising housing prices in China) by calling into doubt of currently accepted interpretations of western economic theories (e.g. housing price should experience cycles).
4. *Case Study of Chinese Housing Bubble*: Apply Chinese data into generic models and China-specific models, and observe the difference of simulation results.
5. *Model Validation*: Validate the set of SD models that are built and further extend upon the proven D-W economic model.

Each of these major steps in the research design is discussed in detail in the following sections.

### 3.1 Step One - Platform Shift: From Economic Platform to SD Platform

In the first step, the classic D-W stock-flow model is directly translated into a basic SD model. It is intuitive because the stock-flow model is the foundation of the SD methodology. This step of the research aims to prove that the SD model can be constructed to perfectly replicate the original model and its simulation results in Wheaton (1999). We can think of it as switching the modeling platforms. If successful (in the sense that the results can be perfectly replicated), it will enable us, in the subsequent stages, to get beyond the realm of a static analytic platform and run simulations on a modifiable SD platform.

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<sup>33</sup> As mentioned in the literature review section, the D-W model is a classic real estate system model based on a static analytical platform. It later was converted into a stock-flow model in Wheaton's 1999 paper to become dynamic.



In this part of thesis, the detailed version of Sterman (2000) housing market cyclical model should also be discussed. When we translate the Wheaton model into its SD form, it is obvious that Sterman and Wheaton, both aiming at analyzing real estate market cycles, have studied the issue from two different domains but arrive at the same model structure and conclusion. In this sense, their respective models can serve to validate each other.

There are a few important variables that are discussed but omitted in Wheaton (1999) that can be modified to explore further theoretical underpinning. For example, we can include natural vacancy rate and construction cost into the model equations. The effect of these two parameters can be observed using SD model easily and avoid solving the complex differential equations in the original stock-flow model.

### **3.2 Step Two - Generic Model Modification: Explore Alternative Assumptions**

D-W model is classic because it is extremely concise and usefully explained the cyclic behavior that exists in the US real estate market. However, such finding is based on certain assumptions that are made when constructing the basic model equations. It makes sense now to take advantage of the computational power of the SD version of D-W model, to find out that when we simply change one assumption in the original model, would the cyclic behavior of the real estate market be still observed.

The modifications that are to be introduced in this Step 2 are not specific to the Chinese context. Rather, these are important intermediate modifications that will eventually lead to the Chinese housing market bubble research. But here, in step 2 we simply aim to demonstrate the power and flexibility of SD model in terms of complementing and extending upon traditional economic model to analyze housing market, thus showing the advantages of combining the two methodologies. We will start with the reasonable modification of the basic assumptions of the following four features.

### 3.2.1 Delay Mechanism in the Construction Industry

The first feature that has been added is to elaborate on the type of delay mechanism that characterizes the time lags in the econometric stock-flow models. Implicitly, in Wheaton (1999), the stock-flow model presumes a static delay in the completion of new housing. It means that housing production exits the construction process in exactly the same quantity and order that they enter the production process. In other words, the construction-completion rate exactly equals to the construction-starting rate a few periods ago. In SD terminology, this is referred to as “pipeline delay structure”.

However, empirically it is observed that the construction industry behaves differently. As an alternative to the pipeline delay structure, this research introduces what is called a “first-order delay” structure, which makes the construction-completion rate proportional to the total ongoing construction in the pool during the construction period. For example, developers may put more resources into construction when there is more demand for housing (maybe more construction workers are hired, or they work more overtime). In this way, construction will likely to finish earlier. Would this change prevent the market cycle from happening because the supply of the market can adapt more rapidly to the change in demand? In this step, we test the hypothesis that, with the first-order lag structure, the modified model will give entirely different results – specifically, showing reduced price cyclicity in the medium to long run.

### 3.2.2 Delay Mechanism in the Adaptive Expectation Process

In the scope of the discussion of the delay mechanism, in System Dynamics, Sterman has repeatedly emphasized the adaptive expectations on price change. This is in line with the concept of anchor effect or loss aversion in the behavior economics literature. The delay mechanism here is called information delay, and it is different from the delay in the construction industry which is defined as material delay. Information delay describes the delay between the timing when market price information comes out till the time and developers accept such information, by when the investment decisions may have been made based on past price information. When such delay mechanisms have

been added into the SD model, what effects can be observed as regard to market cycles?

### 3.2.3 Land Supply Constraints and Land Creation

The third feature explored is related to the land supply component, which is a key component in the housing industry. However, the scarcity of land is not discussed in the D-W model. This research introduces an extra component to represent the “land reserve” mechanism. The amount of land reserve at any given time depends upon two variables: initial land reserve (agriculture land) plus demolition (reusable land). Two opposite types of land markets scenarios will be studied and different land policies are discussed. In the first scenario, the land market is entirely detached from the housing market, where land price is not sensitive to land availability. This is a simplified scenario in countries where land quota and distribution rely mainly on the political regime instead of market supply-demand, such as in the planning economy in China before 1978.

In the second scenario, new construction would not take place due to the unaffordability or unavailability of land. This conforms to the theory of residual land value, where land price is decided by the housing price minus construction costs. This will test the hypothesis that the simulation result may demonstrate the upward spiral trend of housing price instead of cyclic housing price, based on low land reserves. Empirically, land-constrained cities with high demand demonstrate the same price trend such as in New York City, San Francisco, and Hong Kong. And of course, the simulation results may also demonstrate the cyclic trend of housing price if there is an abundant level of land reserve and irrational construction activities, such as in the case of Las Vegas.

The modification of the model for both features mentioned above can be proven to be theoretically and empirically reasonable. In this step, we will still use the same dataset that was used in Wheaton 1999 simply to demonstrate that with some realistic modification of the model assumptions, it is possible that the major finding of market cyclic behavior in Wheaton 1999 may either be amplified or no longer be observed.

### 3.2.4 Internalize the Cap Rate

In the D-W model, and later in Wheaton's stock-flow model, the cap rate is considered to be exogenous. However, econometric research tells us that the cap rate should be internalized as it is proven to be negatively correlated to the rent growth. In this scenario, we will create a model to capture the rent growth change and link such change to the cap rate change. What would this change affect the market cycles?

## 3.3 Step Three – China-Specific Model Modification: Adding Chinese Features

Wheaton (1999) claims that it is only theoretically possible for the D-W stock-flow model to explode and thus demonstrate non-cyclical behavior. The explosive behavior cannot be observed with real world parameters.

This step focuses on the modification of the structure of the SD model by incorporating the market features observed in China, one at a time. This step aims to answer the question whether the basic D-W model is sufficient to explain the bubble-like phenomenon in the Chinese market. If not, then maybe it is because that certain important features such as land financing scheme and speculative demand are left out. They are empirically observed and speculated in the Chinese market, but are not reflected in the D-W model.

### 3.3.1 Limited Housing Demand Growth and Ponzi-like Scheme

As covered in the literature review chapter, there are debates that the current high growth rate of demand in Chinese urban cities are not sustainable. The urbanization process will eventually come to an end and the rural to urban migration will stop. Also, a large component of the current demand is speculative investment: the purchasing power of speculators is not unlimited and the decision of long or short on housing market may switch swiftly once the housing price starts to drop.

### 3.3.2 Speculative Demand with Housing Hoarding

The “speculative investment” feature reflects the phenomenon where speculative investors purchase large amount of housing units. There are two types of speculators. The first type of speculator is more like in Western countries: they purchase extra housing units with the intent to rent them out while awaiting long term capital appreciation. The second type of speculators is mostly observed in Chinese market: they purchase extra housing units but hold them vacant for future immediate resale. Four questions are tested:

1. In the purchasing phase, would the speculative investment drive up the housing price and how would market cyclic behavior change?
2. What if the speculative investors start to sell the vacant units into the housing market in order to cash out due to reasons such as fear or other more attractive alternative investment opportunities? Would this cause market collapse or merely have a short-term price drop and bounce back?
3. If the market were to collapse, would a tipping point exist and under what condition would such tipping point be triggered?
4. What policies can micromanage the “dumping” behavior of speculative investors to avoid market collapse?

### 3.3.3 Land Financing Scheme

The “land financing scheme” features shows that the land supply is not determined by the supply and demand of the housing market. Rather, the land supply is directly affected by (a) quotas imposed by the Central Government; and (b) the local governments need for revenue. In a sense, the local government can manipulate the housing price through its land supply schedule. The following questions are tested:

1. What if the local government changes the land sales policy? Under what condition would the housing price escalate up or down, or fluctuate around a long-term equilibrium price?
2. What land sales policies can be implemented to mitigate such behavior?

These three features cannot be simply integrated into the D-W model formula through changing the existing model equations. Introducing new variables and new structure are essential. The newly created models will be first analyzed using hypothetical data as in Wheaton 1999 to observe the simulation results change due to the model structure change. For land financing scheme, historical data of Nanjing will be applied to conduct a case study.

### **3.4 Step Four – Case Study of Chinese Housing Bubble**

By now we will have a set of SD models that are generated in steps one, two, and three. These SD models are created distinctively with each covering one change of certain market features, and observe the simulation changes against baseline model. There are two main observations.

Firstly, the models in steps one and two are generic models driven by market fundamentals. They can be applied to all housing market studies not restrictive only to the Chinese housing market. The models in step three are only China-specific as they cover certain phenomena that are unique to China that have heavy influence on the current housing price trend. Secondly, some of the models, either generic or China-specific, have reinforcing effects on market volatility, and thus can be considered to be potential factors that contributing to the housing bubbles. On the other hand, other models have balancing effects on market volatility, and thus can be used as mitigation strategies.

This step focuses on three things:

1. Create one model that is made of a combination of generic SD models and set as benchmark model that is driven by economic fundamentals;
2. Create another model that is made of a combination of China-specific SD models;
3. Conduct a case study by applying the Chinese data into both models and compare the simulation results against the historical data, and against each other.

## 3.5 Validation and Model Testing

### 3.5.1 General System Dynamics Model Testing

Model validation and testing process in the SD field is crucial and progressive, and advanced works that written in this aspect have been listed in Table 3-1. It is also an area that is not well addressed in most of the SD Chinese housing literature as identified in the literature review section.

In the SD field, most of the model validation and testing process can be summarized as follows: conduct the calibration and parameter estimation for the model, and then test and examine the fidelity of the model output to historical data (replicating historical data). However, Sterman (2000) has said that a common issue in testing the credibility of the model is that the modelers focus excessively on the replication of historical data and thus ignore the appropriateness of the model assumptions and structure. In this thesis, the 'replicating historical data' has low priority comparing to the validity of model structure and general output behavior. Senge and Forrester (1980) and Barlas (1996) also emphasized testing the validity of the model structure, and then tested the behavior accuracy. Firstly, the structure of the model should be causal-descriptive, then we can consider that the aggregate output of the model should match reality within a certain accuracy level.

<b>(Author, year)</b>	<b>Title of the Paper</b>
(Senge and Forrester, 1980)	Tests for building confidence in System Dynamics models.
(Homer, 1983)	Partial-model testing as a validation tool for system dynamics.
(Barlas, 1989)	Multiple tests for validation of system dynamics type of simulation models.
(Barlas, 1996)	Formal aspects of model validity and validation in system dynamics.
(Sterman, 2000)	Business Dynamics (Chapter 21).
(Oliva, 2003)	Model calibration as a testing strategy for system dynamics models.
(Luna-Reyes and Andersen, 2004)	Collecting and analyzing qualitative data for system dynamics: methods and models.
(Sargent, 2005)	Verification and validation of simulation models.
(Winz, Brierley, and Trowsdale, 2008)	The use of system dynamics simulation in water resources management.
(Qudrat-Ullah and Seong, 2010)	How to do structural validity of a system dynamics type simulation model: the case of an energy policy model.
(Hadjis, 2011)	Bringing economy and robustness in parameter testing: a Taguchi methods-based approach to model validation.
(Groesser and Schwaninger, 2012)	Contributions to model validation: hierarchy, process, and cessation.
(Martinez-Moyano and Richardson, 2013)	Best practices in system dynamics modeling.
(Richardson, 2013)	The past is prologue: reflections on forty-plus years of system dynamics modeling practice.

Table 3-1 Important SD literature that discusses SD model validation and testing

The simulation results of most of the SD models developed in this thesis cannot be proven directly through statistical analysis because some data (e.g. speculative vacancy rate, government fiscal budget, etc.) are not officially collected or cannot be easily obtained. However, the modification process in terms of structural change applied to the model can still be validated through case studies of the current situation of the Chinese market. Then, through applying hypothetical data, we can still observe the system behavior change due to the modification of system structure.

It is also important to realize that the SD model is built upon the D-W stock-flow model, which is validated and recognized in the economic literature. On top of the realm of D-W



model, the integrated SD model's boundary is expanded to include the discussion of land financing component, speculation, and vacancy rate: three additional structures that are considered as important in the Chinese housing market. The model structure will be validated by demonstrating consistency with the descriptive knowledge of the current urban housing market in China, through literature written from Chinese scholars.

The conceptual validity of model building process in this thesis follows from the fact that it satisfies the standard criteria:

1. Theoretical consistency: the model builds upon, and is consistent with, the stock-flow and 4QM models that the economic literature recognizes as fundamental.
2. Descriptively correct: Within the scope of the study, the structure of the model is consistent with knowledge of the current urban housing market in China, as field interviews and Chinese scholars have documented. Specifically, it includes a representation of the land financing phenomenon, and speculative housing demand.
3. Numerically appropriate: The values of exogenous variables such as population, government budget, etc. derive from the best available sources such as the statistical yearbooks. However, the model includes self-calibrated variables that we cannot easily estimate or verify empirically. For example, the vacancy rate data is neither available nor observable from the market. So we attempt to make reasonable assumptions and vary these assumptions in certain reasonable ranges within the model to demonstrate the mechanisms.
4. Sensitivity to assumptions about market behavior: This is seen particularly as we run the model simulation and observe how developers respond to the local governments' release of land, for example in the "command-&-control" or the "market-driven" modes of response.

### 3.5.2 Sterman's 12 Steps of Model Testing

Based on a wide variety of specific testing practice written by system dynamists, Sterman (pp858, 2000) has summarized 12 steps of model testing. The 12 steps are: (1) boundary adequacy tests; (2) structure assessment tests; (3) dimensional consistency test; (4) parameter assessment test; (5) extreme conditions test; (6)

integration error test; (7) behavior reproduction test; (8) behavior anomaly test; (9) family member extension test; (10) surprise behavior; (11) sensitivity analysis; and (12) system improvement.

These 12 steps have been widely used as standard in the system dynamics articles that have been published and cited in the System Dynamics Society from a range of domains. We sampled 17 articles shown in Table 3-2. As we studied their model testing practice, we learned that the (1) boundary adequacy tests, (2) structure assessment tests, and (7) behavior reproduction test are the mostly commonly used test criteria in every article. Also, it appears that (4) parameter assessment test, (5) extreme conditions test, and (11) sensitivity analysis test are also commonly used. The (3) dimensional consistency test and (6) integration error test are normally not mentioned. This is because they are default tests that every model should pass. And (12) system improvement is generally discussed in every article, either quantitatively or qualitatively, in their discussion of model simulation findings.

As a result, the set of models developed in this thesis aims to follow a similar testing procedure as discussed above. The testing procedures may have some simplification to certain extent due to the fact the initial SD model is built based upon proven D-W stock-flow model. The detailed discussions are as following:

#### 1. Boundary Adequacy Tests

The D-W model (DiPasquale and Wheaton, 1996) in its original static four-quadrant form has visually depicted the boundary charts, subsystem diagrams, and even causal diagrams for the initial SD model that this thesis aims to build. Stock-flow maps and model equations, before the model modification process, will remain exactly as in Wheaton (1999).

However, in Steps 2 and 3 of research design, the model's boundary assumptions need to be changed. For example, in Step 2, land component is included in the model. It is

because the housing market volatility is driven by overbuilding during the construction delay but such activity cannot happen when there is limited availability of land.

In Step 3, the model's boundary will be further expanded. We can identify at least the following components, land financing scheme and investors' speculation, as the major components that should be included in the integrated model. These will include new mechanisms (land supply system) and stakeholders (e.g. speculators, local governments) into the new model boundaries. Each boundary expansion will be accompanied by the proof through online resources, archival materials, and review of literature.

## 2. Structure Assessment Tests

This test aims to answer the question whether the model structure is consistent with relevant descriptive knowledge of the system. It is an important test especially for Steps 2 and 3 of the research design to justify the changes that we have made to the D-W model. The newly added model structures, causal diagrams, stock and flow components, and equations are tested through literature review or other valid sources (interview, online materials, etc). As in Step 3, decision rules that capture the behavior of local governments will be built in. Such decision rules and equations used should be validated.

We will demonstrate that the unit of analysis and level of aggregation are appropriate. For example, at what level should we aggregate data? In some cases, national level data may seem appropriate, while in other cases, city level data may be the best choice.

## 3. Dimensional Consistency Tests

In this test, all parameters and equations in each model should be documented. It should be shown that each equation is dimensionally consistent without the use of parameters having no real world meaning. Since the model building process will be

using Vensim software<sup>34</sup>, the unit consistency part of test can be conducted by using “Unit Check” tool in the software.

#### 4. Parameter Assessment

Criticisms of SD methodology frequently involve the discussion of the value of parameters, especially self-calibrated parameters. For those parameters in a SD model where historical numerical data is not available, system dynamists normally estimate values judgmentally using qualitative approach such as from expert opinion and experiences, etc. In SD practice, statistical methods (such as econometrics) and judgmental methods are used together.

In this thesis, we make sure that the parameters in all models have real-life meaning, and their values can be either (1) the hypothetical value within a reasonable range; or (2) recorded historical data; or (3) estimated data based on work from other researchers. We also avoid using parameters whose values need to be determined purely using judgmental methods.

For example, the values of exogenous economic parameters such as population, government budget, construction cost, etc., are quoted from the best available sources such as statistical yearbooks. The value of variables such as vacancy rate cannot be directly observed from the market but can only be estimated from other scholars' field survey. They are thus included in the model with detailed discussions of assumptions.

#### 5. Extreme Conditions

Extreme conditions test will be conducted for each model in this thesis to see how simulation results change and whether such change makes sense. For example, when demand is set to zero, other parameters such as housing price and new construction starting rate should also drop to zero.

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<sup>34</sup> Vensim is a simulation software developed by Ventana Systems which primarily supports simulation such as System Dynamics and Agent Based Modeling.

## 6. Integration Error

The integration error test is normally considered a default test that should be the first simulation test carried out. The results of model simulation should not be sensitive to the choice of time step or integration methods. The time steps in this thesis are (1) “periods” when using hypothetical data; or (2) year or month depending on the time unit of data that each model uses.

## 7. Behavior Reproduction

This test is commonly used in SD articles when the model aims to replicate historical data. In this thesis, this test is done differently for different models in the three steps of research design:

- In Step 1, because the SD model is a replication of the D-W stock-flow model as in Wheaton (1999), the SD model output should be exactly the same as in Wheaton’s paper.
- In Step 2, modifications will be done to the basic SD model. We will compare the model output and the results in Wheaton (1999) qualitatively, including modes of cyclical behavior, shapes of output variable, asymmetries, amplitudes and phasing, etc.
- In Step 3, after incorporating the new features in the Chinese market, we will use historical data and see if the model reproduces the bubble-like behavior like in real world.
- Also notice that the testing process in Step 4 will not aim to perfectly replicate the real world price trend. We can find one event that happens in the real world and observe the market behavior change before and after. We will then make similar change to mimic such event in the SD models and observe if the system demonstrates the same behavior. For example, the national policy of purchase restriction took place in 2011 where the maximum amount of housing units a family can own in the first tier cities are limited to one. This suppressed the speculative demand and led to a short-term drop in housing prices. However, after a brief short-term drop, the housing price began to bounce back. We would

like to see that with the current modified model, we can observe the same price trend change. If we do, then the modified model can be partially validated.

#### 8. Behavior Anomaly

This test, if needed, is only applied in Step 3 of the research design. It is conducted to see if anomalous behaviors will arise when certain assumptions of the model are changed or deleted. For example, starting from the basic D-W model, we have realized that if we change the construction part of the model from the pipeline structure to a first-order delivery structure, the oscillation in the system will disappear. This will challenge the key findings of the D-W stock-flow model.

#### 9. Family Member

This test is likely to be in the discussion of future steps of the thesis, in order to answer the question how generic this integrated SD model can be. For example, can this model generate the behavior observed in other instances of the same system, when used in other Asian countries other than China?

#### 10. Surprise Behavior

This test is only conducted when any of the SD models in this thesis generates counter-intuitive simulation results.

#### 11. Sensitivity Analysis

Sensitivity analysis tests will be conducted to show how simulation result will change with regard to the uncertainties in the model assumptions. In the SD literature, there are three types of sensitivity:

- Numerical sensitivity: it is the most common types of sensitivity analysis as conducted in other fields of research.
- Behavior mode sensitivity: this test will be conducted for every model in Steps 2 and 3 of the research design to see how a change in assumptions of parameter will lead to the behavior change of the model output.

- Policy sensitivity: this test will be conducted for models in Step 3 of the research design when evaluating different alternative policies, to see if certain model assumptions change will reverse the impact of such policies.

## 12. System Improvement Tests

To pass this test, we must identify the policies that will help lead to the housing market's improvement. For example, we should be able to come up with policies that can mitigate the current Chinese housing bubble in the market, and avoid immediate market collapse.

No.	Paper	1. Boundary Adequacy	2. Structure Assessment	3. Dimensional Consistency	4. Parameter Assessment	5. Extreme Conditions	6. Integration Error	7. Behavior Reproduction	8. Behavior Anomaly	9. Family Member	10. Surprise Behavior	11. Sensitivity Analysis	12 System Improvement
1	(Park and Ahn, 2010)	X	X					X			X	X	X
2	(Ghaffarzadegan and Tajrishi, 2010)	X	X					X					X
3	(Fallah-Fini et al., 2010)	X			X	X							X
4	(Bivona and Montemaggiore, 2010)	X	X										X
5	(Anderson, 2011)	X	X		X			X				X	X
6	(Taylor et al., 2011)	X	X			X		X				X	X
7	(Owens, Leveson, and Hoffman, 2011)	X	X	X	X	X	X	X	X	X			X
8	(Feola, Gallati, and Binder, 2012)	X	X	X	X	X	X					X	X
9	(Pierson and Sterman, 2013)	X	X	X	X			X				X	X
10	(Hovmand et al., 2009)	X	X	X	X	X		X	X	X		X	X
11	(Vlachos, Georgiadis, and Iakovou, 2007)	X	X			X		X				X	X
12	(Georgiadis and Michaloudis, 2012)	X	X	X		X	X						X
13	(Zarghami and Akbariyeh, 2012)	X	X					X					X
14	(Martinez-Fernandez et al., 2012)	X	X	X		X		X				X	X
15	(Hwang, Park, and Lee, 2009)		X										X
16	(Eskinas, 2011)		X	X	X			X					X
17	(Eskinas, Rouwette, and Vennix, 2009)		X					X					X
	(Park and Ahn, 2010)	Policy analysis for online game addiction problems											
	(Ghaffarzadegan and Tajrishi, 2010)	Economic transition management in a commodity market: the case of the Iranian cement industry											
	(Fallah-Fini et al., 2010)	Optimizing highway maintenance operations: dynamic considerations											
	(Bivona and Montemaggiore, 2010)	Understanding short- and long-term implications of "myopic" fleet maintenance policies: a system dynamics application to a city bus company											
	(Anderson, 2011)	A dynamic model of counterinsurgency policy											
	(Taylor et al., 2011)	Science, engineering, and technology in the policy process for mitigating natural-societal risk											
	(Owens, Leveson, and Hoffman, 2011)	Procedure rework: a dynamic process with implications for the "rework cycle" and "disaster dynamics"											
	(Feola, Gallati, and Binder, 2012)	Exploring behavioural change through an agent-oriented system dynamics model: the use of personal protective equipment among pesticide applicators in Colombia											
	(Pierson and Sterman, 2013)	Cyclical dynamics of airline industry earnings											
	(Hovmand et al., 2009)	Victims arrested for domestic violence: unintended consequences of arrest policies											
	(Vlachos, Georgiadis, and Iakovou, 2007)	A system dynamics model for dynamic capacity planning of remanufacturing in closed-loop supply chains											
	(Georgiadis and Michaloudis, 2012)	Real-time production planning and control system for job-shop manufacturing: A system dynamics analysis											
	(Zarghami and Akbariyeh, 2012)	System dynamics modeling for complex urban water systems: application to the city of Tabriz, Iran											
	(Martinez-Fernandez et al., 2012)	Sustainability of Mediterranean irrigated agro-landscapes											
	(Hwang, Park, and Lee, 2009)	Korean Real Estate Market Mechanisms and Deregulation of Mortgage Loans											
	(Eskinas, 2011)	Houdini: a system dynamics model for housing market reforms											
	(Eskinas, Rouwette, and Vennix, 2009)	Simulating urban transformation in Haaglanden, the Netherlands											

Table 3-2 Selected System Dynamics Papers in Different Domains and Their Model Validation and Testing Practice



## 4 Step One – Platform Shift: From 4QM to SD Model

The objective of this chapter is to describe a basic housing market model based on the SD framework that exactly replicates the 1999 Wheaton stock-flow model. This will serve as a demonstration, or “proof of concept”, and will link the SD model to the classical urban economics literature.

System dynamists often take the 4QM, or its more formal dynamic elaboration in the stock-flow model, as a basic starting-point platform for building a SD model of an office or housing market (Mashayekhi et al., 2009; Eskinasi, 2014). In this thesis, we take similar approach and use the stock-flow model in Wheaton (1999) as a basic platform for our development of a set of baseline SD models. It is important to emphasize that although the stock-flow model in Wheaton (1999) is based on the principles of the office market, the same principles are applied to the housing market. Using DiPasquale and Wheaton’s own words in their book “Urban Economics and Real Estate Markets” (pp10-11, 2006):

*“A reasonable question is how all of this (4QM model) works in the case of real estate that is mainly occupied by its owner. In this case, the four quadrants still hold.....The demand for single-family homes depends on the number of households, their incomes, and the annual costs of owning a home. This annual cost is equivalent to rent..... Lower interest rates, for example, imply that with the same annual payment (rent), households can afford to pay a higher purchase price.....”*

The only conceptual change is that we equate the “rent” in the office market to the “shadow rent” or “mortgage payment” in the housing market. Housing price can be seen as the present value of net rents as if it were rented out.

### 4.1 The Basic Equations in the Stock-Flow Model of Wheaton (1999)

In subsequent sections of this chapter we will describe some initial modifications to this basic model in order to explore its the application to the Chinese context in later

chapters. For now, we only focus on how to exactly replicate the stock-flow model with the SD technique. Our first SD model exactly replicates the mathematical equations defined in the stock-flow model. We use the same parameter values as in the Wheaton's 1999 paper in order to confirm the validity of this replication process.

In Wheaton's semi-hypothetical U.S. aggregate office market there is an initial employment work-force of  $E_0$  equal to 10 million to represent demand, occupying 2,500 million square feet of office space (initial stock  $S_0$ ). The initial equilibrium rent is  $R_0$  equal to \$20 per square feet per year. With a market cap rate ( $r$ ) of 5%, the equilibrium asset price  $P_0$  is set at \$400 per square foot. The construction rate equals the demolition-growth rate  $\delta$  at 0.10, and the market is at equilibrium. The elasticities are  $\beta_1$  equal to 0.4 for demand (or  $-\beta_1 = -0.4$  to represents a negative value of demand elasticity), and  $\beta_2$  at 2.0 for supply. Then an unexpected external shock affects the market: an immediate and permanent shift in the demand curve from 10 million to 15 million in the work force. This sudden jump happens at time stamp 1.

There are six important formulas that govern the stock-flow model that are describe in Wheaton (1999).

$$D_t = \alpha_1 E_t R_t^{-\beta_1} \tag{1}$$

In Equation (1), it is assumed that the market clears (so that vacancy rate is neglected) at every period, and demand  $D_t = S_t$ . Here  $S_t$  denotes the total stock. When we want to incorporate vacancy rate in the future, we can simply change  $S_t$  to  $(1 - V_t)S_t$  where  $V_t$  is the vacancy rate.

$$R_t = (S_t / \alpha_1 E_t)^{-1/\beta_1} \tag{2}$$

Equation (2) is a simple transformation of the Equation (1) by introducing the assumption  $D_t = S_t$ . This equation calculates the rent level for a given point in time,  $t$ .

$$E_t = E \quad (3)$$

In the case of office market discussion, the demand is the number of employees that require office space. In the initial stock-flow setting, the employment level will start at 10 million people at time stamp 0, and will encounter an unexpected expansion to 15 million people at time stamp 1. The demand,  $D_t$ , for any point in time  $t$  is an input parameter to the model (i.e., it's not calculated by the model but rather fed into the model).

$$S_t = S_{t-1}(1 - \delta) + C_{t-n} \quad (4)$$

Equation (4) defines the total stock change along certain time span. The total stock at time  $t$  equals to the housing stock of last period (time  $t-1$ ), minus the demolition that took place during this period, plus the newly finished construction that has started  $n$  periods ago.

$$C_{t-n}/S_{t-1} = \alpha_2 P_t^{\beta_2} \quad (5)$$

$$P_t = R_{t-n}/r \text{ (myopic/prices)} \quad (6)$$

In Equation (5),  $P_t$  represents the housing price prediction at time  $t$ . The equation indicates that the construction-starting rate at time  $t-n$ , is determined by a combination of the housing stock at time  $(t-1)$ , supply elasticity  $\beta_2$ , as well as the housing price prediction at time  $t$ . The crucial issue is the way in which future price  $P_t$  is forecasted. In Equation (6) we use the simplest form where myopic expectations assume that developers take current market price of housing as the price  $n$  periods later when they finish the construction. For the first step of the replication process, all the developers are assumed to be 'myopic' as in Wheaton 1999. That is, they will extrapolate current rents forward as calculated in Equation (6). Also, they will ignore the construction that is going on in the pipeline.

**4.2 Model SD1: Baseline Model with Myopic Forecasting of Price**

Figure 4-1 is the causal loop diagram (CLD) representation of the DiPasquale-Wheaton model, which includes all the variables in the 4QM model and the causal relationships among them. Figure 4-2 presents our SD replication of Wheaton’s stock-flow model following the equations listed above. Parameters such as  $\alpha_1$  and  $\alpha_2$  in Equations (2) and (5) are scaling factors equivalent to constants. As a result, they are only shown in the equation, but are not visible in the SD model diagram.

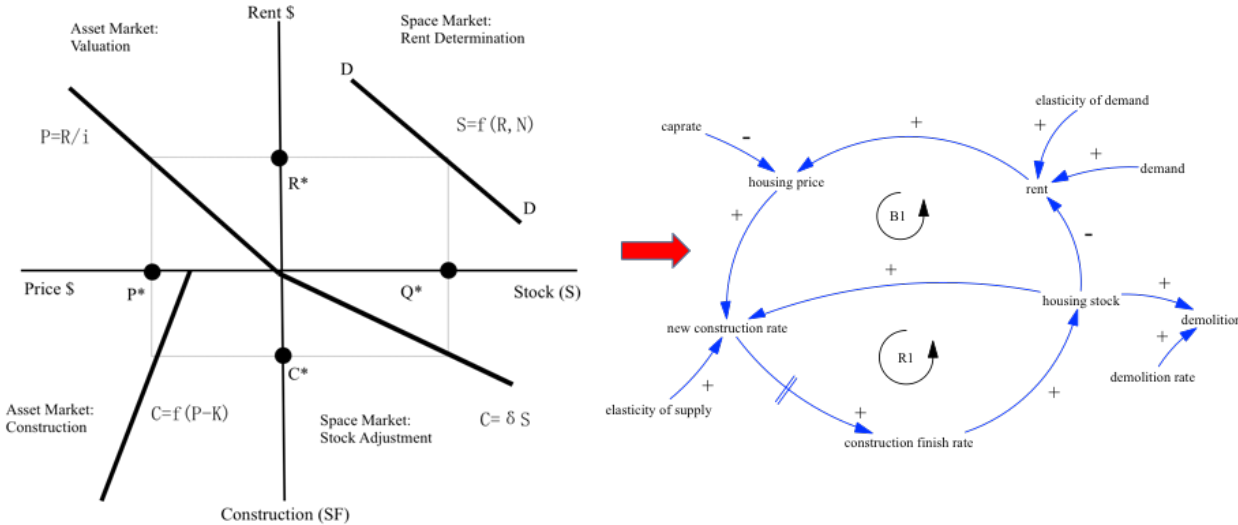


Figure 4-1 The causal loop diagram representation of the DiPasquale-Wheaton model

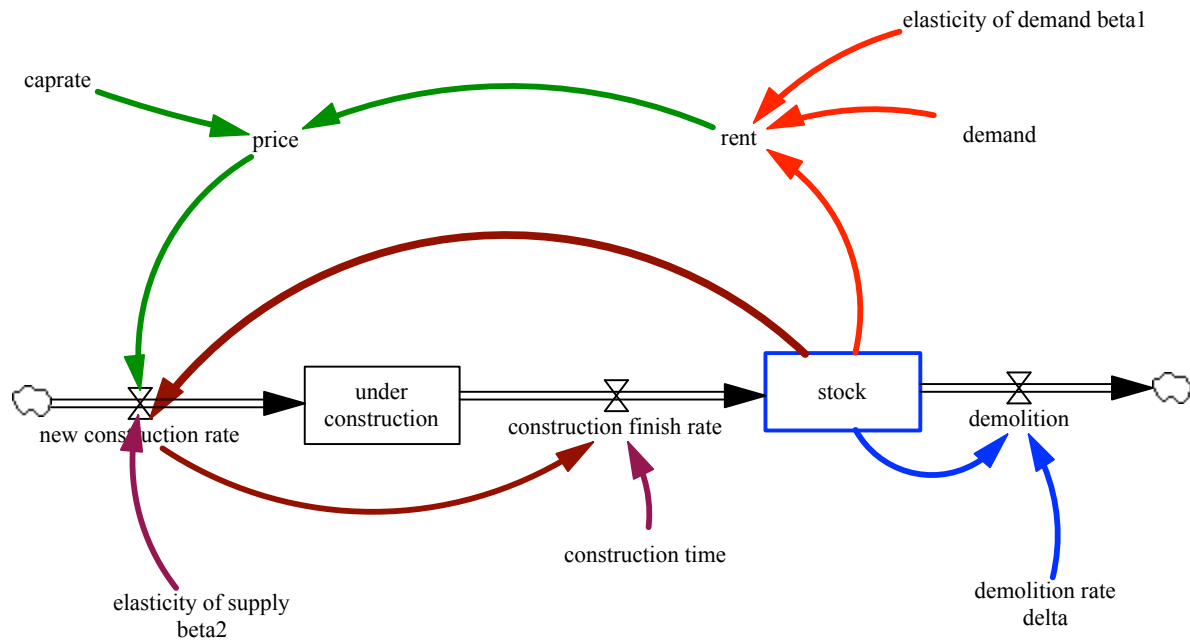


Figure 4-2 SD1: baseline model - the SD representation of the stock-flow model in Wheaton 1999

In order to be consistent in our replication process, throughout this chapter the steady-state solution of the model remains the same as in Wheaton (1999):

$$\begin{aligned}
 E_t &= 10 \text{ million (workers)} \\
 S^* &= 2,500 \text{ million sqft} \\
 R^* &= 20 \text{ dollar/sqft} \\
 r &= 0.05 \\
 P^* &= 400 \text{ dollar/sqft}
 \end{aligned}$$

We can follow the causal relationships indicated by the arrows to see, for example, how the impact of a sudden increase in demand is reflected through the real estate markets. In the beginning, because the increase in demand (from 10 million to 15 million) was unexpected, the supply of office space, namely, the current 'stock', remains unchanged. As a result, as indicated by the red arrows, the rent rises. The cap rate (asset market

yield) remains constant<sup>35</sup>, so the rent increase leads to an increase in the price of property assets, as shown by the green arrows. A rising property price triggers reaction in the stock-flow part of the SD model, which occurs along the main double-arrow flow from left to right.

From the supply side, the developers increase construction rate responding to the higher asset prices (greater development profitability), aiming to meet the increased usage demand that led to the price increase. Wheaton assumes a space delivery lag of “n” periods will occur due to the time required for site planning and construction. In his stock-flow model, the “n” period construction delay takes on a value of 5 time-periods to represent a short construction duration, or 8 time-periods to represent long construction duration. One thing that needs to be pointed out for clarification is that in the system dynamics modeling, for the 5 time-periods we have to use numerical value of 4, and for the 8 time-period, we need to use numerical value of 7 for simulation. It is because that n period construction means if new construction takes place at period 1, it will be finished at period n. As a result, for simulation, we need to input the time interval between construction starting time and construction finishing time, which is n-1.

In the original stock-flow model, the rate of construction completion exactly equals to the rate of construction starts “n” periods earlier. Given a fixed delay time, the quantities of finished stock coming out from the development lag occur in precisely the same order and amounts as the corresponding quantities of construction starts going into the lag. The mathematical relationship will be that the construction “outflow” at time (t) equals to the construction “inflow” (starts) “n” periods earlier where “n-1” is the average time required for construction.

The newly finished construction adds to the stock. This added stock will offset the ongoing demolition, which is assumed to be proportional to the pre-existing stock. In

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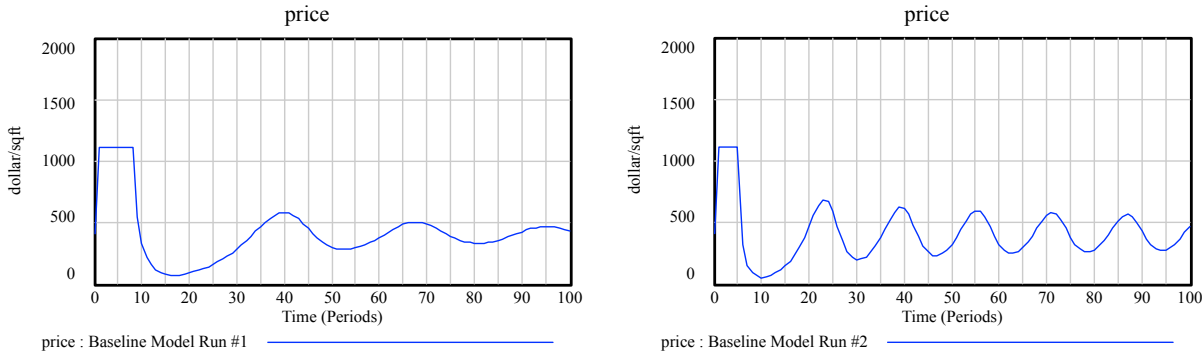
<sup>35</sup> Cap rate is short for capitalization rate. It is essentially the rent-to-price ratio and is the yield that investors demand in order to hold the real estate assets. In Wheaton (1999), the cap rate is treated as an exogenous variable. Its value is determined based on the long term interest rates and returns in broader capital market for assets in other categories.

such a system model we can expect the stock to keep rising until it meets the new, increased level of demand, after which the increased supply will start to bring down the rent and thus the property price. When the price starts to drop, the construction will slow down, bringing the stock to a level that will be maintained net of demolitions so that the entire real estate system reaches a new steady-state equilibrium.

It should be noted that in both the stock-flow model and the SD model, the initial values of the variables are exogenous and are preset except for two key variables whose initial values are endogenously determined by the system:

- 1) the rent variable is calculated from the total stock of office space, the quantity of demand, and the rental elasticity of demand as in Equation (2); and
- 2) the rate of new construction starts is jointly determined by the stock, the elasticity of supply, and the property price as in Equation (5).

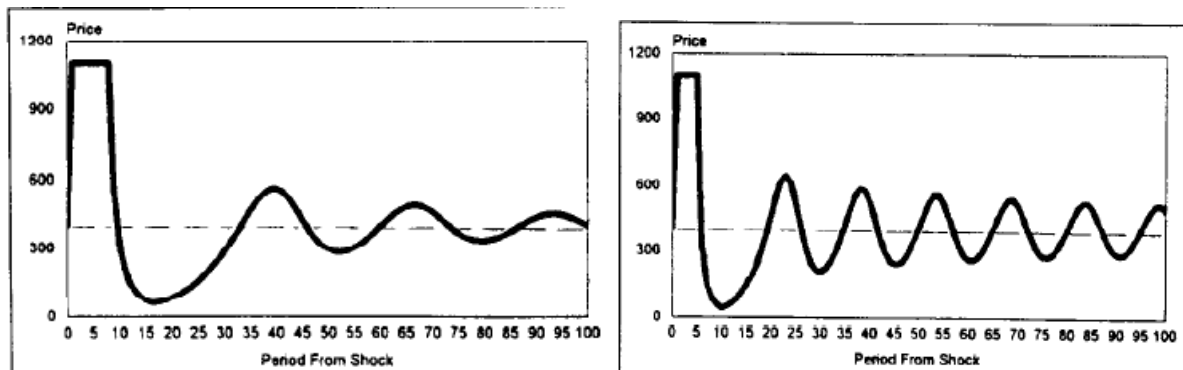
Figure 4-3 shows the simulation result of Model SD1, which represents the case of myopic price forecasting in Wheaton’s original stock-flow model, where developers assume that the current market price when construction starts would be the market price when construction finishes. The key numerical values of the parameters are described in the caption of Figure 4-3, and are the same values used in Wheaton 1999. The SD1 model indicates that the demand jump instigates the dynamic oscillation in the market, which is shown in the graphs.



Baseline Model Run #1: Market reaction to a 50% demand shock (lag: n=8; depreciation rate:  $\delta = 0.05$ ; demand elasticity = -0.4; supply elasticity = 2.0)  
 Baseline Model Run #2: Market reaction to a 50% demand shock (lag: n=5; depreciation rate:  $\delta = 0.10$ ; demand elasticity = -0.4; supply elasticity = 2.0)

Figure 4-3 Replication of Wheaton's 1999 stock-flow model simulation results

The oscillations shown in the chart closely replicate those shown in Wheaton (1999) as shown in Figure 4-4. Given the demand shock, the price variable has difficulty reaching a steady state, which was the main point of Wheaton (1999). As we can observe, there is minor discrepancy between the simulation result of the baseline SD model and Wheaton (1999) result. It is because the Vensim software that we use to build SD models captures the value change on a gradual basis but not a sudden jump between time stamps, such as when value changes between time stamp 0 and 1. Also, Wheaton's simulation may use approximate values when calculated by Excel.



Left: Market reaction to a 50% demand shock (lag:  $n=8$ ; depreciation rate:  $\delta = 0.05$ ; demand elasticity =  $-0.4$ ; supply elasticity =  $2.0$ )

Right: Market reaction to a 50% demand shock (lag:  $n=5$ ; depreciation rate:  $\delta = 0.10$ ; demand elasticity =  $-0.4$ ; supply elasticity =  $2.0$ )

Figure 4-4 Wheaton's (1999) original stock-flow model simulation results for comparison

### 4.3 Model SD2: Baseline Model with Perfect Forecasting of Price

The Model SD1 assumes that the developers are myopic. In Model SD2, we discuss the case where developers are forward looking. Perfect foresight assumes that people know the future perfectly, and rational expectations state that people make investment decisions with all the available information. Wheaton discussed the case of rational expectation in his 1999 paper and concluded that when agents act rationally with perfect foresight, market oscillation would not occur. In his stock-flow model, the forecast of  $P_t$  with perfect foresight is defined as in Equation (7).

$$P_t = P_{t-1} * (1 + r) - R_{t-1} \tag{7}$$



Together with Equations (2), (4) and (5), we have Equation (8)

$$\left[ \frac{P_t(1+r) - P_{t+1}}{P_{t-1}(1+r) - P_t} \right]^{-\beta_1} = 1 - \delta + \alpha_2 P_t^{\beta_2} \tag{8}$$

In other words, the developers will have perfect knowledge of the construction that is going on in the pipeline. For the second step of the replication process, we will consider that all the developers have perfect foresight of  $P_t$ , which is the second scenario that is discussed in Wheaton’s 1999 paper.

However, integrating a second-order non-linear differential equation like in (8) is complicated. With the SD model, a simple way of simulating the perfect foresight scenario is to add the construction that is in the pipeline to the stock, and calculate the new price level based on the total potential stock at any given time stamp. The revised model is shown as in Figure 4-5.

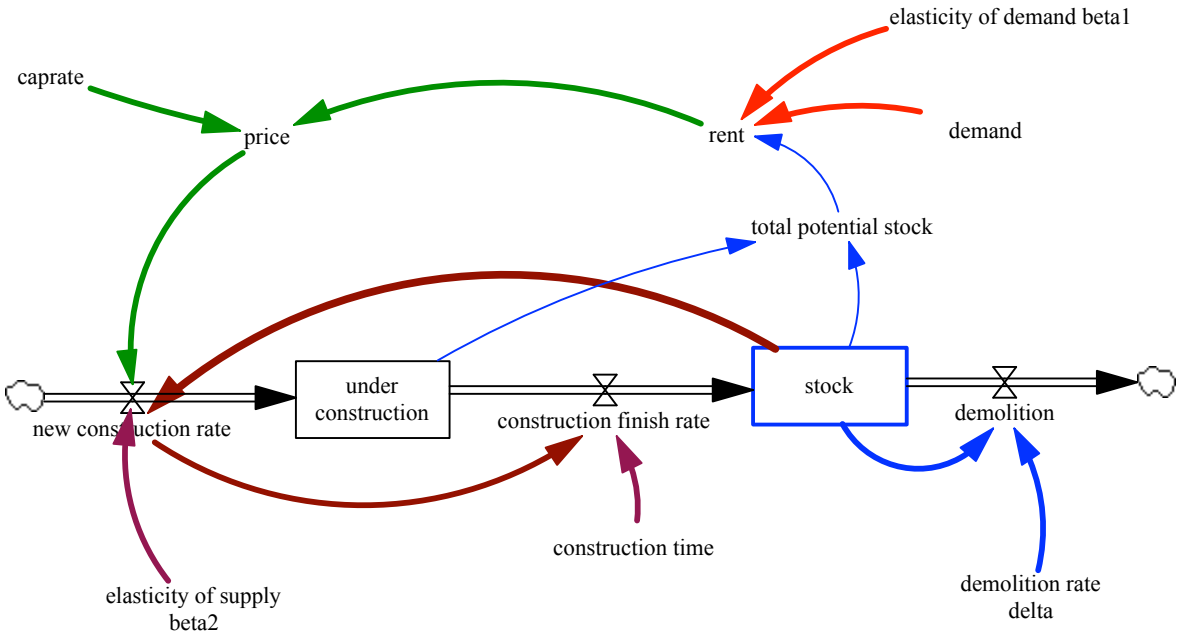


Figure 4-5 SD2: modeling with perfect foresight by adding pipeline construction into the stock before calculating the price level

For each round of price calculation, we will take into considerations of the total potential stock of the system, and thus avoid the over-construction that occurs in the myopic forecasting scenario. As we can see from the simulation results presented in Figure 4-6, the cyclical behavior of price trend disappears and an equilibrium stage is reached smoothly. This reconfirms the finding in Wheaton (1999).

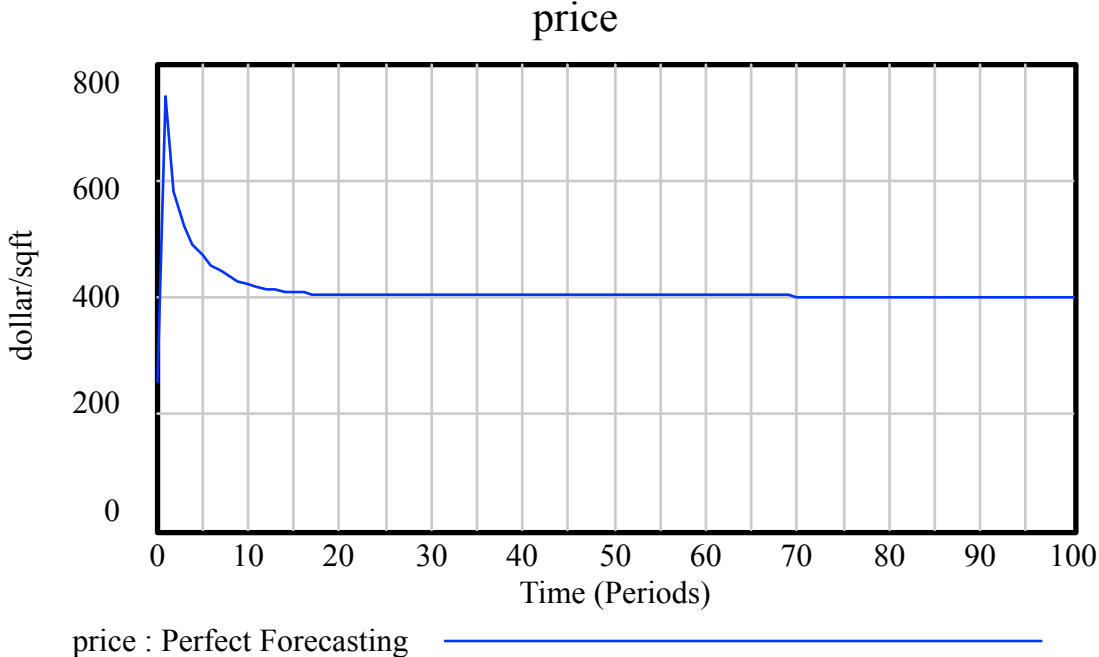


Figure 4-6 Modeling results with perfect price forecast

**4.4 Model SD3: Baseline Model with Steady Demand Growth**

Wheaton (1999) also discussed a stock-flow model driven by economic growth. The depreciation rate of many types of real estate is quite small, and property demand should originate from an expanding economy. The Equation (3) is replaced with (3'), where  $\eta$  stands for the demand growth rate.

$$E_t = E_{t-1}(1 + \eta) \tag{3'}$$

Equation (3') is a more realistic assumption. In Equation (3), the demand growth is a step input, meaning, the demand has an immediate “jump” from 10 million workers to 15

million workers at time stamp 0 and remains at the new higher level. In reality, such migration process of workforce takes time and thus the use of either a ramp growth function or exponential growth function to simulate the demand growth seems more appropriate. Ramp growth function refers to the scenario where the demand starts to rise linearly at a constant rate at time stamp 0. In Equation (3'), it is an exponential growth function where at time zero the demand grows exponentially at rate of  $\eta$ .

The model is modified as Model SD3 shown in Figure 4-7. As we can see, the 'demand' and 'stock' are simulated with similar stock-flow structure:

- demand increases exponentially with the growth rate, and
- stock decreases exponentially with the demotion rate.

Mathematically, it is not hard to notice that the two rates  $\eta$  and  $\delta$  are equivalent.<sup>36</sup> In Model SD3, we have also added a variable 'S/E' to represent the space utilization rate.

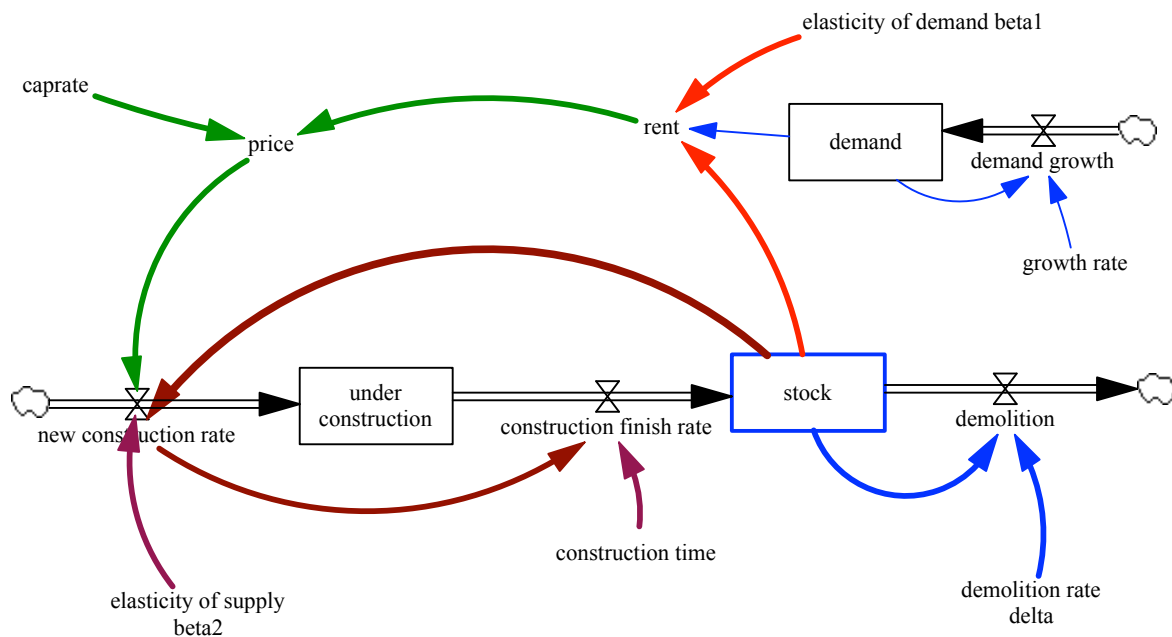


Figure 4-7 SD3: the SD model driven by steady economic growth

<sup>36</sup> Wheaton (1999) also noted that “in effect the rate parameter  $\delta$  is shifted from being a constant rate of depreciation to being a constant rate of economic expansion.”

Using this modified model, three types of growth-depreciation relationships were simulated. The numerical values that were used for simulation are listed in Table 4-1. In developing countries, the economy expands and the stock depreciates rapidly. This can be represented with a large growth-depreciation gap. In developed countries, where economic expansion and depreciation rates are lower, the use of a small growth-depreciation gap may be more representative.

Small growth-depreciation gap	$\eta = 0.01, \delta = -0.05$	gap=0.06
Medium growth-depreciation gap	$\eta = 0.02, \delta = -0.07$	gap=0.09
Large growth-depreciation gap	$\eta = 0.03, \delta = -0.10$	gap=0.13

Table 4-1 Three types of growth-depreciation relationships in SD3 model

The simulation result is shown in Figure 4-8. It copes with the finding in Wheaton (1999) that, as the growth-depreciation gap increases, the model oscillates with greater amplitude.

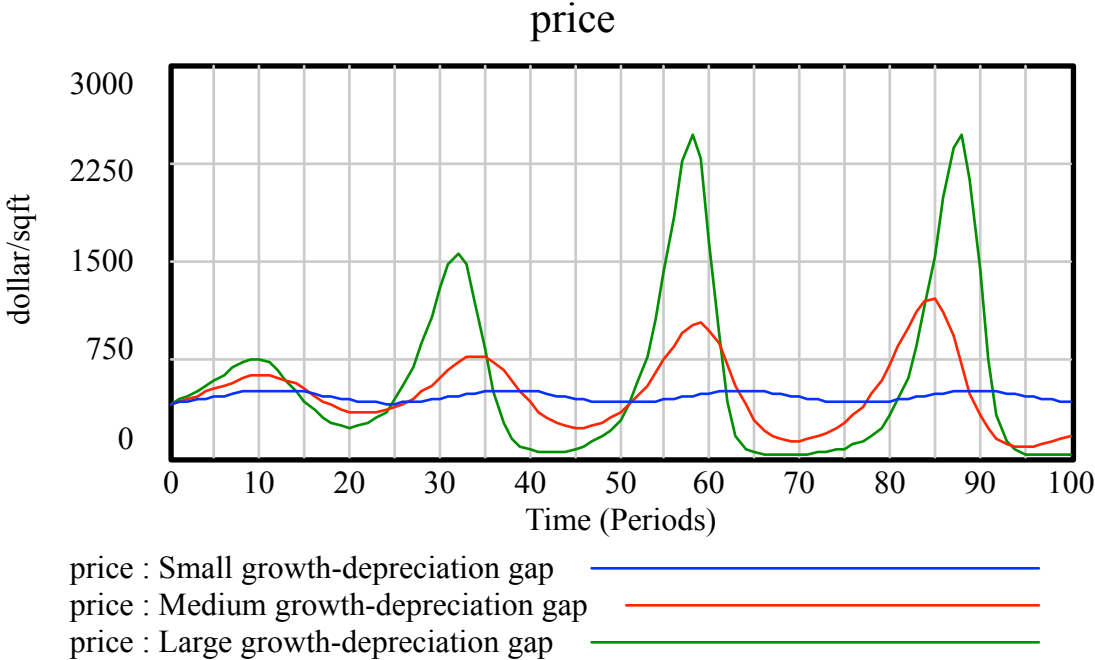


Figure 4-8 Stability of the SD3 model with regard to growth-depreciation relationship

### 4.5 Model SD4: Add Vacancy Rate and Construction Cost

In the Wheaton 1999 paper, the parameters of vacancy rate and construction cost are not included in the discussion to make the equations concise. However, here with SD baseline models, we can easily build those two parameters into the equations by slightly modifying Equations (2) and (5),

$$R_t = (S_t(1 - V_t)/\alpha_1 E_t)^{-1/\beta_1} \tag{2'}$$

$$C_{t-n}/S_{t-1} = \alpha_2(P_t - K_t)^{\beta_2} \tag{5'}$$

$V_t$  is the vacancy rate and  $K_t$  is the construction cost at time stamp  $t$ . Within the scope of this chapter, we assume that both parameters are exogenous to the model and have constant value. We will give a vacancy rate of 10% and construction cost  $K=100$  \$/sqft to run the simulation with SD1 model. We adjusted the value for alpha 1 and alpha 2 so that the system was initially at the equilibrium stage. The revised model is shown in Figure 4-9.

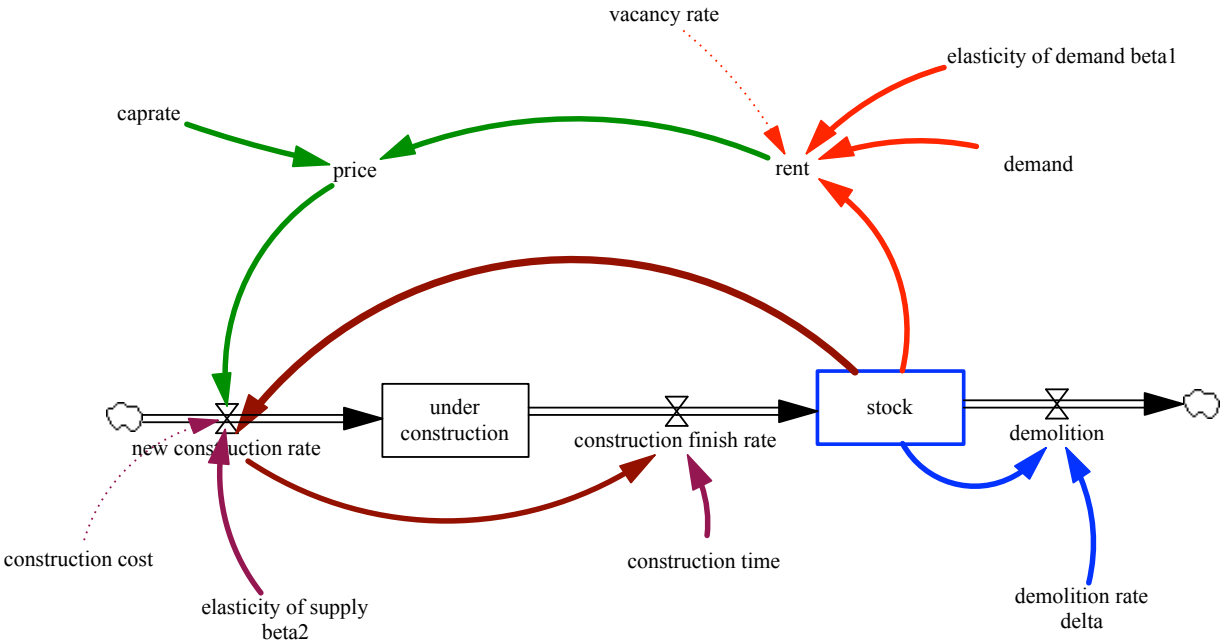
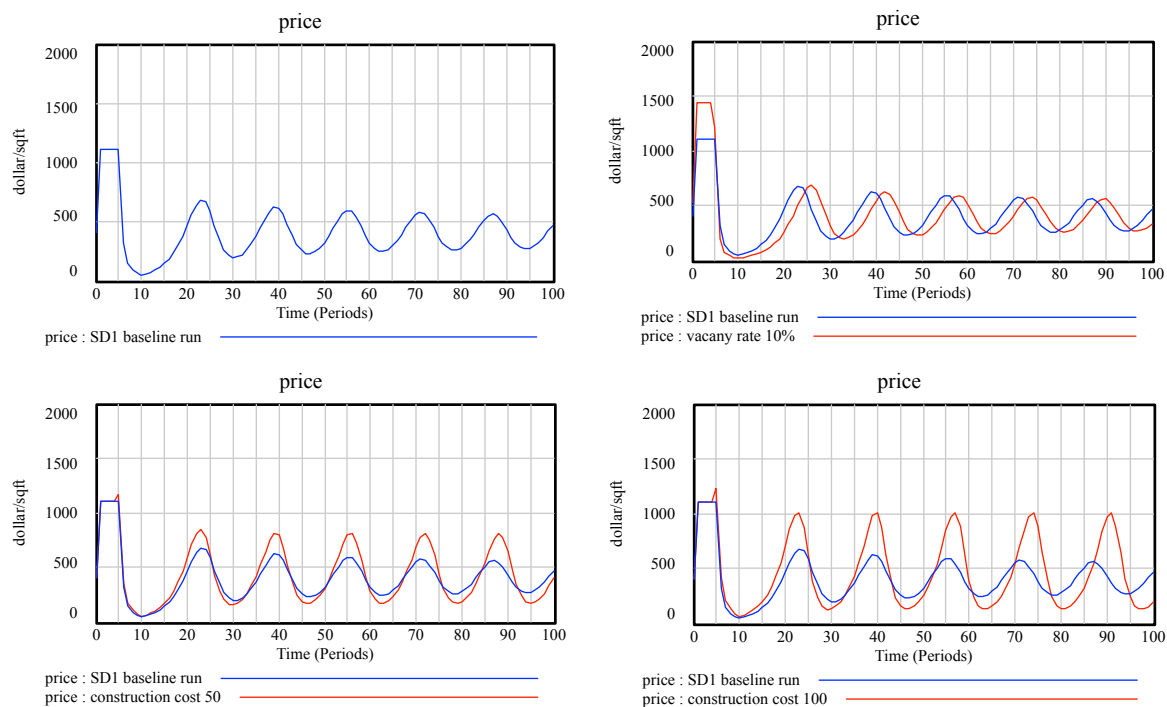


Figure 4-9 Model SD4: add vacancy rate and construction cost variables

When we introduced the demand jump, the simulation results are shown in Figure 4-10. It is important to note that the current change in Model SD4 only apply to the model equation change, the model structure is not modified and remains the same as in Model SD1.



Upper-Left: SD1 model baseline run - market reaction to a 50% demand shock (lag:  $n=5$ ; depreciation rate:  $\delta = 0.10$ ; demand elasticity =  $-0.4$ ; supply elasticity =  $2.0$ ); Upper-Right: baseline run vs. vacancy rate =  $0.1$ ; Lower-Left: baseline run vs. construction cost =  $50$ ; Lower-Right: baseline run vs. construction cost =  $100$

Figure 4-10 Model SD4: Introducing vacancy rate and construction cost components as exogenous variables

When we treat the vacancy rate as a constant variable, it will only affect the value of the first local maxima, but it will not affect the long-run cyclicity of housing price or the steady-state price. This is because the increase of vacancy rate can be seen as a reduction of initial stock, or, another jump of demand that is more than 50%. However, a fixed construction cost does affect the magnitude of the cyclic behavior as seen in the lower-left and lower-right graphs of Figure 4-10.

The higher the construction cost, the same-order minima and maxima display greater amplitude. This is because in the new construction rate formulation, an increase of construction cost induces a reduction of new construction rate, thus taking longer to fill the gap between current stock level and the desired stock level.

#### 4.6 Model SD5: Adding Income to the Demand Function

In Equation (1) of the stock-flow model, we have made an assumption that the relationship between the stock and the chosen exogenous economic variable (e.g. office employment  $E_t$ ) is known. The demand is simplified, or, operationalized by subsuming the income and number of household into a generalized demand. However, for the purpose of this thesis, it is more appropriate to change the definition of variable  $E_t$  in Equation (1).

$$E_t = \varphi * N_t * Y_t \tag{9}$$

where,  $N_t$  represents number of households,  $Y_t$  represents the average household income, and  $\varphi$  represents the average portion of household income (budget share) that is spent on housing. It is important to note that Equation (9) is a simple form of the traditional economic equation to quantify the demand, where there should be approximate elasticities associated with  $N_t$  and  $Y_t$  respectively. In short, Equation (9) assumes that the demand for housing is proportional to the sum of all households' income in the targeted housing area.

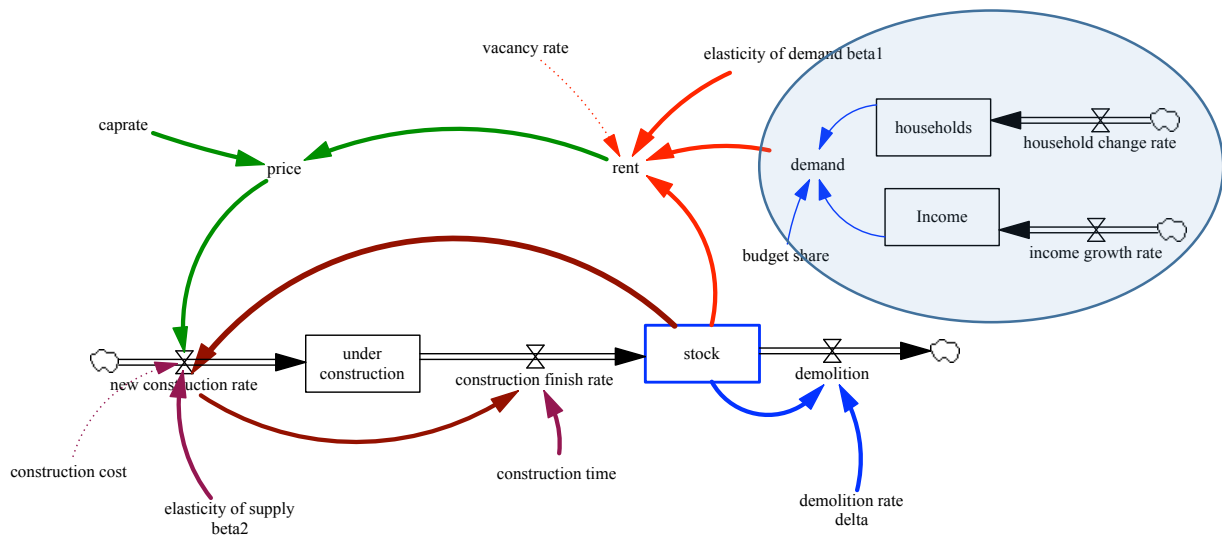


Figure 4-11 Model SD5: Adding income to the demand function

The Model SD5 is not used to run simulation and provide different results at this stage. It is a demonstration of how we treat the demand component. It is important to have the stage set up for the future chapter when the real world data are involved. The increase in the number of households in a city or region is largely due to migration, and the increase of household's income is due to regional or sectorial economic growth. Both factors are important to the housing market study but their growth rates are different, and the mechanisms boost their growth are different. For example, the housing purchase ability is normally for the households age between 25 to 55. The pattern of demographic transition is thus important to be used to model with the number of households that possess such purchasing power. That is why we should separate households and income parameters to simulate demand.

#### 4.7 The Baseline Models' Validation and Testing

After we constructed the baseline models SD1-SD5, we tested the models with SD validation standards described in Chapter 3.



### 1. Boundary Adequacy Tests

The boundary adequacy is proven in the original stock-flow model, and thus remains the same for all replicated models in this chapter. However, there are some important concepts and variables (e.g. land availability, vacancy rate, etc.) that should be included into the model boundary but have been currently left out for simplicity reasons. The behavior of the model could change significantly when such variables are incorporated. This aspect of boundary expansion process will be discussed in Chapter 5 when the baseline models are modified. As per the current baseline models, our goal is to replicate the stock-flow model of Wheaton 1999. We have so far included all of the key parameters in the original stock-flow model.

### 2. Structure Assessment Tests

The structure assessment for the baseline models are direct because we are translating directly from the stock-flow model. The model structures, causal diagrams, parameters and equations are consistent with the proven DiPasquale-Wheaton 4QM listed in their book "Urban Economics and Real Estate Markets" (1996), as well as Wheaton's stock-flow model (1999). The structure is consistent with the descriptive knowledge of the concept of a real estate system. Similar structure is also confirmed in Geltner et al. (2014). In terms of unit of analysis, it is a macroeconomics model and the level of data aggregation at city or national level is appropriate.

### 3. Dimensional Consistency

The dimensional consistency, or "units checking" is not required at this stage. This is because parameters such as  $\alpha_1$  and  $\alpha_2$  are used for scaling and balancing the units but without actual meaning. Other parameters with real world meaning are in their common units as listed in the Appendix of this chapter.

### 4. Parameter Assessment

The numerical values of the model parameters are based on the simplified data from the US aggregate office market used in the Wheaton stock-flow model. They are semi-hypothetical data and the values are within a reasonable range according to recorded

historical data. Parameters such as demand elasticity and supply elasticity are estimated based on work from other researchers (Wheaton, Torto and Evans, 1997; Wheaton and Rossoff, 1998).

#### 5. Extreme Conditions

The SD models are also tested with extreme conditions, meaning each equation makes sense even when its inputs take on extreme values. For example, when demand is zero, or when the housing stock is infinite, then the rent and housing price would be driven to zero. It is also important to know that the initial status of each model is at equilibrium. In other words, when the demand remains unchanged (without a step jump or exponential growth), the system will remain at equilibrium stage.

#### 6. Integration Error

The simulation results remain unchanged when the the time stamps of simulation are reduced.

#### 7. Behavior Reproduction

The SD models indeed reproduce the cyclical behavior as observed in the housing market. That came as no surprise as purpose of this step is to exactly replicate Wheaton's stock-flow model.

#### 8. Behavior Anomaly

So far the simulation results of SD1-SD3 mimic the research findings of stock-flow model. There are no abnormal or unexpected results observed.

#### 9. Family Member

The initial Model SD1 is built to analyze office market, but it can be also used to analyze housing market and industrial property market.

#### 10. Surprise Behavior

Because it is a replication process, there is no surprise behavior observed.

## 11. Sensitivity Analysis

The models SD1-3 demonstrate that the system's oscillation behavior is highly sensitive to construction time, demand-supply elasticities, as well as the growth-depreciation gap. It is also the research findings in Wheaton (1999).

## 12. System Improvement Tests

The 4QM is in its most concise form because some important parameters are excluded or simplified in order to build a canonical model. It helps to explain the formation of real estate market cycles. In the following chapters, we modify this original model and identify the policies that have a positive impact on the housing market such as reducing market volatility, avoiding asset bubbles, etc.

### 4.8 Summary of the Chapter

Chapter 4 conducted the first step of the research design and translated 4QM and its stock-flow version into a system dynamics model. The variables marked in red are newly added onto the original causal look diagram (as in Figure 4-1.)

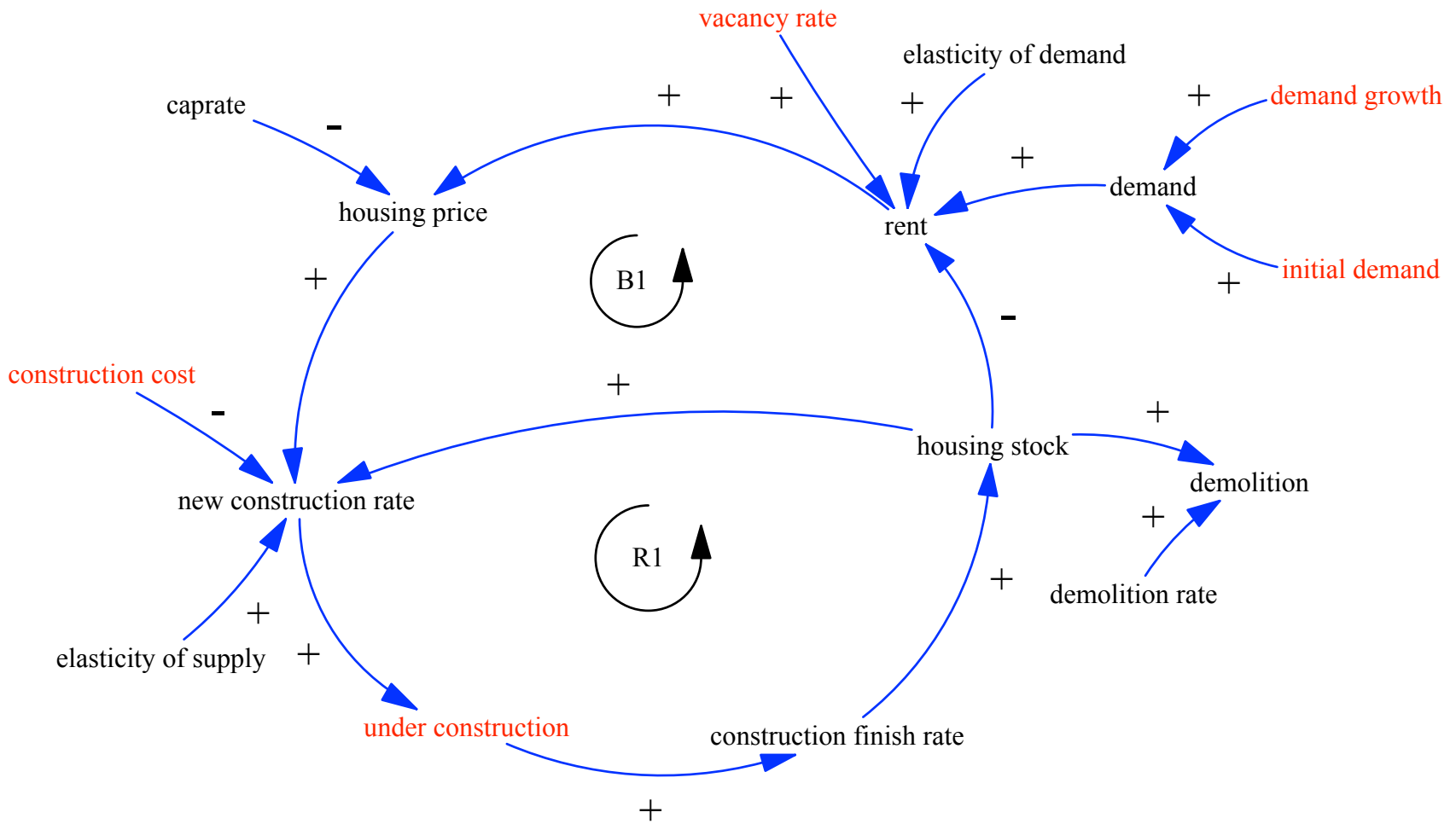


Figure 4-12 Causal loop diagram at the end of Chapter 4

A summary of the set of Model SD1-SD5 is shown in Figure 4-2. It lists the parameter of the model we modified, how we have modified, which benchmark baseline model it is compared to, and its contributing effect on market volatility. A (+) sign indicates that the parameter positively contributes to the market volatility, such as higher amplitude of local maxima and minima of the cycles, or longer cycles. A (-) sign indicates that the parameter negatively related to the market volatility, meaning, they can prevent the market cycles from occurring. An (n) sign indicates that the impact of the parameter is neutral.

Model	Parameter	Description of the Model Modification and Main Findings	Compare to	Volatility
SD1	Economic Shift	The real estate market cycles are endogenous when facing an external shock. The cycles are sensitive to construction delay, supply and demand elasticities, and growth-demolition rate.	Benchmark	+
SD2	Investors' forward looking Behavior	Instead of having myopic investment behavior, if the investors are forward-looking and take into account of the construction in the pipeline, then the housing market cycles tend not to occur.	SD1	-
SD3	Demand Growth	When the model is driven by steady demand growth, the gap between growth rate and demolition rate impacts how volatile the cycles are. When the gap is large (i.e. higher growth rate, or bigger demolition rate), then the housing cycles have higher volatility.	Benchmark	+
SD4	Natural Vacancy	A constant natural vacancy rate will not affect the long run cyclicity of housing price.	SD1	n
SD4	Construction Cost	The higher the construction cost, the more volatile the housing price is.	SD1	+
SD5	Income Growth	Growth in income and growth in the number of households should be separated. Since income growth is a positively contributing component of demand growth, it increases market volatility.	SD3	+

Table 4-2 A summary of Model SD1-5 and their relationship to market volatility

#### 4.9 Commonly Used Variables and Formulations in the Baseline Models

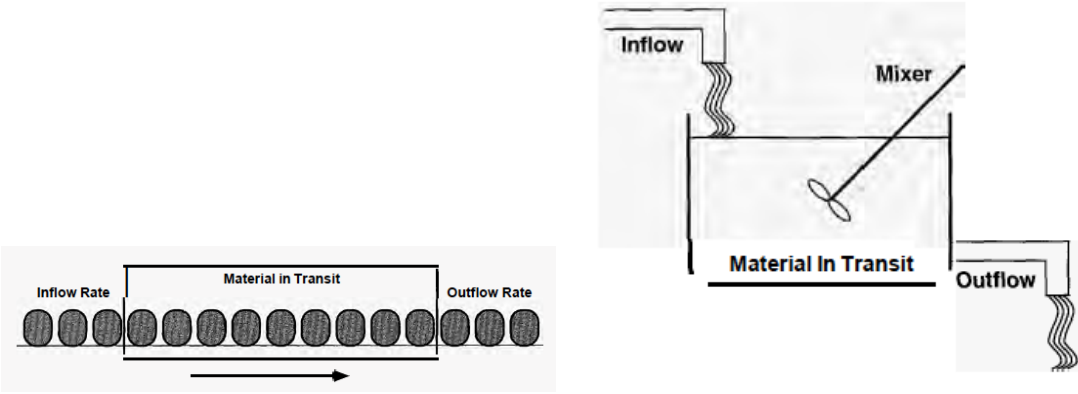
	Variable	Formulation and Comments	Units
$\alpha_1$	Alpha 1	= equilibrium rent ^ elasticity of demand beta1*initial stock/initial demand	NA
$\alpha_2$	Alpha 2	= demolition rate delta/equilibrium price ^ elasticity of supply beta2	NA
$\beta_1$	Elasticity of demand beta1	0.4	Dmnl (dimensionless)
$\beta_2$	Elasticity of supply beta 2	2	Dmnl
$\gamma$	Cap Rate	0.05	Dmnl
$\delta$	Demolition rate delta	0.05 or 0.1	Dmnl/period
$\eta$	Economic growth rate	Various values	Dmnl
$\varphi$	Portions of household income spent on housing	1/3 (hypothetical)	Dmnl
$C_{t-n}$	New construction rate	= stock*alpha2*(price-construction cost)^elasticity of supply beta2	Sqft/period
$C_t$	Construction finish rate	= DELAY FIXED (new construction rate, construction time , initial stock*demolition rate delta)	Sqft/period
$E_0$	Initial demand	10 million	People
$E_t$	Demand	1e+06*(10+STEP(5,1))	People
$K_t$	Construction cost	50 or 100	Dollar/sqft
$n$	Construction time	5 or 8	Periods
$N_t$	Number of households	Use historical data in the next chapter	Households
$P_t$	Price	=rent/caprate	Dollar/sqft
$R^*$	Equilibrium rent	20	Dollar/sqft
$R_t$	Rent	=(stock*(1-vacancy rate))/(alpha1*demand))^(1/elasticity of demand beta1)	Dollar/sqft
$S^*$	Equilibrium stock	2500 million	Sqft
$S_p$	Under construction (or pipeline construction)	=INTEG (new construction rate-construction finish rate, initial stock*demolition rate delta*construction time)	Sqft
$S_t$	Stock	= INTEG (construction finish rate-demolition, initial stock)	Sqft
$S_t * \delta$	Demolition	= stock*demolition rate delta	Sqft/period
$V_t$	Vacancy rate	0.1 (hypothetical)	Dmnl
$Y_t$	Average household income	Use historical data	Dollar/household

Table 4-3 Commonly used variables and formulations in the baseline models

# 5 Generic Market Features That Needs to Be Addressed

## 5.1 Delay Mechanism in the Construction Industry

In real estate industry, a construction delay is the process whose output (construction finished units) lags behind the input (construction starting units) in some pattern. In general, the assumption is made as in Wheaton (1999) that the construction delay in the real estate industry can be modeled with pipeline delay structure: individual items exit the delay queue in the same order they entered and after exactly the same processing time. In general, the delay patterns can be pipeline delay structure, or first-order material delay structure, or higher-order material delay structure. Unlike the stock-flow model, the SD model can more explicitly depict causal flows and processes that govern the system. The comparison of pipeline delay and first-order delay structures is shown in Figure 5-1.



Left panel: pipeline delay structure; Right panel: first-order delay structure. The key difference resides in the relationship between 'Material in Transit' and 'Outflow'. Image source: Sterman (2000)

Figure 5-1 Pipeline delay structure vs. First-Order delay structure

However, should pipeline delay structure be the optimal delay structure to model the construction industry? DiPasquale and Wheaton (1996) discussed how supply schedule for new construction can be shifted. Higher short-term interest rates and stricter zoning

and building regulations will decrease the level of new construction at the same price level. Combining real options analysis and game theory, Grenadier (1996) found that for the development projects that already started, the developers tend to rush for early completion while the housing price is rising, and tend to delay completion time when the price is dropping, waiting for the price to bounce back. Similar delay pattern also applies to the finished real estate projects. When market is not performing, the developers who do not have cash-flow issues can choose to hoard the finished units from sales to the market.

Suppose the real estate system does not exhibit construction delay as modeled by the pipeline structure. Instead, suppose that greater volume of construction corresponds to periods when there is more pressure and incentive to complete projects quickly, resulting in a construction completion rate that is proportional to the stock of property under construction. This is what in SD terminology is called a '*first-order material delay*' structure and it is used to model the construction delay.

In Sterman (2000), he discussed the boom and bust of the commercial real estate markets. The causal structure is shown in Figure 5-2. As we can see, the construction delay is modeled as a first-order delay structure, instead of a pipeline structure. In reality, this is a reasonable assumption due to the constraint of construction resources in one region. Such resources cannot follow the exact schedule of the pipeline structure as determined by the developers' investment expectations (Sterman 2000). Also, there are mixed types of housing properties that require different lengths of construction time. Making assumptions that they will start and finish at the same time is not realistic.



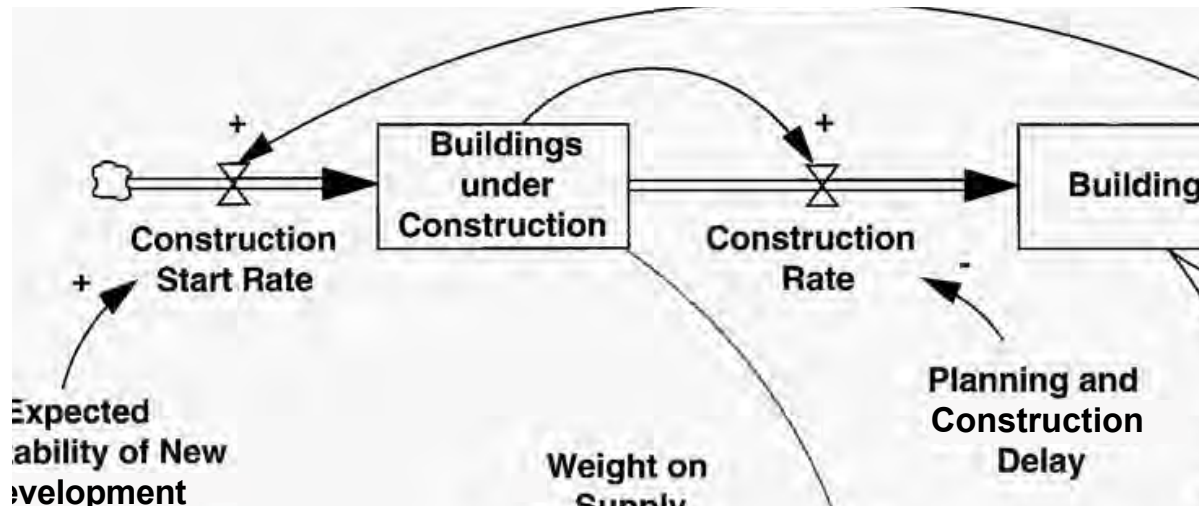
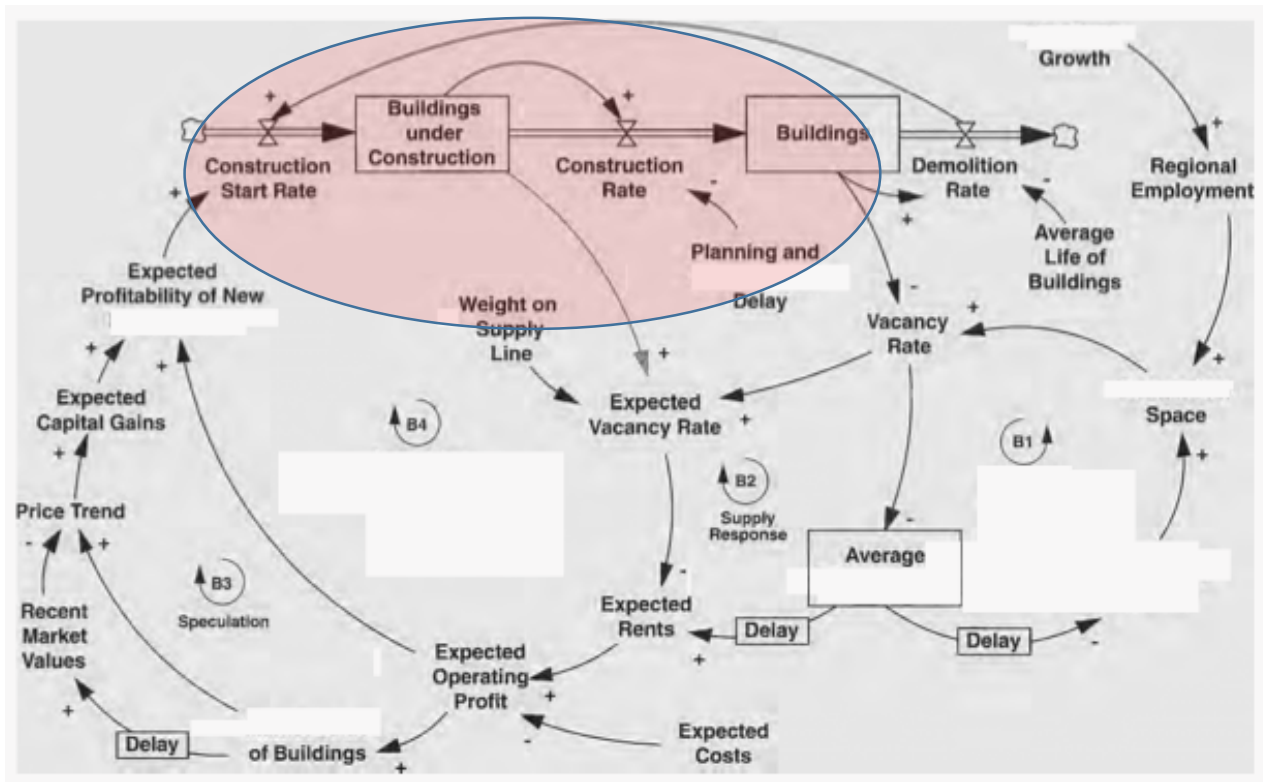


Figure 5-2 Modeling construction pipeline in Sterman (2000)

Since the thesis is concerning the Chinese housing market, we can take a look at the construction starting and finishing rate data collected from the China Statistical Yearbook that are shown in both Table 5-1 and Figure 5-3. As we can see, there is really not a solid pipeline delay structure demonstrated.

Units (10,000 sqm)						
Year	Real Estate Under Construction	Real Estate Finishing Rate	Real Estate Starting Rate	Housing Under Construction	Housing Finishing Rate	Housing Starting Rate
2005	304,904	118,125	158,373	166,143	66,141	87,896
2006	345,152	120,705	190,494	187,898	63,046	101,307
2007	414,941	134,247	208,416	226,159	68,820	112,579
2008	489,110	147,066	235,313	269,918	75,969	118,090
2009	577,357	164,539	293,561	312,039	82,101	146,650
2010	706,379	175,427	386,111	376,588	86,879	176,020
2011	917,063	226,020	370,678	465,729	102,513	153,581
2012	1,061,721	241,315	406,639	516,797	107,327	163,649
2013	1,227,045	257,234	282,075	573,119	107,375	128,580
2014	1,251,886	264,780	206,887	594,324	108,775	94,306
2015	1,193,993	265,656		579,855	100,357	

Source: China Statistical Yearbook 2016, Form 10-16

Note: Construction starting rate (n) is calculated by using the following formula  

$$\text{Under construction (n+1)} - \text{Under construction (n)} + \text{Construction Finishing rate (n)}$$

Table 5-1 Construction starting rate, finishing rate, and under construction (2005-2015)

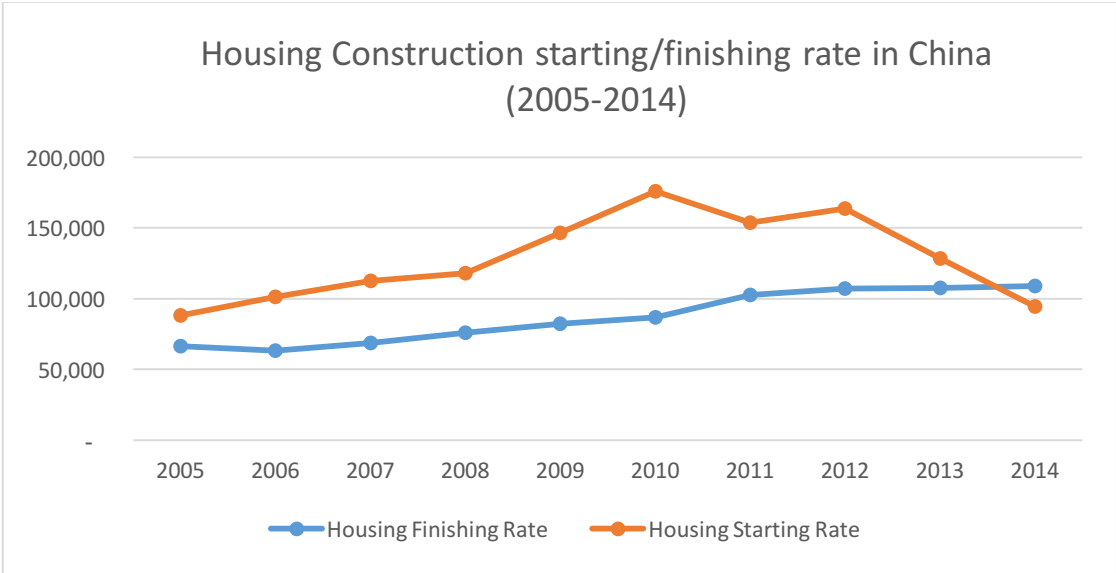


Figure 5-3 Housing construction starting and finishing rate in China (2005-2014)

## 5.2 Information Delay in the Asset Market

Different from the traditional economics theory where all human behavioral changes are being rationalized, in behavioral economics, a few scholars have observed the complications in the abnormal behavior of the market participants who may not be the simple utility maximizers. For example, 'loss aversion' appears to manifest itself in investors' behavior, as a reluctance to sell shares or other equity, if doing so would result in a nominal loss. It is similar to the concept coined by Thaler (1980) as 'endowment effect'. This helps to explain why housing prices rarely/slowly decline to market clearing levels during periods of low demand. Genesove and Mayer (2001) used data from downtown Boston in the 1990 to show that 'loss aversion' determines the condominium sellers' behavior in the housing market, and they set higher asking prices compared to the original purchase price and exhibit a much lower sale chances than other sellers.

The delay between the market information comes out and the time that developers accept such information is called information delay. Such delay would affect the investment decisions. It is as if the investors were making investment decisions based on past price information. The price change in the housing market may not be efficiently and quickly delivered to all developers due to the market transparency and market inefficiency. Even if such information is quickly delivered to the developers, they will still have an adjustment process to digest the information and make investment decisions. This process is referred to as adaptive expectations or exponential smoothing to reflect the fact that people do not change their belief immediately upon receiving new information. It is also a process where investors hesitate to make investment decisions due to market uncertainty.

## 5.3 Supply Constraint in the Land Market

Geography is a key factor of land supply constraint. Through satellite-generated data, Saiz (2010) has shown that the residential development is effectively curtailed by

geographic terrain and bodies of water. Peng and Wheaton (1994) empirically examined the effect the land supply on housing price in Hong Kong. The results show that land constraints in Hong Kong have caused higher housing price as well as higher housing output.

Other land-supply constraints for new housing development are imposed by the national, regional, and local planning regimes which regulate the supply of land (Bramley, 1999), although Aura and Davidoff (2008) found that loosening regulatory constraints such as zoning in individual cities would have little effect on housing prices, and large price effects would have to be based on coordinated efforts to manage constraints across markets.

Green et al. (2005) mentioned that in the absence of land constraints, the housing market should be able to absorb increases in demand more rapidly, as the assumption of elastic supply holds. However, when land supply is constrained, at least in short term, the supply will not be perfectly elastic. They also hinted that the discussion of land supply is essential and should be incorporated to the DiPasquale and Wheaton model.

#### **5.4 Investment Inflow in the Capital Market**

Another issue that is commonly discussed regarding the traditional D-W 4QM model is that the cap rate is considered as exogenous. However, in the real estate “system dynamics model” created by Geltner et al. (2014), the market required cap rate in the commercial real estate market is actually endogenous. It is determined by the supply (owners selling) and demand (investors buying) in the asset market as shown in Figure 5-4.

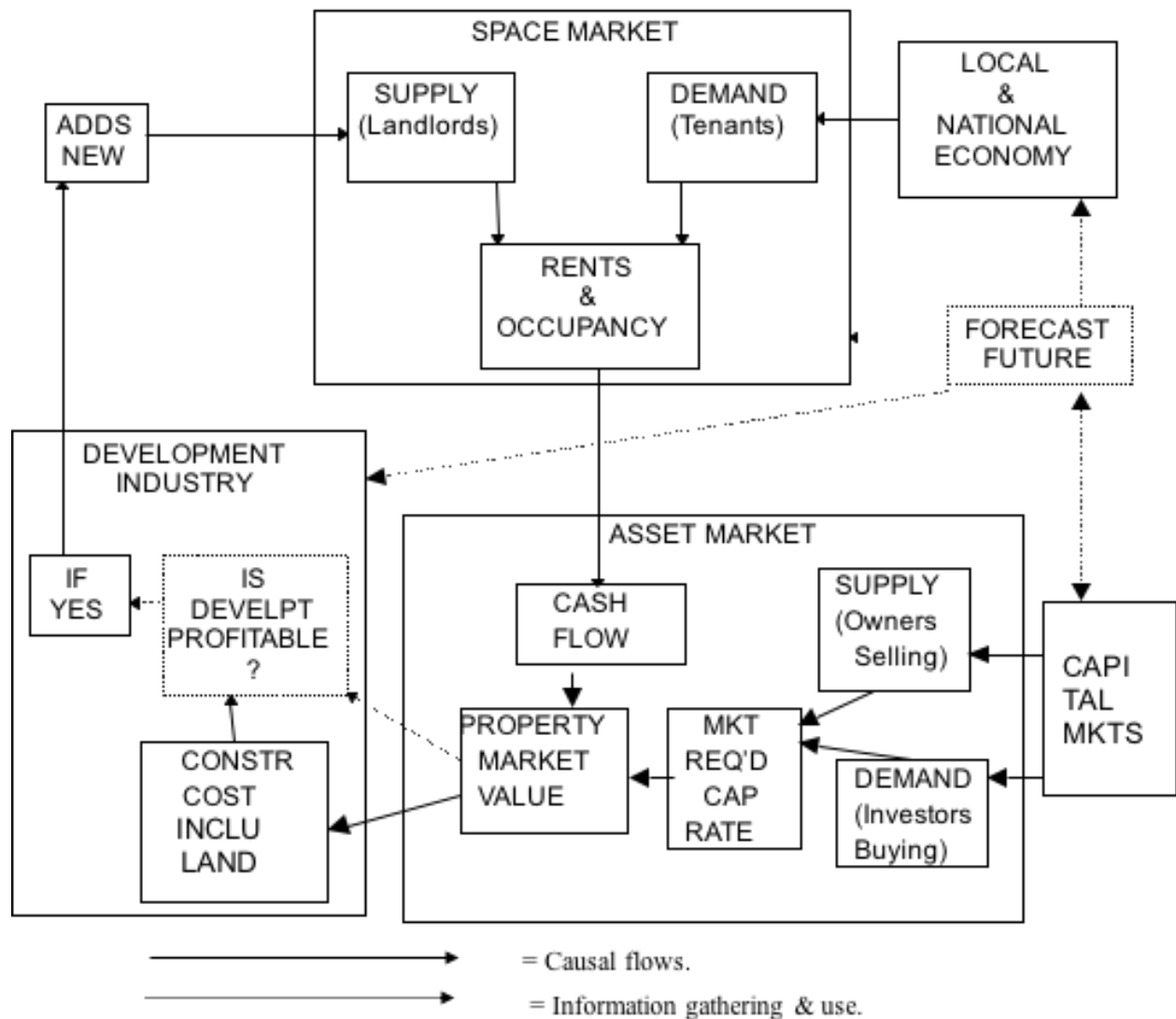


Figure 5-4 The real estate system: interaction of the space market, asset market, and development industry (Geltner et al. 2014)

For example, when the rent level drops, it may be due to the fact that new supply of housing stock created excess supply in the space market. As a result, the investors will cut back from investing in the housing industry due to the expected future reduction of rent. Or, they will ask for higher returns (i.e., a higher cap rate), reflecting the higher risk of investment. Similarly, if the rent level is growing, more investment capital will flow into the housing sector and push down the cap rate.

Several econometric analyses have told us that the cap rate and rent growth rate should be negatively correlated (Hendershott and MacGregor, 2005; Clayton, Ling, and

Naranjo, 2009). That means that instead of being exogenous, cap rate should be an endogenous parameter in the housing model and demonstrates an inverse relationship with rent growth.

## 6 Step Two – Generic Model Modification: Alternative Assumptions

Along with Chapter 5, the objective of Chapter 6 is to address the first research question of this thesis: “Can SD methodology be used to complement and extend upon the findings of urban economics models, such as D-W model?” This chapter demonstrates how SD models can improve upon the traditional economic models and lead to new research findings by altering some of the underlying assumptions. To do this, we created a set of alternative generic models (SD6-SD9) by modifying the structure, equations, or adding new parameters. They are called “generic models” because the modifications are designed to make the model more representative of the housing market in general and are not specific to the Chinese context. Also, the components that have been modified, either adding time delay, land constraint, or cap rate change, are rational modifications. Their value can be measured and represented by market fundamentals.

It is important to point out that Model SD6 through Model SD9 are distinct from each other, and are not built incrementally. Each alternative model is modified by changing only one part of the baseline models that are created in Chapter 4. The baseline model can be either Model SD1 or Model SD3 from Chapter 4, depending on the different assumptions we made on the demand increase: the demand assumption in Model SD1 is a finite sudden shift, while in Model SD3 is an infinite steady growth. The newly created models SD6-SD9 are mapped on top of the 4QM as in Figure 6-1. They spread on the side of Asset Market:

- Model SD6: Explores an alternative delay pattern in the construction sector;
- Model SD7: Explores the information delay caused by the price adaptation process;
- Model SD8: Introduces land supply considerations into the model and analyzes how the constraint of land and new land creation strategies affect the model;
- Model SD9: Explores price behavior when the cap rate is linked to the rent growth.

## The DiPasquale-Wheaton Four Quadrant Model

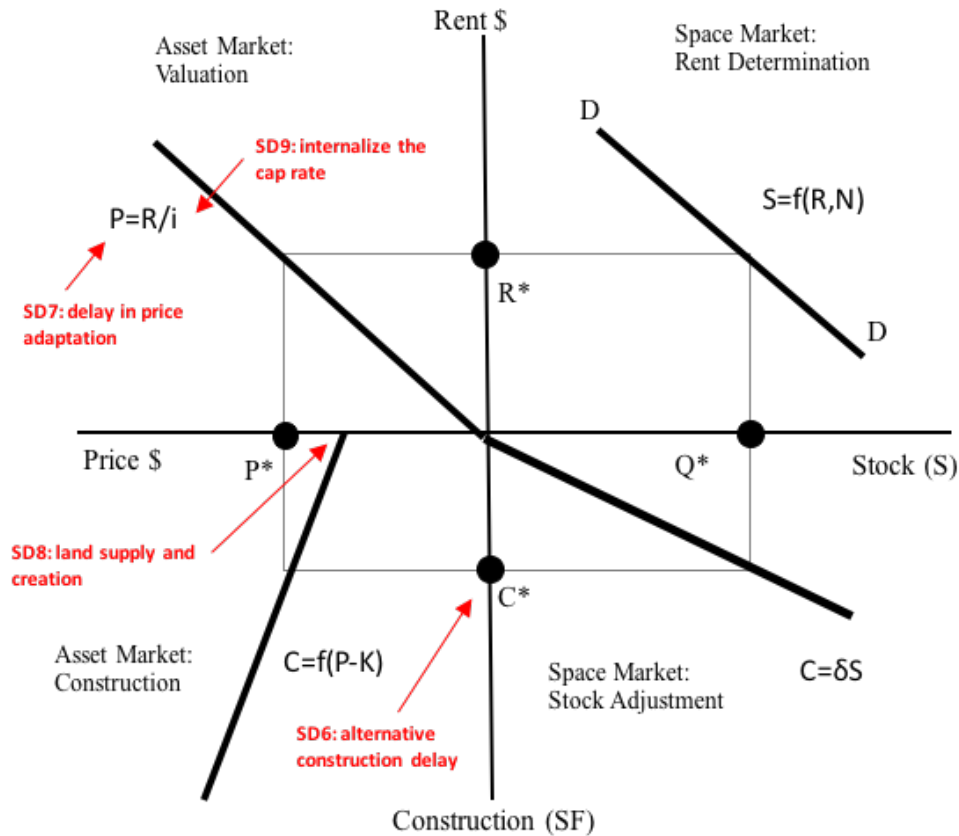


Figure 6-1 Mapping generic models SD6-SD9 on the 4QM

By examining the change in behavior of the model under specific altered conditions compared to the baseline model, we can determine alternative assumptions that need to be made in order for the housing market to demonstrate cyclic behavior. We can also decide which components have the reinforcing impact on the market volatility, and which components can be used to balance such volatility. Those reinforcing components, when combined with other reinforcing components, may have escalating effects on market volatility. Those balancing components, can be used to incorporate into the new policies as mitigating strategies.



## 6.1 Model SD6: Delay Mechanism in the Construction Industry

### 6.1.1 Pipeline Delay vs. First-Order Delay

Model SD1- 4QM baseline model, shown in Chapter 4 enables us to see that the construction process in Wheaton (1999) implicitly assumes what in system dynamics is called a '*pipeline delay structure*'. In the pipeline structure, individual items exit the delay queue in the same order they entered and after exactly the same processing time. The type of oscillation found in the Wheaton (1999) stock-flow model relies on the assumption that construction process follows the pipeline structure.

### 6.1.2 Model Description and Simulation Results

Figure 6-2 shows how the first-order delay structure is accommodated in the SD6 model. The modification from baseline model is circled by an oval outline. The “under construction” variable is used as a device to count all the housing units that are under construction at each point of time. The exit rate, or construction completion rate, equals the “under construction” stock amount divided by the construction time. The visual difference of Model SD6 from Model SD1 is that the arrow coming into the “construction finishing rate” is no longer directly from the the “new construction rate” but from the “under construction” box.

To see how this differs from the pipeline delay structure, consider a simple example. Construction starts at beginning of years 1,2,3,4 are 1,2,0,0 million square meters respectively and the pipeline lag is 2 years, leading to a pipeline completion rate of 0,0,1,2 M m<sup>2</sup> at the beginnings of the years, respectively. But the amount of construction in process at the beginning of each year is 1,3,2,0 M m<sup>2</sup> respectively. This would result in first-order delay completion rates of 0.0, 0.5, 1.5, 1.0 M m<sup>2</sup> in years 1,2,3,4 respectively, instead of the original completion rates of 0,0,1,2 in the pipeline delay structure.

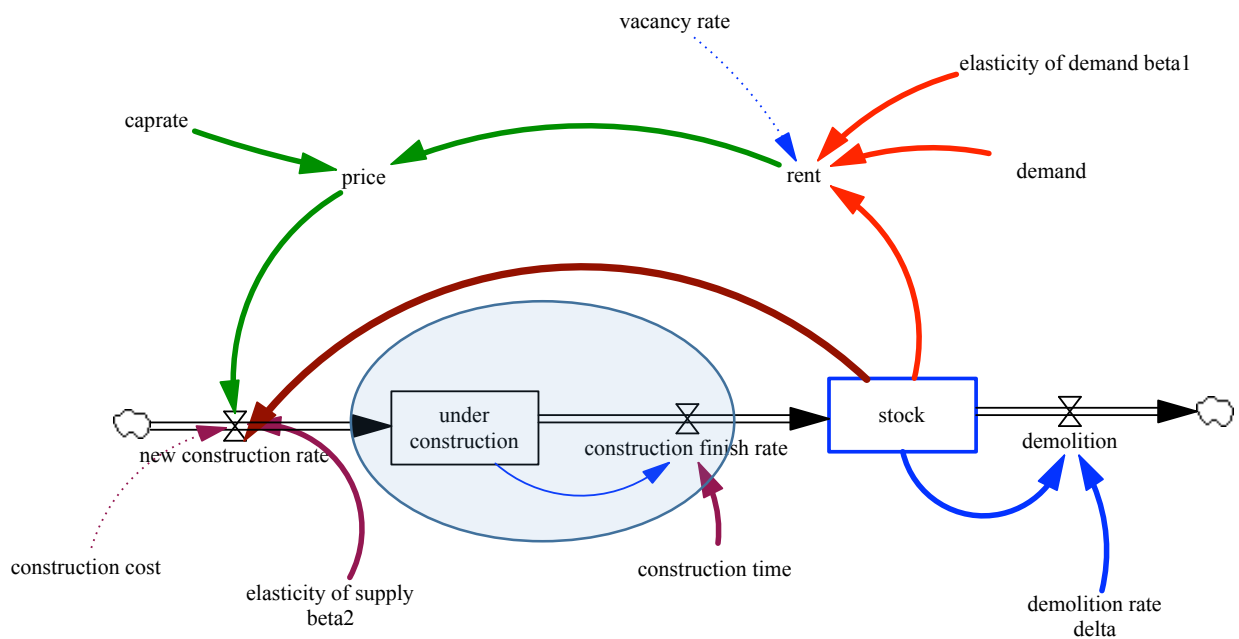
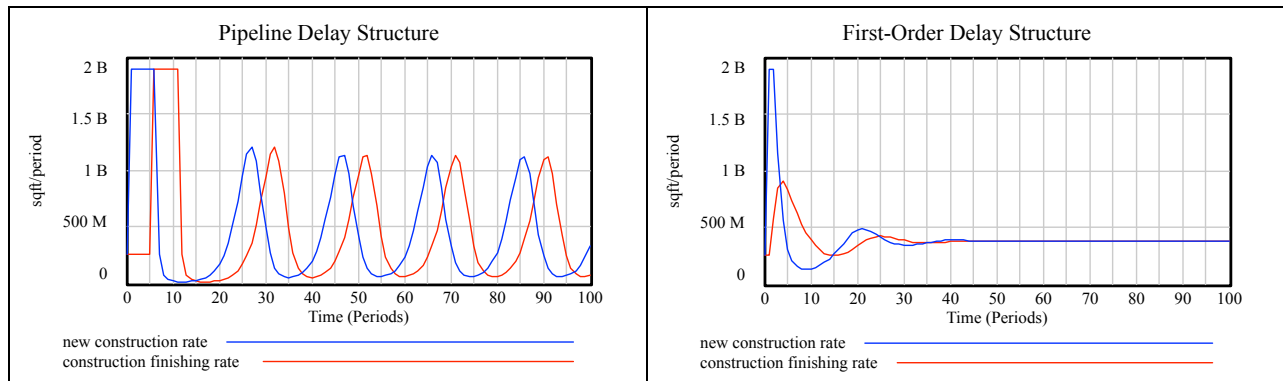


Figure 6-2 Model SD6: Construction delay switches from pipeline structure to first-order delay structure

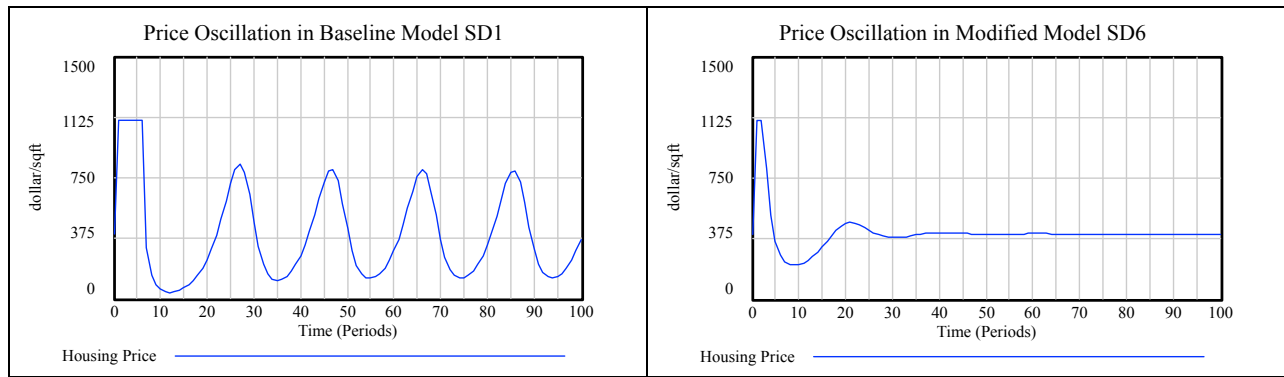
Figure 6-3 shows the differences in graphs between a pipeline delay structure that is simulated by Model SD1 in Chapter 4 and a first-order delay structure simulated by Model SD6, with exactly the same input for all system parameters. In the pipeline delay structure (left panel), the construction finishing rate trails the new construction rate exactly 5 time periods later. Under the same setting, the first-order delay structure (right panel) avoided the 5 time periods delay and have construction finished starting from time period 1. In the long run, the first-order delay structure can result in a more stable system in the construction industry.



Pipeline delay structure (left panel) vs the First-order delay structure (right panel). Market reaction to a 50% demand shock (lag:  $n=5$ ; depreciation rate:  $\delta = 0.10$ ; demand elasticity =  $-0.4$ ; supply elasticity =  $2.0$ )

Figure 6-3 Construction starting and completions based on pipeline delay structure vs the first-order delay structure

Simulation results in Figure 6-4 confirms that the dampening of the price oscillations resulting from change of delay structure assumption. With the first-order delay structure the first local maximum exhibits the same initial price jump, but after that the system shows a less local minimum and less oscillation and reaches a steady state price much more quickly. This is because with the first-order delay structure, more finished construction is delivered to the market sooner and thus triggers the price to drop earlier than with the pipeline model, where finished construction won't be delivered to market till the end of construction period. Further, this earlier price drop will reduce the "myopic" type of new construction starting rate in the future. What has been found above implies that with one assumption change, the major finding of Wheaton model for the US office market, the corn-hog cycle, disappeared.



Left panel: price simulation with Model SD1; Right panel: price simulation with Model SD6 under the same parameter setting after the construction delivery structure is changed to first-order delay structure. (Market reaction to a 50% demand shock, lag:  $n=5$ ; depreciation rate:  $\delta = 0.10$ ; demand elasticity =  $-0.4$ ; supply elasticity =  $2.0$ )

Figure 6-4 Price oscillation reduced significantly when construction delivery structure is changed to first-order delay structure

### 6.1.3 Policy Implications

The reality is that the cyclic behavior does exist in the real estate market. Assuming that the proven DiPasquale-Wheaton is correct, the simulation result of Model SD6 suggests that the implementation of certain policies aimed at altering the construction schedule could help achieve and/or maintain a stable price. Policies guiding the construction industry schedule can help to reduce market volatilities. Even without policies, the construction industry can still behave in a streamlined manner and it is attributed to a set of real options related strategies.

De Neufville and co-authors (2006, 2008, 2011) have advocated incorporating the concept of “Flexibility in Engineering Design” into large real estate projects. Flexibility in engineering design promotes the idea of hedging downside risks and taking advantage of up-side opportunities through actively engaging real options analysis during the project development phase. It can be seen as one type of construction streamlining that includes the following options:

- Project delay option: Choose when to start a project.
- Modular production timing option: Start and pause project at any time and recommence later (or abandon).

- Phasing option: The project phase can be parallel or sequential. Once a phase started, it must be completed, but the start of any other phase can be delayed or abandoned.
- Expansion option: The project can be expanded horizontally (when there is land bank), or vertically (requires permits) at a later stage.

The benefits of flexibility in design can be simulated with a simplified model. We know that in the baseline model, the equilibrium price is 400\$/sqft. Now we modify the parameter of “construction time” in Model SD6. It is no longer a constant of 5 periods. We inserted the following logic:

Construction time = IF (Price>600\$/sqft, n=2, n=8)

When price is relatively high compare to the long run equilibrium price (i.e. 600\$/sqft), then the construction is faster with average construction time of 2 periods; when price drops below 600\$/sqft, the construction is slower, with average of 8 periods. As we can see from the simulation results in Figure 6-5, the peak price drops faster and the price at trough is higher than the base run case.

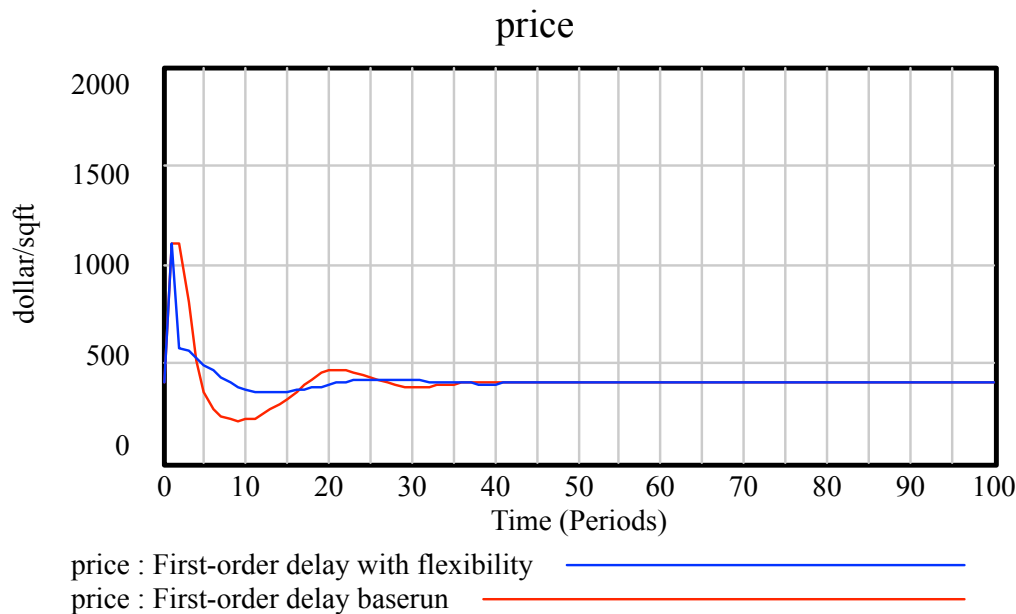


Figure 6-5 Construction time is flexible vs fixed

In summary, policies can be made to promote the concept of flexibility in design into the construction phase of housing development. This enables the project to react to exogenous changes in the economic environment. Such policies might include provisions to streamline construction during periods of rapid housing demand growth, and/or to enforce a reduced rate of development when and where housing demand is not growing so fast.

## 6.2 Model SD7: Delay Mechanism in the Adaptive Expectation Process

### 6.2.1 Perceived Price: The Adaptive Expectation Process of Price Change

In system dynamics literature, the discussion of the price-setting process is different from in the economic literature. In the classic economic literature, price-setting is immediate and is determined by the equilibrium price and a function of the supply-demand relationship:

$$P = P^* * f(s, d)$$

Where  $P$  is price,  $P^*$  is equilibrium price,  $f(s, d)$  represents the supply-demand relationship.

By contrast, the SD literature takes a different approach. Sterman (pp814, 200) suggested that the expectations about price are strongly conditioned by past prices and can often be modeled by adaptive expectations. In other words, there is a discrepancy between the actual price in the market and the perceived price by the key market stakeholders. There is an adjustment process for such discrepancy to reduce to zero when actual price and perceived price coincide.

### 6.2.2 Model Description and Simulation Results

As we can see in Model SD7, the only change is the loop at northwest corner that we added regarding the price change. It is the delay process from price adaptation that we

added. The adjustment time is set to be 2 periods for the investors to adapt to the new price into their investment decisions. The adjustment time can either represent the sum of time spent for the new price information to arrive at and accepted by the developers.

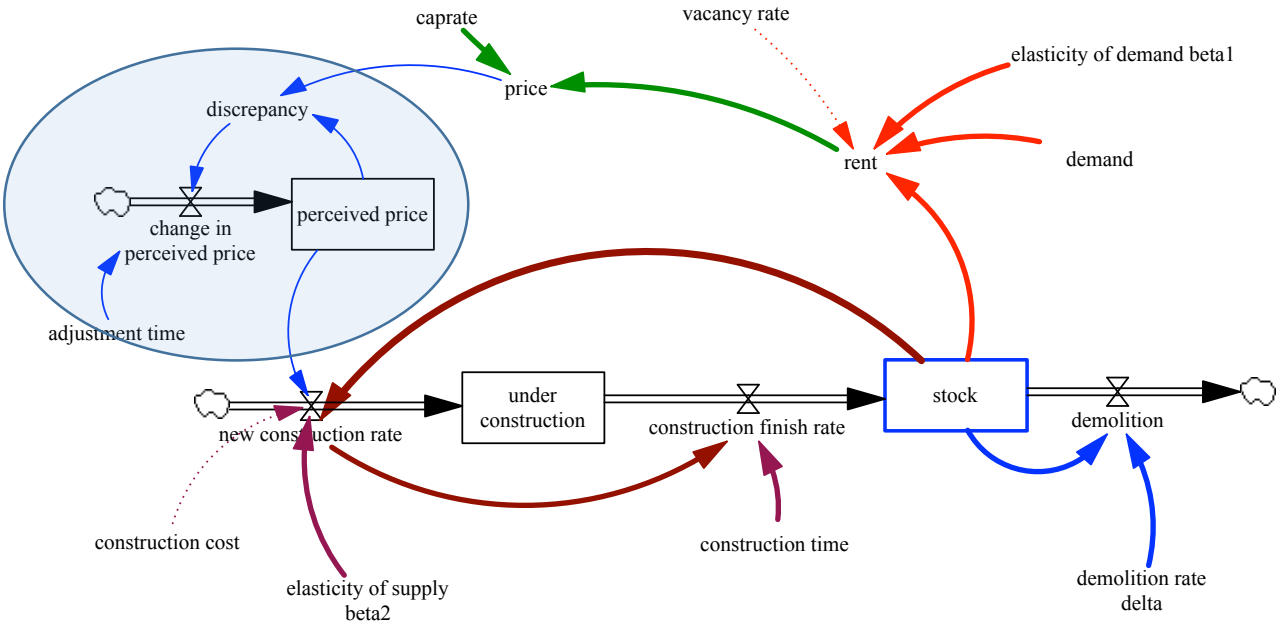
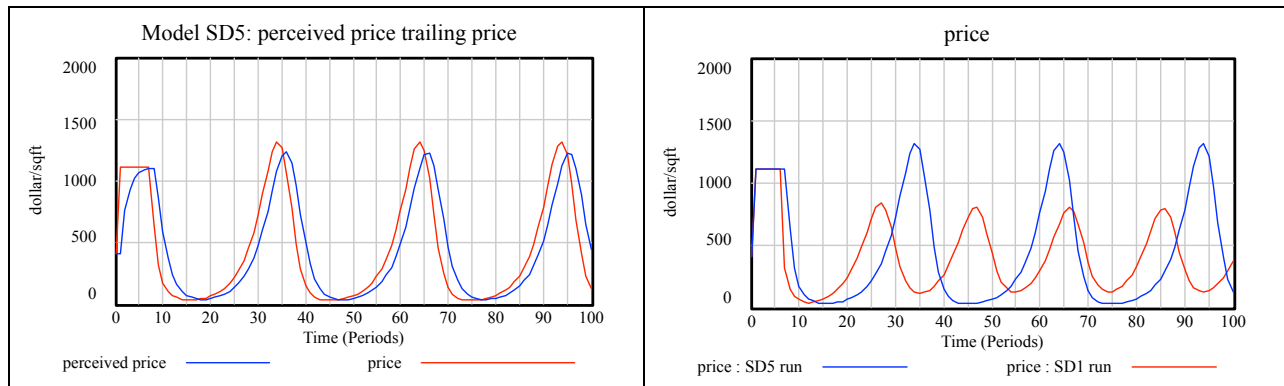


Figure 6-6 Model SD7: Incorporate "adaptive expectations on price change" component

The simulation result is shown in Figure 6-7. In the left panel, we can see that the perceived price trails the actual price by an adjustment time of 2-time period. In the right panel, we can see that the housing cycles become more volatile due to the delay from the price adaptation process. It is because such delay and the time delay in the construction process, both actively hindered the ability of the construction process to catch up with the demand change at the beginning, resulting in a temporal higher price spike at the first local minima (compare to Model SD1). In turn, such a high price spike will lead to large amount of new construction initiated during both delay periods, and results in larger swings in the oscillation. The effect is essentially the same as simulate SD1 model with a construction time of  $n=7$  instead of  $n=5$ .



Market reaction to a 50% demand shock (lag:  $n=5$ ; depreciation rate:  $\delta = 0.10$ ; demand elasticity =  $-0.4$ ; supply elasticity =  $2.0$ , adjustment time  $n'=2$ )  
 Left panel: in SD7, the perceived price lags the actual price change by  $n'=2$  time periods. Right panel: the simulation price with adaptive expectation process in SD7 has lower frequency but more volatile with bigger local maxima and minima, when compare to price simulated from SD1.

Figure 6-7 Price oscillation magnified when information delay from adaptive expectation is incorporated

### 6.2.3 Policy Implications

The delay in the price adaptation process is especially prominent in the real estate development industry where decisions are made with gut feelings by ignoring the boom and bust of real estate cycles (Hernandez, 1990; Thornton, 1992). In the field of behavior economics, this gives the implication that behaviors such as anchor effect and loss aversion will contribute to the volatility in the market. Fast, efficient, and accurate information distribution channel is important. Encouraging market participants to quickly act upon such information is even more important.

The delay in the adaptive expectation process can be also considered as delay in investment decision making. This implies that uncertainties created by frequent government policy interventions in the housing market will further distort the process and may indirectly create more volatility. In real option theory, the undeveloped land can be seen as a call option that the land owner has the right, without the obligation, to develop the land. When facing uncertainty created by the policy intervention, the real estate projects maybe further delayed due to the irreversibility of exercising land option



value. Riddiough (1997) suggests that regulatory interventions put the land value under risk and may cause a rush for the developers to start development when an investment hurdle is met, and cause a delay of project when such hurdle is not met. Holland, Ott, and Riddiough (2000) suggest that from a broader policy perspective, transparency and stability are important factors in encouraging real estate investment.

### 6.3 Model SD8: Land Supply Constraints and Land Creation

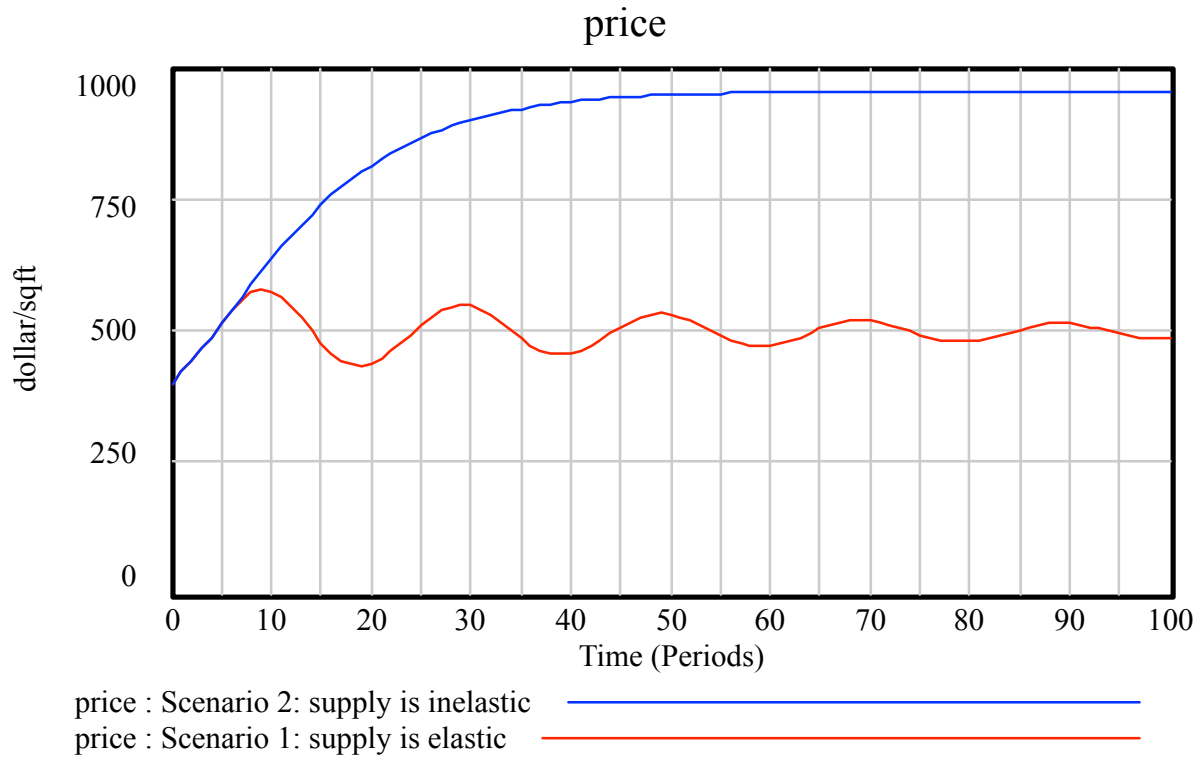
#### 6.3.1 The Necessity of Land Component

In 4QM or Wheaton's stock-flow model, the land component was not discussed in detail. The land price is considered to be included in the value setting of supply elasticity. In general, scarce land leads to inelastic supply and the ray-line that depicts the price-construction relationship in the third quadrant becomes more horizontal: for the same price level, less new construction will take place. It is fair to claim that the basic stock-flow model operates on the assumption that in the target housing market, there is always abundant and freely traded land available. In other words, a necessary condition for overbuilding – and thus for market cycles to occur – is that supply has to be more elastic than demand.

We first take a look at the simulation results change using baseline Model SD3 – steady growth model<sup>37</sup>. For the initial setting, the demand growth rate is at 2% annually, and demolition rate is at 5%, construction time is 5 periods. We consider two scenarios. In the first scenario, the supply is more elastic than demand; while in the second scenario, the supply elasticity reduces significantly to mimic an inelastic case. The simulation result is shown in Figure 6-8. As we can see, in the inelastic case, the market cyclicity disappeared and housing price continues climbing till it reaches a higher equilibrium price. It makes us wonder what role various levels of land supply would play in the 4QM.

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<sup>37</sup> For demonstration purpose, in the case of the inelastic supply, using either Model SD1 or SD3 will have similar results.



In scenario 1, the supply elasticity is set at 2.0, demand elasticity is 0.4; in scenario 2, the supply elasticity is set at 0.5, demand elasticity is 0.4.

Figure 6-8 Model SD3 simulation results: supply is elastic vs supply is inelastic

### 6.3.2 Model Description and Simulation Results

In the following section, we will explore one hypothetical but special situation where the housing supply from the developers still remains elastic as in the baseline case, but the supply of land is controlled, potentially making the land supply inelastic. This is reasonable assumption as the scarce land reserve can well be restrained to limited amount due to natural constraints such as bordering mountains, rivers, or oceans, or it is limited due to the zoning policies that prohibit development from further agriculture land reclamation. The following conditions apply:

1. For the target market, the land has only certain amount of land reserve for housing development;
2. The initial land reserve level can vary;

3. The amount of land reserve is unknown to the housing developers, thus not affecting the supply elasticity of new construction.

As shown in Figure 6-9, in Model SD8, we have added the “land reserve” component to reflect different levels of land availability. We have made assumptions that the initial land reserve is at a fixed amount, and it can take on a value small enough to reflect the scarcity of land supply, or a value large enough to represent abundant amount of land. Variables such as new construction rate and stock in the model are measured in square foot. We will thus need to add a new variable FAR (floor-area-ratio) in order to convert the floor area to land use. FAR is dimensionless. Land use area will be equal to new construction area divided by FAR.

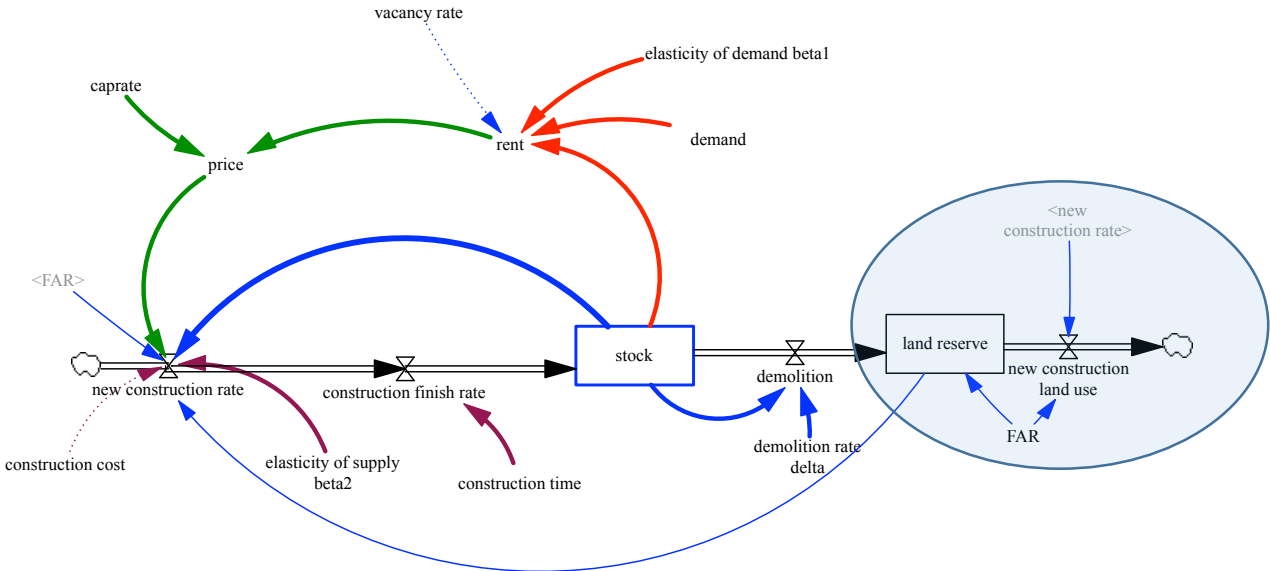


Figure 6-9 Model SD8: the “land reserve” parameter is incorporated

We run simulations in two stages, both starting with a certain amount of land reserve waiting to be disbursed. In the first stage, we assume that the only increase to the land reserve comes from the demolition process, and the only decrease of land reserve comes from the land use by the new construction. It is observed that simulation results vary with different levels of land reserve. In the second stage, when land resource is

scarce, multiple land creation strategies are explored, with some strategies having advantage over other strategies. We will use simulation to demonstrate how such change will affect housing price.

### *6.3.2.1 Stage One: Simulation at Different Land Reserve Levels*

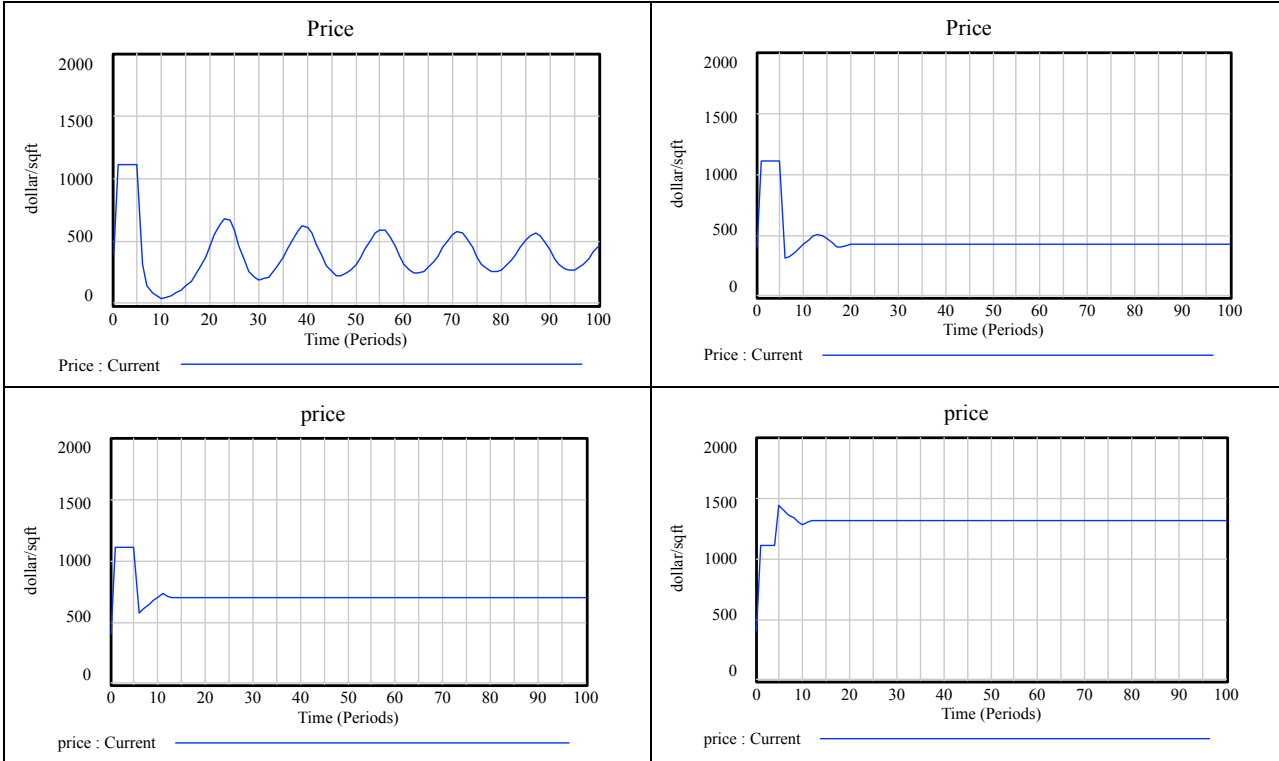
In stage one, when new construction happens, land will be deducted from the land reserve. At the same time, new land will be created through the demolition process. Although the amount of expected new construction at each time period is determined in the asset market governed by Equation (5), it can only happen when there is enough land reserve.<sup>38</sup> If the land reserve is used up, then the new construction can only happen at the maximum rate as the demolition rate. The following numerical assumptions are made:

- FAR: We start the FAR with value of 1 for simplicity so that we can equal land surface area to construction floor area. In this way, we can easily compare it with the results from the baseline model.
- Initial land reserve: This directly controls the amount at which maximum amount the new construction takes place. In the baseline Model SD1, the initial total stock of housing is at 2.5 billion sqft, and this provides a reference for us to set up the numerical scale of the initial land reserve. In Model SD6, for the initial land reserve, we set at four different levels and run simulations 4 times in order to observe its impact on housing price: (1) high land reserve level at 5 billion sqft; (2) low land reserve level at 2 billion sqft; (3) rare land reserve level at 1 billion sqft; (4) no land reserve at 0 sqft.
- Demolition rate is set at 10%.

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<sup>38</sup> In this part of modeling, we do not get into the discussion of land price. The more complicated version of the model should reflect that land scarcity would trigger higher land price level and thus drive down new construction rate. In this simplified case, we stay out of the supply-demand in the land market and only focus on the quantity of land reserve. This is because in some political economy dominated countries such as in China or Singapore, land is owned by government. Land supply and land price are not decided by the market.

The simulation results are shown in Figure 6-10. When the initial land reserve is high, the simulation result is exactly as the results from the baseline model SD1. However, when the initial land reserve is limited, the oscillation effect disappears. The land reserve serves as a constraint imposed to the system, and there is simply not enough land left for the new construction to happen to trigger the over- and under- building effects. Equilibrium price level is quickly reached. The new price is jointly determined by the increase in demand and the amount of land reserve that is integrated into the real estate system. As the result shows, when the land reserve further drops to zero, the equilibrium price for housing market reaches higher levels. Visually, this could be thought of as the rectangular box in the DiPasquale-Wheaton's 4QM growing bigger.



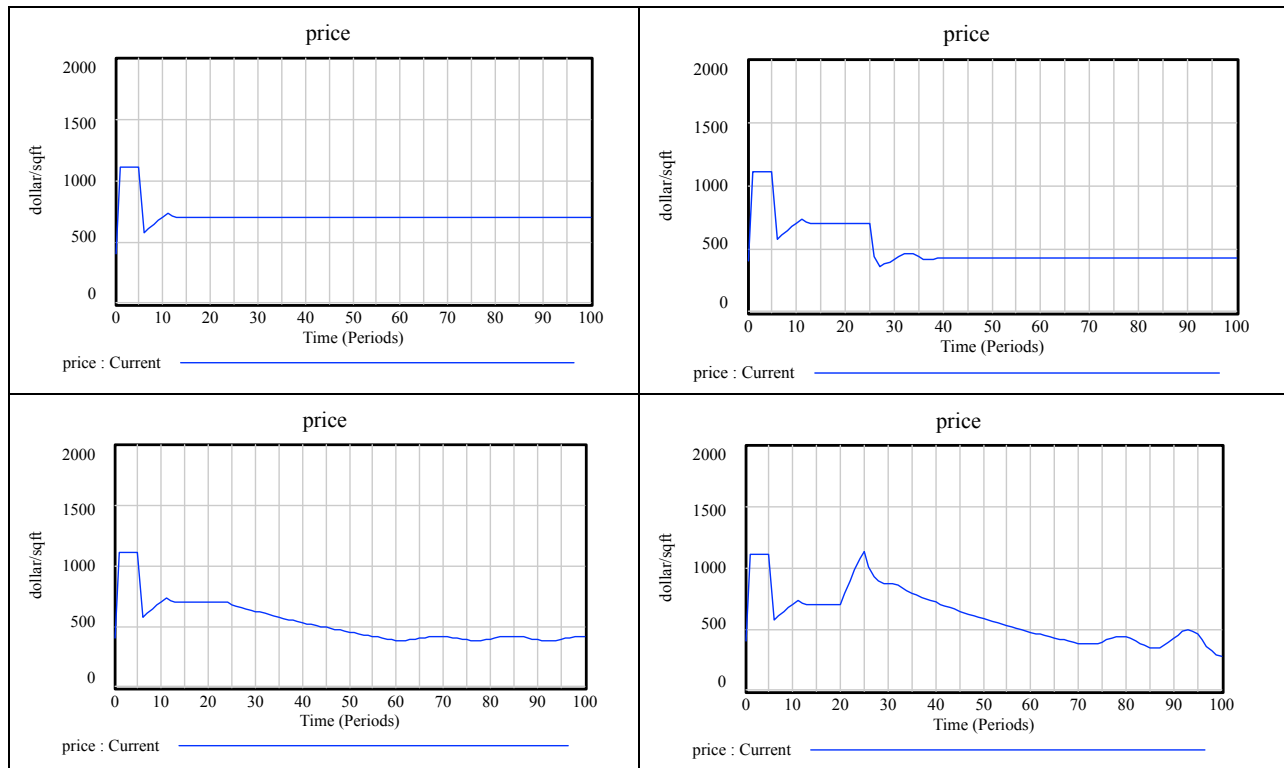
Upper-left panel: high initial land reserve @ 5 billion sqft; Upper-right panel: low initial land reserve @ 2 billion sqft; Lower-left panel: rare initial land reserve @ 1 billion sqft; Lower-right: no initial land reserve @ zero sqft.

Figure 6-10 Price oscillation disappeared and equilibrium is quickly reached when the initial land reserve reduced from high quantity to low quantity

### 6.3.2.2 Stage Two: Different Land Creation Strategies

We start off stage two experiment by assuming that there is not enough initial land reserve. For example, we assume that the initial land reserve is at the “rare” level at 1 billion sqft to accommodate the demand increase caused by 5 million additional people. We can set up simulations for the following three strategies:

- Strategy 1: Expand the land reserve by 100%. This will be simulated through an injection of extra residential land of 1 billion sqft to the land reserve at time stamp  $T=20$ . In reality, such land supply can happen when building a new subway line, or building a new bridge, or land creation through landfill in a river or ocean. In the case of the subway line or bridge, land that was previously inaccessible becomes practical to meet housing demand; in the case of landfill, the land is essentially created where previously there was no land.
- Strategy 2: Through relaxation of zoning policies, the FAR can be increased - for example, from 1 to 1.1 on a compound basis from time stamp 20. This models the reality that buildings get taller than previous ones and the open space gets smaller, such as in NYC and Shenzhen, China. The FAR increase is only applied to the land created by each round of demolition.
- Strategy 3: Besides increasing FAR, we can also increase the demolition rate by 50% from 0.1 to 0.15 at time stamp 20. This occurs when an increasing amount of demolition takes place in order to create new developable land in downtown areas.



Upper-left: rare initial land reserve @ 1 billion sqft; Upper-right: Strategy 1, double land reserve;  
 Lower-left: Strategy 2, increase FAR; Lower-right: Strategy 3, increase FAR and demolition rate.

Figure 6-11 Housing price change with three land creation strategies (based on assumptions of limited land reserve)

The simulation results are shown in Figure 6-11. Among all three scenarios, Strategy 1 is the most efficient in bringing down the housing price in short time without market fluctuation. Strategy 2 shows that increasing FAR can also bring down the housing price at a gradual rate. Scenario 3 shows the most fluctuation. The initial demolition increase surpasses the speed at which newly finished constructions feed in, and this vacuum period drives up the housing price to a new spike, and then price starts to fall down gradually due to the increase of FAR.

### 6.3.3 Policy Implications

The finding in this section is straight forward. That is, by controlling land supply, the housing price can be manipulated. In stage one, when land reserve is controlled at a lower level without new land supply, the housing price cycles are unlikely to happen

because the overbuilding scenario will not happen due to land constraint. However, the new equilibrium housing price will be higher than previous housing price.

On the other hand, when new land is created, either through relaxation of zoning policy, or infrastructure expanding, or increasing demolition and FAR, the housing price can be gradually brought down. Among all three strategies, new land creation is the most effective strategy of which the effect is immediate.

## 6.4 Model SD9: Internalize the Cap Rate in the Capital Market

### 6.4.1 Cap rate: Exogenous or Endogenous

Cap rate is the rate of return on a real estate property that the investors can get. It is the ratio of income that the property generates and the value of the property. For all simulations in the previous models, the cap rate is considered exogenous and set at a stable value of 0.05 (or 5%). In this section, we aim to internalize the cap rate and making it endogenous by establishing the relationship between cap rate and rent growth rate.

In the causal loop diagram, this change actually created another balancing loop for the system. Initially, the rent increase will trigger the price increase through Equation (6) in Chapter 4. When cap rate is made endogenous, the rent increase will drive down the cap rate and trigger the housing price to increase further, thus creating a second-order effect.

### 6.4.2 Model Description and Simulation Results

The Model SD9 aims to internalize the cap rate into the model and make it endogenous. Modified upon the baseline Model SD3, the structure of Model SD9 is shown in Figure 6-12. The cap rate is modified to be a stock variable with initial value at  $r_0 = 0.05$ . The change rate of cap rate is negatively related to the rent growth rate change. For simulation purpose, the equations are simplified as the following:



$$g_t = (R_t - R_{t-1})/R_{t-1}$$

$$\sigma_t = -g_t * \tau$$

$$r_t = r_0 + \int_0^t \sigma_t dt$$

where  $R_t$  is rent at time  $t$ ,  $g_t$  stands for the rent growth rate at time  $t$ ,  $\sigma_t$  is the change rate of cap rate at time  $t$ , and  $r_t$  is the cap rate at time  $t$ .  $\tau$  is a coefficient to represent the relationship between  $\sigma_t$  and  $g_t$  and in this model, we have simplified the relationship to be linear and use a value of 1/100 for simulation.

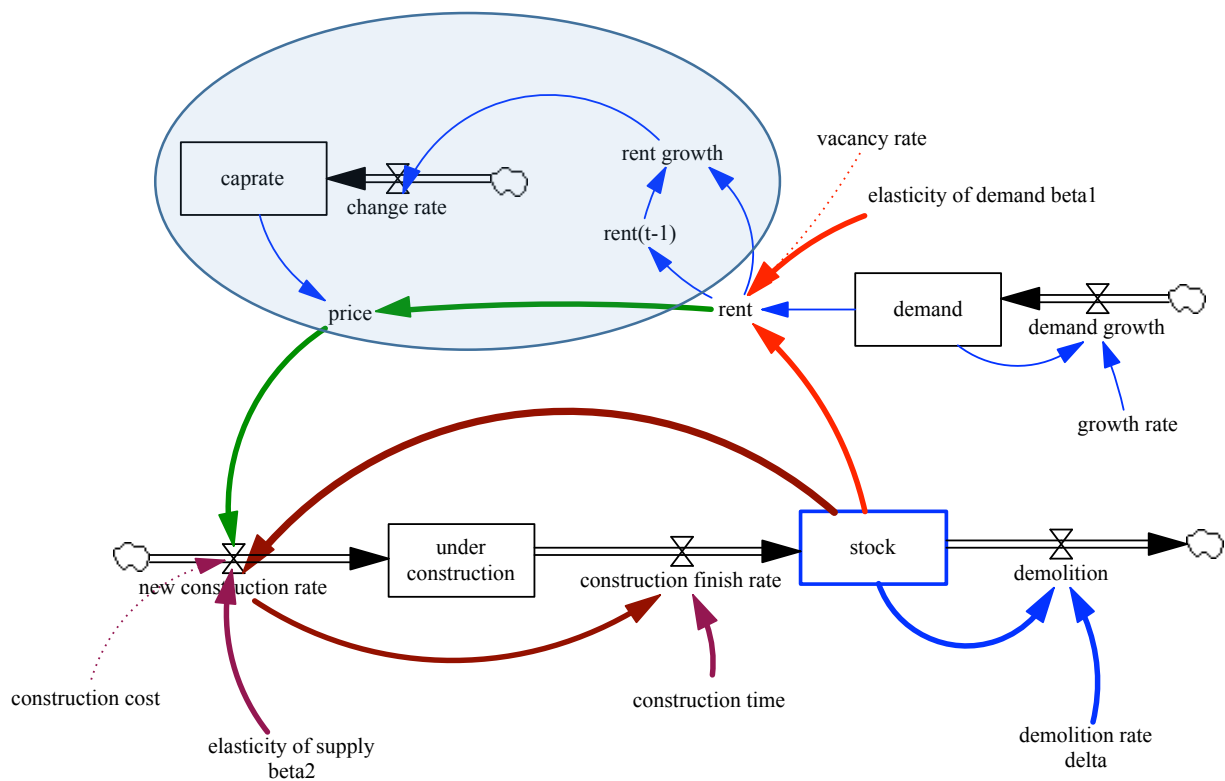
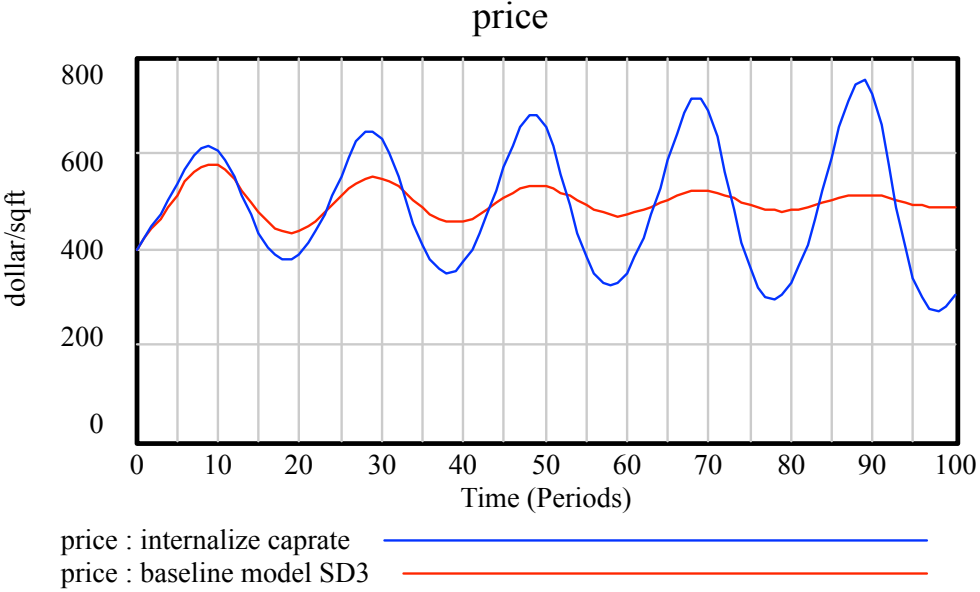


Figure 6-12 Model SD9: Internalize the cap rate by linking it to the rent growth

The simulation result is shown in Figure 6-13. When the cap rate is made endogenous, the price amplitude increases but occurs at the same frequency as when cap rate is

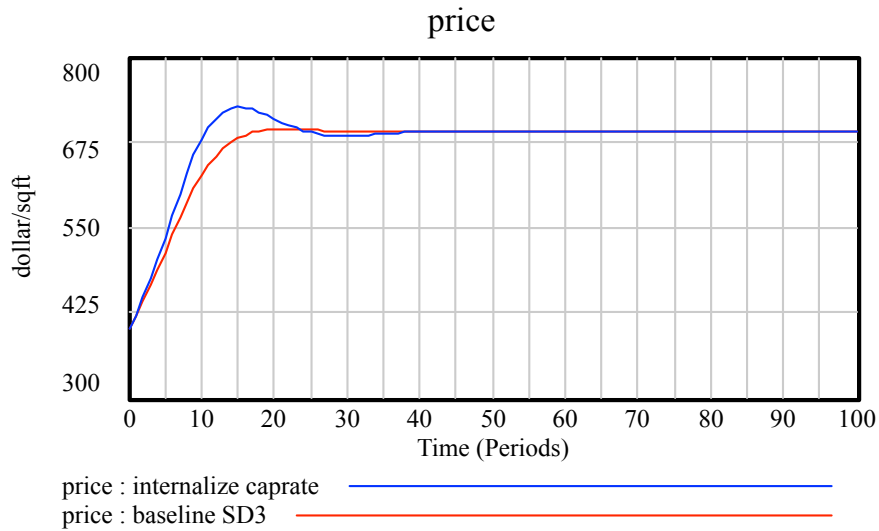
exogenous. The overshooting effect at the right hand panel is observed when compared to the baseline model run, creating higher peaks and lower troughs. Mathematically, it is because an increase of rent will trigger a decrease of cap rate. From Equation (6) of Chapter 4, we can see that the price level will increase further than in the scenario of keeping cap rate constant. When cap rate is exogenous, the price cycles exists but have a tendency to diminish in the long run. However, when cap rate is made endogenous, such tendency is dependent upon the relationship between  $\sigma_t$  and  $g_t$ . The price can have an amplifying effect when the coefficient is bigger (i.e.  $\tau = 1/100$ ), or a diminishing effect when the coefficient is smaller (i.e.  $\tau = 1/300$ ).



Demand growth = 0.02, demolition rate = 0.05, construction time = 5, elasticity of demand = -0.4, elasticity of supply = 2.0

Figure 6-13 Simulation result of SD9: price trends when cap rate is endogenous vs. exogenous

When we make the model inelastic by setting elasticity of supply at 0.8 and run the simulation, we can see that the price peaks at a higher value at the first local maxima when comparing to the baseline model SD3 where cap rate is a constant of 0.05. This is due to the overshooting effect of first price peak created by the cap rate decrease.



Demand growth = 0.02, demolition rate = 0.05, construction time = 5, elasticity of demand = 0.4, elasticity of supply = 0.8

Figure 6-14 Simulation result of SD9 when cap rate is made endogenous and supply is made inelastic

### 6.4.3 Policy Implications

As we have described before, the housing price growth will attract more capital investment into the real estate sector while the investors expect that the growth pattern will continue. The concentration of capital investment will push down the cap rate. This phenomenon manifest itself in terms of lower interest rates or mortgage rates. As a result, the housing price, in the short run will have a second order effect of increase. In the long run however, higher housing price will induce more construction, resulting in an increase in supply. The increased supply should bring down the housing price. It is a balancing loop.

However, this balancing effect will not work when the land supply is severely constrained, as in the inelastic case shown in Figure 6-14. In the context of this thesis, this is especially important for the case of China. In China, the stock and bond markets are not mature. As a result, there are few investment channels and most of the capital investment flows to the real estate, especially housing sector. As a result, the housing price are pushed to significantly higher level. However, higher housing prices do not

trigger enough new construction because the land supply is controlled by local government, and is also subject to the Central government's land quota system.

The creation of healthy, alternative investment channels would help reduce the over-concentration of capital in the housing sector which, in turn, would have a stabilizing effect on housing prices. Also, the land supply should be made elastic so that in a rising market when cap rate is pushed down, enough new construction can happen to bring down the housing price. Relaxation of zoning regulations and increase land supply will have positive effects.

## 6.5 Model SD6 to Model SD9 Validation and Testing

For the subset of models with the generic features, we test them with SD validation standards described in Chapter 3.

### 1. Boundary Adequacy Tests

The model boundary is expanded in each of the sub-models comparing to the original stock-flow model depicted in Chapter 4. The boundary is expanded to individually include the construction industry, investor's decision delay, land constraint, and capital market. These are generic features as they are applicable to all housing markets. In the later Chapters 7 and 8, we will further expand the boundary to include discussions of China-specific phenomena such as ghost cities, speculative demand, and land financing scheme.

### 2. Structure Assessment Tests

The structure assessment for the generic models is consistent with the descriptive knowledge of the concept of the housing system. The modifications in this chapter are supported with evidence listed in Chapter 5.

### 3. Dimensional Consistency

The dimensional consistency, or "units checking" is performed for each sub model. All variables with real world meaning are in their common units.

#### 4. Parameter Assessment

The numerical values of the model variables are currently still using hypothetical data from Wheaton (1999).

#### 5. Extreme Conditions

The sub models in this chapter are also tested with extreme conditions, meaning each equation makes sense even when its inputs take on extreme values. For example, when demand of the integrated model is set to zero, the rent and housing price would be driven to zero; when the demand remains unchanged (without a step jump or exponential growth), the system will remain at equilibrium stage.

#### 6. Integration Error

The simulation result is stable when the time step is set to small units in Vensim.

#### 7. Behavior Reproduction

The purpose of this subset of models is not to fit data to the historical housing price point to point because we are using hypothetical data. However, the behaviors produced by the model are already theoretically explained.

#### 8. Behavior Anomaly

There is no anomaly observed from the simulation results of integrated model.

#### 9. Family Member

The model can be used in similar situations in other contexts where the construction industry is streamlined, or when land constraint prevails.

#### 10. Surprise Behavior

There is no surprise behavior observed so far.

#### 11. Sensitivity Analysis

The sensitivity analysis is conducted with regard to key variables with estimated value such as the price change ratio with regard to cap rate.

## 12. System Improvement Tests

The system can be improved by incorporating housing components with Chinese features that are not generic to all housing market. The tasks are done in the following Chapters (7, 8, 9, and 10)

### 6.6 Summary of the Chapter

Chapter 6 conducted the second step of the research design and added generic features into the system dynamics model. The variables marked in green in Figure 6-15 are newly added onto the causal loop diagram at the end of Chapter 4 as in Figure 4-12.

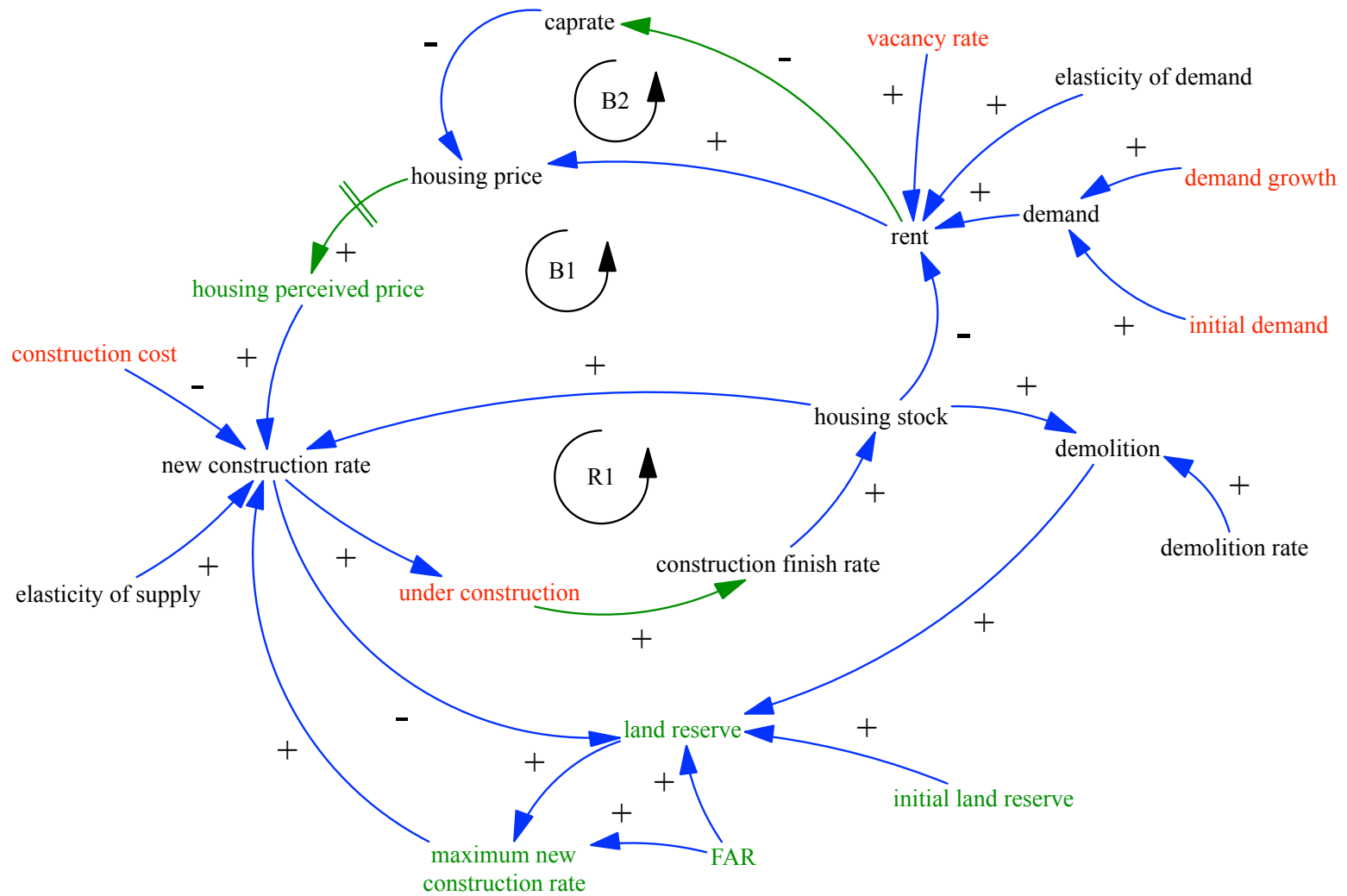


Figure 6-15 Causal loop diagram at the end of Chapter 6

A summary of the set of Model SD6-SD9 is shown in Table 6-1. It lists the parameter of the model we modified, how we have modified, which benchmark baseline model it is compared to, and its contributing effect on market volatility. A (+) sign indicates that the parameter positively contributes to the market volatility, such as higher amplitude of local maxima and minima of the cycles, or longer cycles. A (-) sign indicates that the parameter negatively related to the market volatility, meaning, they can prevent the market cycles from occurring.

Model	Parameter	Description of the Model Modification and Main Findings	Compare to	Volatility
SD6	Construction Behavior	When the housing under construction is streamlined (i.e. construction rate is responsive to market demand), instead of following pipeline structure, the housing cycles tend not to occur.	SD1	-
SD7	Information Delay	The adjustment process for the developers to recognize and accept the price change is a form of information delay, and it can increase the price volatility.	SD1	+
SD8	Land Constraint	Land supply closely relates to the supply elasticity. When land supply is constrained, housing price will climb but housing cycles diminish.	SD1	-
SD9	Cap Rate	Cap rate is internalized, and negatively related to the rent growth rate. This increases the market volatility.	SD3	+

Table 6-1 A summary of Model SD6-9 and their relationship to market volatility



## 7 Special Market Features in the Chinese Urban Housing Market

The models developed to this point have added some usual generic features into the housing system model, such as number of households, income growth, construction cost, general vacancy rate, land constraint, etc. In an ideal housing market, we would expect that such market fundamentals could explain the housing price change and the expected boom and bust cycles of housing market.

But in the case of the Chinese housing market, using city level and residential development level data, Wang and Zhang (2014) investigated the role of fundamental factors such as urban population, urban Hukou, income growth, land supply, and construction costs. Their results indicate that although these factors can account for a major proportion of the actual housing price increase, in several coastal cities the actual increase in housing prices deviates largely from what can be explained by these fundamentals. The implication is that there are other market features that exist in China but are not well captured by the generic features.

The purpose of this chapter is to explore in detail the special features that are unique to the Chinese housing market. The results of this exploration will support why and how we build the SD models in the subsequent chapters. It is not to indicate that the special features covered here are the answers to the potential bubble component of the housing price structure, but it does address the issue of evaluating their impacts on the the housing market.

Historical data is important but the data needed for any thorough time-series analysis of Chinese housing market is limited. There is no official data collected on housing vacancy rate, which is a major parameter of any housing market studies. Even the nature of the data collected in the Chinese Statistical Yearbook is not consistent from year to year. Data quality is also questionable. Recently, the governor of Liaoning province admitted publicly that the provincial GDP from year 2011 to 2014 has been manipulated and some statistical data are forged with an increase of 20%-30% by the previous governor (Zhu, 2017). As a result, this chapter focuses more on gathering the

empirical evidence and the causal structure of the special features so that they can be integrated into the housing system model. The newly created SD models in Chapter 8 can run on hypothetical data that is within a reasonable range, and enable us to observe the effect of the special features on the housing price change.

There are two important concepts related to the Chinese context that need to be defined upfront. The first one is the concept of the ‘tiers of cities’, and the second one is ‘vacant units’.

There are four tiers of cities in China. Depending on the sources, there may be other definitions of the number of tiers that result in five or more tiers. In the news, the first and second-tier cities are generally mentioned together, while the third and fourth tier-cities are grouped together. The first tier cities are comprised of megacities with names that are familiar to most people, Beijing, Shanghai, Guangzhou, and Shenzhen. The second tier cities are comprised of a list of 35 or more large cities depending on the various ways to define from different sources. In this thesis, we use the definition from Fang et al. (2016) attached in the Appendix to this chapter.<sup>39</sup>

There are two types of vacant units. The first type (V1) comprises housing units that have been constructed but cannot be sold because the demand is not there and thus left vacant. This is the case that is mostly observed in some of the third or fourth tier cities, and especially in the cases of the ghost cities. The second type of vacant units (V2) are units that have been sold to speculative investors, and intentionally left vacant with expectations of future high capital gains. This case is mostly observed in first and second tier cities. This distinction is important because the vacancy rate that is quoted in multiple sources can either refer to the vacant units as in the first case (lack of demand – no one to buy the units), or in the second case (speculative demand – units

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<sup>39</sup> Although another way to understand the Chinese tiers of cities as written in Fortune Magazine is as following: “The division of China’s cities into five tiers says more about each city’s relationship with the central government than its viability as a consumer market. Tier 1 cities such as Shanghai and Shenzhen are the megalopolises of China—the largest and the wealthiest. Tier 2 cities are their slightly smaller, slightly less well-off cousins, like Hangzhou and Wuhan. Nearly all cities from the top two tiers are in China’s east or near coastal areas. Tier 3 and Tier 4 cities are smaller and less affluent still, and are geographically dispersed. The fifth tier is everything else.” (Louise Keely, 2015)

purchased by buyers that simply don't need to use them), or a mix of those two. Distinguishing between these two types of vacancy is important for all four Chinese features discussed in this chapter. It is because in different tiers of cities, the underlying mechanisms of vacant units are different, although they are all referred to as "vacancy".

There are four features that we believe that have strong impacts on the Chinese housing market and we have previously presented in a conference paper in Chengdu, China (Zhang, Geltner, and de Neufville, 2015). Fang et al. (2016) have confirmed these four features from data they collected from Chinese Statistical Yearbooks from national to municipality level, and concluded that the same features may contribute to the 'risks of housing boom' in China. However, their discussion stops short when assessing whether current housing boom is a bubble, because *"to forcefully determine the presence of a housing bubble, one needs to develop a systematic framework of supply and demand of housing that fully accounts for the growth of Chinese economy, the frictions in the Chinese financial system, and the strategic behavior of local governments in supplying land"*. In this thesis, the eventual overarching system dynamics model developed for the Chinese housing market is certainly less ambitious in achieving a complete systematic framework but it is a first step in addressing the important Chinese market features and incorporating them into one preliminary operational framework. The special features we include in this thesis are:

1. Chinese urban housing demand growth:

Demand growth, as shown in Model SD5, has two components: household growth and household's income growth. The demand in this feature refers to the general demand, or usage demand. Chinese household's Income growth has been increasing steadily at an annual rate of about 10% in recent years. The growth of the number of households in the case of first and second tier cities, is driven by migration. What if the migration pattern stops or diverges to other regions? In the case of lower tier cities or ghost cities, we present the case where the housing units were built expecting the high future demand growth that has never been there in the first place, thus resulting a large amount of vacant units as defined in vacancy type V1.

## 2. Speculative demand and housing hoarding:

Different from feature one, feature two focuses on another category of demand - speculative demand – that is mainly found in the first and second tier cities where speculative investment behavior exists. The housing speculators buy extra housing units and leave them vacant in expectation of future capital gain. They are effectively hoarding available inventory of housing units. The large amount of vacant units falls into the category of vacancy type V2.

## 3. Chinese local government's land financing scheme:

Feature three refers to the phenomenon of local governments' reliance on revenue from land sales in order to meet their annual capital expenditure and fiscal budget. It exists in cities of all tiers but local governments' land selling behaviors are different. In the first and second tier cities, the land price is high but the land supply quota is limited. The local governments have to plan carefully the amount of annual land disbursement in order to maximize its total land sales revenue within a certain time span. The land sales pressure is not high as they can rely on tax revenues from other sources such as local industries. In the case of some lower tier cities, the local governments rely heavily on land sales revenue. They sell land to maximize the revenue upfront and promise the developers with a great future demand that will never be there (Ren and Song, 2016). Feature one tells the story of overbuilding from the demand side; this feature tells the same story from the land supply side.

## 4. Chinese central government's policy interventions:

Chinese central government has the power to intervene in the housing market from either the supply side or demand side. For example, they can control the annual land quotas that each local government is allowed to disburse; they can set up policies to suppress the market speculators by restricting them from buying a second housing unit. As of early 2017, the central government is planning on implementing a property tax in

order to target the speculative demand discussed in feature two.<sup>40</sup> However, some of the government policies only have impact in short term and considered inefficient when going against the basic supply-demand relationship in the housing market.

These four features are also inter-related. It is hard to discuss one without mentioning the other. For example, in feature one, a precondition for a city to be built based on a promising but non-existent demand, is that the local government wants to sell more land to meet fiscal expenditures, which leads to feature three discussion of land financing scheme. Another example, one of the well-known policy interventions in feature four is “home purchase restriction.” This purchase restriction policy is also known as “One Housing Policy” that allows households in first and second tier cities to purchase only one housing unit, although the detailed implementation process varies from city to city. This policy aims to suppress the speculative demand, which is covered in feature two. The following sections of this chapter will talk about all four features separately but interactively.

There are certainly other features that may have a drastic impact on the housing market in general, and which can cause the potential bubble to burst. For example, the risk of credit default was the key trigger that caused the US subprime mortgage crisis back in 2008. In China, the central government has set the down payment rate at an extremely high level compared to the US, at about 30% or more, which at first glance would appear to significantly reduce the credit default risk. However, the loan structure in China is twisted. From the macro level, the proportion of mortgage loans has been increasing rapidly. From the micro level, the leverage used by the mortgage borrowers is extremely high. There is the down payment loan<sup>41</sup> which counts for about 15%-20% of the housing price at a much higher annual interest rates of 8-10%. This loan allows the borrowers to meet the down payment requirement and thus further increasing leverage to purchase houses at a much higher price. As a result, we cannot eliminate

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<sup>40</sup> “China will implement property tax as soon as 2017”, Radio Free Asia, July 15, 2016. See <http://www.rfa.org/mandarin/yataibaodao/jingmao/yf2-07152016105125.html>.

<sup>41</sup> For the discussion of pros and cons of down payment loan in China (in Mandarin), see <http://history.people.com.cn/peoplevision/n1/2016/0303/c371452-28168339.html>.

the credit risk as a potential contributor to the bust scenario. However, it is not yet in the scope of this thesis because the use of high leverage cannot yet to be generalized across different Chinese housing markets and its potential scale and impact lack valid data support.

## 7.1 Finite Demand Growth in Chinese Urban Housing Market

### 7.1.1 First and Second Tier Cities - Supply for Increasing or Diminishing Demand?

It is well known that the housing demand is quite strong in most of the first and second tier Chinese cities. Between 2003 and 2013, housing prices demonstrate an annual growth rate of 13.1% in the first tier cities, 10.5% in the second tier cities, and 7.9% in the third tier cities, as well as an average annual household income growth rate of 9.0% (Fang et al., 2016). People who are arguing against the concept of housing bubble always attribute the housing price increase to the demand growth contributed by the natural population growth, rural to urban migration during the urbanization process, and especially income growth.

The natural population growth is a long term indicator and the growth rate has been steady at around 0.5% since the turn of the century. According to the 2016 Chinese Statistical Year Book, in year 2000, there is an urban population of 459 million which counts for 36.2% of the total population. By 2015, this number climbed to 771 million and accounted for 56.1% of the total population. That is a net increase of 312 million in 15 years, almost equivalent to the entire US population. Gao (2016) has attributed the price surging in the first-tier cities to the continuing migration pattern and the desirability of mega-cities. High housing prices do not seem to stop the flow of migrants. Liu and Shen (2014) found that in recent years, the skilled workers have been flooding into Beijing, Shanghai, Guangzhou, and Shenzhen in favor of the job opportunities despite the high housing cost. They also pointed out that the skilled migration demonstrates regional heterogeneity, with most of the coastal provinces of China having a net inflow of skilled migrants, and central provinces having a net outflow of skilled migrants.

There are also factors that argue against the idea of constant demand growth suggested by the migration activity described above. The first factor is the existence of Hukou system in China. It is a registration system that controls the population flow from one region to another and it is especially harsh for non-skilled migrants. Without local Hukou, these migrants cannot have access to basic local public services such as school system or medical care. According to an Economist article<sup>42</sup>, a 2010 survey by Renmin University in Beijing found that one third of migrants aspired to build a home in their home village rather than buying one in the city and only 7% of them identified themselves as city people. Not only are the non-skilled migrants considered second class citizens, they are also earning minimum wages compared to the urban residents. In general, they are neither eligible nor able to purchase housing units.

Gan Li (2014) and his research team have pointed out that the actual progress of urbanization process is inflated by the reclassification process: if a rural area is reclassified as urban, residents living in the area becomes urban residents, or the so-called “redefined migrants”. The key is that these new urban residents have never migrated and thus cannot be seen as creating extra demand for urban housing. Their number is huge as shown in Figure 7-1.

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<sup>42</sup> “Migration in China: Invisible and heavy shackles”, The Economist, May 6, 2010. Online see <http://www.economist.com/node/16058750>.

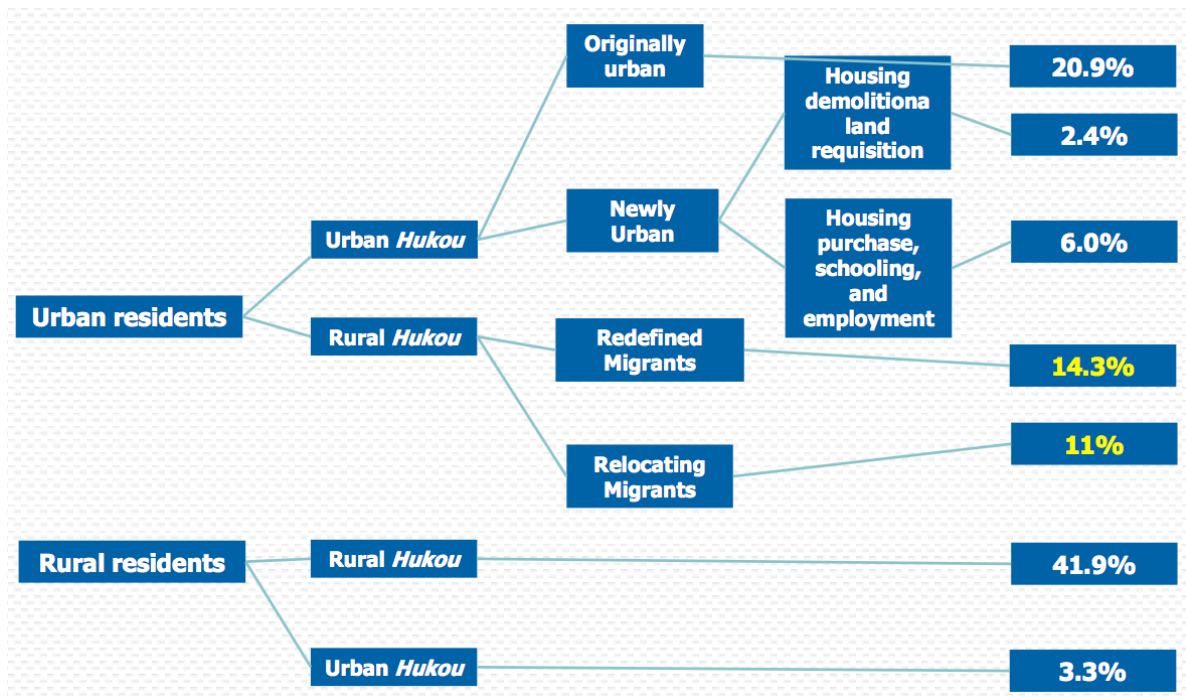


Figure 7-1 More redefined migrants than relocating migrants (Gan Li, 2014)

It is not reasonable to assume that in the long run, the urbanization process and the rate of migration will be sustained. It is likewise not reasonable to assume that the rate of income growth, which is closely linked to the Chinese economy, will continue indefinitely. There are already voices advocating that China should be aware of excessive urbanization and excessive peri-urbanization, and that the Chinese government should give less emphasis to the quantity of growth and the growth rate (Chen, Liu and Tao, 2013).

### 7.1.2 Ghost Cities – Supply for Non-Existent Demand

Shiller (2013) has said that housing bubbles are generally preceded by “land fever”. Land fevers have the contagion effect where promoters subdivide land into many parcels for investors and then promote the sale of these parcels with a grand vision of a future town or community. A similar phenomenon is happening in China except it happens at greater frequency, on a larger scale, and within a shorter period of time. The cities with high vacancy rates are third or fourth tier cities and some northern cities, such as Erdos, Huizhou, Changzhou, etc. The high vacancy rate is caused by the large



city-scale new construction (called “Zaocheng Yundong”) where anticipated demand did not materialize (Zheng, Wang, and Tu, 2015). According to a Chinese government survey, until the end of 2013, there over 3,500 new cities and districts were being planned in China, and these were expected to host 3.4 billion people.<sup>43</sup> The current Chinese population is “only” 1.35 billion. The underlying incentive is that the local governments want to use new city construction to boost local GDP, which is one of the major criteria to evaluate their political performance – and thus represents the only path to potential promotion.



Figure 7-2 An online Mandarin poster summarizing the frenzy of new cities construction  
 Note: Each blue cube is one new district and each orange cube is one new city under planning. The cubes are separated and categorized under different Chinese provinces.

<sup>43</sup> NetEasy data blog, “Chinese Frenzy in New City Construction”, online see <<http://data.163.com/16/0715/07/BS0FR2U100014MTN.html>>

The process of “Zaocheng Yundong” is simple: the local government sells large amounts of land to developers promising a huge increase in demand for housing through population increase and job creation. The local government receives the land sales revenue to support its fiscal budget expenditure.<sup>44</sup> The construction activity of building a new city certainly boosts the local GDP. Through the housing development process, the land is no longer considered agriculture land, and thus the nominal land value increases. This process is ideal except when it comes time to face the consequences: When the demand does not materialize, the newly developed city will likely become a ghost city looking like the development in Figure 7-3. And this will likely become the problem to solve for the next mayor.<sup>45</sup>



Figure 7-3 Residential buildings in the Meixi Lake Development near Changsha, Hunan Province

Photo source: Laura Mallonee. See < <https://www.wired.com/2016/02/kai-caemmerer-unborn-cities/#slide-9>>

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<sup>44</sup> This is generally referred to as local governments’ “land financing scheme” and will be covered in details in later part of this chapter.

<sup>45</sup> In China, the local government officials do not stay at one location long, normally just one term of 5 years. Then they are transferred to another region for a promotion, depending on the GDP growth of their current term.

The general definition for a ghost city in China is “a new development that is running at severe under capacity, a place with drastically fewer people and business than there is available space for (Shepard, 2015).” New York Times once commented on Ordos in Mongolia using “There is just one thing largely missing in the city’s extravagant new central district: people”.<sup>46</sup> The phenomenon of Chinese ghost cities has become popular topics internationally since the broadcast of “China’s Real Estate Bubble” in CBS News’ “60 Minutes” program on March 3, 2013. Using their words, ghost city is “like the city of built for a million people who didn’t show up”.

It is hard to estimate the exact number of ghost cities in China because of its ambiguous and unquantifiable definition. It goes back to the fact that there is no official statistical data on housing vacancy rate. Some journalists just use photos of empty buildings and streets, or counting lights at night to judge whether a city is a ghost city or not. Recently, some academic papers start to target this topic by inventing scientific methods to evaluate if a city is a ghost city or not. Chi et al. (2015) used Baidu positioning data to present the spatial distribution of the vacant housing area within a city. Jin et al. (2017), based on data of 535,523 recent residential projects development, found that the average vitality of residential projects in newly developed urban areas is only 8.8% of that in old urban area, implying the existence of ghost cities.

Both cases – first or second tier cities where the construction is happening at unprecedented speed in anticipation of infinite demand; or in the ghost cities where an entire city is built for non-existent demand – highlight the importance of accurate demand forecasts. Gan (2017) already suggested that there is an oversupply of 50 million housing units in the Chinese urban areas. Since the end of 2015, the Chinese government has switched the policy focus from building more housing stock for future migrants to lower construction speed and reducing the existing unsold housing stocks.<sup>47</sup>

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<sup>46</sup> “Chinese city has many buildings, but few people” by David Barboza, New York Times. October 19, 2010. Online see <http://www.nytimes.com/2010/10/20/business/global/20ghost.html>.

<sup>47</sup> “Chinese Central government has decided to focus on ‘reducing existing housing stock’”. New.cn. Written in Mandarin. Online see <http://news.cn/fortune/caiyan/ksh/107.htm>.

This policy shift demonstrates the pessimistic view of future demand from the Chinese central government's point of view.

It is thus not rational either to assume that demand will grow at a steady rate indefinitely, or to supply housing according to such demand prediction. As a result, there is the need to construct a model or a set of models, that allows us to vary the demand as parameters so that we can explore in different future scenarios.

## 7.2 Speculative Demand and Housing Hoarding

*“Actually, property values have doubled and tripled and more -- so people in the middle class have sunk every last penny into buying five, even 10 apartments, fueling a building bonanza unprecedented in human history. No nation has ever built so much so fast.”*

- CBS “60 Minutes” on ‘China’s Real Estate Bubble’<sup>48</sup>

This section introduces a unique and important feature of the Chinese housing market: the prominence of speculative demand. It represents ownership of housing units purely as investment vehicles, without the intent to rent it out. Such housing units remain vacant, and are thus not utilized to meet demand for housing purpose. We approach this topic by discussing two factors: speculative investors and vacancy rates (V2).

### 7.2.1 Speculative Investors in the Housing Market

Speculative investors largely exist in the Chinese housing market due to the fact that alternative investment channels, such as mature stock and bond markets, are very limited. The housing market serves as a major means to invest capital. Also, the price of housing in first and second-tier cities has been rising rapidly without any long term decline, and, as of 2017, the Chinese market had yet to experience a full price cycle. As a result, the Chinese investors have formed a false belief that the housing price will keep on rising indefinitely. Since the capital gain portion of housing is growing so fast,

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<sup>48</sup> Correspondent: Lesley Stahl, August 03, 2014. Online see <http://www.cbsnews.com/news/china-real-estate-bubble-lesley-stahl-60-minutes/>.

and there is no property tax, the speculative investors have no need to depend on the rental income and can afford to leave the units vacant. This means that housing units acquired for speculative demand are not used to offset the actual demand for housing that people can live in. This is what makes the ongoing Chinese speculative demand so special.

This kind of speculative investment has become an important topic in the academic research of Chinese housing market (Allen et al., 2012; Wu, Gyourko, and Deng, 2012; Ren, Xiong, and Yuan, 2012). Guo and Huang (2010) claim that the enormous size of speculative investment has driven up property prices. The rapidly rising housing prices provide an environment for exuberant expectations, and the speculation in the housing market might be further stimulating the existing housing boom (Dreger and Zhang, 2012). Instead of running away from the market, Chinese speculators tend to rush into the market whenever tightening monetary actions are taken by the government (Yao, Luo, and Loh, 2013). Chen and Wen (2017) have interpreted the Chinese housing boom as a rational bubble emerging from the economic transition, which drives people to speculate in the housing market with high expectation of capital gains and future demand. They have shown that such speculative investment behavior can create a self-fulfilling housing bubble that grows much faster than a benchmark that is driven by economic fundamentals.

There is a saying that the Chinese people are buying housing units are just like they buy cabbages in the supermarket (Figure 7-4). Facing high prices, the speculators use both down payment loans and high leverage to purchase housing in the first and second tier cities, and spread the equity thin. It is also common for the early rounds of speculators to sell the housing units and use the sales money to achieve even higher leverage and bet more aggressively on the rising market.<sup>49</sup>

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<sup>49</sup> “Chinese speculators use bank for collateral”, article in Mandarin, March 2, 2016. Online see <http://www.wenxuecity.com/news/2016/03/03/5025045.html>.





Figure 7-4 Housing sales opening ceremony for a development in Xi'an, China - "buying housing units like buying cabbages in the market with the presence of housing speculators"

Image source: Weixin platform. October 13, 2016. Online <http://m.v4.cc/News-2460560.html>

The source of speculative capital has no geographic boundaries. There is a phenomenon generally referred to as regional “speculative group” that is specific to Chinese housing market. Speculators from the same region pool their investment funds and organize tour groups travelling around China looking at properties in various markets. They then pick a target market, unite their funds and purchase large amount of housing at short time to push up the housing price dramatically. They then sell their units, pocket the profit, and move to the next market. It started as the (in)famous “Wenzhou housing speculative group”<sup>50</sup> and the similar speculation mode has been replicated by other regions.

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<sup>50</sup> “This history of Wenzhou speculative housing group”, October 31, 2016. Finance.Sina.com.cn. Online see <http://finance.sina.com.cn/china/gncj/2016-10-31/doc-ifxxfysn8209109.shtml>.

A Google Scholar research of publications in Chinese language that contains “Chinese housing, speculative demand” shows that over 400 papers are published in Mandarin since 2010. These papers generally assume that speculative demand exists, and exists on a large scale. However, a crucial fact is that the speculative demand cannot be distinguished from the usage demand, and thus there is no statistical data to demonstrate the amount of speculative demand. A common consensus is that the current vacancy rates of the sold housing units in China is extremely high and a large portion of it can be attributed to speculative investors.<sup>51</sup>

### 7.2.2 Vacancy Rate in the Housing Market

There is no official data on vacancy rates in China. But housing researchers using different approaches commonly report high vacancy rates. There are four sources that have listed their statistical estimate for vacancy rate in the Chinese housing market.

Source one: Glaeser et al. (2016) used the data from Urban Household Survey (UHS) and calculated the vacancy rate close to 20% in first tier cities and about 13% in other lower tier cities, as shown in Figure 7-5. Their definition of vacancy rate is a percentage calculated by the number of housing units left empty by investor owners, divided by the total number of housing units owned or occupied by the city’s residents.

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<sup>51</sup> “The truth of vacant housing: one unveiling myth”. Article from China.com.cn written in Mandarin. Online see [http://www.china.com.cn/economic/node\\_7098055.htm](http://www.china.com.cn/economic/node_7098055.htm) Access date: March 1, 2017

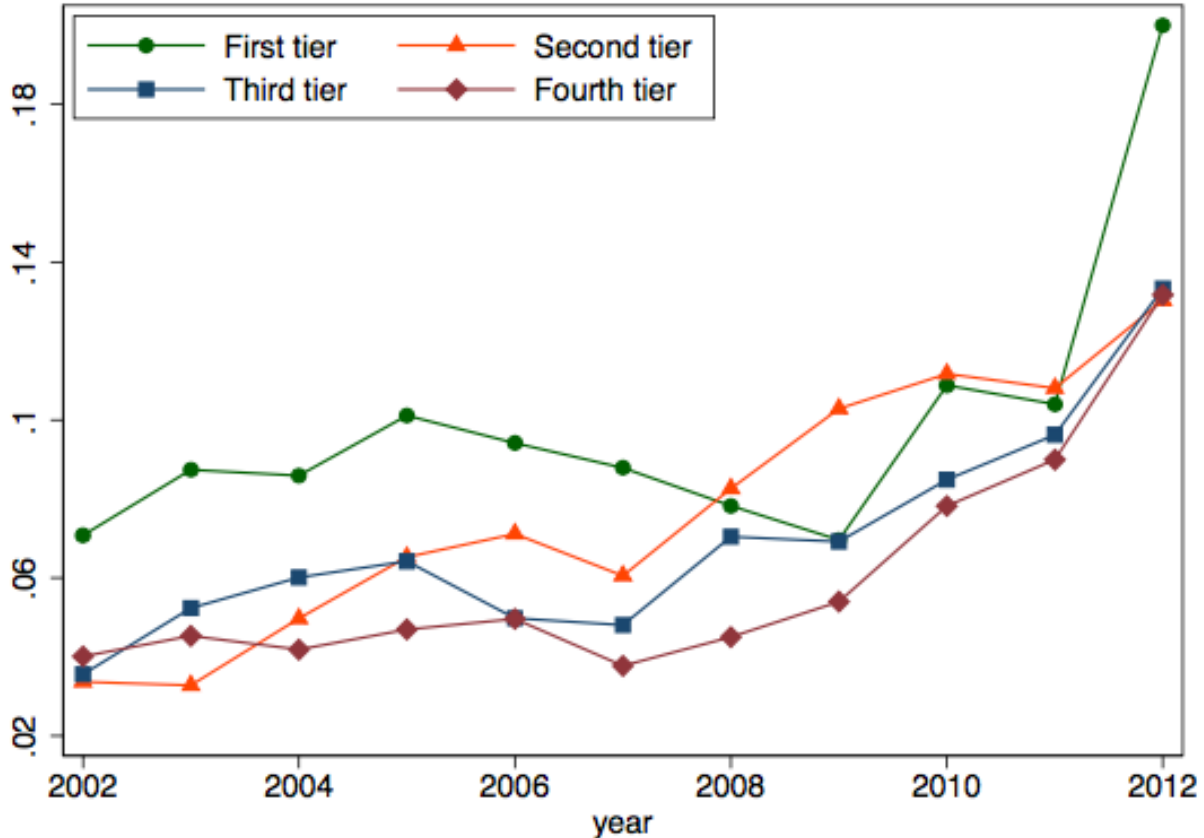


Figure 7-5 Household vacancy rates 2002-2012 of 36 cities from urban housing survey (Source: Glaeser et al., 2016)

Note: The vertical axis is vacancy rate in fraction. For example, 0.18 means 18%.

Source two: Professor Gan Li and his research team employ about 2,500 students and conduct China household finance survey (CHFS)<sup>52</sup> every other year since 2011. After the most recent CHFS survey in 2015, they have reported a nationwide housing vacancy rate of 22.8%, or about 54 million units. The current vacancy rate is based on the 2015 sample of 40,000 households in 363 cities/districts. As shown in Figure 7-6, for first tier cities, Gan also found vacancy rate in the same range as Glaeser et al., at 19.8%. However, for the lower tier cities, Gan reported a much higher vacancy rate at about 25.2%.

<sup>52</sup> China Household Finance Survey (CHFS) is a survey under the leadership of Prof. Gan Li. The survey and research center is at Southwestern University of Finance and Economics, Chengdu, China. Online see <http://www.chfsdata.org>.



### Vacancy rates by city-tiers

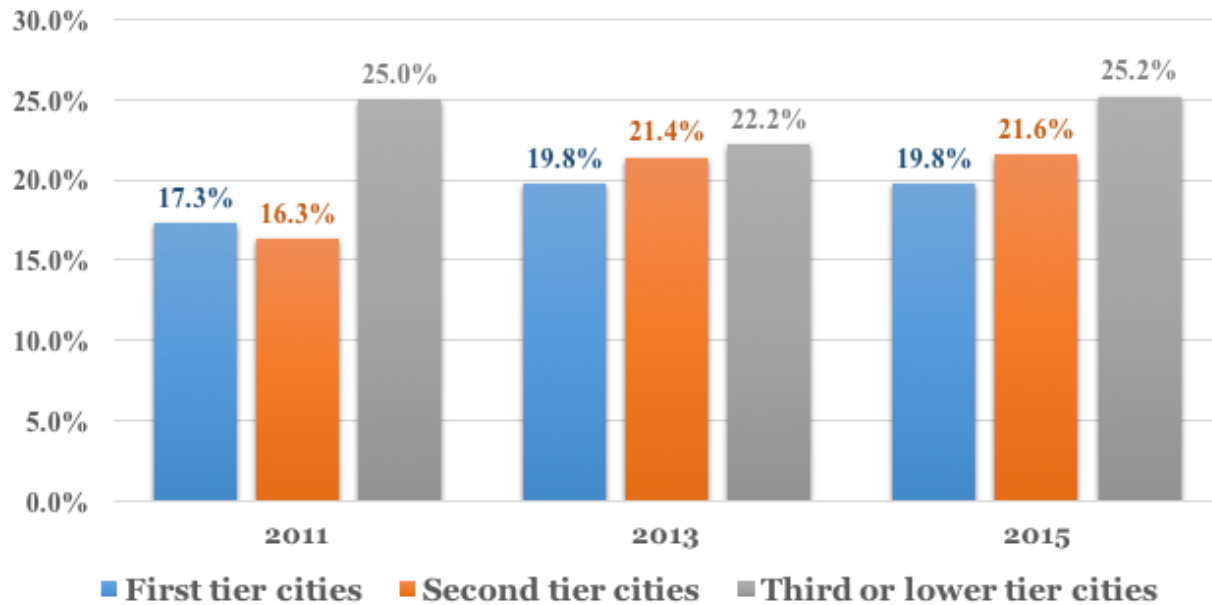


Figure 7-6 Vacancy rate by city tiers in survey of 2015 (Source: Gan, 2017)

Source three: Huang (2015) has reported on behalf of China International Capital Corporation (CICC)<sup>53</sup> an urban vacancy rate of 18% as shown in Figure 7-7. The definition of the vacancy rate here is general: all houses other than primary residences are considered vacant.

### 18% broad vacancy rate by end-2013

	Urban	City	Township
<b>Total</b>			
Total housing units (mn)	261	154	107
Occupied housing units (mn)	215	130	85
Vacant housing units (mn)	46	24	22
Vacancy rate	18%	16%	21%

Figure 7-7 Vacancy rate by the year end of 2013 in China (Source: Huang, 2015)

<sup>53</sup> CICC is one of China's leading investment banking companies and semi-state owned.

Source four: Wu, Gyourko, and Deng (2016) have reported low but rising vacancy rates on average –from 5% in 2009 to 7% in 2013. They challenged the reporting of high vacancy rates from other researchers because such high rate would have exerted a material dampening effect on housing price appreciation that is not observed in most market. It is interesting to note that their calculation is based on the same database as Glaeser et al. (2016). However, if we take a look at their reporting in Figure 7-8, we can see that actually it can be consistent with Glaeser. The time period of the analysis from Wu, Gyourko, and Deng is from 2002-2009. Their reporting is at the same level as Glaeser et al. (2016). The major vacancy rate jump, as Glaeser et al. claimed, comes after 2010. The high vacancy rate reported by Gan Li (2017) is also during the same time period from 2010 on.

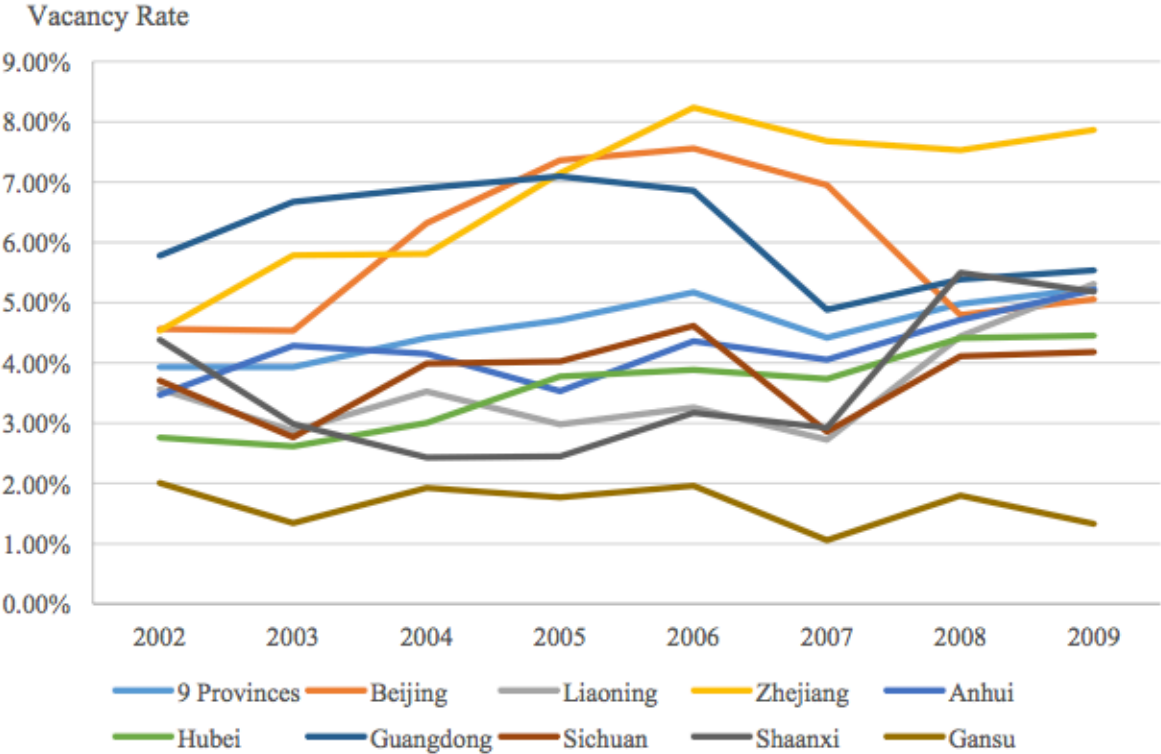


Figure 7-8 Vacancy rate of 9 provinces in China (2002-2009) (Source: Wu, Gyourko, and Deng, 2016)

Among all sources, only the national survey data from China Household Finance Survey (CHFS) lead by Prof. Gan Li offers insights to the composition by usage of the vacancy units such as vacation use, long term vacant, weekend use, etc. In the detailed breakdown of the vacancy rate, there is a category which counts for a large portion of the vacation rate and it is called the “long term vacant” rate. It is about 6.61% and accounts for about 15.8 million units. We consider this rate as a close estimate of the speculative vacancy rate and will use rate around this range for simulation purposes in Chapter 8.

### 7.3 Chinese Local Governments’ Land Financing Scheme

#### 7.3.1 The History of Land Financing Scheme

Before the model building process, it is worthwhile to provide some background context into the unique system of local government finance that has evolved in recent years in China. A report for the IMF spotlighted this issue (Lu and Sun, 2013) and pointed out that the receipts from the sale of land lease rights are the main source of revenue for local governments’ debt servicing payments. This finding is also confirmed by recent work of other researchers (Ding, 2003, 2007; Hsing, 2010, Deng, Gyourko, and Wu, 2012). As a result, a drop in housing market prices that results in lower land prices could hurt the debt servicing ability of local governments and the local government-financing platform (LGFP). This could further impair the asset quality of national banks (Sheng and Soon, 2015).

In China, developers and investors can lease urban land for terms of 30 years for industrial use, 50 years for commercial use, and 70 years for residential use. The ability to lease land is critical because it directly links land and the capital market thereby allowing local governments to tap into the capital markets, while still allowing the central government to technically maintain ownership of the land. Income that comes from land leasehold sales transactions has since become an important component in local governments’ fiscal revenue structure.

Fiscal reforms in the 1990s enhanced the role that land plays in local government revenues. In 1992, the leadership of Chairman Jiang Ze-min and then vice Prime Minister Zhu Rong-ji initiated a new “tax sharing system,” fully implemented in 1994 (Xiang, 2008). This is a landmark in China’s fiscal reform. It set policy between the Chinese Central Government and local governments regarding the collection, sharing, and spending of various taxes, such as the corporate tax, income tax, land-lease revenue, etc. Numerically speaking, the central government previously had access to only 22% percent of the total tax revenue, but after the 1994 tax reform its share rose to 56%; with the local governments’ share falling correspondingly from 78% to 44% (Li, 2012). This change is widely considered to be the root of the “Fiscal-Power” conflicts (*qianquan maodun*) between the Chinese central government and local governments (Liu, 2014). While the reform took tax revenue from the local governments, it did not reduce the actual tasks assigned to the local governments (Zhou, 2006). In short, the fact that central government has the dominant financial power while the local government has the actual duty to perform crucial government functions (including the provision of urban infrastructure) has created a mismatch between authority and responsibility (Jiang, Liu and Li, 2007).

As a form of compromise, the central government gave local governments the autonomy to use most land and real estate related tax income. The decentralization of land regulation power, plus the implementation of the tax sharing system, gave local governments a channel to achieve their fiscal needs. As a result, local governments focus on creating their private disposable “purses” through land sales, and aim to further develop the local real estate related industry. For example, in 2009, land sales in Hainan province amounted to 10.2 billion RMB, and accounted for about 34% of the province’s total fiscal budget (*caizheng yusuan*) (Ouyang, 2012).

These developments gradually evolved into the so-called land based municipal financing mechanism, or in short, “land finance scheme.” It means that local governments rely on income from land related sales to increase their fiscal budget. There are four primary channels of land financing (Yue, Teng, and Wang, 2009):

1. Direct land “sale”;
2. Free industrial land development, with the expectation of collecting tax revenue from the industry later;
3. Tax revenue from real estate development industries; and
4. Use of land sales income as collateral to obtain loans from central banks.

Li and Luo (2010) organized these channels into three categories:

1. Land finance I is the narrowest. It includes direct land tax and indirect tax from real estate and construction industries.
2. Land finance II mainly includes the land sales fees (effectively, the up-front price of the leasehold sales, the full present value of the leaseholds).
3. Land finance III consists of loans obtained from the central banks using land as collateral to take on debt.

### 7.3.2 Maximize Land Sales Revenue

The process of land finance has its internal flaws: The local government, positioned as a monopoly in land supply, can effectively control the quantity, location, and use of the land. The local government officials naturally plan land sales around their own best interests (Tao, Yuan, and Cao, 2007). Under the pressures of local economic growth and regional competition, and in order to maximize their economic achievement within the assigned five-year tenure for a government official, local government leaders have prioritized non-residential land use and exploited the maximum land-lease sales price from residential land sales (Wang and Tu, 2014). By favoring industrial land use, local governments constrain the supply of land for residential use and push up the land price to maximize the total land sales revenue (Zhang, Wang, and Xu, 2011; Zheng and Shi, 2011). Li and Luo (2010) report that on average at the national level only 15% of the total land goes into residential use. Based on land transaction data between 2003 and 2005, industrial land prices were typically only a third of residential land prices (Tao et al., 2009).

The exclusive right to sell the leasehold of land to private developers gave the local governments the incentive to convert agricultural land to developable land around the urban fringe and sell as much land as possible in order to obtain the maximum land sale fees.<sup>54</sup> The land “seizure” cost, which refers to the money that the local government pays to obtain land from farmers, is minimal (Jiang, Liu and Li, 2007). Based on 30 cities’ land reclamation and sales data, the estimated land sale price to developers has been 18 times the cost paid to the farmers (Wang, 2005).

On the other hand, research also indicates that local governments taking advantage of their monopolistic position can morph into speculators. Based on provincial level data from 1995 to 2010, it is found that land price is positively correlated with the magnitude of land hoarding by local governments (Du and Peiser, 2014). Zheng et al. (2014) established the relationships among land sales, infrastructure improvement, and land price and pointed out that the local governments can strategically set the annual land disbursement quota in order to achieve the highest land sales revenue over a certain time span.

Facing such profit, local governments have used land finance heavily to fuel urban development and finance infrastructure. Based on land transaction data from 1999 to 2007, analysts estimated that sales of land counted for more than 30% of local governments’ budgets (Liu and Jiang, 2005; Li and Luo, 2010).

Local governments also use the potential of land sales fee revenue as collateral to start a second round of fund-raising. While they are not allowed to borrow directly from government-owned central banks, they can set up entities related to the local governments and use land transfer fees (leasehold sales revenue) or potential conversion-in-progress agriculture land stock as collateral to borrow money under the name of such an entity (Liu and Zhang, 2010).

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<sup>54</sup> The term “fees” in this context simply refers to the proceeds the local governments obtain from the sale of the land leaseholds.

Since 2010, local governments have taken on so much debt that they face great difficulty to pay even the interest let alone the principal, thus creating what has been termed a “local government debt crisis”.<sup>55</sup> By June 2014, local governments in 84 key cities in China had a total debt of 8,700 billion RMB, equivalent to about 1,500 billion US dollars (Zhang, 2014), almost comparable in magnitude to the U.S. municipal bond market as a fraction of GDP. In order to repay the debt, the municipalities are forced to borrow more money, or sell more land that they can have immediate access to, thus potentially getting trapped in a vicious cycle (Yang and Huang, 2010). Ren, Xiong, and Yuan (2012) also have pointed out that the government is the dominant power in terms of land supply and this special feature may affect the dynamics of housing prices.

The current urbanization process in China may well be actually financed just through land finance. The disadvantage is that with the leverage of debt, the effect of the initial large amount of land sales fees has been magnified. Since land is a scarce resource, such continuous “self-financing” will not last forever. Also, from what has been listed above, because the local governments are trying to meet the fiscal budget goals, their land sales behavior can affect the future housing price trends. For example, in a scenario where a local government is trying to rely on land sales to meet fixed revenue goal: when it sells into a rising market such as in the first tier cities, it only needs to sell limited amount of land to meet the goal, which leads to less development, and results in further driving up the future housing and land price; similarly, if it sells into a falling market such as in a ghost city scenario, it will have to sell a lot more land to meet the goal, more development than needed happens, and this further drives down the future housing and land price. In short, the needs of the government can make higher housing prices higher, or lower housing prices lower. It is thus necessary to incorporate this self-enforcing mechanism into the housing market model.

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<sup>55</sup> <http://cn.nytimes.com/china/20130624/cc24localdebt/>

## 7.4 Chinese Central Government's Policy Interventions

The overly heated housing market and the potential bubble has also raised concerns of the Chinese Central government. In response, the Central government has implemented strict policies to micromanage the potential housing bubble. A history of the milestone policies in the real estate sector are listed in Table 7-1.

Among all policies, the “New National Ten” that came out in April, 2010 in Beijing is considered to be the most influential policy. One of the key items of the “New National Ten” is generally referred to as home purchase restriction (HPR), or in Mandarin “Xian Gou Ling.”<sup>56</sup> Like there used to be the (in)famous ‘One Child Policy’ in China, HPR is also called ‘One House Policy’. It is used to target the speculative demand by preventing any household from purchasing more than one unit of housing.

As of 2015 about 50 cities had implemented HPR since its inception in Beijing, as shown in Figure 7-9. But each city has its own interpretations of the policy and can modify HPR accordingly.<sup>57</sup> Among them, Beijing is considered to have the strictest interpretations: households with Beijing Hukou that own two or more housing units cannot buy any more housing units; households without Beijing Hukou have to have a record of paying income tax five years in a row to be eligible to purchase their first housing unit. In another first tier city, Shenzhen, the interpretations of HPR is relatively loose: households with Shenzhen Hukou can purchase two units, and households without Shenzhen Hukou can purchase one unit.

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<sup>56</sup> The original document can be found in Mandarin see <<http://baike.baidu.com/item/国务院关于坚决遏制部分城市房价过快上涨的通知>>

<sup>57</sup> A list of examples can be found in Mandarin see <<http://baike.baidu.com/item/限购令>>



<b>Timeline</b>	<b>National Policies Guiding the Private Housing Market</b>
2001 March	Real estate companies are allowed to go public.
2001 June	Regulatory measures on the sale of commercial houses became effective.
2002 May	Land for commercial use must be granted via tender, auction, or bidding.
2003 August	Real estate industry becomes a “pillar industry of the national economy”.
2004 August	Local governments start to play a key role in land supply chain.
2005 March to May	“Old National Eight” policy and “New National Eight” regulation measures aim at stabilizing home prices.
2006 May	“National Six” real estate market regulation measures promote small condos and put restrictions on mortgage down payments (>30%).
2007 all year	Government raised interest rate six times and reserve requirement ratio 10 times.
2007 September	Minimum down payment on second home mortgages is increased to 40%; Maximum monthly payment to income ratio is 50%. Tightening of real estate loans.
2007 November	Foreign investors are banned from many real estate investment projects.
2008 October and December	Various measures are announced to stimulate the housing market, including tax changes and interest rate deduction for homebuyers.
2010 January	“National Eleven” real estate market regulation measures focus on reining in speculative activities (Home Purchase Restriction).
2010 April	“New National Ten” purchase restriction rules. <sup>58</sup>
2010 September	Third mortgages are eliminated. Minimum down payment for first mortgages is maintained at 30%.
2011 January	“National Eight” real estate market regulation measures increased minimum down payment for second mortgages to 60%. Other tightening measures include taxes and land transactions.
2013 March	Tax on home resale capital gain raises from 1% to 20%. <sup>59</sup>

Table 7-1 Nation policy timeline since 2001 (Barth, Lea, and Li, 2012)

<sup>58</sup> This item is not listed in Barth Lea and Li (2012) but added by author.

<sup>59</sup> This item is not listed in Barth Lea and Li (2012) but added by author.



Figure 7-9 Home purchase restriction timeline across cities in China (Du and Zhang, 2015)

The effect of HPR, at least in short term, was immediate. The housing price and transaction volume have dropped nationwide. Du and Zhang (2015) found that the HPR reduced the housing price in Beijing by an annual rate of 7.69%. Sun et al. (2014) also found that Beijing’s HPR policy triggered a 17-24% decrease in resale price, and a deep reduction in the transaction volume of the for-sale market. Cao, Huang, and Lai (2015) claimed that the HPR has triggered substantial decline of housing price nationwide but has no effect on the still ongoing construction boom, implying its ineffectiveness in correcting the housing bubble in long term. As of this writing, there are no research conclusions regarding the longevity of the effects of HPR.

Indeed, ever since 2014, some second tier cities such as Changsha in Hunan Province gradually started to loosen or entirely eliminate the HPR. By early 2016, most of the cities other than the first tier cities, had eliminated the HPR.<sup>60</sup> This is because the Chinese Central government has realized that there are large amount of unsold housing stocks existing in the market and thus geared the policy direction to eliminate the

<sup>60</sup> Report of the elimination of home purchase restriction. See <http://news.sohu.com/20160202/n436688166.shtml>.

accumulation of unsold stocks<sup>61</sup>, in order to further prevent overbuilding in the housing sector. In general, the HPR rule can be seen as a short-term and short-lived remedy to “cool down” the housing market but not considered an effective long term strategy.

As of 2017, the most advocated and expected long term housing policy would be the implementation of a property tax. There is no property tax in China and that is why the local government mainly relying on selling land to meet the fiscal budget. Once the property tax around 1.5% is implemented, it can be seen as an increase of cap rate and thus directly decrease the housing price. It also increases the holding cost of current housing owners. The speculative investors who possess multiple vacant units will have to either rent the vacant units to offset the property tax, or sell them in order to reduce the holding cost. Income from property tax will be collected by the local government and can replace “land financing scheme” to offer the long term cash flow on an annual basis. The property tax is first implemented in Shanghai and Chongqing and is speculated to be effective nationwide by the end of 2017.<sup>62</sup>

There are also opposing opinions that the government regulations are not effective and can potentially damage the market. These interventions are unlikely to have any effect on controlling the housing price because the price increase is due to the demand increase resulting from the income increase, and supply increases resulting from the rising construction cost (Chow and Niu, 2011). Wu, Gyourko, and Deng (2012) suspect that the policy interventions such as the implementation of a property tax or purchase restriction policy will help control speculative investment but will also unintentionally discourage usage demand because the speculative demand and usage demand are not distinguished from each other.

As described above, the frequent government interventions represent an important factor that governs the price trend of Chinese housing market. It is thus necessary to

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<sup>61</sup> Online resource, see <<http://finance.sina.com.cn/china/gncj/2016-09-10/doc-ifxvukhx4758380.shtml>>

<sup>62</sup> “China will be collecting property tax from 2017”, See <http://www.rfa.org/mandarin/yataibaodao/jingmao/yf2-07152016105125.html>.

evaluate the immediate impact of such policy interventions and the possible consequences using an integrated housing market model.

## 7.5 Appendix of Chapter 7

### List of Cities by Tiers (Source: Fang et al., 2016)

First tier includes: Beijing, Shanghai, Guangzhou, and Shenzhen.

Second tier includes the following 36 cities: Beihai, Changchun, Chang-sha, Chengdu, Chongqing, Dalian, Fuzhou, Guiyang, Haikou, Hang-zhou, Harbin, Hefei, Hohhot, Jinan, Kunmin, Lanzhou, Nanchang, Naijin, Nanning, Ningbo, Qingdao, Sanya, Shenyang, Shijiazhuang, Suzhou, Taiyuan, Tianjin, Urumqi, Wenzhou, Wuhan, Wuxi, Xi'An, Xiamen, Xining, Yinchuan, and Zhengzhou.

Third tier includes the following 85 cities: Xuancheng, Fuyang, Chu-zhou, Huangshan, Anqing, Bengbu, Wuhu (from Anhui Province); Ningde, Zhangzhou, Quanzhou (from Fujian Province); Jiayang, Zhong-shan, Dongguan, Qingyuan, Yangjiang, Heyuan, Shanwei, Huizhou, Zhaoqing, Jiangmen, Foshan, Shantou, Shaoguan (from Guangdong Province); Hengshui, Langfang, Zhangjiakou, Baoding, Xingtai, Qinhuangdao, Tangshan (from Hebei Province); Jiamusi, Qiqihar (from Hei-longjiang Province); Zhumadian, Nanyang, Luohe, Xuchang, Puyang, Xinxiang, Luoyang, Kaifeng (from Henan Province); Changde (from Hunan Province); Xilingol, Baotou (from Inner Mongolia Province); Jiangyan, Suqian, Zhenjiang, Yancheng, Huai'an, Lianyungang, Nantong, Changzhou, Xuzhou (from Jiangsu Province); Fuzhou, Shangrao, Yichun, Xinyu, Jiujiang, Pingxiang, Jingdezhen (from Jiangxi Province); Songyuan, Jilin (from Jilin Province); Wuludao, Chaoyang, Tieling, Panjin, Yingkou, Dandong, Anshan (from Liaoning Province); Liaocheng, Dezhou, Rizhao, Zaozhuang (from Shandong Province); Yuncheng (from Shanxi Province); Dazhou, Nanchong, Leshan, Mianyang, Deyang, Luzhou (from Sichuan Province); Changji (from Xinjiang Province); and Taizhou, Jinhua, Shaoxing, Huzhou, Jiaxing (from Zhejiang Province).

### 8 Step Three – China-Specific Model Modifications

The objective of Chapter 7 is to address the first research question of this thesis: “Can certain features in the Chinese housing market lead to bubble results? If so, under what circumstances may it happen and what are the possible explanations?” To answer this, we created a set of China-specific SD models (SD10-SD12) through modifying the baseline models in Chapter 4. Model SD10 through Model SD12 are distinct from each other, and are not built incrementally. Different from models in Chapter 6, the newly created models in this chapter are not generic because these features that have been incorporated into the baseline models are unique to the current Chinese housing market. It is not saying that similar features cannot be found in other countries, but they are not universally applicable in all markets.

#### The DiPasquale-Wheaton Four Quadrant Model

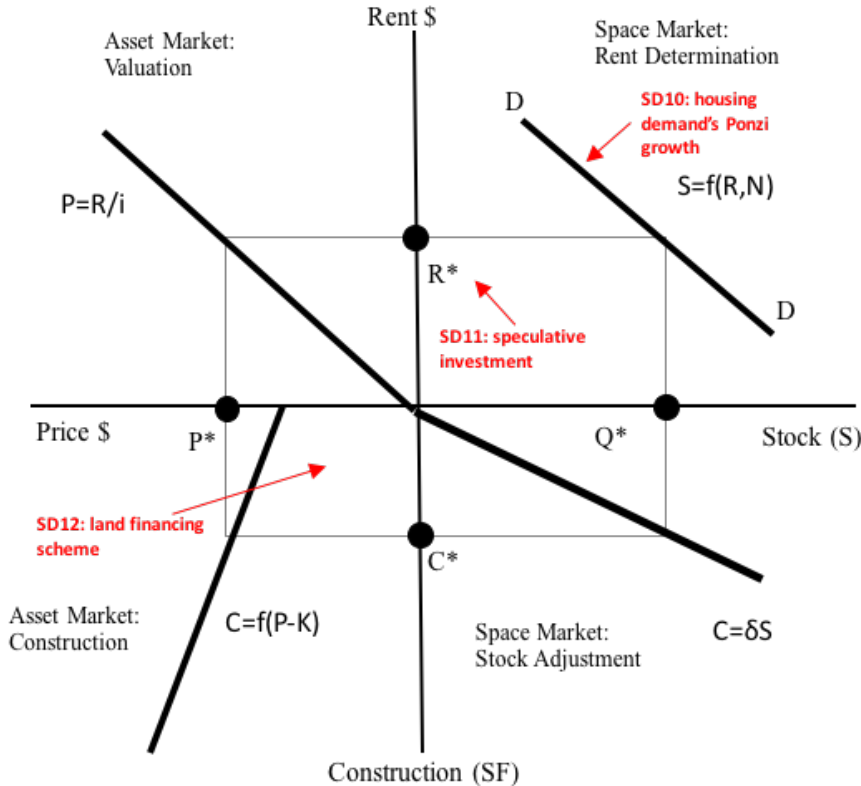


Figure 8-1 Mapping China-specific models SD10-SD12 on the 4QM

The China-specific features that have been covered in this chapter are mapped in Figure 8-1.

- Model SD10: Simulate the scenario when the housing demand growth is like in a Ponzi-like recruitment process where perception of growth from the developers varies differently from reality;
- Model SD11: Explore a special situation where speculative investors purchase housing units without renting them out, but rather leave them empty and wait for capital growth;
- Model SD12: Explore the special land supply mechanism where the amount of land supply is decided by a monopolistic land owner – specifically, the Chinese local governments.

It is important to note that these components – limited demand growth, speculative housing investment/hoarding, and land financing schemes – are mechanisms that cannot be rationalized with traditional economic theory. However, they can create price volatility that derail from the value of price governed by economic fundamentals. As such these elements can contribute to both the formation and collapse of price bubbles. By examining the price surge of each modified model as compared to the baseline model, we can determine the bubble component in the price structure. Understanding the cause of such bubbles can lead to the development of various mitigation strategies, which can then be evaluated through simulation.

## **8.1 Model SD10: Finite Housing Demand Growth**

### **8.1.1 Demand Growth and Ponzi-like Recruitment Process**

The Ponzi Scheme, often also referred to as pyramid or “chain letter” scheme, is a fraudulent recruitment process where the previous investors’ payoff relies on the unlimited recruitment process of new investors. Chinese housing market is not a Ponzi scheme but they do have similarities. The foremost reason that makes the Chinese housing boom look like a Ponzi scheme is the perception of the recruitment process of the new investors coming into the market. It is important not to confuse the definition of

investors here as speculative investors. The investors here refer to the general demand, they can be usage demand, speculative demand, etc. As shown in Figure 8-2, Mrotzek and Ossimitz (2008) have depicted how a Ponzi process would break down sooner or later. In process (A), the market information is that the recruitment process will be everlasting because there is assumed to be unlimited number of outsiders to become insiders. However, the reality as in process (B) shows, the pool of outsiders is limited. Once the outsider pool is empty, an avalanche of pricing falling is inevitable. Process (A) and (B) thus depict the difference between a false perception and reality.

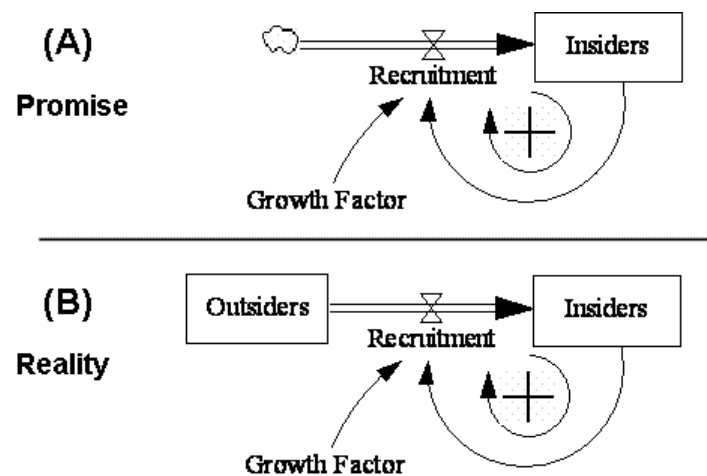


Figure 8-2 General escalation archetype of Ponzi-scheme (Mrotzek and Ossimitz, 2008)

In the case of Chinese housing market, we can think that there is an invisible dealer under the guise of “housing experts” that are hired by housing developers. They manage to persuade the current investors to purchase the housing units because there will be enough other housing buyers to be recruited into the purchase process later, thus guaranteed that the housing value can only increase over time. The investors that buy at time  $t(0)$  and sell at time  $t(n)$  at a profit can only do so if, at  $t(n)$  there are more investors willing to pay a higher price than the original investor paid at  $t(0)$ . In the Ponzi scheme, the money is not put to use. Rather, the “dividends” paid to early investors is taken directly from the deposit of later investors. Likewise, in Chinese market, the value of the asset sold at  $t(n)$  is not based on its earning potential, but a willingness of a

subsequent investor to put money into the scheme. That is the only way of ensuring that the previous investors profit.

If this recruitment process were mathematically true, then within short period of time, the entire Chinese population would have to participate to make it work. However, the characteristic of “locality” of housing have put a boundary (or limit) of such recruitment activity within a specific geographic location, such as within gateway cities like Beijing, Shanghai, and Shenzhen. The pool of outsiders, on the other hand, has no boundaries. The new round of buyers can be migrants from other regions, or free flow of capital from abroad. However, the pool of outsiders is not finite and will eventually dry up. The neglected issue is that such “outsider” pool is not infinite. Gastwirth (1977) has mathematically proved that in a pyramid scheme, the vast majority of participants have less than a 10% chance of recovering their initial investment. On average, half of the participants will recruit no one else, and about one-eighth of the participants will recruit three or more people.

### 8.1.2 Model Description and Simulation Results

In the case of the housing market research, we have so far encountered the case where the perception of demand increase is a known finite number as in baseline Model SD1, or is a steady infinitely growing number as in baseline Model SD3. In the case of Chinese urban housing, Model SD3 is more appropriate. However, the model is assuming that there will be constant number of rural-to-urban migrants, or, there will constant population growth. In reality, this is not always the case. Inspired by the Ponzi-like recruitment process, we have incorporated a similar component to the SD baseline Model SD3 to represent the finite demand growth. The modified Model SD10 is shown in Figure 8-3.



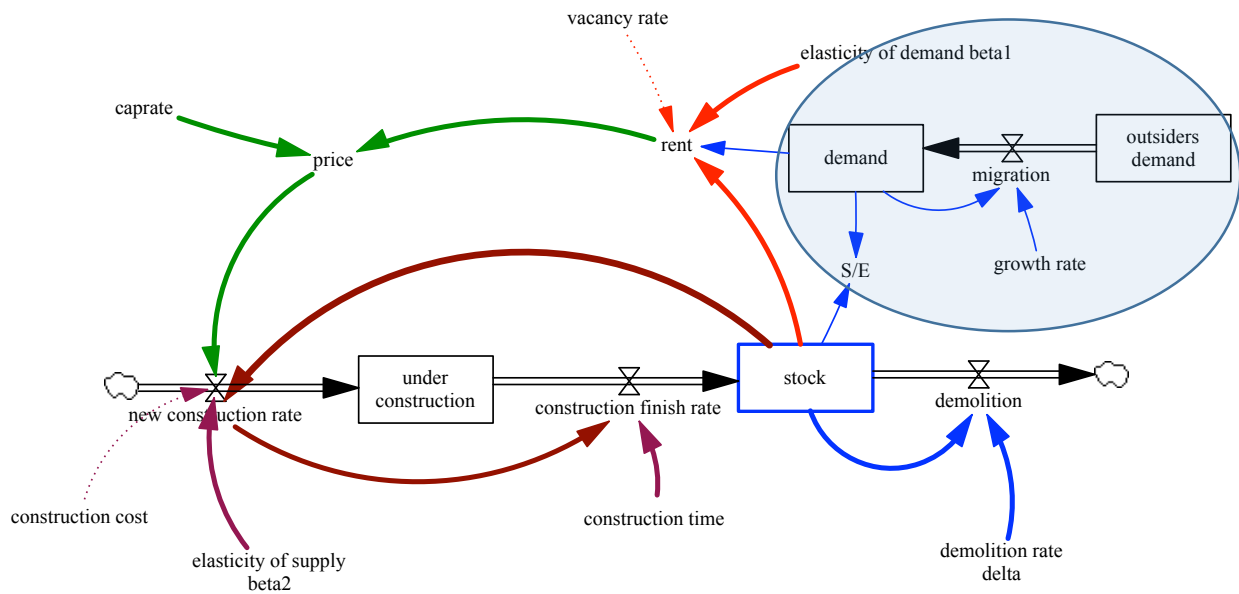
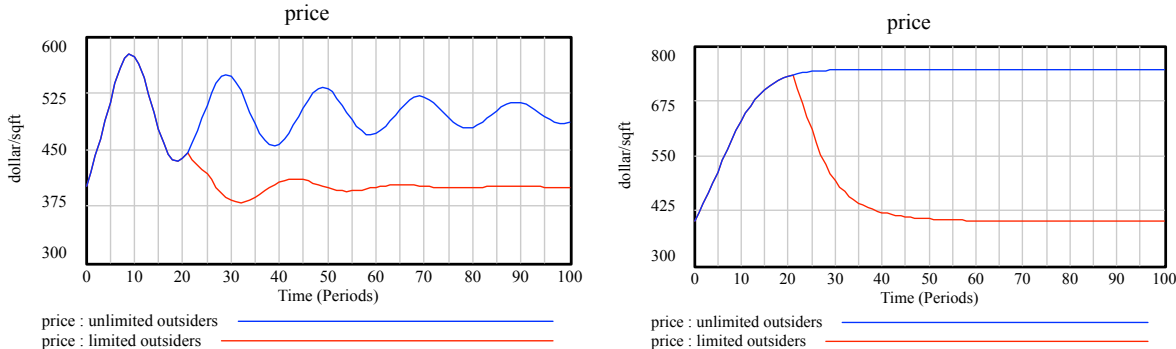


Figure 8-3 SD10: Revised model when the housing demand growth is finite

In Model SD10, we assume that the housing demand demonstrates the characteristics of a Ponzi-like recruitment process. We compare two cases. The initial demand is identical to the baseline model SD3 and increases exponentially at certain growth rate. In the first case, the pool of outsiders is infinite and the model basically is exactly as the baseline model SD3 in Chapter 4. In the housing context, this model is representative of an infinite demand comprised of migrants from other market areas, speculative investors, or infinite population growth. In the second case, the pool of outsiders is finite. It depicts the case where demand in the target market is increasing at a steady growth rate and the perception of the investors in the market is that such growth rate will be sustained in the long run. However, the migration stops at certain point when the pool of “outsiders demand” is exhausted.

The simulation result of Model SD10 is shown in Figure 8-4. In the left panel, the simulation is run based on the assumption that the supply is elastic and set at 2.0. As we can see, when the pool of outsiders is infinite, the market still shows cycles initially. But when the pool of outsiders is empty, the housing price will not have a chance to

bounce back but continuing dropping and reach the equilibrium price. The right panel shows the simulation result when supply is inelastic and set at 0.7. It shows the similar trend of market collapsing. The infinite outsiders case represents the perception of housing price trend of developers or local governments. The construction happens based on the assumption that the demand growth is sustainable. The finite outsiders case represents the reality when such demand growth is no longer met.



Left panel: housing prices when supply (=2.0) is elastic; Right panel: housing prices when supply (=0.7) is inelastic. Initial demand is 10 million people, and exponential growth rate is at 2%. In “unlimited outsiders” case, the pool of “outsiders demand” is infinite. In “limited outsider” case, the pool of “outsider demand” is set at 5 million people. Construction time  $n=5$  periods. Demolition rate is 5%. The supply elasticity is set at 0.7 to represent the inelastic demand, and at 2.0 to represent elastic demand.

Figure 8-4 When "outsiders demand" is unlimited vs limited, and compare the case of elastic supply and inelastic supply.

In another scenario, the growth rate of demand is not a constant set at 2%. The growth rate has a second-order growth rate of 10% to mimic the fast Ponzi recruitment process, the herd effect, with the number of insiders growing at an escalating speed. The simulation result is shown in Figure 8-5. We can see that the first local maxima and minima demonstrate much higher amplitude and thus create a bubble component. The discrepancy is driven by the “housing frenzy” or the abnormal amount of housing buyers who believe that the housing price will only continue rising. At time stamp 12, the outsider demand pool is drained off and price plunges and will drop way below the long-run equilibrium price.

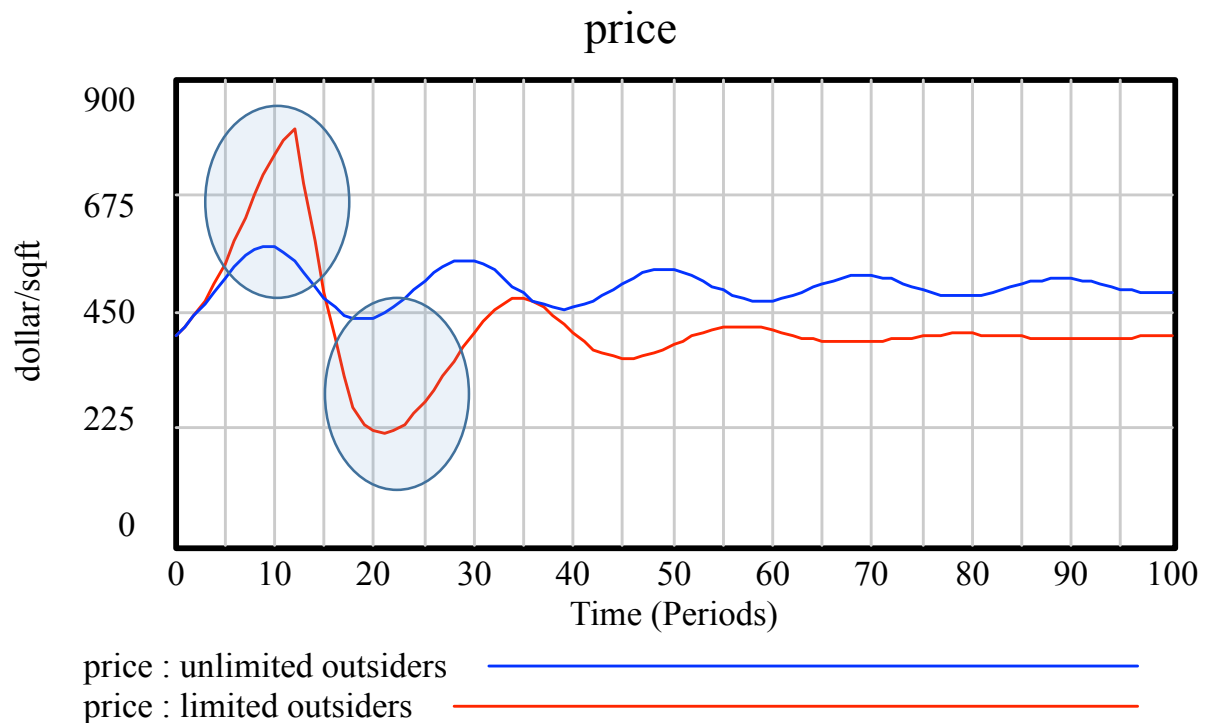


Figure 8-5 When the demand growth is limited and demand's exponential growth rate is not constant but has its own growth rate

### 8.1.3 Policy Implications

The simulation conducted in SD10 can be a good explanation of the formation of declining cities from the developers' misperception. Initially the city is built based on the perception that an infinite number of people will move to live and work there with a steady growth rate. However, due to a sudden economic downturn or collapse of certain pillar industry, the migration pool is drawn empty, and the migration process stops. The result is a collapse in the housing market. In an extreme case, the model can be modified to analyze the case of ghost cities in China. Many attributed the formation of Chinese ghost cities to the excessive investment from local governments pursuing GDP growth (Yu, 2014; Sorace and Hurst, 2016). They sell land to developers promising fast demand increase in order to obtain land sales revenue to sustain the infrastructure investment. The ghost cities were built entirely aiming to host a false perception of demand that was never there in the first place.

## 8.2 Model SD11: Speculative Demand and Housing Hoarding

### 8.2.1 Speculative Demand in Chinese Market

As explained in details in Chapter 7, although the speculative demand in the Chinese housing market has the same traits as any real estate speculation, it does have its own specific characteristics. For example, in the US housing market, the speculators are landlords. They invest for future capital gain but at the same time they also rent the housing units out and thereby fulfilling some of the housing demand. But in China, the housing speculators left the units empty. In one sense, it is like hoarding a scarce resource (housing) and perpetuates its scarcity. This process however created a large amount of hidden inventory or untapped supply that could be unleashed at any moment, and thus posing potential danger to the housing market. The speculative investors have no reason to keep the property if/when the price drops. It's not like they have tenants that are paying the rent. As a result, the speculative demand can be very fragile, and can suddenly evaporate. Speculative demand in the Chinese market can be quantified but there is no accurate data available. However, we can derive an estimated number from the vacancy rate that are reported by other scholars for modeling purpose.

### 8.2.2 Model Description and Simulation Results

Model SD11 is still simulated with the baseline model data and modified upon baseline Model SD3, which serves as the baseline model. The model structure is shown in Figure 8-6.

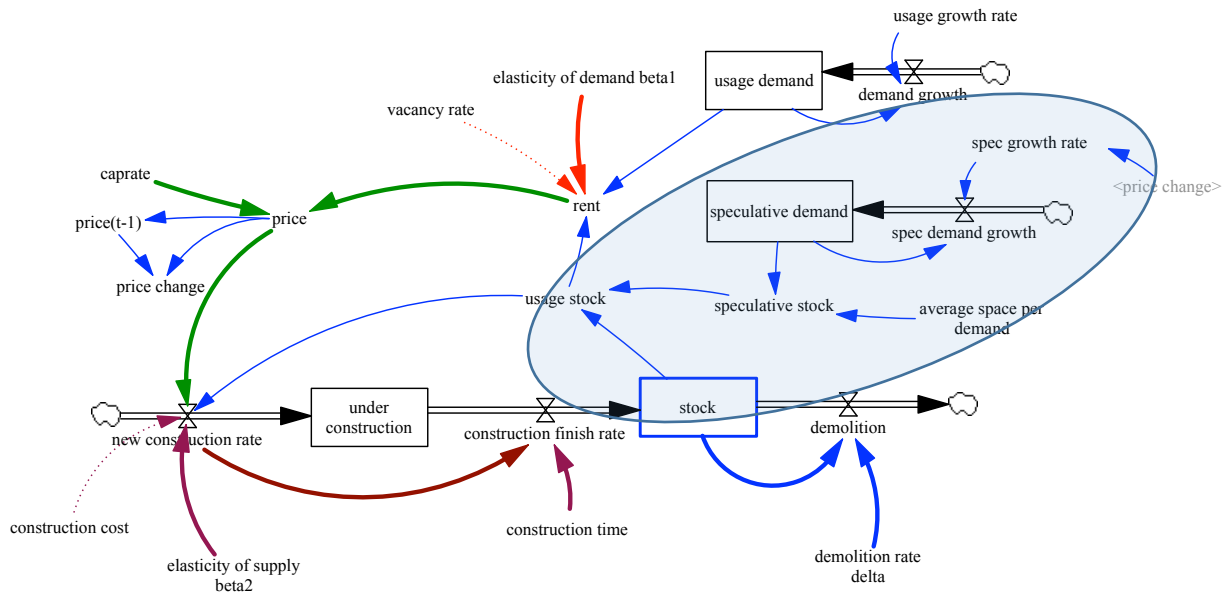


Figure 8-6 Model SD11: incorporate speculative demand into the baseline model

In Model SD11, a major new parameter is the speculative demand. It is a stock variable that is driven by the speculative demand growth rate. The parameter of price change captures the price percentage change from one period to the next period, and we assume that the speculative demand growth rate is proportional to price change rather than to absolute price levels. Contrary to the traditional economic theory where demand diminishes as price increases, when price is rising comparing to previous period, there will be an increase in speculative demand; when price is falling, there will be a reduction speculative demand.

A simplifying assumption has been made that each unit in speculative demand requires the same average space consumption as in usage demand at the initial equilibrium stage. This assumption is just for simplification purpose at this stage and will be revised in the next two chapters to make it more realistic. It is a simplified way to calculate the total speculative stock. At every time stamp  $t$ , the total stock equals to the sum of usage stock and speculative stock. An important concept is that the speculative stock remains vacant. The rent level is only decided by the usage demand and usage stock. The new construction is also jointly decided by the usage stock and housing price.

A few important assumptions of parameter values are listed here:

Initial usage demand = 10 million people

Initial total stock=2.5 billion sqft

Usage demand growth rate = 2%

Initial speculative demand = 1 million people

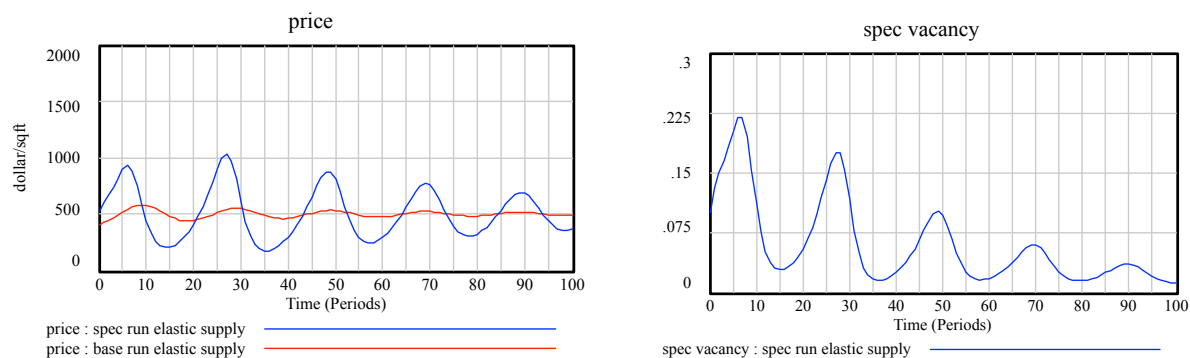
Initial speculative stock = 0.25 billion sqft

Two important new assumptions of model functions are listed here:

Speculative demand growth/decline rate = housing price increase/decrease rate

Total stock=speculative stock + usage stock

As shown in Figure 8-7, the speculative demand has created more market volatility when compared to the baseline case. The simulated speculative vacancy rate starts with 10% and reaches highest of 22.5% before it drops to a low of 2%. It is within the reasonable range that is found in the current field of research. Comparing to the baseline case, the speculative demand can create high price peaks and troughs in the market and the deviation can be seen as a contributing factor of a bubble component.



Left panel: price level with and without speculative demand component when supply is elastic (=2.0);

Right panel: speculative vacancy rate change

Figure 8-7 Price effect of speculative demand when supply is elastic

The bubble effect is especially prominent in housing market where housing supply is inelastic as marked in the oval circle in Figure 8-8, showing price level with and without speculative demand component when supply is inelastic (=0.8). Before time stamp 13,

the price climbing beyond the baseline case, can be seen as the bubble forming phase where more and more speculative investors hoarding the housing units and leave them vacant. After time stamp 13, it can be seen as the bubble bursting phase where the investors gradually releasing the units into the housing market for sale.

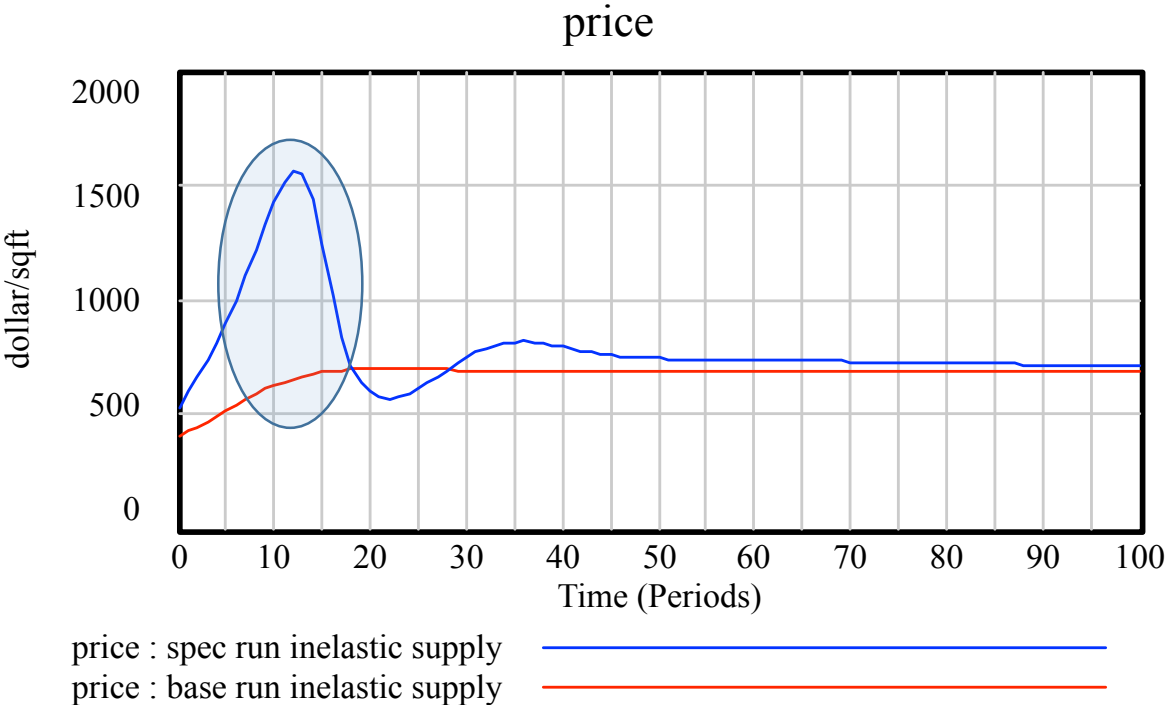


Figure 8-8 Price effect of speculative demand when supply is inelastic

8.2.3 Policy Implications

Most of the housing policies as listed in Chapter 7 are aiming to suppress the speculative demand as the government believes that it is the main reason that is driving up the housing price. In the annual economics meeting of the Chinese central government in December 2016, President Jinping Xi has advocated the following advices regarding the housing market<sup>63</sup>:

<sup>63</sup> “Housing should be used for living, not used for speculation”. Source: Xinhua net. Online See < <http://wallstreetcn.com/node/279956>> and also see < [http://news.xinhuanet.com/fortune/2016-12/16/c\\_1120134160.htm](http://news.xinhuanet.com/fortune/2016-12/16/c_1120134160.htm)>.

*“(We) should insist on the definition that housing units are used for living, not for speculation. We need to combine the strategies from finance, land, tax, investment, and legal aspects, and speed up the setup of long term mechanisms to adapt to the basic market fundamentals as well as the Chinese market situation. In this way, we can suppress the housing bubble, and control the magnified market cycles. At the macro level, the government needs to tighten the currency policy; at the micro level, the housing loan policy should support the usage demand but prohibit the loan from flowing to housing speculators”.*

In the past, central government policies such as purchase restriction rules and adjustments of loan requirement have demonstrated short-term effect in cooling down the housing market. In 2017, based on President Xi’s talk, it is speculated that the housing market will aim for setting up the long-term mechanisms to eliminate the speculative demand by combining policies from multiple fields, while differentiating the speculative demand from the usage demand.

The simulation result of Model SD11 has demonstrated the potential danger of the existence of housing units hoarded by the speculative demand. The essence is not to eliminate speculative demand, but to force the current and future housing speculators to rent out the housing units to the usage demand. Short-term policies such as purchase restriction rules have short-lived effect and the housing price bounced back quickly. Speculators have enough means to ride the wave without releasing the units to the market. However, long-term policies such as implementing property tax will increase the holding cost of speculators and force them to at least considering renting the units out in order to counter the holding cost.

### **8.3 Model SD12: Land Financing Scheme - When Land Supply is Monopolistic**

#### **8.3.1 Land Financing Scheme of Chinese Local Governments**

This section aims to use the Chinese “land financing scheme” that is discussed in Chapter 7 as background, and incorporate it into the SD model structure. The goal is to observe how government land supply policy, which functions independently of the land and housing market, can significantly affect the housing price trend. Although we use Chinese land supply system as the main context, similar systems can be frequently



found in other Asian countries such as in Singapore, Malaysia, and India. This feature can thus be generalized and used in other political economy contexts.

In Chapter 6, we have discussed the “land scarcity” issue. However, it was focusing uniquely on the natural constraint of land, providing that there may be not enough land left for the new development to happen. The land scarcity scenario was using the cases of Hong Kong, San Francisco, or New York City as background. In this section, we focus on the discussion of the land supply mechanism in a political economy market, and replace the traditional “invisible hands” in the land market with a local government agency that controls the land supply. We will explore how the interests of the local government and local developers can be aligned or detached, and how such behaviors may affect the housing price in the market.

In Wheaton’s 1999 stock-flow model paper, he mentions that he adopts the standard view that the flow of capital assets depends upon their price relative to replacement costs, and argues that the model can be easily improved by incorporating the construction cost ( $K$ ), which by theory also includes land cost. We have modified the equation by replacing Price ( $P$ ) in the model with  $(P-K)$  in all equations. In view of the major role of land cost as suggested in the previous section, our first modification is to include the cost of development land into the model (in effect, the price developers must pay to the local government for purchase of leaseholds).

### 8.3.2 The Difference of Local Government’s Budget Goals

The local governments need to sell land to meet their budget goals. In Figure 8-9 and Figure 8-10, our SD model suggests that the local government’s behavior can strongly determine whether land prices drive housing prices into an unstable spiral or not, depending on whether the local government land sale behavior is aimed at “maximizing revenue” or aimed at a “fixed revenue” target.

- “Maximize revenue”, that is, to sell as much land as possible as long as it is under the land quota or

- “Fixed revenue” that is, to supply land until sales meet revenue requirements.

As in any SD causal loop diagram, the arrows show the flow of causality among the key parameters or elements in the system. A positive relationship means that the subsequent (downstream) element changes over time in the same manner or direction as the prior (causal) element, and a negative relationship indicates the opposite.

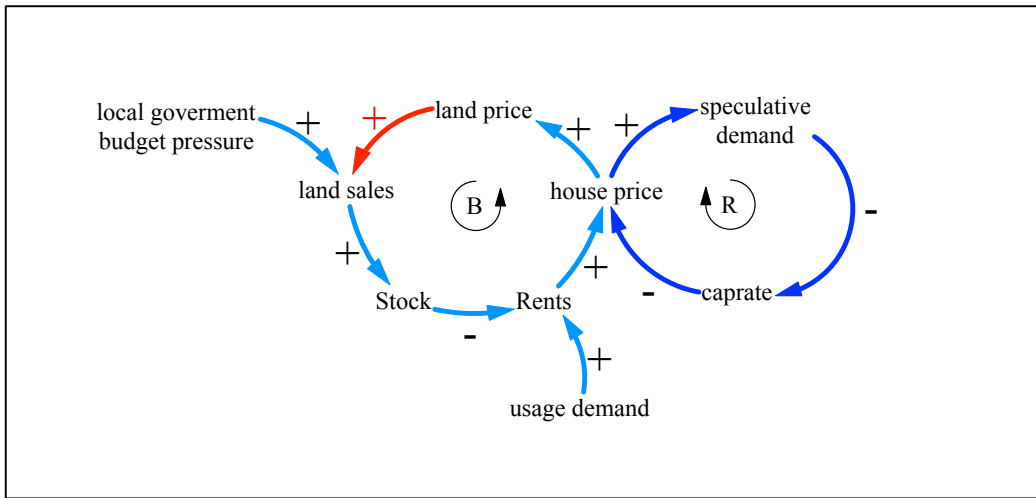


Figure 8-9 China's housing market system with local government's "revenue maximizing" behavior: higher land price leads to more land sold for development.

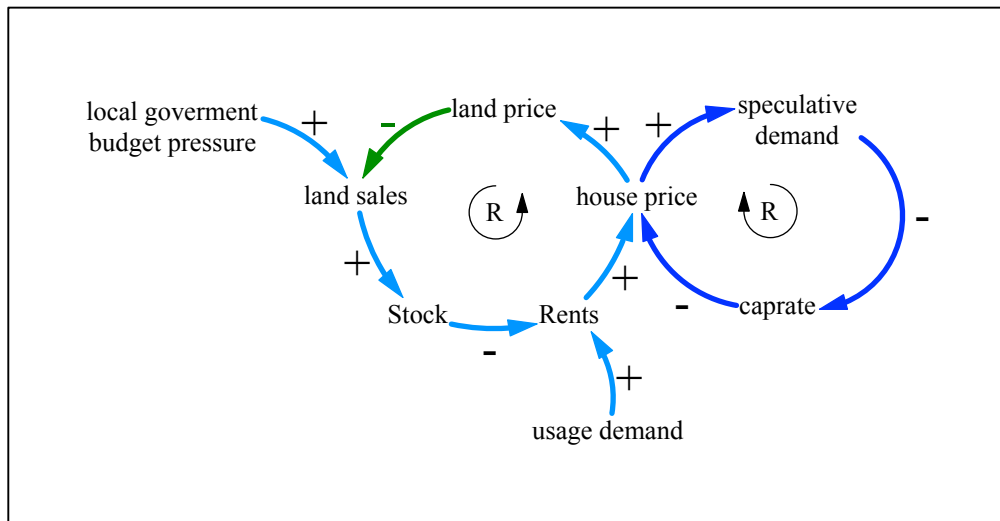


Figure 8-10 China's housing market system with local government's "fixed budget" behavior: higher land price leads to less land sold for development

As the figures show, the system is described largely by two loops. The main loop is on the left, representing the fundamental housing market. It relates land prices to local government land sales behavior, which in turn affects the stock of housing in the market, which in turn affects rents and house prices, and then, via the Residual Theory, land prices are affected once again.<sup>64</sup> The secondary loop on the right reflects another nonmarket feature in the Chinese housing market which is discussed in the previous section, the speculative demand for housing, not as a consumption good for its use in providing housing services, but merely as a store of money (a largely non-productive “investment” asset that usually is not rented out). In this section, we only focus on the main loop that is on the left. Assuming myopic behavior, this loop tends to reinforce whatever is happening in the main fundamental housing market loop, and thereby can cause the results to be magnified. The model shows how the system can be sensitive to local governments’ land sales behavior.

As Figure 8-9 shows, when the local government is revenue maximizing, the system does not tend overly toward house price bubbles. The housing market loop on the left acts as a balancing loop, which means that it tends to keep the system in balance, not spiraling out of control. The key point is that rising land price leads the revenue-maximizing local government land sales authority to sell more land acreage. This leads to an increase in the supply of housing, which puts downward pressure on rents and/or house prices, which in turn closes the loop in a dampening manner by putting downward pressure on land prices, thereby counteracting or dampening the initial trigger which was rising land prices.<sup>65</sup>

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<sup>64</sup> The “Residual Theory” refers to the residual theory of land value, a basic concept in urban economics. The Residual Theory says that land value is a derivative, and it goes back to Ricardo, “The Principles of Political Economy and Taxation,” 1817. A now classical elaboration of Ricardo’s principle is in E. S. Mills, “Urban Economics,” 1972, page 40: “...land rent is a residual, equal to the excess of revenues from the sale of goods produced on the land over remunerations to non-land factors used in production.”

<sup>65</sup> We have not yet incorporated, but can easily do so and will do, the effect of local government artificially constraining the proportion of residential land sales in favor of industrial land. This could be reflected in another decision node in the system in which the local government decides on the proportion of land sales that is to be residential.

On the other hand, when the local government land sales authority is aiming at a “fixed revenue” type of target, the relationship between the “land price” and “land sales” variables is a negative relationship. This changes the main housing market loop on the left from “balancing” to “reinforcing” in SD terminology. An increase in land price now causes the local government land sales authority to reduce the amount of land sales (in acreage), as selling less acreage of land will suffice to meet the fixed revenue budget target due to the higher land price per acre. Also, holding land for future sales can increase revenue as they will be sold at a higher price. Thus, higher land prices lead to less land sales which results in less stock of housing in the market than would otherwise occur, in spite of rapidly growing housing demand (reinforced by speculation in the right-hand loop). The reduced (or less rapidly growing) housing supply drives up rents and prices, leading to higher land prices (again via the Residual Theory), and the loop continues in an upward spiral.

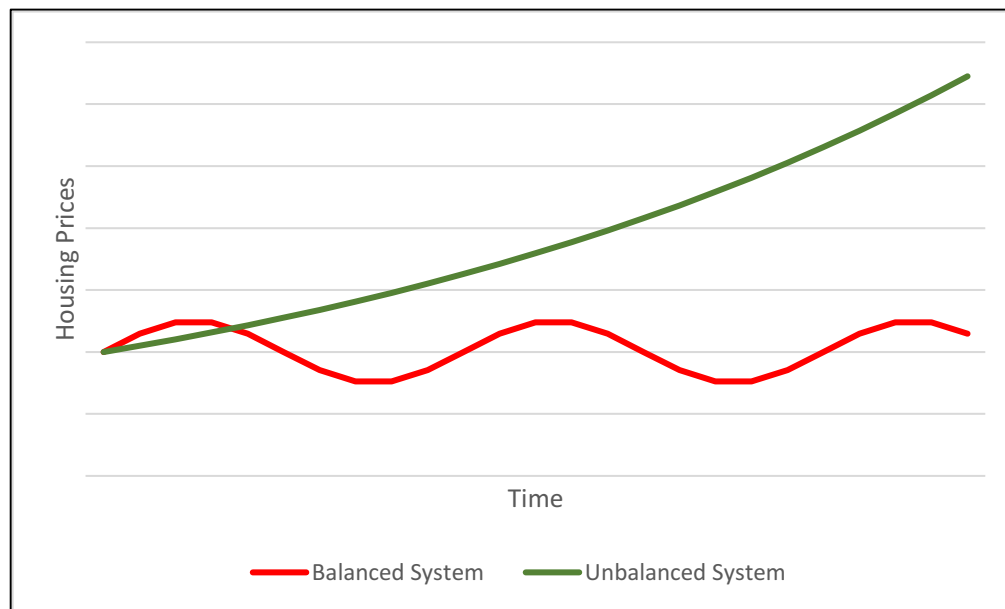


Figure 8-11 Two different price dynamics tendencies resulting from two alternative land sales behaviors (SD mental model)

As Figure 8-11 shows, the different nature of the local government land sales behavior leads to dramatically different housing price dynamics, in theory. Revenue maximization behavior in which higher land prices lead to more sales of land area to developers

(positive price elasticity of land supply) results in a system that is fundamentally balanced dynamically, even if it may experience cycles that tend to revert to the mean over time. (And those cycles could be rather exaggerated, especially due to the reinforcing usage demand and speculative demand loops.) Fixed revenue targeting behavior in which higher land prices lead to less sales of land acreage into the development process (negative price elasticity of land supply) results in the system tending to spiral out of control, with ever higher housing prices. (Once the bubble bursts, the same system dynamics would lead prices to collapse rapidly in a self-reinforcing manner, if the land sales behavior remains the same.)

The situations above only work when the local government is in a dominant position, with the private housing developers having to follow the order given from the local government with regard to the quantity of land being purchased and quantity of development that actually takes place. In this thesis, we refer to this system as a “command-&-control” system. If the developers can make investment decisions independently, such as purchase land and start development when they choose rather than necessarily within two years, then this would help to limit the ability of the system to spiral downward (though it might still tend to spiral upward). Developers could “land-bank”, or hold land undeveloped to ride out downturns in the market.

### 8.3.3 Incorporating Budget Goals into SD Model

In the following section, we will explore the above-described SD model with Chinese characteristics. The goal is to compare the simulation results with and without the land finance scheme component and the speculative demand component. While the data is semi-hypothetical, it has some pedigree in the literature, and can provide interesting results for gaining insight into the system behavior.

According to the residual land value theory, the land price is introduced into the model by deducting the construction cost from the housing price. This reflects the maximum price that the real estate developers are willing to pay for the land. Through competitive bidding process, this should equal to the market price of the land. However, such price

can be compromised if the developers have pre-collaborative negotiations before bidding. The local government will have an initial government budget that it wishes to be met from land sales revenue, and such budget will be growing at a certain rate. The government budget, divided by the land sales price, equates to how much land the local government intends to sell every year. In some cases, the intended amount of land-sales will also be restricted by the land quota system that is strictly implemented by the central government upon local governments, or the potential land reserve limit. For example, when land quota is set at 10 million square meter by the central government, or the land reserve is running out, and the government budget from land sales requires the land sales to reach 15 million square meter that year to meet the target. The local government can only sell 10 million square meter of land.

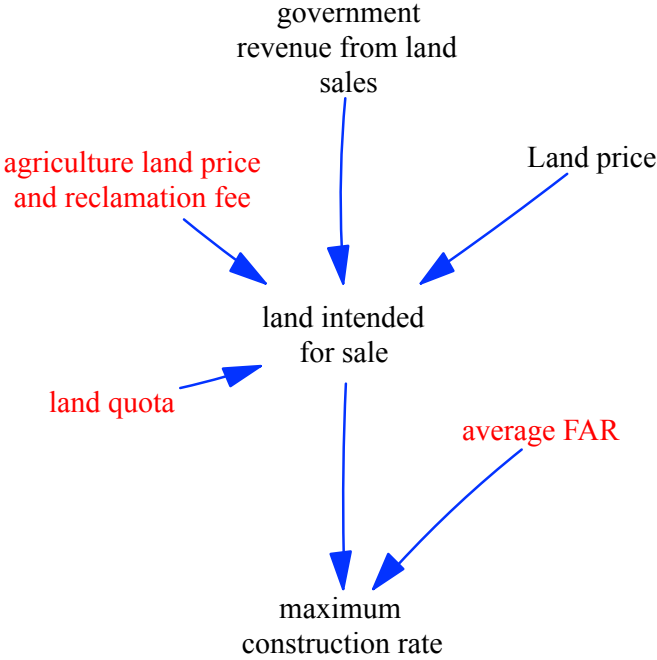


Figure 8-12 The SD chart of the local government's "land finance scheme" component

We will now further analyze into the decision-making process of the local government (as discussed in the previous section), and the interactive decision-making process between the local government and private developers, in order to accurately modify the model structure.

Depending on the local government's land sale behavior discussed in the previous section, the local government's budget variable is programmed either as aiming at "maximizing revenue" or aiming at a "fixed revenue" target. The "maximizing revenue" system refers to the situation that the local government will sell as much land as possible as long as it is under the land quota. The "fixed revenue" target system refers to the situation that once the revenue target is met, the local government has no incentive of supplying more land. The two systems can be seen as two extreme cases in the land supply spectrum. We assume that we do not know which system any Chinese local government is adopting at the moment. However, we believe that in reality the system is somewhere in-between the two systems and we are examining each case as an archetype.

#### 8.3.4 Developers' Reaction Toward Local Government's Motives

Depending on the reactions from the private developers toward the local government's intention, the two different model structures are named as "command-&-control" system and "market-driven" system. The major difference between the "market-driven" system and "command-&-control" system resides in the equation of the variable "new construction rate". Both systems may lead to upward spiral effect of housing price, but "command-&-control" system is essential condition to lead to a downward spiral effect.

##### Command-&-Control system:

An important modification is that the new construction rate is not calculated based on original Wheaton model, which is a straightforward econometric type supply elasticity function (with the threshold step representing minimum replacement cost). Instead, the SD model assumes that the local government needs to meet a certain budget goal every year. When they sell the land, no matter what the quantity is, it is assumed that due to collaboration, the local developers must absorb the entire supply at the system-implied price (which of course, reflects the rents, which in turn reflect the supply and demand balance). And the model assumes that the developers will start the development of the land almost instantly instead of hoarding it (although a certain

construction delay may apply, that is, a specified time of construction). While this may represent a simplified and somewhat extreme or archetypical case, it will be instructive for analytical purposes. The key characteristic in the command-&-control system is that all the land that is sold by the local government will be eventually converted to finished housing stocks and be supplied to the housing market. In this system, the new construction rate equals to the maximum construction rate that is jointly decided by the local government's budget need and the land quota. For example, if the local government needs to sell 10 million square meter of land to meet the target, and it is below the land quota set by the central government, then the developers have to develop all 10 million square meter of land into finished housing stock.

#### Market-Driven system:

In the market-driven system, the developers are profit-maximizers like a private sector capitalistic firm. For example, when the market is down, they will not purchase land from the local government. Or, even if they have purchased land, they can and will choose not to develop the land. In other words, in the market-driven system, the decision-making process of private developers is the key driving force. The supply of new land for development from the local government only establishes an upper limit or ceiling on the amount of new development; it does not fix a definite amount of development. Eventually, the amount and rate of housing stock production will depend upon the investment decisions of private developers.

#### 8.3.5 Model Description

In Model SD12, we analyze the scenario where the land owner aims to maximize the land sales revenue. This hypothetical case is a simplified case of the current Chinese land market situation that we will elaborate in further detail in Chapter 7. The goal is to see how the land owner can manipulate the housing price in the target market through controlling the levels of land supply.

Model SD12 is fundamentally different from Model SD8, the model of finite land supply. The discussion in stages one and two of Model SD8 are based on the assumption that



land price is not a parameter in the modeling process. We have only focused on the discussion of land quantity and whether such quantity can support the new development. The relationship between land price and land availability is not established yet. This can be the case for countries like China where the local government is the monopoly owner of land, and thus controls land price and supply.

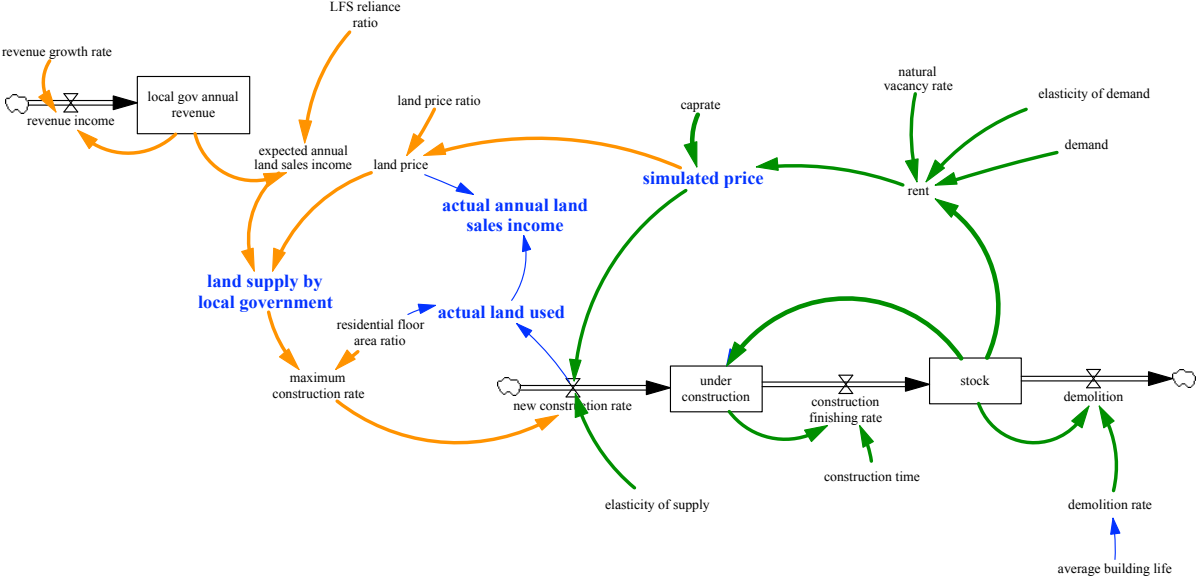


Figure 8-13 Model SD12: Land Financing Scheme is built into SD model

The detailed simulation of land financing scheme component needs real world empirical data because variables such as local government’s land sales income, local government’s budget, floor area ratio, etc are important to achieve the realistic results. For this reason, we defer the simulation analysis for land financing scheme to Chapter 10 when we conduct the case study using real data and demonstrate the effect of land financing scheme.

**8.3.6 Policy Implications**

We have learned that the land constraint imposed by the land financing scheme, like any other types of land constraints, can significantly increase the housing price. We should notice that this land constraint is different from the land constraints discussed in

Chapter 7 and 8 due to its very special land supply mechanism. In the previous land constraints mechanisms, when facing high housing prices, the governments cannot create new land efficiently due to the geographic constraints or regulatory restrictions such as the case in Manhattan or San Francisco.

When it comes to land financing scheme in China, the local government, sitting on abundant land reserve, has the incentive to limit the land supply in order to push the housing price higher, thus driving the land price higher. Higher land prices mean more revenue for the local government. This reversed incentive of land supply mechanism shows significant contrast when compared to an efficient market where higher housing price will trigger additional housing construction. On the other hand, in some declining cities, when the housing prices drop, the local government will do anything it can to supply more land in order to meet the land sales budget. In short, the existence of land financing scheme has turned what should be a balancing loop into a price reinforcing loop.

As a result, it is essential to eliminate the current land financing scheme and provide a more rational mechanism for the local government to supply land. To do so, the local governments will have to rely less on the land sales income. However, this is not easy task without significant reform of tax revenue sharing structure. One possible solution is the implementation of property tax. Property tax revenue does not rely on continuous selling of land but instead is based on the existing housing stock. It is a more sustainable and stable annual income.

#### **8.4 Model SD10 to Model SD12 Validation and Testing**

For the integrated model with all three features, we test the models with SD validation standards described in Chapter 3.

##### **1. Boundary Adequacy Tests**

The model boundary is expanded in each of the sub-models comparing to the original stock-flow model depicted in Chapter 4 as well as the generic models depicted in

Chapter 6. The discussions of China-specific phenomena such as ghost cities, speculative demand, and land financing scheme are included into the system. Through the simulation with hypothetical data, we can see that the behavior of the model changes when the new components are incorporated.

## 2. Structure Assessment Tests

The structure assessment for the integrated models is consistent with the descriptive knowledge of the concept of the housing system. The modification added speculative demand and land financing scheme in the Chinese housing market are supported with evidence listed in Chapter 7.

## 3. Dimensional Consistency

The dimensional consistency, or “units checking” is performed for each sub model. The only issue is that the parameters  $\alpha_1$  and  $\alpha_2$  are used for scaling but without actual meaning. Their definitions and equations however, makes dimensional consistency test difficult.

## 4. Parameter Assessment

The numerical values of the model variables are currently still using hypothetical data from Wheaton (1999) for demonstration purposes.

## 5. Extreme Conditions

The SD sub models are also tested with extreme conditions, meaning each equation makes sense even when its inputs take on extreme values. For example, when demand of the integrated model is set to zero, the rent and housing price would be driven to zero; when the demand remains unchanged (without a step jump or exponential growth), the system will remain at equilibrium stage.

## 6. Integration Error

The simulation result is stable when the time step is set to 0.01 in Vensim.

## 7. Behavior Reproduction

The purpose of this subset of models is not to fit data to the historical housing price point to point because we are using hypothetical data. However, the behavior produced by the model can be theoretically explained.

## 8. Behavior Anomaly

There is no anomaly observed from the simulation results of integrated model.

## 9. Family Member

The model can be used in similar situations in other contexts where housing speculation or land constraint prevails.

## 10. Surprise Behavior

There is no surprise behavior observed so far.

## 11. Sensitivity Analysis

The sensitivity analysis is conducted with regard to key variables with estimated value. They are price elasticity of cap rate, and price elasticity of speculative demand.

## 12. System Improvement Tests

The system can be improved by incorporating components from Chapter 5 and 6. The tasks of integrating will be conducted in Chapter 9 and 10.

## 8.5 Summary of the Chapter

Chapter 8 conducted the second step of the research design and added China-specific features into the system dynamics model. The variables marked in purple shown in Figure 8-14 are newly added onto the CLD at the end of Chapter 6 (as in Figure 6-15).

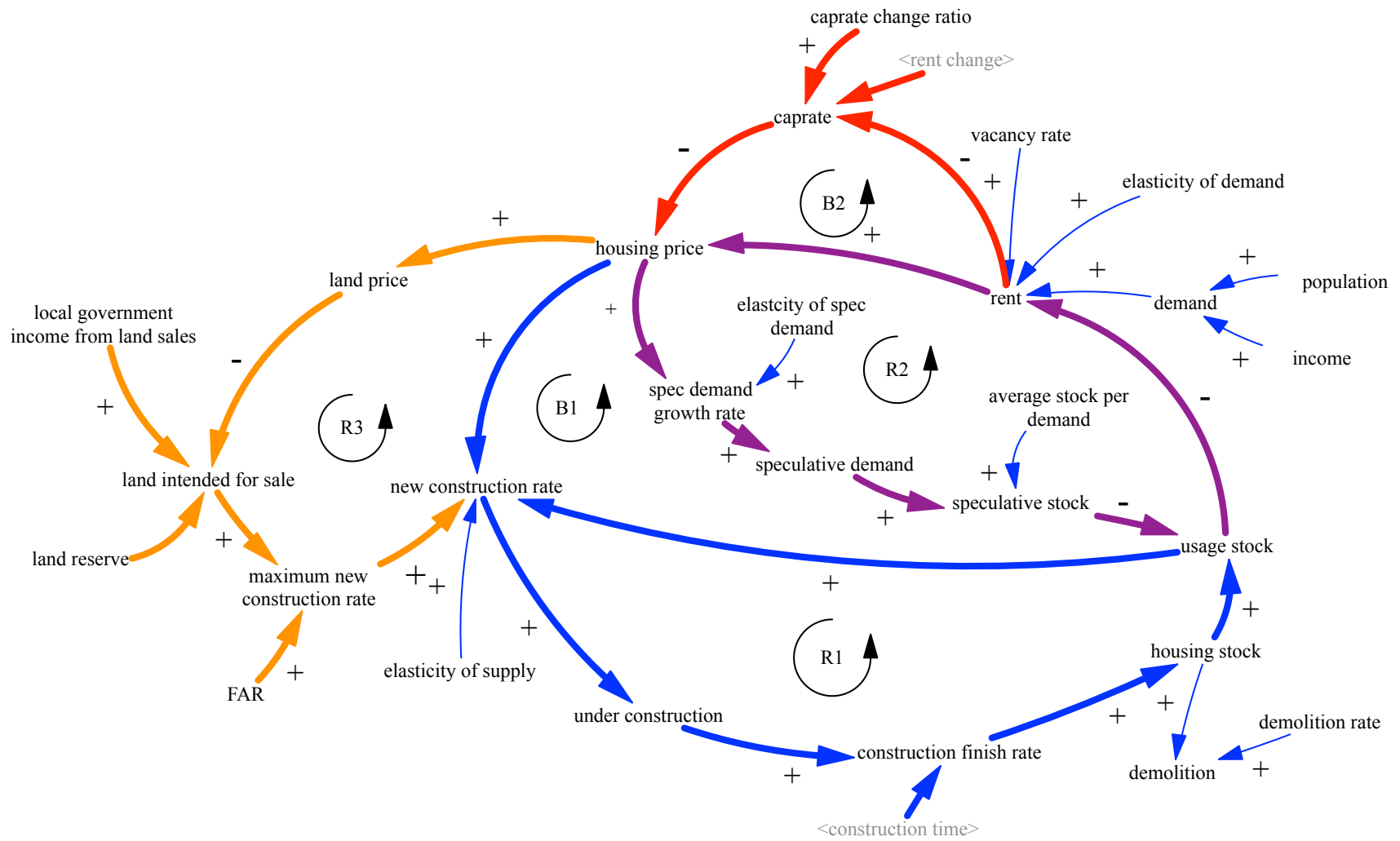


Figure 8-14 Causal loop diagram at the end of Chapter 8

A summary of the set of Model SD10-SD12 is shown in Table 8-1. It lists the parameter of the model we modified, how we have modified, which benchmark baseline model it is compared to, and its contributing effect on market volatility. A (+) sign indicates that the parameter positively contributes to the market volatility, such as higher amplitude of local maxima and minima of the cycles, or longer cycles. A (-) sign indicates that the parameter negatively related to the market volatility, meaning, they can prevent the market cycles from occurring.

Model	Parameter	Description of the Model Modification and Main Findings	Compare to	Volatility
SD10	Unsustainable Demand Growth	When the demand growth is similar to the Ponzi recruitment process, the housing price experiences cliff-like plunge once the demand growth is exhausted. Depending on the growth rate, the price can peak at much higher and drops at much lower price level.	SD3	+
SD11	Speculative Demand	The existence of speculative demand that uses housing as a means of money storage (without meeting the demand for housing) increases the market volatility.	SD3	+
SD12	Land Financing Scheme	When the land supply is monopolistic, the land owner aims to maximize land sales revenue	SD3	+

Table 8-1 A summary of Model SD6-9 and their relationship to market volatility

## 9 Integration of Sub Models SD1 Through SD12

### 9.1 Summary of Model SD1-SD12

Chapters 4 to 8 have presented a set of modified SD models. Each model focuses on one key aspect of the housing market. The result of each simulation is then compared to the baseline model. The baseline model can be either Model SD1 or Model SD3, depending on whether the external impact imposed on the system (i.e. economic shift) is an immediate jump (as in Model SD1) or a gradual exponential growth (as in Model SD3). Through comparing the results of each successive simulation run to one of the two baseline models, we have identified and analyzed how each of the key aspects modeled impacts the volatility of housing price.

A summary of the set of 12 SD models is shown in Table 9-1. It lists the parameter of the model we modified, which benchmark baseline model it is compared to, our main findings and its impact on market volatility. Models SD1-SD9 are generic models as they are applicable to all housing markets. Models SD10-SD12 are China-specific models as they focus on the features that are unique to Chinese housing market. A (+) sign indicates that the parameter positively contributes to the market volatility, such as higher amplitude of local maxima and minima of the cycles, or longer cycles. A (-) sign indicates that the parameter negatively related to the market volatility, meaning they can prevent the market cycles from occurring or at least diminish the local maxima and minima. An (n) sign indicates that the impact of the parameter is neutral.

Model	Parameter	Description of the Model's Main Findings	Compare to	Effect of Volatility on Housing Market
SD1	Economic Shift	The real estate market cycles are endogenous when facing an external shock. The cycles are sensitive to construction delay, supply and demand elasticities, and growth-demolition rate.	This is Baseline Model I	+
SD2	Investors' Behavior	Instead of having myopic investment behavior, if the investors are forward-looking and take into account of the construction in the pipeline, then the housing market cycles tend not to occur.	SD1	-
SD3	Demand Growth	When the model is driven by steady demand growth, the gap between growth rate and demolition rate impacts how volatile the cycles are. When the gap is large (i.e. higher growth rate, or bigger demolition rate), then the housing cycles have higher volatility.	This is Baseline Model II	+
SD4	Natural Vacancy	A constant natural vacancy rate will not affect the long run cyclicity of housing price.	SD1	N
SD4	Construction Cost	The higher the construction cost, the more volatile the housing price is.		+
SD5	Income Growth	Growth in income and growth in the number of households should be separated. Since income growth is a positively contributing component of demand growth, it increases market volatility.	SD3	+
SD6	Construction Behavior	When the housing under construction is streamlined (i.e. construction rate is responsive to market demand), instead of following pipeline structure, the housing cycles tend not to occur.	SD1	-
SD7	Information Delay	The adjustment process for the developers to recognize and accept the price change is a form of information delay, and it can increase the price volatility.		+
SD8	Land	Land supply closely relates to the supply		-



	Constraint	elasticity. When land supply is constrained, housing price will climb but housing cycles diminish.		
SD9	Cap Rate	Cap rate is internalized, and negatively related to the rent growth rate. This increases the market volatility.	SD3	+
SD10	Unsustainable Demand Growth	When the demand growth is similar to the Ponzi recruitment process, the housing price experiences cliff-like plunge once the demand growth is exhausted. Depending on the growth rate, the price can peak at much higher and drops at much lower price level.		+
SD11	Speculative Demand	The existence of speculative demand that uses housing as a means of money storage (without meeting the demand for housing) increases the market volatility because of the speculators' long and short position along with price's moves.		+
SD12	Land Financing Scheme	When the land supply is monopolistic, the local government as the sole land owner supplies land with limited quantities in order to maximize land sales revenue.		+

Table 9-1 A summary of modified SD models and their relationships to market volatility

## 9.2 Integrated Generic SD Model Driven by Economic Fundamentals

The goal of this section is to advance the traditional D-W model by incorporating realistic features that can enhance the ability of D-W model for housing market analysis. We will refer to it as the integrated generic SD model to distinguish from the integrated Chinese SD model that is going to be built in the next section. The integrated generic SD model is generic because it is driven by economic fundamentals that are applicable in all housing markets – i.e., they are not specific to the Chinese context. This generic model is built and developed based on the baseline SD models covered in Chapter 4, 5, and 6. Models SD1-SD3 are basic models for the purpose of replicating Wheaton's 1999 stock-flow model. They serve as the starting structure for this integrated SD model.

### 9.2.1 Integrated Generic Model: Modifications Made from 4QM

The generic modifications that have been covered in Chapter 4 and 6 are:

Model SD4: Natural vacancy and construction cost

Model SD5: Number of households and income growth

Model SD6: Construction behavior (and its delay mechanisms)

Model SD7: Information delay

Model SD8: Land constraint

Model SD9: Cap rate (apply go both generic model and China-specific model)

In this integrated model, we have selectively included some but not all of the models above.

From Model SD4- natural vacancy and construction cost, we have included natural vacancy rate but not the construction cost. Natural vacancy rate is currently set as an exogenous constant in the integrated model.<sup>66</sup> It is an important variable and should we decide to change it an endogenous variable in the future work, it is already built into the model. Regarding the construction cost, since most of the model variables are related to the absolute price level, instead of the difference of price level and construction cost, we decide to leave it out of the final model building. Should we in the future research decide to include construction cost in the discussion, we can simply switch the 'Price' variable  $P$  in every equation with the difference of 'Price' and 'construction cost' ( $P-K$ ).

From Model SD5-number of households and income growth, we have included both population and per capita income as exogenous variables. We assume that the number of people per household is constant through the model simulation periods and thus use variable 'population' to replace 'number of households', and per capita income to replace household income. The demand is modeled as the multiplication of population and per capita income.

From Model SD6-construction behavior, we have used the first-order delay structure to model construction behavior to replace the pipeline delay structure used in Wheaton (1999). This change is in line with the SD literature of describing real estate market in

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<sup>66</sup> The complete version of vacancy discussion: see Wheaton (1990).

Sterman (2000). At any given time, the construction finishing rate is proportional to the total 'under construction' stock divided by the construction time.

We chose not to include the Model SD7-information delay. The information delay due to uncertainty during the housing development phase is observed in the housing market, but the actual delay time is not statistically available. In the case of Chinese housing market, the housing development happens and finishes at fast speed. The only information delay could be partially due to the frequent government policy intervention. Although theoretically we can include the discussion of information delay in the model, empirically there is not enough solid data to prove that such modification would be necessary at the current stage.

We also did not include the Model SD8-land constraint into the model structure. It is because this feature is closely related to, and can be even seen as part of, the Chinese land financing scheme feature. In China, the land disbursement schedule is controlled by the local government, which imposes the land constraint to the new construction. We thus decide to include it in the other integrated model which includes Chinese features which will be discussed in later this chapter.

Lastly, model SD9-cap rate is included as an endogenous variable in the integrated model. This is one of the major modifications to the integrated model so far. Internalizing cap rate actually adds another balancing loop: when rent level goes up, cap rate gets suppressed, thus further increases the housing price, more new construction takes place and adds to the total stock, thus further brings down the rent level.

### 9.2.2 Integrated Generic Model: Model Structure and Description

The integrated generic model structure is shown in Figure 9-1. The arrows marked in green are from the original D-W model structure. The arrows marked in red highlight the modifications to the model as described in section 9.2.1.

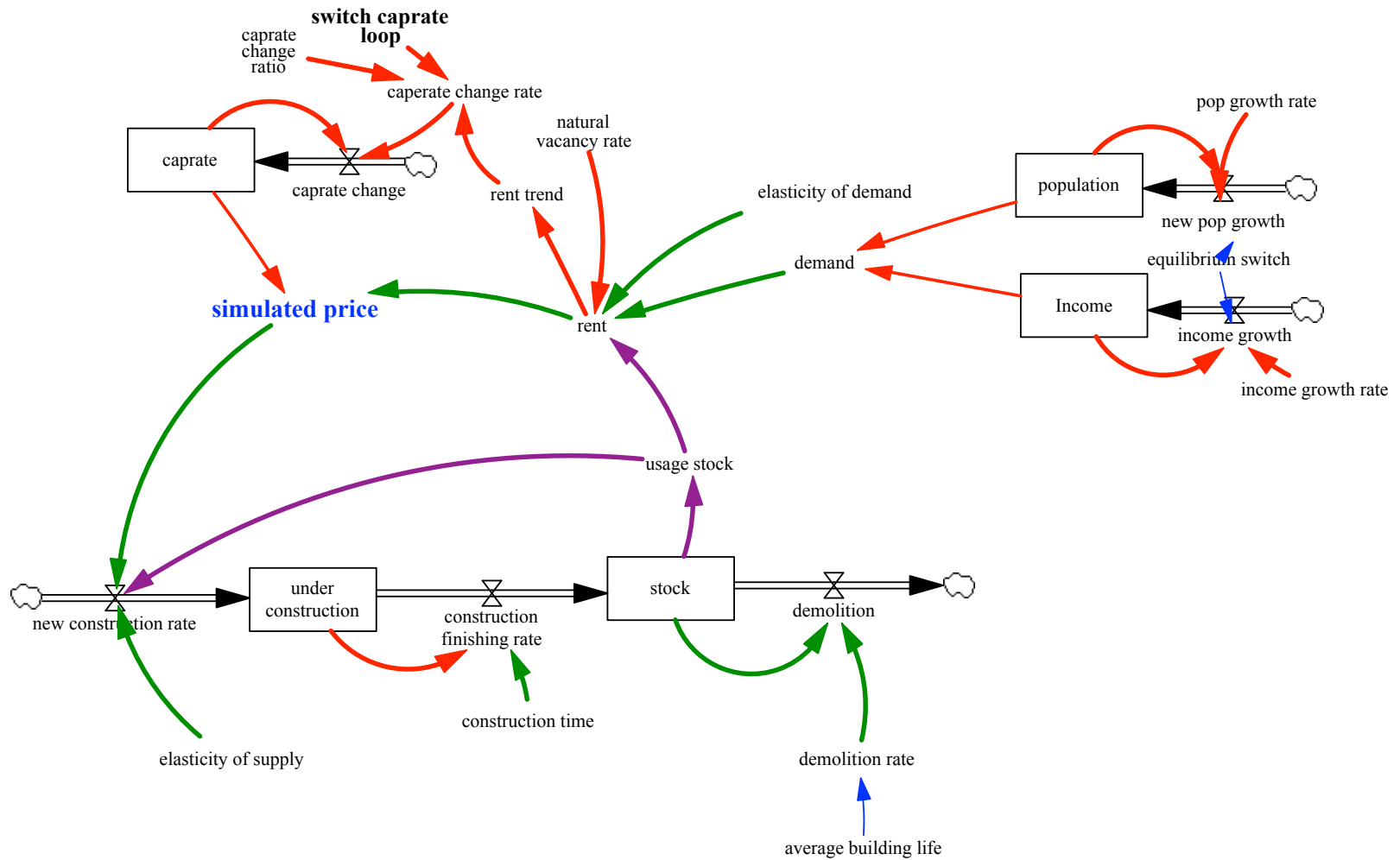


Figure 9-1 The structure of integrated generic SD model driven by economic fundamentals

As shown in Figure 9-1, the variables that marked in green arrows have been discussed fully in Chapter 4. In the following discussion we will focus on the modifications highlighted in red arrows.

The demand is represented by the multiplier of a city or a region's population and its per capita income. Both variables are stock variables and their rates of change represent the annual population growth/decline and per capita income change. In other words, the assumption is that the demand is proportional to the city's GDP. Both rates of change are represented by a 'growth rate' that is determined by variables such as 'empirical growth', 'projected growth' and 'time threshold'.<sup>67</sup> 'Empirical growth' represents the variable input is relying on existing historical statistical data; 'Projected growth' represents the variable input using the estimated data into the future; and 'time threshold' is the time division line between empirical data and projection data. The purpose is that for exogenous model variables such as population growth and income growth, we aim to use as many empirical data as possible for the starting point, and only use estimated data as input for the time horizon into the future.

The stock variable "under construction" captures the buildings that are currently in the pipeline. Every year's construction completion rate is derived by dividing the total buildings under construction with the construction time. It represents a first-order delay structure in the SD terminology.

The natural vacancy rate is included in the model equation. Instead of using 'stock', we use  $\text{stock} \times (1 - \text{vacancy rate})$  to calculate the rent. As mentioned before, in the current implementation of the model, the natural vacancy rate remains exogenous for simplicity.

The cap rate is internalized by linking the cap rate change rate with the rent level change rate. The stock variable "caprate"'s change rate is captured by the following equation:

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<sup>67</sup> The detailed breakdown is shown in the final model only. The variables are consolidated at the moment for simplicity reasons.

$$\begin{aligned}
 \text{caprate change rate (\%)} \\
 &= - \text{rent trend (\%)} * \text{caprate change ratio} * \text{switch caprate loop} \\
 &\quad * \text{equilibrium switch}
 \end{aligned}$$

**Assumption 1:** *The cap rate change ratio is negatively related to the rent change: when rent level goes up, the cap rate goes down.*

The intermediate variable “rent trend” captures the per-period rent change in percentage. The variable “caprate change ratio”, gives the percentage change of caprate in response to one percent change in rent. As shown in the equation, the cap rate change rate is negatively related to the rent change.

There are also two binary “switch” variables in the equation which is commonly used in SD modeling to control the on/off of certain causal loop. The “switch caprate loop” is an on-off switch to control the entire cap rate loop: when it is set at 1, the loop is turned on and the cap rate becomes endogenous and will change with the rent changes; when it is set at 0, the loop is turned off and the cap rate becomes exogenous and remains constant at the initial value throughout the modeling process.

The “equilibrium switch” is a variable to test the initial equilibrium stage of the system by cutting off the exogenous changes that are imposed to the system. In this way, we make sure that the SD model starts from an equilibrium stage which is a prerequisite for most of the SD model testing.

At this stage, a new loop has been formed that is the cap rate loop. As we can see in Figure 9-1, when rent increases, the cap rate change rate will be negative and thus suppressing the cap rate. This will cause the price to increase further, more construction happens and adding to the housing stock. As a result, the rent will decrease. This is a balancing loop.

### 9.3 Integrated China-Specific SD Model Driven by Chinese Market Features

The integrated China-Specific SD model is developed on top of the integrated generic model and incorporates the Chinese features introduced in Models SD10-SD12 and discussed in Chapters 7 and 8. By building on top of the generic model, we have assured that the basic economic fundamentals are included. Any difference in simulation results from the generic model is triggered by the Chinese housing market features. In other words, we want to use the simulation results of the generic model as the reference point or baseline to compare and demonstrate the effects of Chinese market features.

#### 9.3.1 Integrated China-Specific Model: Modifications Made from the Integrated Generic Model

The SD modules of Chinese market features from previous chapters are added:

Model SD10: Unsustainable demand growth

Model SD 11: Speculative demand growth

Model SD 12: Land financing scheme.

One thing to note before modeling is that in most of the Chinese cities, Model SD10 and Model SD11 in general do not coexist for the following reason: the phenomenon of speculative demand usually exists in the first and second tier Chinese cities where the housing price is climbing and the demand is strong;<sup>68</sup> unsustainable demand happens in third or fourth tier cities and ghost cities where the city is built based on a projected demand but the actual demand never materialized. In order to add model SD10-unsustainable demand growth to our combined model, the structure does not need to be altered much. The only parameter that needs to be changed is the assumption of demand growth rate by using ‘perceptive demand growth’ before certain time threshold and ‘real demand growth’ afterward.

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<sup>68</sup> Although there are cases where the housing speculation groups (“Chao Fang Tuan”) target small cities because they have the financial power of buying out all the available housing units, and thus form a monopoly power from the supply end to push up the housing prices. Such strategy would not work in large cities where the supply is relatively abundant.

The land financing scheme exists in Chinese cities of all tiers, and it is just a matter of degree of financial reliance on land sales for different local governments. For example, in first-tier cities such as Beijing, Shanghai, Guangzhou, and Shenzhen, there are multiple sources of tax revenue income from local industries. As a result, the local governments in these first-tier cities have relatively lower reliance on land sales revenue.

On the other hand, in some second or lower tier Chinese cities where alternative sources of tax revenue are not abundant, land sales revenue counts for a substantially large percentage of the local governments' annual revenue. Thus, these local governments will tend to rely more heavily on the land sales revenue. Both Model SD11: speculative demand growth and Model SD12: land financing scheme involve model structure alternations. We will incorporate them into the model one at a time and each model is controlled by a binary switch so that we can observe their effects either combined or individually.

### 9.3.2 Integrated China-Specific Model Description— Speculative Demand Component

The model structure that includes the speculative demand component is shown in Figure 9-2. The generic model portion that is constructed in 9.2.2 and some initial variables are largely hidden from the model view in the figure so that we can focus on the logic of the speculative demand component. The arrows marked in purple highlights the modifications made to the model to represent the speculative demand component.



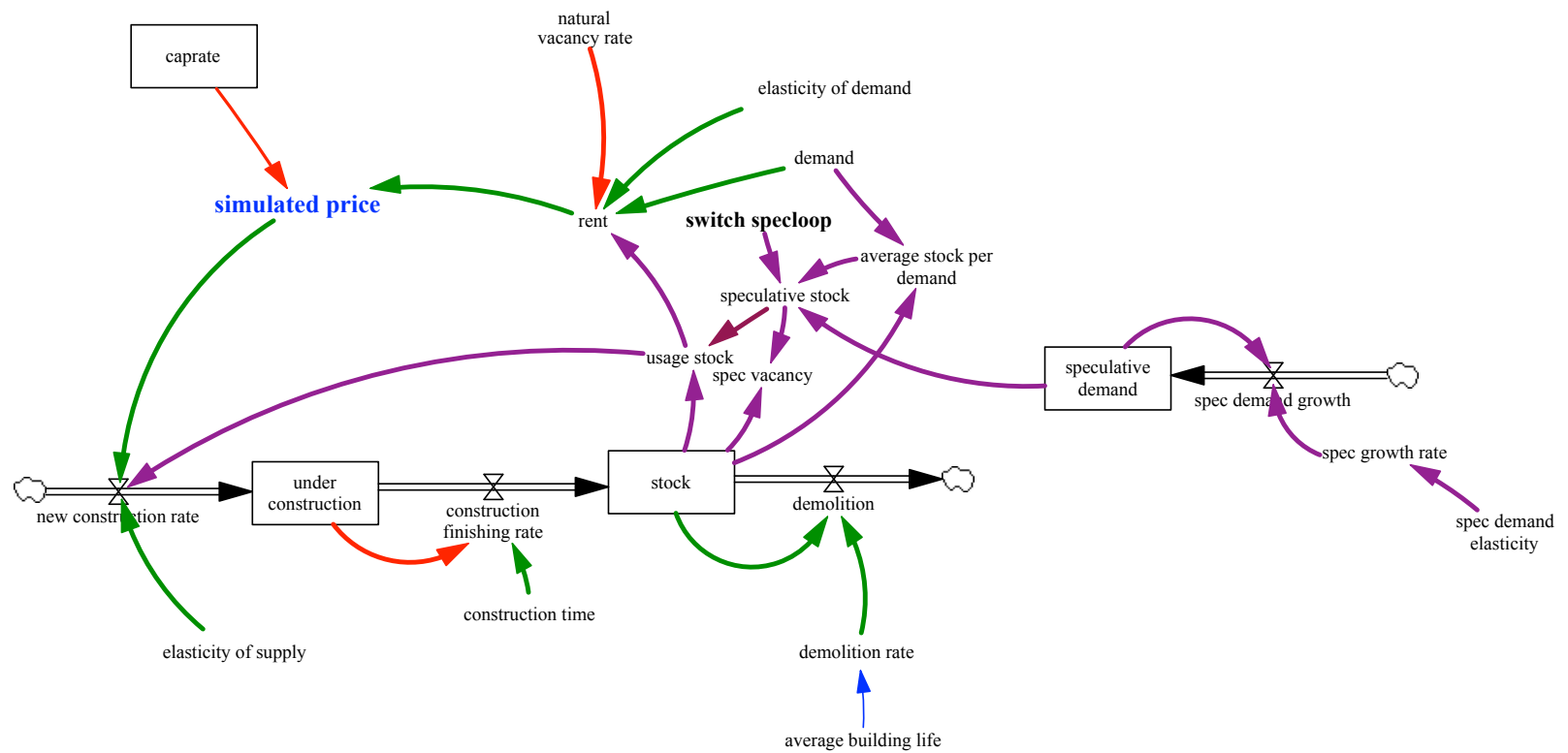


Figure 9-2 The integrated China-Specific SD model driven by Chinese market features – speculative demand component is highlighted with purple arrows

The important variable introduced to the current version of the model is the “speculative demand” stock variable. It separates the housing speculative demand from the usage demand. Further it separates the housing speculative stock from the usage stock.

***Assumption 2:*** *there is an initial percentage of population that are considered to be speculators, thus the same percentage of the demand (unit in RMB) is considered to be the speculative demand.*

A crucial assumption of the model is that the speculative demand, as a stock variable, changes subject to certain conditions: the speculative demand growth rate is jointly determined by the rent percentage change, as well as the price elasticity of speculative demand.

***Assumption 3:*** *when rent goes up, the speculative demand increases because more speculators will purchase expecting a continuous housing price increase; when rent level drops, the speculative demand decreases as the speculators will sell the housing units expecting a price decline.*

*Speculative demand growth rate (%)*  
 $= \text{rent change rate}(\%) * \text{price elasticity of speculative demand}$

The rent change rate (%) is captured by the ‘rent trend’ variable. Different from the common demand elasticity in economics terms, the “price elasticity of speculative demand” is positive.

From the speculative demand, we can derive the total speculative stock that exists in the market by the following equation.

*Speculative stock = speculative demand \* average stock per demand*

Speculative stock is an important intermediate product of model simulation because of its special characteristic in the Chinese housing market: the speculative stock remains vacant and the speculators are not willing to rent it out. Speculative stock is also important in the sense that we can conduct “what-if” analysis at any time point by forcing all the speculative stock to be dumped into the housing market all at once –

simulating a massive sell-off by investors - and observe if such action would impose potential danger to the housing market collapse.

Dividing the speculative stock by total stock, we can achieve the speculative vacancy rate:

$$\text{Speculative vacancy rate} = \frac{\text{speculative stock}}{\text{total stock}} * 100\%$$

It is important to monitor the speculative vacancy rate to ensure that it is within a reasonable range during simulation. There is no statistical data of any vacancy rate in China but there are different sources of estimations. For this integrated model, we want to make sure that the speculative vacancy rate produced by the model is within the range of realistic estimation of the vacancy rates reported by other scholars as covered in Chapter 7.

***Assumption 4:*** *The speculative demand has preemptive purchase power because the speculative purchasers normally have more financial resources compared to those purchasing the units for actual housing (usage demand).*

The total housing stock is the sum of usage stock and speculative stock.

$$\text{Total stock} = \text{usage stock} + \text{speculative stock}$$

Since the speculative housing stock in China is often left empty, the usage stock thus represents the stock that is available for living for the total demand in a city. As a result, the “usage stock”, replaces “total stock” in the equations that are used to calculate rent and new construction rate.

The “switch specloop” is used in the model to control the effect of the speculative demand loop. When it is set at 1, the speculative demand is considered as part of the housing market; when it is set at 0, the speculative demand and speculative stock does not exist and all demand is considered as usage demand.

The newly added speculative demand loop is a reinforcing loop. When rent level increases, there will be more speculative investors rush into the housing market and buying out housing stock. As a result, the portion of usage stock will decrease and this will trigger the rent level to increase further.

### 9.3.3 Integrated China-Specific Model Description– Land Financing Scheme Component

The model structure that includes the land financing scheme component is shown in Figure 9-3. Again, the generic model and the speculative demand component are largely hidden from the model view for demonstration purpose. The arrows marked in orange highlight the modifications of the model to represent the land financing scheme.

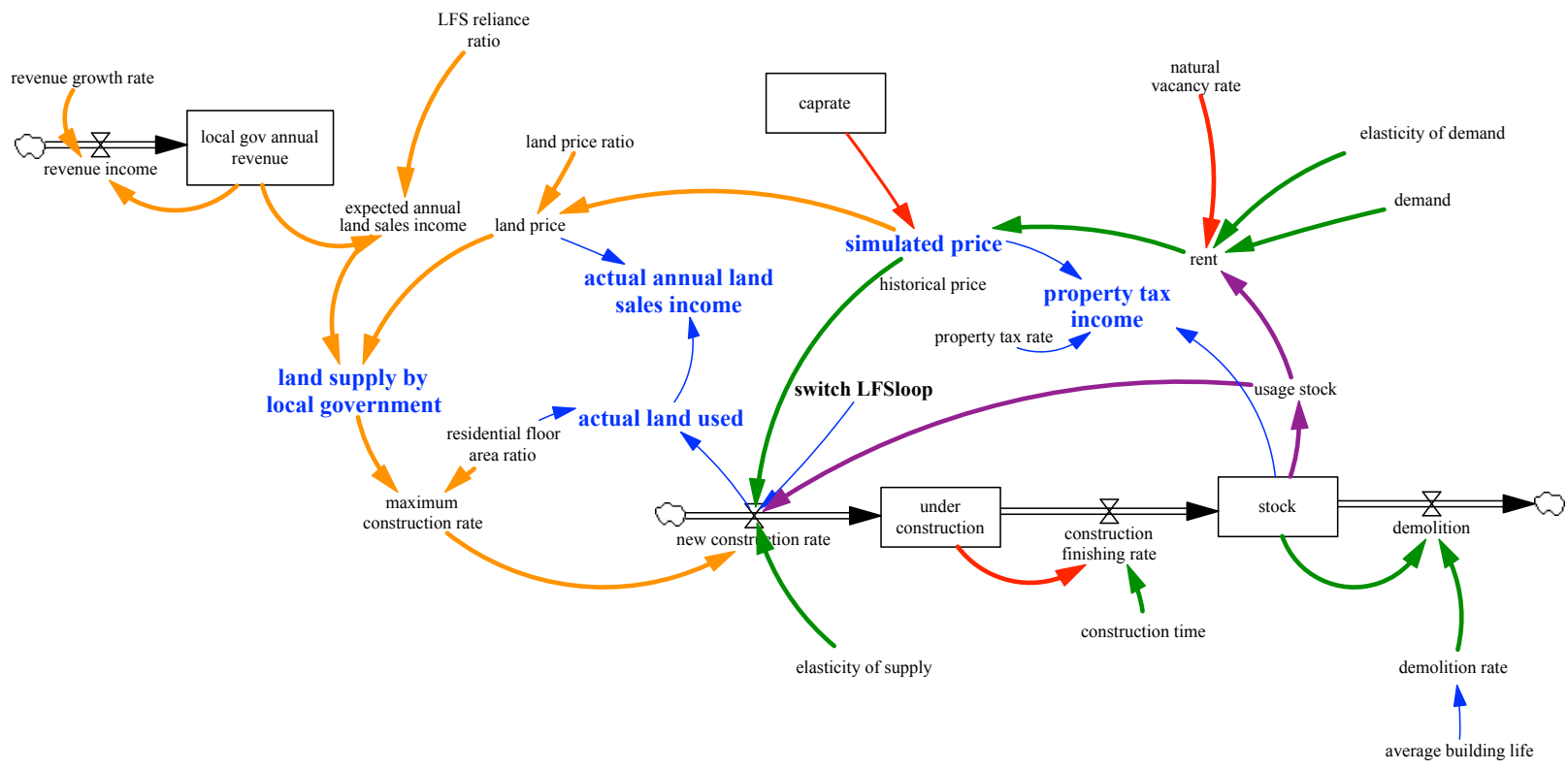


Figure 9-3 The integrated China-Specific SD model driven by Chinese market features– land financing scheme component marked with orange arrows

The most important variable in the land financing scheme component is the “land supply” variable. In the 4QM, the land supply is not limited. It is assumed that at a certain price level, a certain amount of new construction takes place, and there is sufficient land available for that to happen. However, as we discussed in Model SD8, land constraint issue plays a key role in determining the housing price trend.

In this model, the annual land supply is determined by the local government’s land sales which is closely related to the land financing scheme. The annual land supply with the average floor-area-ratio (FAR) of the city determines the maximum construction rate that can happen. It serves as the upper threshold for the variable “new construction rate”.

At the same time, the “expected land supply” is also calculated. This variable measures what would be the theoretical land supply level required to support the construction demand, as if the land financing scheme were not in place. The difference between the actual land supply and expected land supply implies the land shortage or oversupply that is induced by the local government’s motivation.

For simplicity, the land price in this model is assumed to be in proportion with the housing price. When housing price goes up, land price goes up; when housing price drops, land price drops.

$$\text{Land price} = \text{housing price} * \text{land price ratio}$$

The annual land sales revenue is driven by two exogenous variables: local government’s annual revenue and its LFS reliance ratio. For both variables, we also set up the “empirical growth rate”, “projected growth rate”, and “time threshold” so that we can use the existing statistical data that we have collected till the time threshold, and use projected data beyond the time threshold.

$$\text{Annual land sales revenue} = \text{local government's revenue} * \text{LFS reliance ratio}$$

The local government revenue is considered to be exogenous at the current stage of model building. LFS reliance ratio stands for land financing scheme reliance ratio. It is a ratio that represents the percentage of the local government's revenue that will be attained through selling land. In terms of definition, we need to be clear here that the annual land sales revenue is not part of the local government's general revenue. It is stored in a separate account that is entirely at disposal of local government's needs and does not need to be handed to the Chinese Central government.

The amount of land supply is jointly determined by the annual land sales revenue and land price through the following equation:

$$\text{Land supply} = \frac{\text{annual land sales revenue}}{\text{land price}}$$

The newly formed land financing scheme loop is also a reinforcing loop. When the housing price increases, land price increases. If the local government's land sales income increases at a slower speed, that will lead to a shortage of land sales to the developers. As a result, less new construction will start, less new housing stock will be added, and another round of price soaring will happen.

#### 9.3.4 The Integrated China-Specific SD Model

The overarching view of the integrated China-Specific SD model's causal loop diagram is shown in Figure 9-4 and a concise version of the model is shown in Figure 9-5. The basic 4QM is marked in green arrow; the generic modifications are marked in red arrow; the speculative demand component is marked in purple arrow; and the land financing scheme component is marked in orange arrow. Exogenous input and initial values are marked in blue arrow.

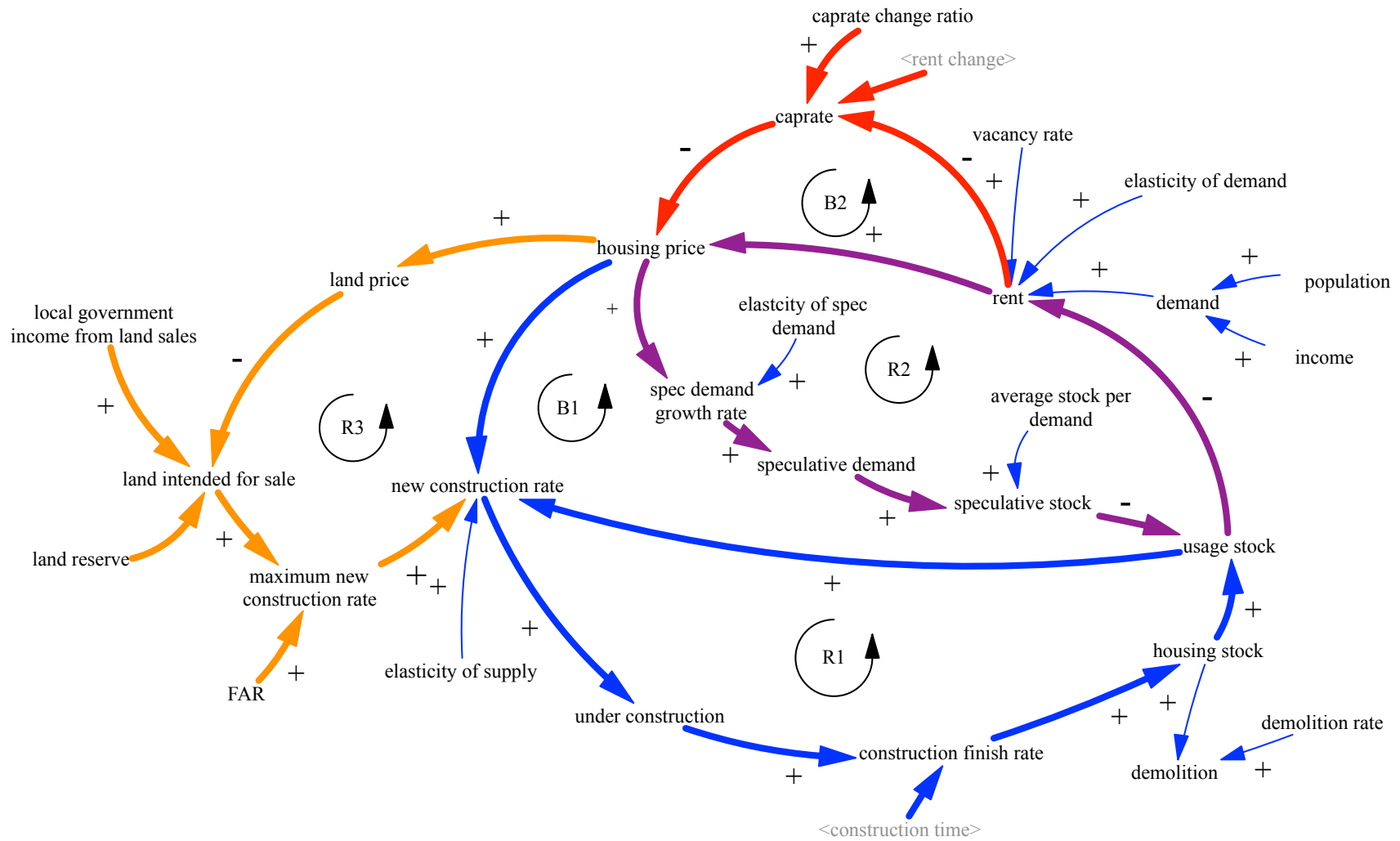


Figure 9-4 Three new loops appear in the integrated model



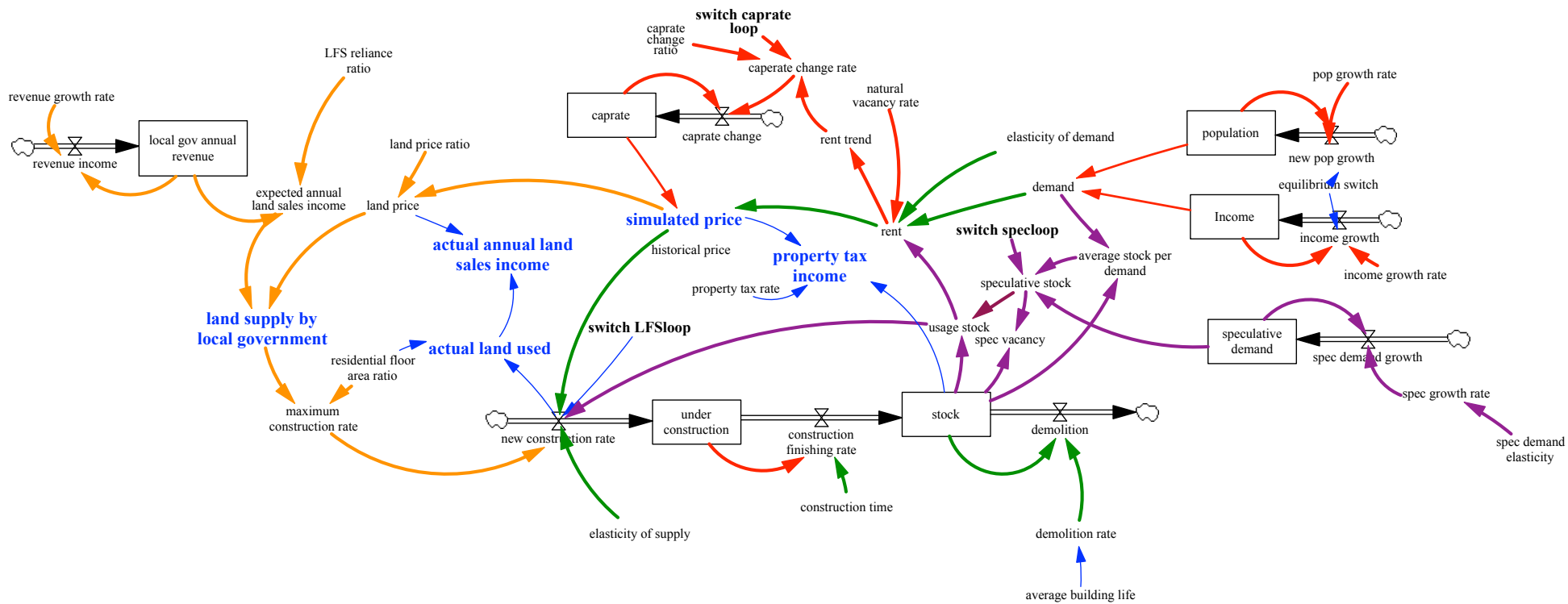


Figure 9-5 The integrated China-specific SD model with cap rate loop, speculative demand loop, and land financing scheme loop

## 9.4 Commonly Used Variables and Their Formulation

Variable		Formulation and Comments	Units
Alpha 1	$\alpha_1$	= initial rent ^ elasticity of demand initial usage stock (1-natural vacancy rate) / initial demand	NA
Alpha 2	$\alpha_2$	= demolition rate /initial price ^ elasticity of supply	NA
Average building life	$b$	Exogenous constant	Years
Average stock per demand	$\frac{S_t}{E_t}$	= stock/demand	Sqm/RMB (note: RMB is Chinese currency)
Cap Rate	$\gamma$	= INTEG (caprate change, initial cap rate)	Dmnl
Cap rate change rate	$\%or_t$	= - rent trend * caprate elasticity*switch caprate loop	Dmnl
Cap rate change	$dr_t$	= caprate* caprate change rate	Dmnl
Cap rate change ratio	$\beta_3$	Calibrated	Dmnl
Construction finish rate	$CF_t$	= under construction / construction time	Sqm/year
Construction cost	$K_t$	Exogenous constant	RMB/sqm
Construction time	$n$	Exogenous constant	Year
Demand	$E_t$	= Population * Income	RMB
Demolition rate delta	$\delta$	= 1/ average building life	Dmnl/year
Demolition	$S_t * \delta$	= stock*demolition rate	Sqm/year
Elasticity of demand	$\beta_1$	Exogenous constant	Dmnl
Elasticity of spec demand	$\beta_4$	Exogenous constant	Dmnl
Elasticity of supply	$\beta_2$	Exogenous constant	Dmnl
Empirical income growth rate	$ye_t$	Exogenous	Dmnl
Empirical LFS ratio	$lfse_t$	Exogenous	Dmnl
Empirical population growth	$ne_t$	Exogenous	Dmnl

Empirical revenue growth	$ge_t$	Exogenous	Dmnl
Equilibrium switch	$IO_E$	Binary 1 or 0	Dmnl
Expected annual land sales	$RL_t$	= LFS reliance ratio * local gov annual revenue	RMB (Chinese currency)
Expected land supply	$LE_t$	= stock*alpha2*(price)^elasticity of supply/residential floor area ratio	Sqm
Historical price	$P_{ht}$	Exogenous	RMB/sqm
Income growth	$dY_t$	= Income*income growth rate*equilibrium switch	RMB/year
Income growth rate	$y_t$	= if then else (Time<time threshold, empirical income growth rate, projection income growth rate)	Dmnl
Initial average stock	$Sa_0$	Exogenous constant	Sqm/RMB
Initial cap rate	$r_0$	Exogenous constant	Dmnl
Initial demand	$E_0$	= INITIAL (initial pop * initial income)	RMB
Initial income	$Y_0$	Exogenous constant	RMB/person
Initial gov revenue	$G_0$	Exogenous constant	RMB
Initial percentage of speculative pop	$\%spec$	= Exogenous constant * Equilibrium switch	Dmnl
Initial population	$N_0$	Exogenous constant	Persons
Initial price	$P_0$	Exogenous constant	RMB/sqm
Initial rent	$R_0$	= INITIAL(initial price*Initial cap rate)	RMB/sqm
Initial total stock	$S_0$	= INITIAL(initial average stock*Initial pop)	Sqm
Initial usage stock	$SU_0$	= initial total stock*(1-initial percentage of spec pop)	Sqm
Land price	$PL_t$	= price*land price ratio	RMB/sqm
Land price ratio	$LPR$	Exogenous constant	Dmnl
Land supply by local gove	$L_t$	= expected annual land sales/land price	Sqm
Land Financing Scheme (LFS) reliance ratio	$LFS$	= if then else (equilibrium switch=0, 1, if then else (Time<time threshold 2, empirical LFS ratio, projection LFS ratio))	Dmnl
Local gov annual revenue	$G_t$	= INTEG (revenue income, initial gov revenue)	RMB
Maximum construction rate	$CM_t$	= land supply*residential floor area ratio	Sqm/year
Natural vacancy rate	$V_t$	Exogenous constant	Dmnl
New	$CN_t$	= min (maximum construction rate, usage	Sqm/year

construction rate		stock*alpha2*(price)^elasticity of supply) * switch LFSloop + (1-switch LFSloop) * usage stock*alpha2 *(price)^elasticity of supply	
Per capita income	$Y_t$	= INTEG (income growth, initial income)	RMB/person
Population	$N_t$	= INTEG (new pop growth, Initial pop)	Persons
Pop growth	$dN_t$	= population*pop growth rate*equilibrium switch	Persons/year
Pop growth rate	$n_t$	= if then else (Time<time threshold, empirical pop growth, projection pop growth)	Dmnl
Projected income growth rate	$yp_t$	Exogenous	Dmnl
Projected LFS ratio	$lfsp_t$	Exogenous	Dmnl
Projected population growth	$np_t$	Exogenous	Dmnl
Projected revenue growth	$gp_t$	Exogenous	Dmnl
Rent	$R_t$	=(usage stock*(1-natural vacancy rate)/(alpha1*demand))^(1/elasticity of demand)	RMB/sqm
Rent trend	$dR_t$	= TREND (rent, Time Step, 0)	Dmnl
Residential FAR	$FAR$	Exogenous constant	Dmnl
Revenue growth rate	$g_t$	= if then else (Time<time threshold, empirical rev growth rate, projection rev growth rate)	Dmnl
Revenue income	$dG_t$	= local gov annual revenue*revenue growth rate*equilibrium switch	RMB/year
Simulated price	$P_t$	=rent/caprate	RMB/sqm
Spec demand growth	$dES_t$	= spec growth rate*speculative demand*equilibrium switch	RMB/year
Spec growth rate	$es_t$	= rent trend*spec demand elasticity	Dmnl
Speculative demand	$ES_t$	= INTEG (spec demand growth, initial demand*initial percentage of spec pop)	RMB
Speculative stock	$SS_t$	= average stock per demand*speculative demand*switch specloop	Sqm
Spec vacancy	$VS_t$	= speculative stock/stock	Dmnl
Stock	$S_t$	= INTEG (construction finish rate-demolition, initial total stock)	Sqm

Switch cap rate loop	$IO_{cap}$	Binary 1 or 0	Dmnl
Switch LFSloop	$IO_{lfs}$	Binary 1 or 0	Dmnl
Switch specloop	$IO_{spec}$	Binary 1 or 0	Dmnl
Time threshold	$TT_1$	Exogenous till data available date	Year
Time threshold 2	$TT_2$	Exogenous till data available date	Year
Under construction	$S_p$	=INTEG (new construction rate-construction finish rate, initial stock*demolition rate*construction time)	Sqm
Usage stock	$SU_t$	= stock – speculative stock	Sqm

Table 9-2 Commonly used Variables and Formulations in the integrated models

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## 10 Step Four: Case Study of Nanjing, China – Empirical Data and Model Testing

Chapters 4-9 have focused on the construction of a set of models, and used hypothetical data to demonstrate the effect of certain market features on the behavior of the system. In this Chapter, we will apply the empirical Chinese data into the integrated model and observe the results. The most direct analysis is to compare the housing price produced by the model with the actual historical housing price.

### 10.1 The Merits of Picking a City for Case Study

The Chinese market features such as land financing scheme and speculative demand are city-specific phenomena. If the integrated model were run with the national or provincial aggregate data, the effects of these features would be lost in the average, aggregate data, canceling out what are effectively distinct, localized characteristics. As a result, before we apply the real world data, we have chosen to analyze a specific Chinese city and present that analysis in the form of a case study. If the result is satisfactory, we can apply a similar approach to other cities.

When choosing the city for case study, we want to choose from among the cities where the Chinese market features are believed to be prevalent. In this way, the impact of the Chinese market features on housing price trend can be demonstrated through the model simulation results.

For the feature in Model SD10: Unsustainable demand growth, we aim to find a city that was built on the promise of a future increase in demand but where in reality, the projected demand growth did not materialize. This feature will require us to pick a third or fourth tier city, or even a ghost city. Although focusing on this feature can serve as a bubble bursting scenario for the Chinese housing market, it is not the current focus of this thesis which aims at analyzing the potential housing bubbles. Model SD10 is a feature that will only be used when we analyze declining or ghost cities.

For the feature in Model SD 11: Speculative demand growth, we compare the price-to-rent ratio across the major cities, and use this variable as an indicator of the degree of presence of speculative demand: A higher price-to-rent ratio implies a larger presence of speculative demand. Price-to-rent ratio has been frequently used as a signaling parameter for identifying speculative housing bubbles by comparing to the fundamental economic values (Case and Shiller, 2003; Goodman and Thibodeau, 2008).

For the feature in Model SD 12: Land financing scheme, we compare across cities by calculating the land finance scheme (LFS) reliance ratios. This ratio is calculated by dividing the local government's annual land sales by local government's general revenue. If the ratio is high, the local government has a higher reliance on land financing scheme to support its infrastructure expenditures, instead of relying on tax revenue.

LFS ratio is a standard that is well used and accepted in China in analyzing the market feature of land financing scheme (Zheng and Shi, 2011). Zhigang Hu, the vice president of Chinese Real Estate Association:<sup>69</sup>

*“When this (LFS reliance) ratio passes 50%, there shall be potential high risk. Besides the land sales revenue, there is also the tax revenue coming from the real estate sector. And the two revenue sources combined for even a higher percentage. In this way, the real estate sector has bonded with the local government and the local economy. When the economy is not performing, the local government has to stimulate the real estate market. When the housing price reached a high level that people cannot afford anymore, the local government is not willing to suppress the real estate sector. Also, the land financing scheme is closely related to political achievement. Many cities should have aimed for diversified economy. Instead, they all aimed for new city construction, ghost city construction, and short term revenue increase. But this cannot last forever should one day the real estate sector not perform.....”*

## 10.2 The Choice of City of Nanjing

For the first indicator, price-to-rent ratio, we are relying on the quarterly price-to-rent ratios calculation by Wu, Gyourko and Deng (2016) for the 12 major Chinese cities from 2009-2014, as shown in Figure 10-1. It is not surprising that the first tier cities such as Beijing and Shanghai have the highest price-to-rent ratio, with the highest reaching 55.

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<sup>69</sup> The interview is in Mandarin. Translated by author. Online see <<http://chuansong.me/n/1680240651524>>



Also, we can see that second tier cities such as Nanjing and Hangzhou also demonstrated high ratios, in the range between 45 and 55. Thus, any of these four cities are potential candidates for the case study.

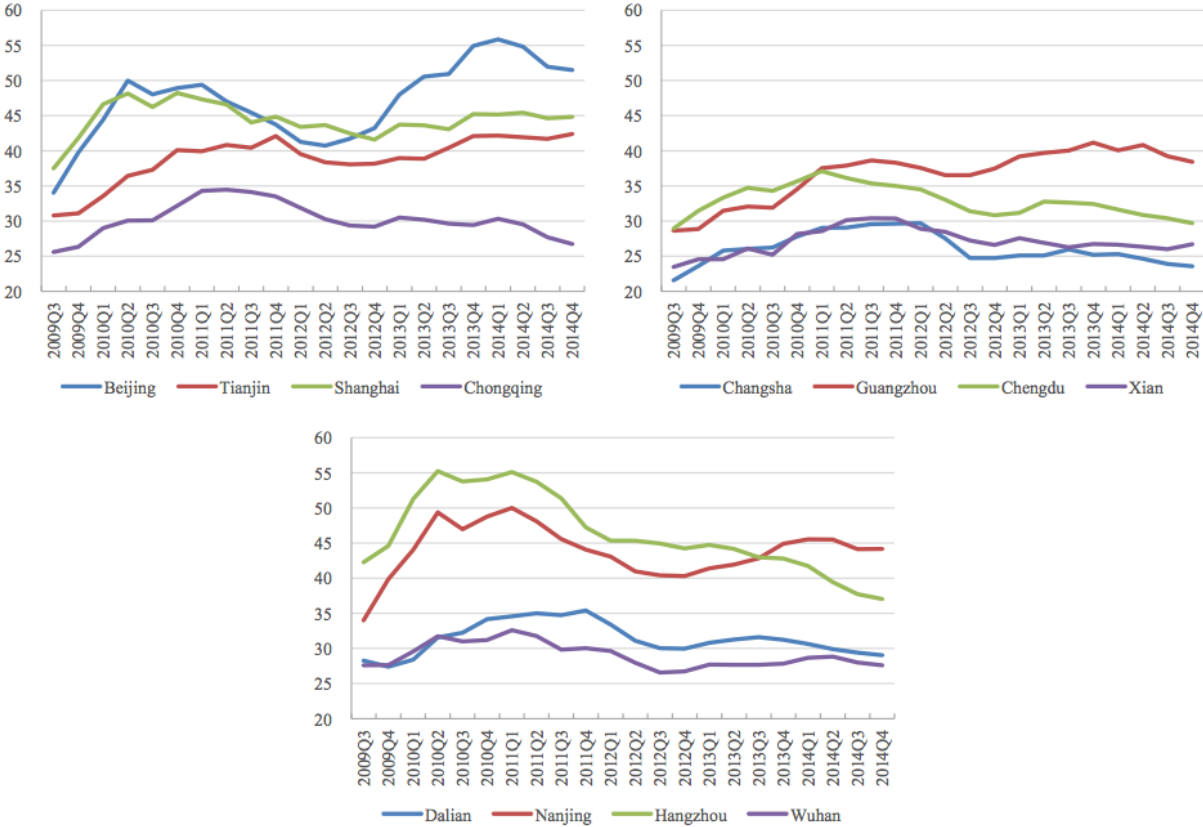


Figure 10-1 Quarterly price-to-rent ratios in 12 major cities (Wu, Gyourko, and Deng, 2016)

In the 30 Chinese major cities’ land financing scheme (LFS) reliance ratio ranking, the old capital of China, Nanjing from Jiangsu province, was ranked number one in 2015 as shown in Figure 10-2<sup>70</sup> and in 2016 passed by the city of Hefei from Anhui province.<sup>71</sup> The ranking is based on the “LFS reliance ratio” that is used in the model: the higher the ratio, the higher the rank. The ratio of Nanjing has reached 0.86 in 2015 and 1.55 in

<sup>70</sup> “Land Financing Scheme reliance of 30 major Chinese cities 2015”. The article is in Mandarin Chinese, reported on sina.com.cn. The original source is from [www.china-crb.cn](http://www.china-crb.cn). See <<http://ah.sina.com.cn/news/m/2016-03-31/detail-afxqxcnp8252058.shtml>>. Access date: March 20, 2017

<sup>71</sup> “Land Financing Scheme reliance of 30 major Chinese cities 2016”. The original source is from [www.china-crb.cn](http://www.china-crb.cn). See <http://chuansong.me/n/1680240651524>. Access date: March 31, 2017

2016. The ratio is calculated by dividing the land sales revenue by the local government’s general revenue. We have to clarify that the ratio can have a value that is bigger than 1 because the income from land sales revenue is not counted as part of the local government’s general revenue and saved in a separate income account.

By considering the price-to-rent values and the LFS reliance ratio, we have chosen Nanjing from Jiangsu province for our case study. Nanjing has a high price-to-rent ratio and a high LFS reliance ratio. In fact, both ratios are the highest rank among all major Chinese cities.



Figure 10-2 Land Financing Scheme reliance ratio of 30 major Chinese cities 2015  
 Source: Chinese Real Estate News, online see < <http://ah.sina.com.cn/news/m/2016-03-31/detail-ixqxcnp8252058.shtml>> Access date: April 2, 2017

Nanjing, formerly known as Nankin, is a major city in the east China region and a major center of education, politics, economy, and tourism. It is located to the west of Shanghai as shown in Figure 10-3. Nanjing is also an important city in Chinese history. It has served as the capital city for various Chinese dynasties and most recently as the capital of the Chinese Nationalist Party till 1949. According to the Nanjing statistical yearbook, in 2015, the total population of Nanjing is around 6.5 million, average per capita disposal income of 46,000 RMB, and an average residential area of 36.5 square meters.



Figure 10-3 Location of Nanjing, Jiangsu Province  
Image source: <http://travelneu.com/o/Nanjing-o2.gif>

### 10.3 Variable Types and Data Collection for Nanjing

We have collected data relevant to the City of Nanjing to serve as input into the integrated model. This section lists the various model variables and their data sources. Most of the historical data are collected from various Chinese Statistical Yearbooks.<sup>72</sup> The time frame of the data is from 2006 to 2013 or 2015 depending on the data availability for different variables. And, there are two clarifications:

1. The land auction system was established in 2004. As a result, the land price before 2004 does not reflect the actual land value and we use 2006 as a starting point for modeling.
2. We have used the average pricing and the total surface area of the auction land as the residential land price and land supply by the local government. It is an approximation that is also used in the Chinese land financing research by Zheng et al. (2014).

There are mainly four types of variables that we will use in the integrated model: Exogenous variables, Intermediate variables, Variables with estimated values, and Variables with initial values. Each of these is discussed in detail below.

#### a. Exogenous variables:

An exogenous variable means that the variable is considered exogenous to the system and its value is not calculated by the model but obtained from recorded historical data. The data source for historical data are mostly from various Chinese statistical yearbooks and data collection agencies. The name of the variables and the historical data source are listed in Table 10-1.

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<sup>72</sup> The data collection from statistical yearbooks are kindly provided by Prof. Siqi Zheng from Massachusetts Institute of Technology. Some missing data are collected by the author from the same data source.

<b>Exogenous Variable Name</b>	<b>Units</b>	<b>Time Range (Year)</b>	<b>Variable Data Source (in English and Chinese)</b>
Annual land sales	RMB	2006-2011	China Land and Resources Statistical Yearbook (中国国土资源统计年鉴)
Elasticity of demand	Dmnl	2005	Zheng and Liu (2005) Estimated value of -0.86
Elasticity of supply	Dmnl	2012	Wang, Su, and Xu (2012) Estimated value of 3.42
Housing Price	RMB/sqm	2006-2015	National Data from National Bureau of Statistics of China <a href="http://data.stats.gov.cn">http://data.stats.gov.cn</a> (中华人民共和国国家统计局-国家数据)
Land price	RMB/sqm	2006-2011	China Land and Resources Statistical Yearbook (中国国土资源统计年鉴)
Land supply by local government	Sqm	2006-2011	China Land and Resources Statistical Yearbook (中国国土资源统计年鉴)
Local government annual revenue	RMB	2006-2015	China City Statistical Yearbook (中国城市统计年鉴)
Per capita income	RMB/person	2006-2015	Nanjing Statistical Yearbook (南京统计年鉴)
Population	Persons	2006-2015	Nanjing Statistical Yearbook (南京统计年鉴)
Residential FAR	Dmnl	2007-2012	<a href="http://www.landchina.com">www.landchina.com</a> (中国土地市场网) Calculated value of 1.55

Table 10-1 Exogenous variables' name and data source for the integrated model

All the exogenous variables listed above are directly recorded from statistical yearbooks, except the residential FAR. The residential FAR is calculated by using the data from [www.landchina.com](http://www.landchina.com). We have obtained the information of each land parcel that is auctioned off in Nanjing and the upper limit of the FAR that is associated with the land

parcel, from year 2007 to 2012.<sup>73</sup> We then calculated the average FAR and get an estimated value of 1.55.

b. Intermediate variables:

An intermediate variable is a variable whose numerical value is calculated based on historical data by the author and not directly recorded from existing data sources such as various statistical yearbooks. For example, by analyzing the per capita income for Nanjing every year, we can calculate the “income growth rate” as an intermediate variable. The set of intermediate variables, formula to derive them, and value ranges for Nanjing from year 2006-2013 are listed in Table 10-2.

Intermediate Variables	Units	Formula	Time Range	Minimum Value	Max Value	Mean
Land price ratio	Dmnl	$PL_t/P_t$	2006-2011	26%	48%	37%
Empirical income growth rate	Dmnl	$(Y_t - Y_{t-1})/Y_{t-1}$	2007-2015	9.8%	16%	12%
Empirical LFS ratio	Dmnl	$RL_t/G_t$	2006-2011	36%	99%	62%
Empirical population growth	Dmnl	$(N_t - N_{t-1})/N_{t-1}$	2007-2015	3.3‰	19.2‰	9.6‰
Empirical revenue growth	Dmnl	$(G_t - G_{t-1})/G_{t-1}$	2007-2015	12%	34%	19%

Table 10-2 Intermediate variables’ name and data source for the integrated model

For these intermediate variables, we use the exact calculated number for each year to feed into the model. We only calculate the mean value to use as a reference point for the estimation of the projected future values of these variables. The historical data that we have started with are listed in Table 10-3.

<sup>73</sup> The FAR data of Nanjing is kindly provided by Prof. Siqi Zheng from Massachusetts Institute of Technology.

Year	Population (1000)	Population growth (%)	Per capita income (RMB)	Per capita income growth	Housing price (RMB/sqm)	Local gov revenue (RMB)	Local gov expenditure (RMB)	Land sales (RMB)	LFSratio	land to price ratio
2006	6,072	1.92%	17,538		4,270	24,643,920,000	26,246,140,000	8,754,200,000	36%	36%
2007	6,172	1.64%	20,317	15.85%	5,011	33,018,830,000	34,293,860,000	20,486,790,000	62%	48%
2008	6,245	1.18%	22,337	9.94%	4,786	38,656,000,000	40,466,560,000	17,416,830,000	45%	26%
2009	6,298	0.85%	24,678	10.48%	6,893	43,450,800,000	46,126,620,000	24,774,836,000	57%	27%
2010	6,324	0.42%	27,383	10.96%	9,227	51,880,080,000	54,218,120,000	51,160,593,500	99%	46%
2011	6,364	0.63%	31,100	13.57%	8,415	63,500,180,000	66,620,560,000	48,250,320,900	76%	37%
2012	6,385	0.33%	35,092	12.84%	9,674	73,301,680,000	76,965,690,000			
2013	6,431	0.72%	38,531	9.80%	11,078	83,130,760,000	85,090,850,000			
2014	6,487	0.87%	42,568	10.48%	10,964	90,349,000,000	92,120,000,000			
2015	6,534	0.72%	46,104	8.31%	11,260	102,003,000,000	104,557,000,000			

Table 10-3 Historical data of Nanjing that is collected for model building

c. Variables with estimated value:

These are variables whose numerical values are estimated for Nanjing. When projecting future values, the estimation is normally based on historical data and past trends. For variables where accurate, historical numerical data is not available, estimation is based on the best available sources and the values are maintained within a realistic range throughout the modeling process.

Estimated Variable Name	Units	Estimated Value	Data Source
Average building life	years	20	Online source
Construction time	years	2	Online source
Initial cap rate	Dmnl	5%	Online source
Land price ratio	Dmnl	35%	Based on past trend
Projected income growth rate from 2016	Dmnl	10%~2% declining	Based on past trend
Projected LFS ratio from 2012	Dmnl	60%-30% declining	Based on past trend
Projected population growth from 2016	Dmnl	1%	Based on past trend
Projected revenue growth from 2016	Dmnl	15%	Based on past trend
Initial percentage of speculative population	Dmnl	5%	Author's assumption
Cap rate elasticity	Dmnl	0.2	Calibrated
Spec demand elasticity	Dmnl	2	Calibrated

Table 10-4 Variables with estimated values for the integrated model

In details, the assumption of population of Nanjing and the projected LFS ratio are shown in Figure 10-4.

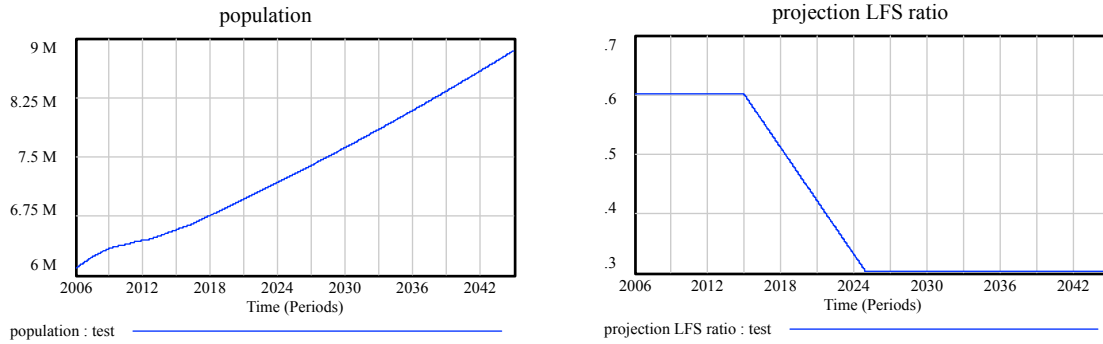


Figure 10-4 Long term projection for the population and LFS ratio for Nanjing

We have also assumed made assumptions on income growth rate for Nanjing as shown in Figure 10-5. As the Chinese economy transit toward mature economy, we have assumed that the growth rate will reduce exponentially from the current 10% growth rate to about 2% in 30 years.

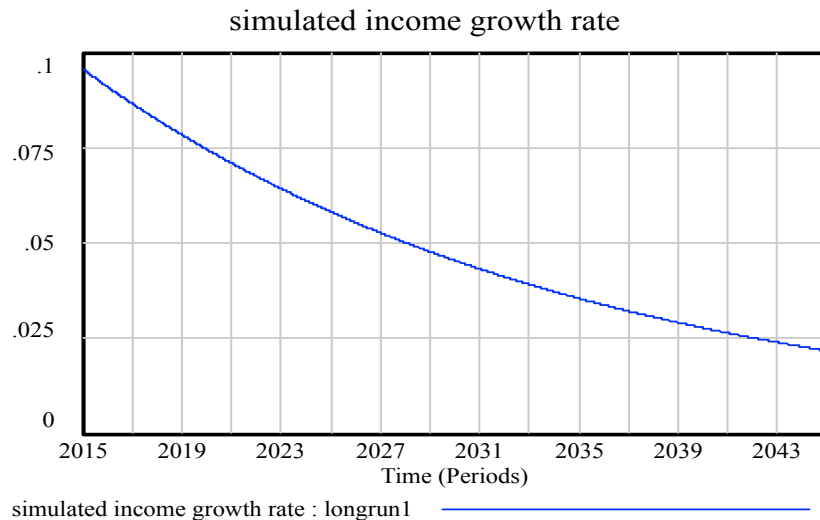


Figure 10-5 Income growth rate assumption for Nanjing in long run

d. Variables with initial value:

Lastly, we deal with the variables with initial values in the integrated model. The purpose of these variables is to set up the initial equilibrium stage for the model. When there are no exogenous impacts that are imposed to the system, the system should stay at equilibrium stage calculated by the variables' initial values. This is a common process for SD modeling. We have chosen to use the data in year 2006 as the starting point and



equilibrium stage. As a result, we recorded here the set of initial value as shown in Table 10-5

<b>Initial Variable Name</b>	<b>Units</b>	<b>Initial Value @ Year 2006</b>	<b>Data Source</b>
Initial average stock	Sqm/person	26	Online source <sup>74</sup>
Initial population	Persons	6,072,000	Nanjing Statistical Yearbook
Initial per capita income	RMB/person	17,538	Nanjing Statistical Yearbook
Initial government revenue	RMB	24,643,920,000	China City Statistical Yearbook
Initial price	RMB/sqm	4,270	National Data from National Bureau of Statistics
Initial rent	RMB/sqm	214	Calculated
Initial total stock	Sqm	157,872,000	Calculated
Natural vacancy rate	Dmnl	5%	Author's assumption

Table 10-5 Variables with initial values to set up the equilibrium stage for the integrated model

We also have to point out that the “rent” variable in the model does not represents the actual market rent for housing. It is calculated by multiplying the housing price and cap rate. As a result, the initial rent is calculated by multiplying the initial housing price and initial cap rate.

## 10.4 Simulation Results Using Historical Data (Year 2005-2015)

### 10.4.1 Equilibrium Stage Setting

As a common standard for SD modeling, the initial stage of the model, regardless how complex it is, should be in equilibrium stage when exogenous variables are not causing the system to change. In other words, the system structure should not generate internal noise.

<sup>74</sup> Source: Nanjing Chenbao (南京晨报) <http://news.qq.com/a/20060929/001418.htm>

In the integrated model, we change the value of the “equilibrium switch” from 1 to 0. In this way, the variables that generate changes to the system are set to be 0. For example, we set the ‘new population growth’ and ‘income growth’ to be 0. In that way, the demand variable remains at its initial value. The simulation starting time point is year 2006 and the initial values of initial variables for the system is set at their respective numerical values at year 2006.

As shown in Figure 10-6, the system remains at its equilibrium stage with the price remain unchanged at its year 2006 level.

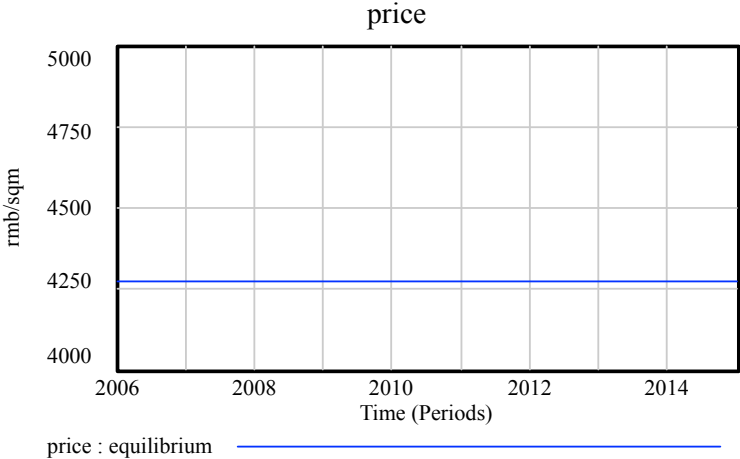


Figure 10-6 The equilibrium stage setting for the integrated system

**10.4.2 Simulation with the Baseline 4QM SD Structure**

In this step, we first turned the “equilibrium switch” back on and enable exogenous variables such as ‘population growth’ and ‘income growth’ to impose changes onto the system. We disabled all generic features such as cap rate loop, as well as the Chinese features such as speculation loop and land financing scheme loop:  
 Switch Caprate loop = 0; Switch specloop =0; Switch LFSloop=0. The goal is to observe the simulation result of using only the D-W model structure.

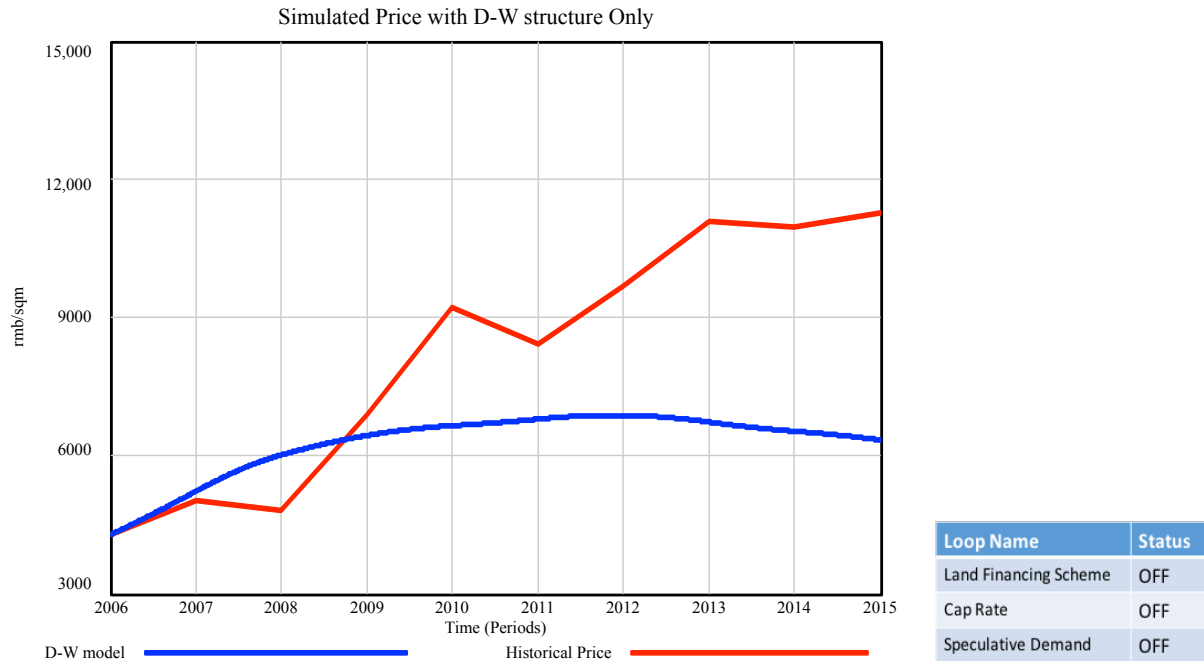


Figure 10-7 Simulated price vs Historical price for 4QM structure

As we can see from the Figure 10-7, the simulated price using only the D-W model structure does not fully explain the price trend from year 2006-2015 for Nanjing. The simulated price is generally below the actual price beyond year 2008. After year 2010, the simulated price starts a long run fall while the actual price keeps on climbing.

It is important to clarify that the significant price drop in year 2008 is caused by the global economic recession that followed the US housing market collapse. This “black swan” event is not built in the model. First this is because no model can predict the economic recession that actually happened in 2008 ex ante. Secondly, the purpose of this SD model is not to replicate the historical data point to point. As a result, no models in the following section have the predictive power of price drop in 2008 to avoid the controversial issue of backward engineering.

Even though the simulated price of 4QM is moderately low when comparing to the actual price, it still represents a short run price increase from 2006 to 2012. From 2012 on, the price drops but the long run price increase from 2006 to 2015 is still 5% per year. This price increase is mostly driven by the population and income growth.

The price trend may change because the simulated price in Figure 10-7 is largely due to the input values to the model for the supply and demand elasticity. In the simulation, the demand elasticity is set at 0.86 and the supply elasticity is set at 3.42. Both are estimated based on the reported value in the literature. It is thus reasonable for us to conduct sensitivity analysis and see whether the simulated price changes when the value of supply and demand elasticities change.

In the Monte Carlo simulation, we set the demand elasticity as a uniform distribution with a value between of 0.5 and 1.5, and we set the supply elasticity as a uniform distribution with a value between 2 and 5. The simulation result is shown in Figure 10-8.

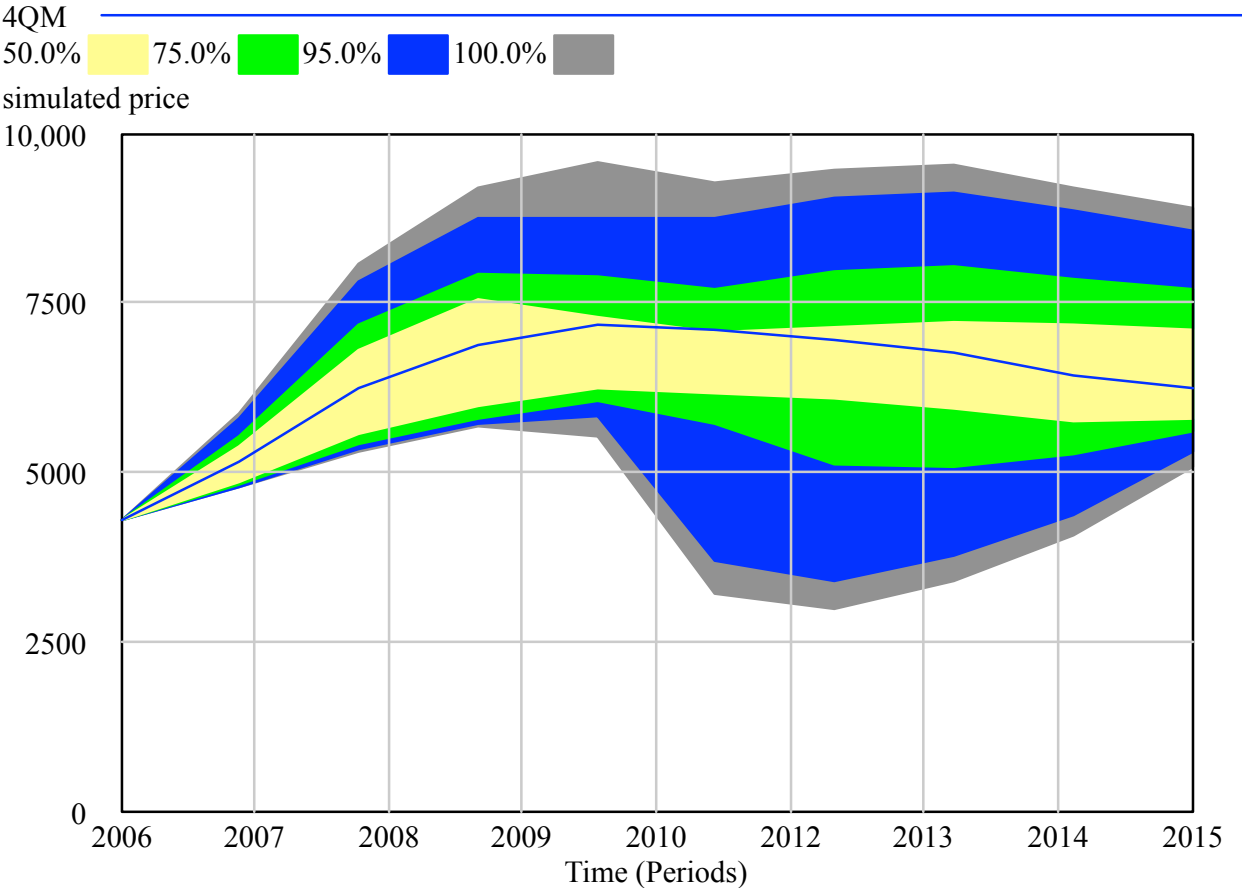


Figure 10-8 Simulated price for 4QM structure when demand elasticity =  $U[0.5, 1.5]$  and supply elasticity =  $U[2, 5]$

We can see that even when the supply and demand elasticities take on extreme values, the price range is still well below 10,000 RMB. The historical price cannot be simply explained by the 4QM.

**10.4.3 Simulation with Integrated Generic Model Structure – Add Cap rate Loop**

In this step we activated the ‘cap rate loop’ by turning the ‘Switch Caprate loop’ from 0 to 1, which causes the cap rate to become internalized. The goal is to see how simulated housing price can increase further when we assume that the increasing rent level will further squeeze the cap rate and thus create a second order effect on the price increase.

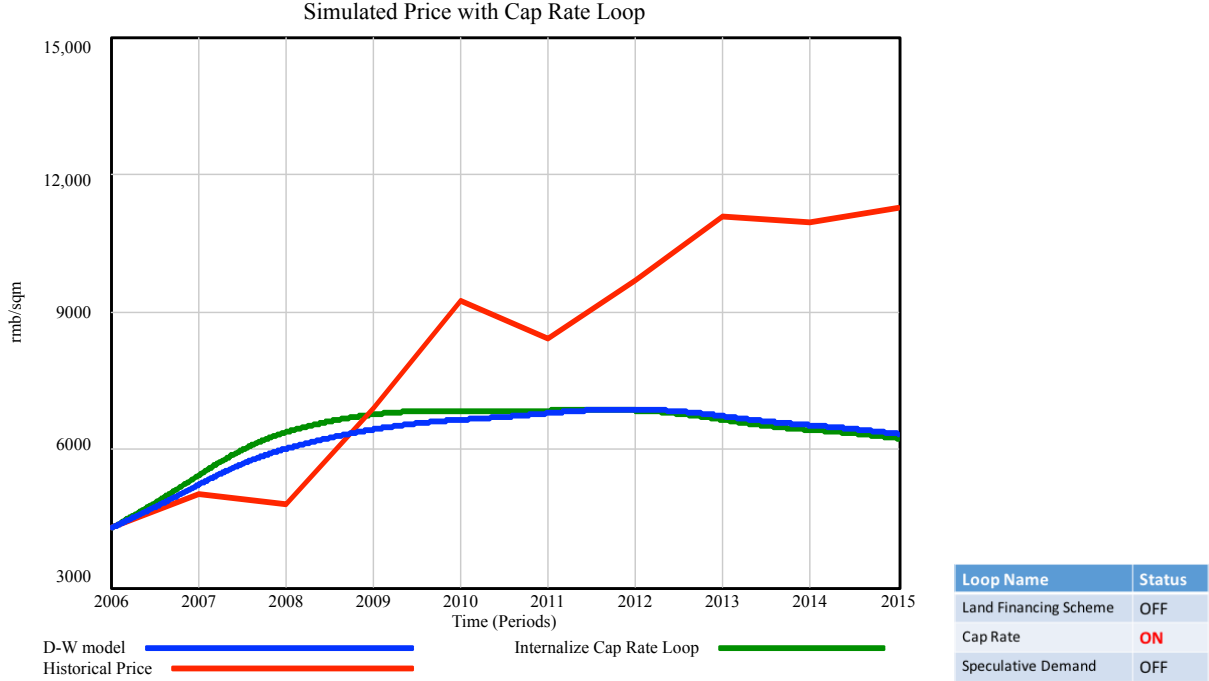


Figure 10-9 Simulated price vs Historical price when Cap rate is internalized

As we can see from Figure 10-9, when cap rate is internalized, the simulated price still demonstrate the same trend as the simulation done with 4QM alone, except the minimum deviations of higher values of peak and trough for the cycle.

In our model, the value for the cap rate change ratio is given an estimated value of - 0.2. There is no recorded or measured value for the cap rate change ratio with regard to price change, and we made the assumption based on two criteria:

- (1) The initial cap rate is set at 5%, and the simulated cap rate should be within a reasonable range (e.g. positive value between 1% and 10%).
- (2) The cap rate change should be negatively related to the price change. When rent level increases, there should be more capital coming into the real estate sector looking for investment opportunities and thus driving down the cap rate.

We can take a look at the cap rate trend as shown in Figure 10-10. The cap rate stays within a reasonable range between 4% and 5%.

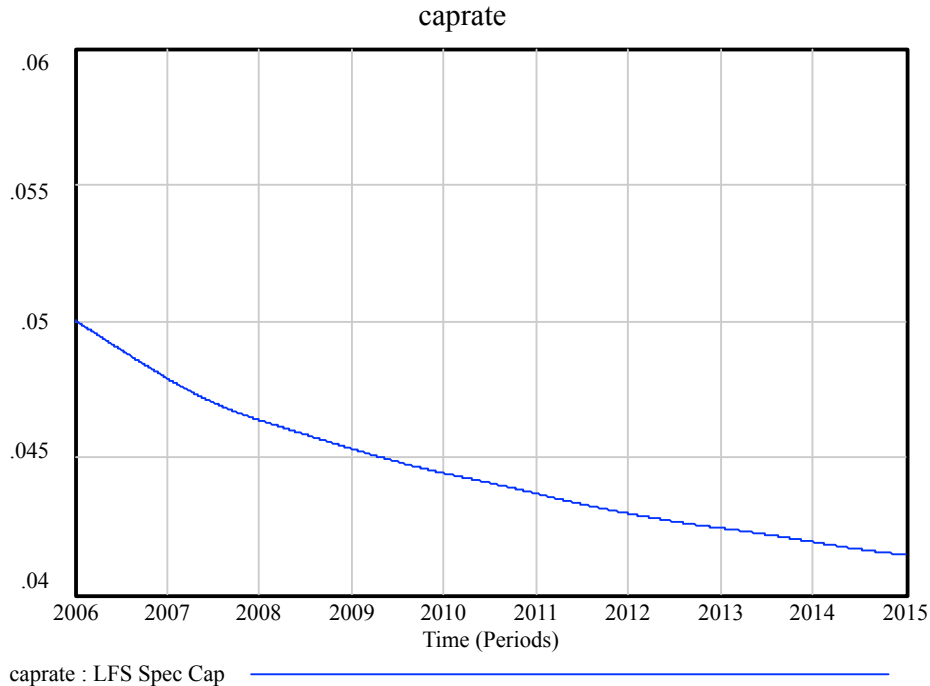


Figure 10-10 The cap rate trend and value when it is internalized

Using the integrated model with cap rate loop alone cannot explain the actual long run housing price trend for Nanjing. The simulated housing price increased until 2010 and then started to fall. There are no mechanisms in the simulated system to maintain the housing price increase for the long run. It is because for cap rate loop to have a

significant impact, we will need significant price change. However, if the status quo price change is depicted as in the basic D-W model, the impact would not be significant.

#### 10.4.4 Simulation with Integrated China-Specific Model Structure – Add Speculative Demand Loop

In this step, we add the speculative demand loop, the first China-specific feature of the housing market. The goal is to see how the existence of speculative demand affects the housing price. Before viewing the simulation results, it is critical to discuss the assumptions made in the model setup for the speculative demand loop.

First of all, we have assumed that the speculative demand has a positive price elasticity. When the housing price is increasing, the speculative demand will increase, and speculative housing stock will increase and will remain vacant. By contrast, when the housing price is decreasing, the speculative demand will also decrease, resulting in less speculative housing stock and fewer vacant units. In the first scenario, when the housing price increases, we have assumed in the model that the speculative demand has preemptive purchasing power and purchases units ahead of usage demand; in the second scenario, when the housing price decreases, we assume that the speculative stock will transform and become usage stock.

Two numerical assumptions are made:

- (1) The initial percentage of population who are speculators are set at 5%. This is within the reasonable range of the possible speculative vacancy rate that is estimated by scholars which are covered in details in Chapter 7.
- (2) The price elasticity of speculative demand is set at 2, reflecting a highly elastic relationship. There is no data that is available to estimate this elasticity. However, we can estimate a reasonable range and conduct sensitivity analysis through Monte Carlo simulation. We currently set its numerical value at 2 for the convenience of simulation purpose.

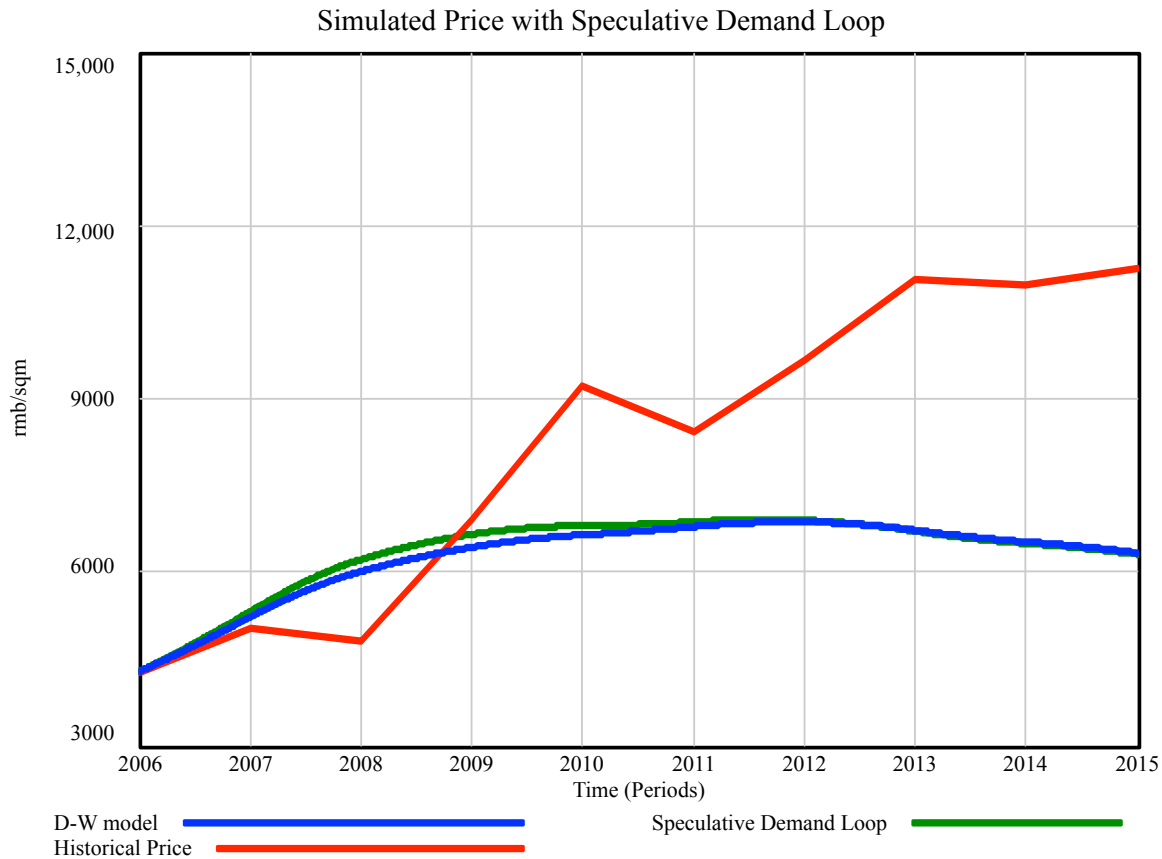


Figure 10-11 Simulated price vs Historical price when speculative demand is included

As shown in Figure 10-11, including the speculative demand loop does not change the simulated housing price trend, except for the slight magnitude change of the peak and trough of the housing cycle. This is surprising because of the commonly held belief that the speculators are responsible for the high housing price. We further check the speculative vacancy rate as shown in Figure 10-12. The simulated speculative vacancy rate is between 3.5% and 8% range which is reasonable.



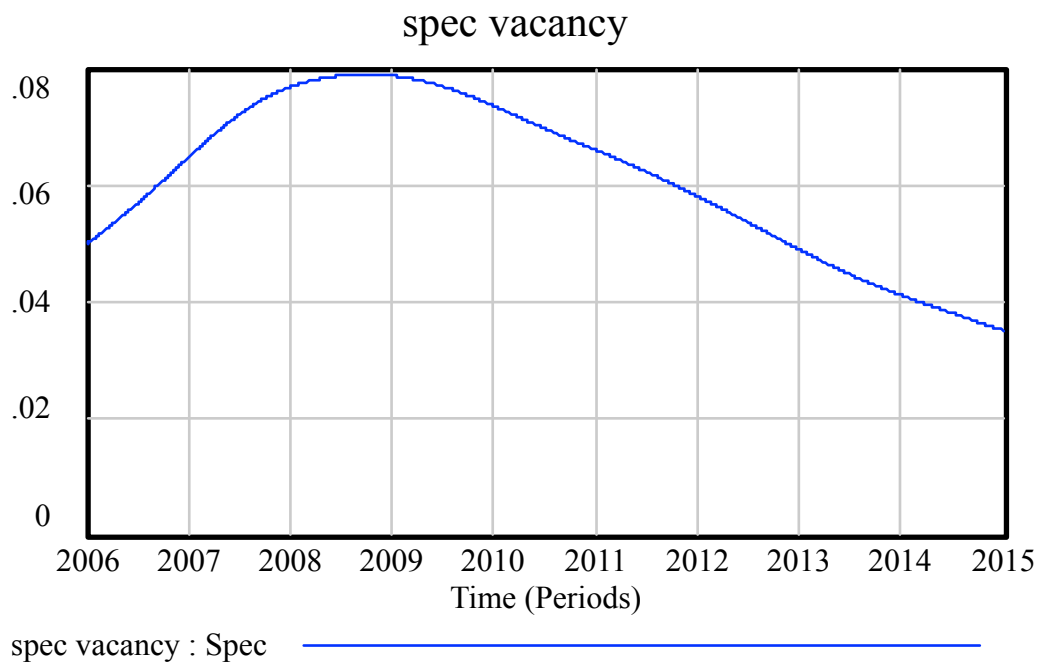


Figure 10-12 Speculative vacancy rate change when speculative demand is included

However, this simulation result may be due to the value set for the price elasticity of speculative demand. As a result, we conducted a sensitivity analysis of this variable. We have set the price elasticity as a uniform distribution between 1 and 4. The simulation result from the Monte Carlo simulation is shown in Figure 10-13. As we can see, the simulated housing price may increase, the general housing trend will not change, demonstrating a cyclic behavior than a price increasing as shown in the historical price.

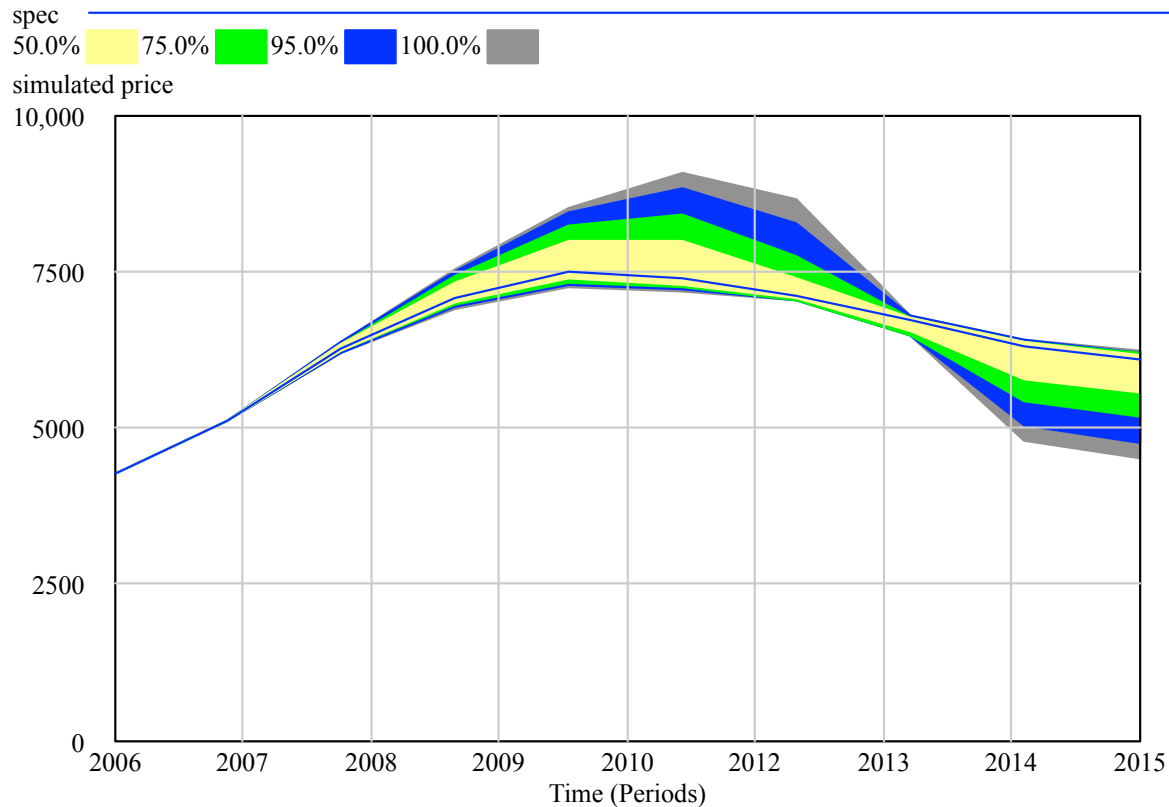


Figure 10-13 Monte Carlo simulation of housing price when price elasticity of speculative demand is set as an uniform distribution between 1 and 4 --  $U[1,4]$

We also show in Figure 10-14 the Monte Carlo simulation results of speculative vacancy rate when the price elasticity of speculative demand is set as  $U[1,4]$ . The simulated price can reach higher peaks and lower troughs when the elasticity is high such as taking on the value of 4. But the highest price is still well below the historical price. As we can see the speculative vacancy rate ranges between 0% and 25% which is already the lowest and highest limit of such vacancy rate that has been reported. This in turn confirms that the range between 1 and 4 is a reasonable and realistic range to conduct Monte Carlo simulation.

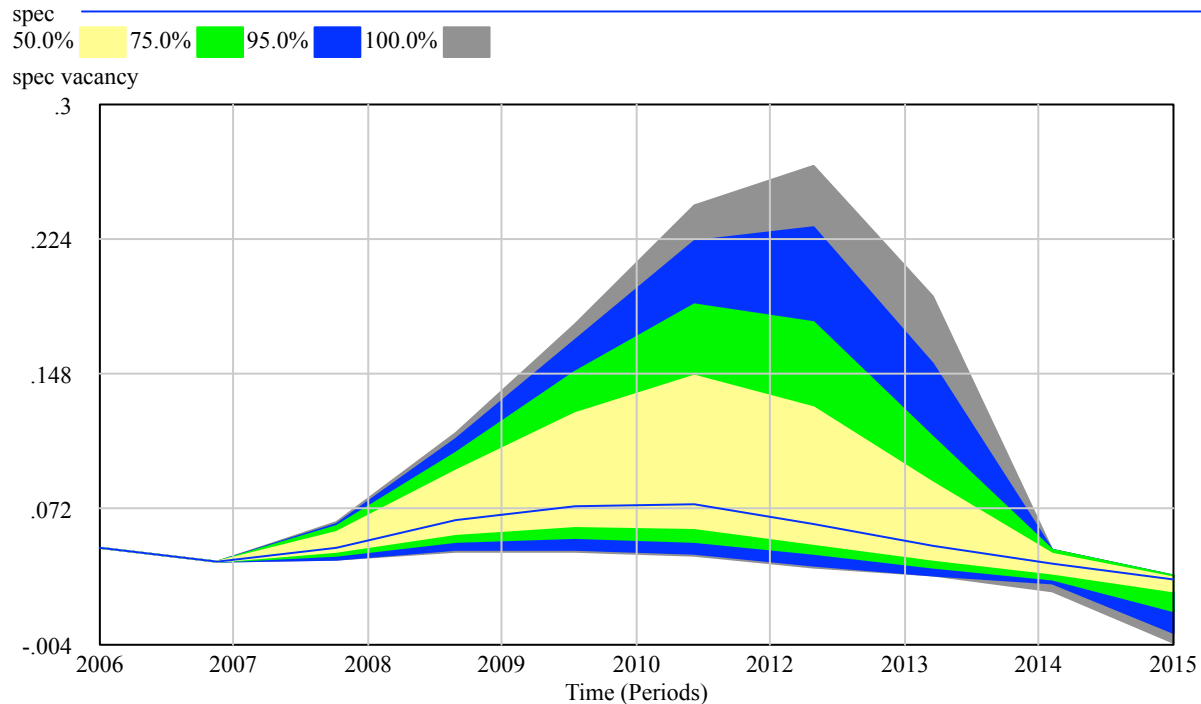


Figure 10-14 Monte Carlo simulation of the speculative vacancy rate when price elasticity of speculative demand is set as an uniform distribution between 1 and 4 -- U[1,4]

In conclusion, it seems that as long as the price elasticity of speculative demand is positive, the speculation loop alone does not change the trend of housing price. The housing price drops after year 2010 and starts to form the housing cycle instead of increasing as the actual housing price did. That means that speculation in the housing market can amplify the peak and trough effects of price trend but do not actually act alone in pushing the housing price up in the past 10 years in Nanjing.

#### 10.4.5 Simulation with Integrated China-Specific Model Structure – Add Land Financing Scheme Loop

The two loops that we studied before, cap rate loop and speculative demand loop, cannot trigger the housing price increase alone. This leads us to think that there is some feature that is the fundamental driving force of price increase and other loops such as cap rate loop and speculative demand loop would just piggyback on it and have significant impacts. In this step, we add the land financing scheme loop, the second

China-specific feature of the housing market. The goal is to see how the existence of land financing scheme affects the housing price.

Different from the previous two features (cap rate loop and speculative demand loop), the land financing scheme does not have assumptions that have estimated numerical values. The land price, as part of the housing price, is simulated by the model. The government land sales revenue is determined by historical data. As a result, the land supply is calculated by dividing the land sales revenue by simulated land price.

The simulation result is shown in Figure 10-15. As we can see, a major change is that the price trend is not tipping downward from year 2012 but continue increasing. With the land financing scheme feature enabled, we have a continuous upward simulated housing price trend.

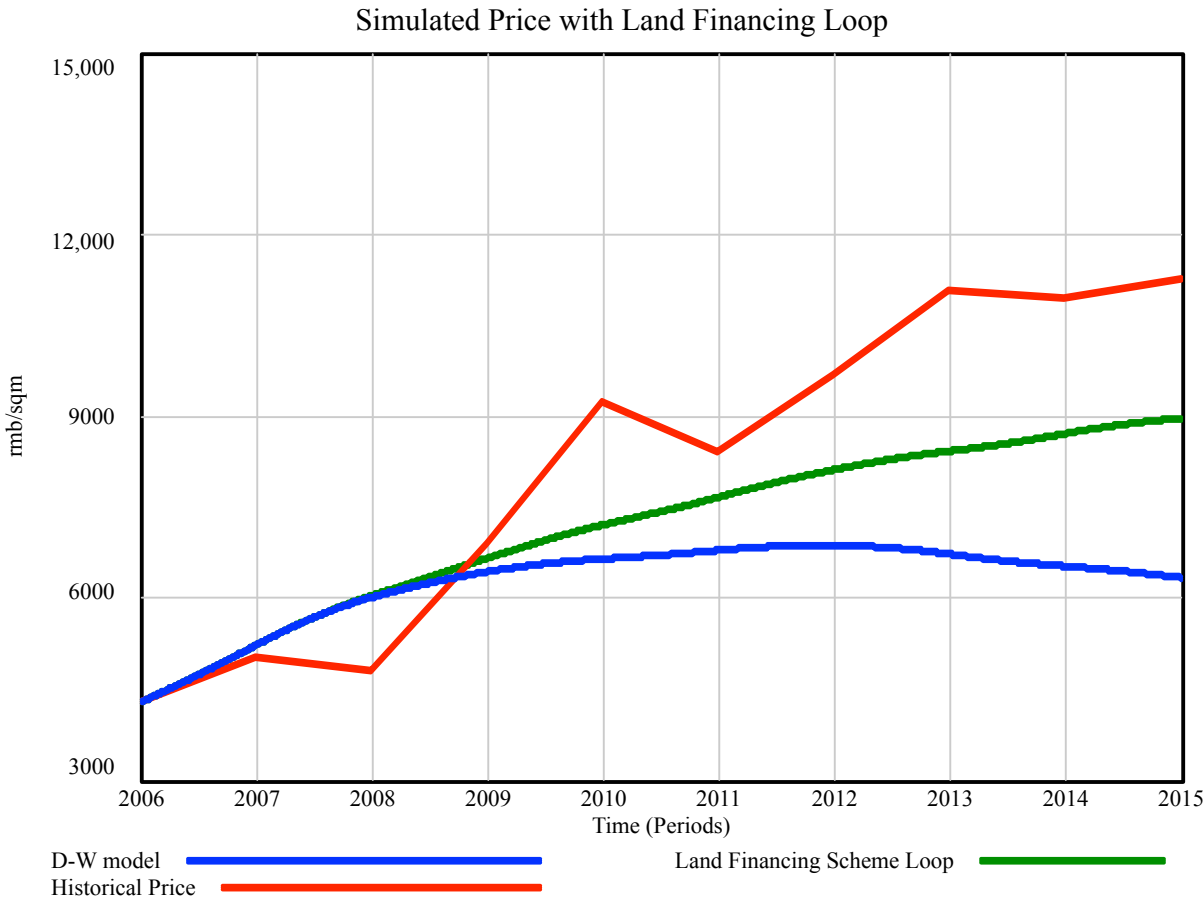


Figure 10-15 Simulated price vs Historical price when land financing scheme is included

We suspect that the simulated housing price trend change is due to a shortage of land supply because this is the first time in the modeling process that we have put an upper limit on the amount of new housing construction that can happen in Nanjing. We compare the land supply with and without land financing scheme in place, as shown in Figure 10-16. As we can see, when land financing scheme is in place, there is a significant shortage of land supply. In other words, the local government of Nanjing does not supply enough land for new construction to happen. As a result, the housing price keeps on increasing.

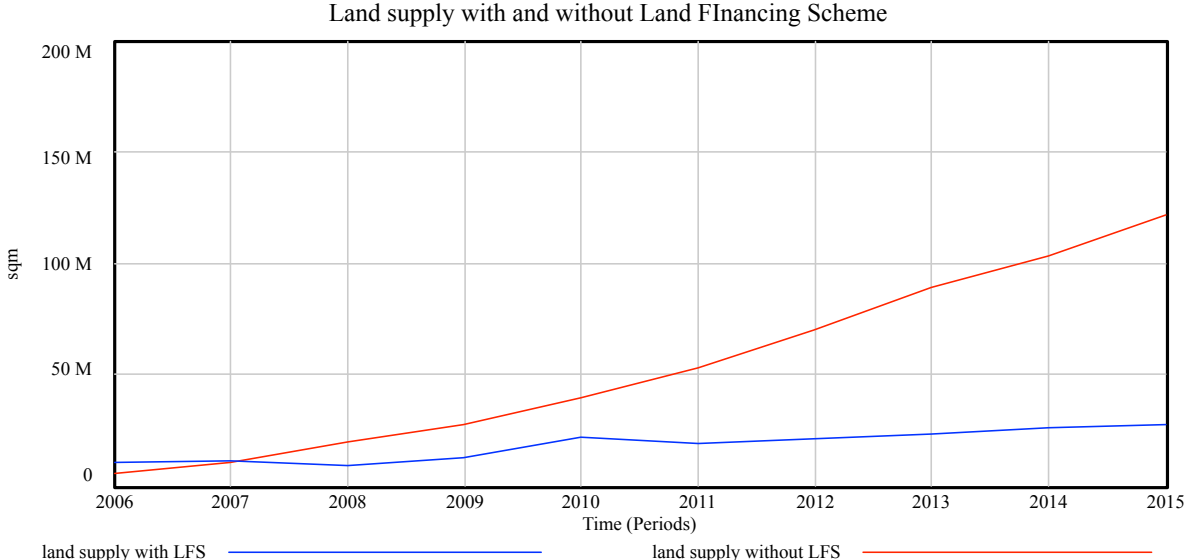
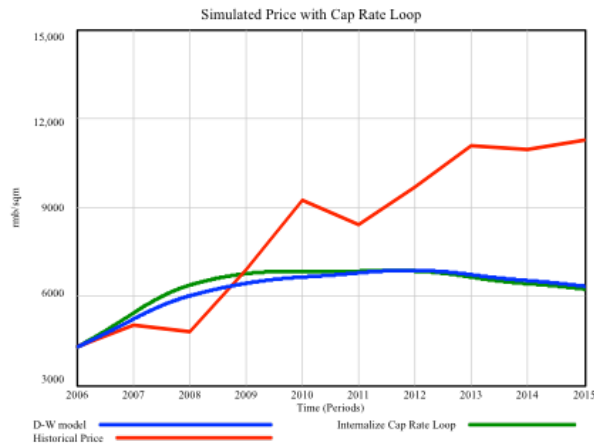
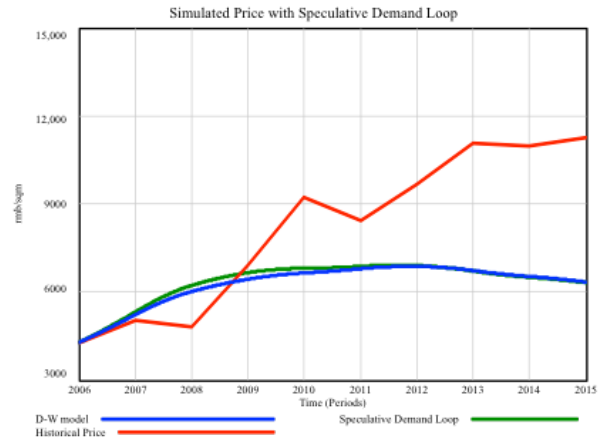


Figure 10-16 Land supply with and without land financing scheme

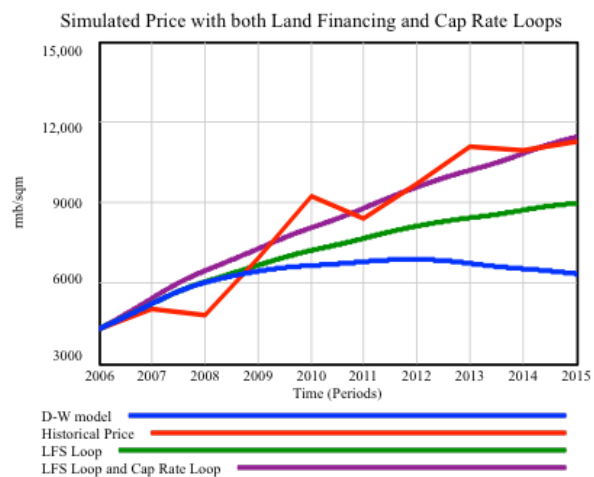
We then piggyback the cap rate loop and speculative demand loop on top of land financing scheme loop separately and the result is shown in Figure 10-17. Before the land financing loop was turned on, there were minimum effects that were observed for both loops. However, the effects of cap rate loop and speculative demand loop are magnified when combined with land financing loop.



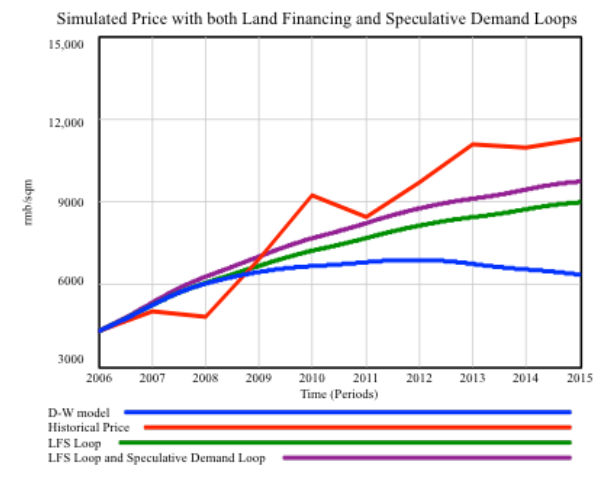
Loop Name	Status
Land Financing Scheme	OFF
Cap Rate	ON
Speculative Demand	OFF



Loop Name	Status
Land Financing Scheme	OFF
Cap Rate	OFF
Speculative Demand	ON



Loop Name	Status
Land Financing Scheme	ON
Cap Rate	ON
Speculative Demand	OFF



Loop Name	Status
Land Financing Scheme	ON
Cap Rate	OFF
Speculative Demand	ON

Figure 10-17 Land Financing Scheme loop creates an amplifying effect for other loops

#### 10.4.6 Simulation with the Integrated Model Structure including all Three Loops

We also notice that with land financing scheme alone, the housing price will not reach the same level as the historical price. In this last step, we combined the effect of all

three loops together. On top of the land financing scheme loop, we activated the cap rate loop and speculative demand loop by setting their loop switches to the value of 1.

The simulation result is shown in Figure 10-18. As we can see, the historical housing price trend is in between the LFS simulated housing price and the price with all three loops. This means that with all three loops, the housing price can be explained through the integrated model.

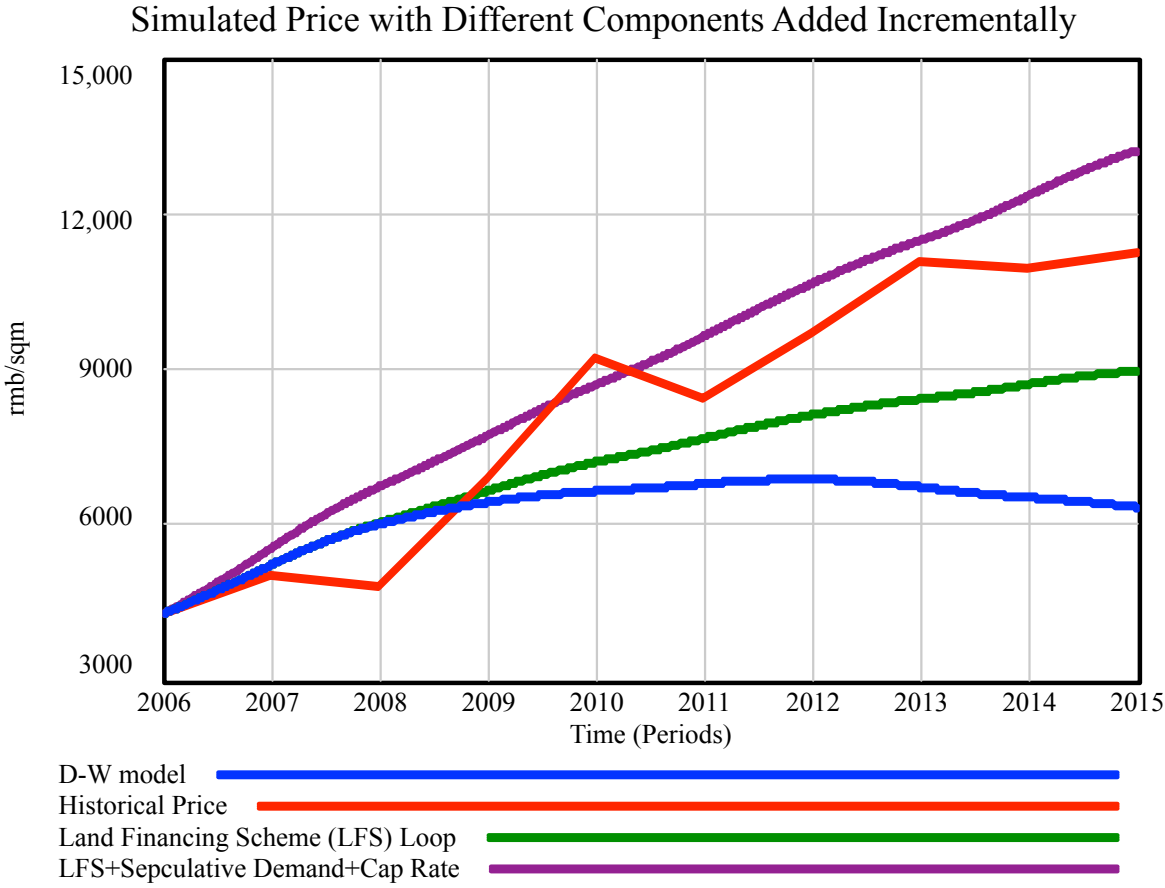


Figure 10-18 Simulated price vs Historical price when land financing scheme loop, cap rate loop, and speculative demand loops are included

So far, we applied the historical data from 2006 to 2015 to the SD model and demonstrated that:

1. The price trend is predominately affected by the land supply. Without the land financing scheme loop, the housing price fluctuates and demonstrates cyclic behavior; with the land financing scheme, the housing price increases continuously.

2. With the land financing scheme loop alone, the housing price does not reach the same magnitude as the historical price level. However, when the cap rate loop and speculative demand loop are added into the simulation, the level of historical housing is reached.

In other words, the land supply affects the upward or downward trend of housing price, and the speculation and cap rate loops affects the level of the housing price. Through the simulations with historical data, we have found that the land financing scheme is the fundamental driving force of price increase. The land financing scheme serves as an amplifier and can magnify the price effect of other loops. Furthermore, the interaction among all three loops (land financing scheme, cap rate, and speculative demand) can actually explain both the housing price trend and scale in Nanjing, a potential bubble component when comparing to D-W model alone.

### 10.5 Simulation Results for Near-Term Scenarios (Year 2015-2025): Potential Market Crisis

In this section we use the current integrated SD model with the Chinese features to run simulations beyond the historical data range, and explore various future scenarios. We are not predicting what future scenario will happen. We want to analyze how the housing market would respond to certain scenarios that *might* happen. To conduct these simulations, we have turned on the switches for all three loops to make them effective, creating a climbing phase of housing price. This will serve as our baseline scenario.

Then we will conduct panic tests on the model. Panic test refers to the situation where a market crisis happens, and may lead to the market to a panic and further trigger the housing market to collapse. For the panic tests, we set the year at 2020 but in reality these scenarios could potentially happen in any year.



### 10.5.1 Five Crisis Scenarios

We will conduct the panic tests for five scenarios.

1. Scenario one: Elimination of land financing scheme. This scenario simulates the scenario where the local government does not need to hold onto the land and release it on a tight schedule, and the land supply is rapidly increased. Given the importance of land supply in our previous model simulations, we expect that the housing market price will drop sharply due to the immediate high supply of housing stock.
2. Scenario two: Financial crisis. In this scenario, we restrict the capital supply into the housing sector, and increase the cap rate to the 6-7% range to represent a high cost for the households to obtain housing mortgages.
3. Scenario three: Elimination of speculative demand. This scenario emulates a panic in the housing market resulting in all of the existing speculative housing stock being immediately converted to usage stock and supplied to the market. We expect the housing market to have a price drop but given the simulation conducted in 10.4, we do not expect the market to collapse.
4. Scenario four: Economic recession. In this scenario, we restrict the demand growth at year 2020, setting both population growth and income growth rate to 0.
5. A combination of the above when one or more scenarios happen at the same time.

### 10.5.2 Simulation Results of Each Crisis Scenario

The simulation result of scenario one: elimination of land financing scheme is displayed in Figure 10-19. The land financing scheme loop is turned off at 2020. That means by year 2020, the land supply is no longer subject to the control of local government's disbursement schedule but responds only to the market need. As we can see, there would be a quick drop in the housing price lasting till around year 2025. In short, when land financing scheme is removed, the housing construction can happen at a much higher rate while consuming the land reserve, thus driving down the housing price.

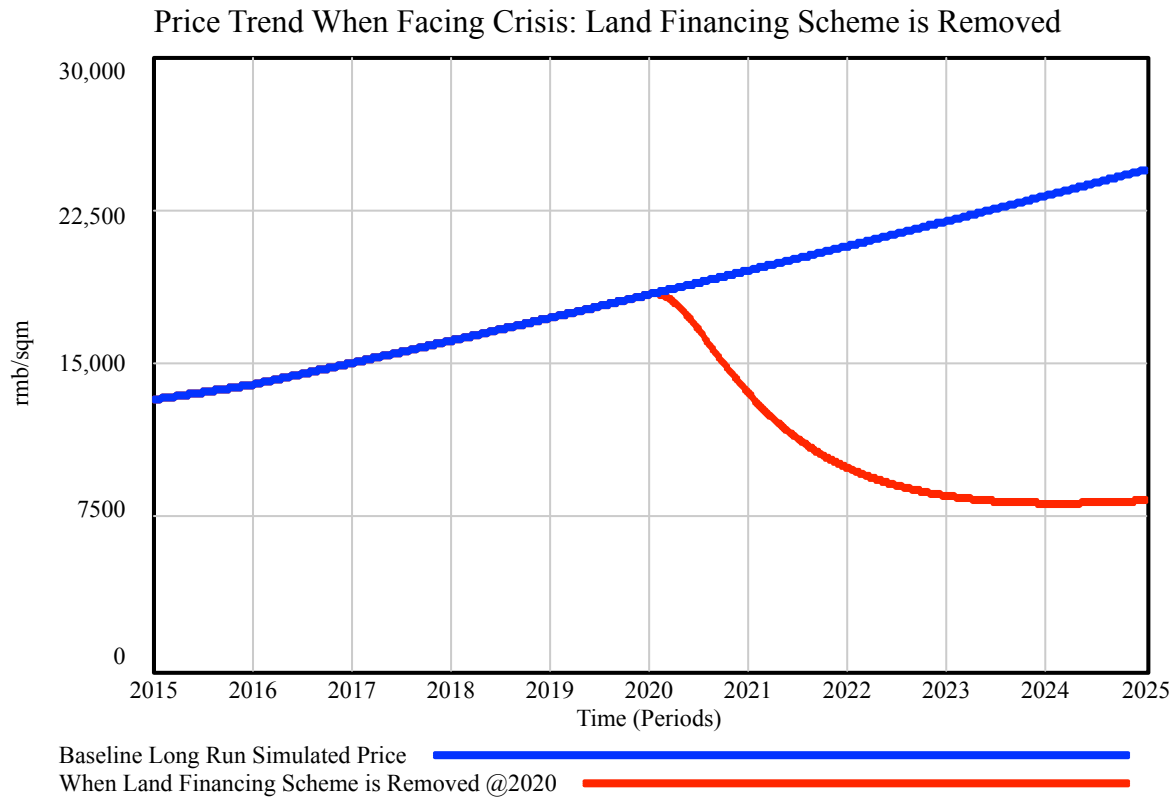


Figure 10-19 Crisis scenario one when land financing scheme is removed.

The simulation result of scenario two: financial crisis is displayed in Figure 10-20. Before the crisis, the cap rate was as low as 4%. In this scenario, we assume that the crisis drives up cap rate to 6% in year 2020. As we can see, that will lead to an immediate and steep price drop and market collapse in 2020.

### Price Trend When Facing Crisis: Financial Crisis Drives Up Cap Rate

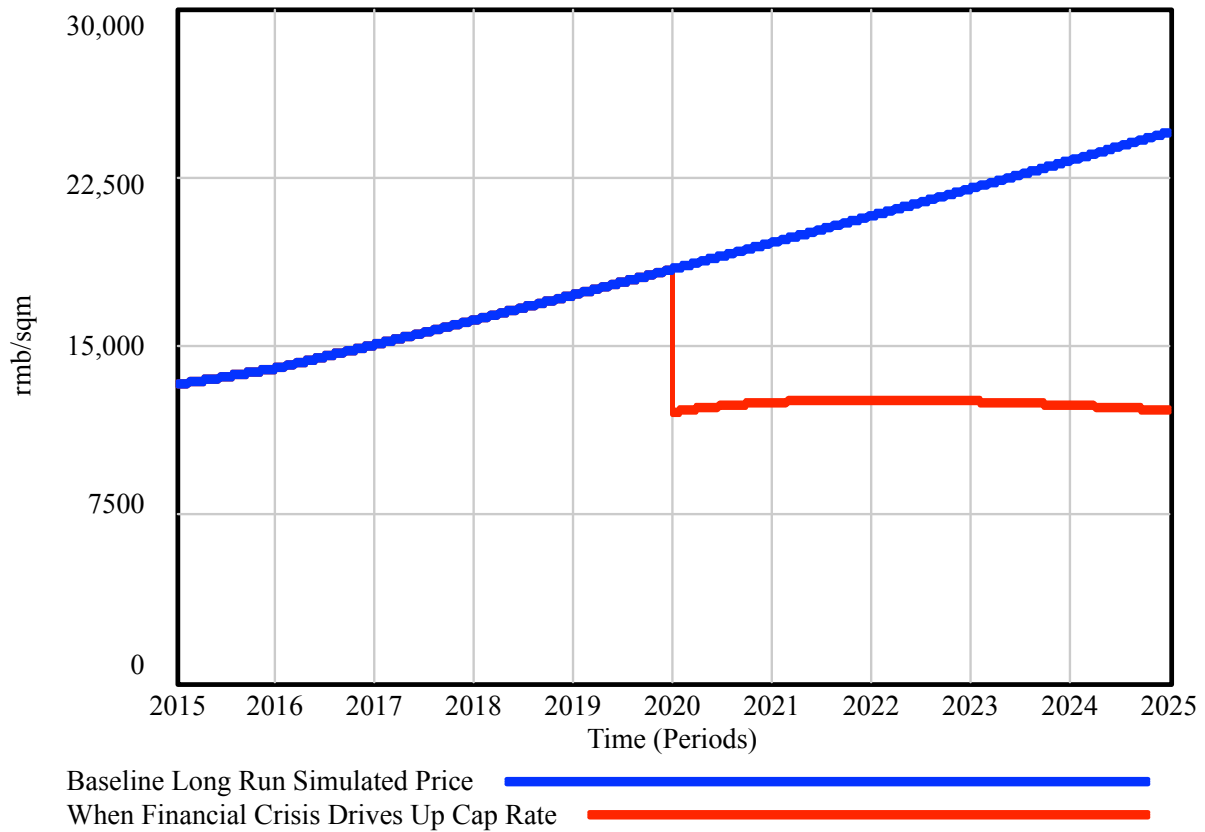


Figure 10-20 Crisis scenario two when financial crisis happens.

For the simulation of scenario three: elimination of speculative demand, we have turned off the speculative demand loop at year 2020. That means about 12% of the speculative stock will be “dumped” entirely to the usage market. As we can see, it will lead to the price drop but the effect is not as significant, market can recover from it immediately.

### Price Trend When Facing Crisis: Speculative Demand Pushed to Usage Market

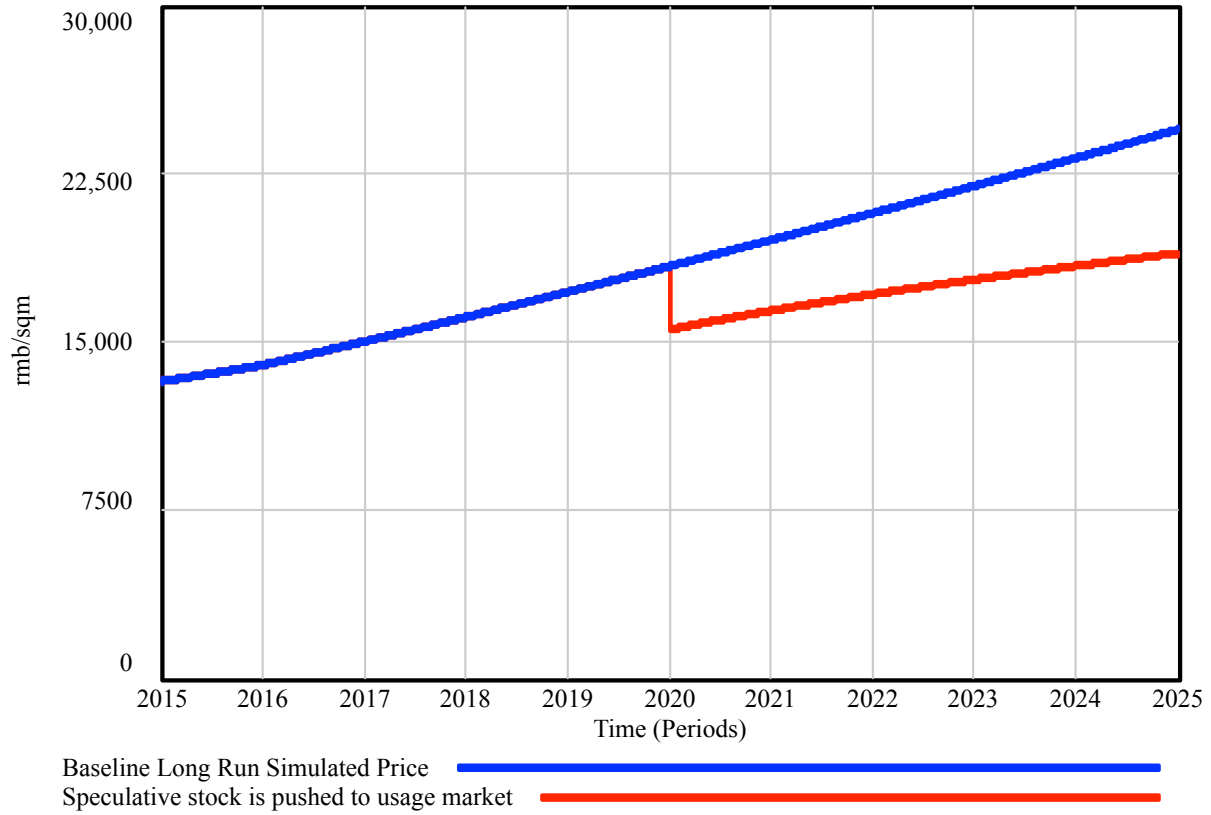


Figure 10-21 Crisis scenario three when speculative demand is eliminated.

Similarly, in scenario four, the sudden decline in demand, the market will also drop when the demand growth is cut off. The entire model is actually driven by the continuous demand growth, namely, population and income growth. When these exogenous driving engines are shut off, the housing price decreases promptly.

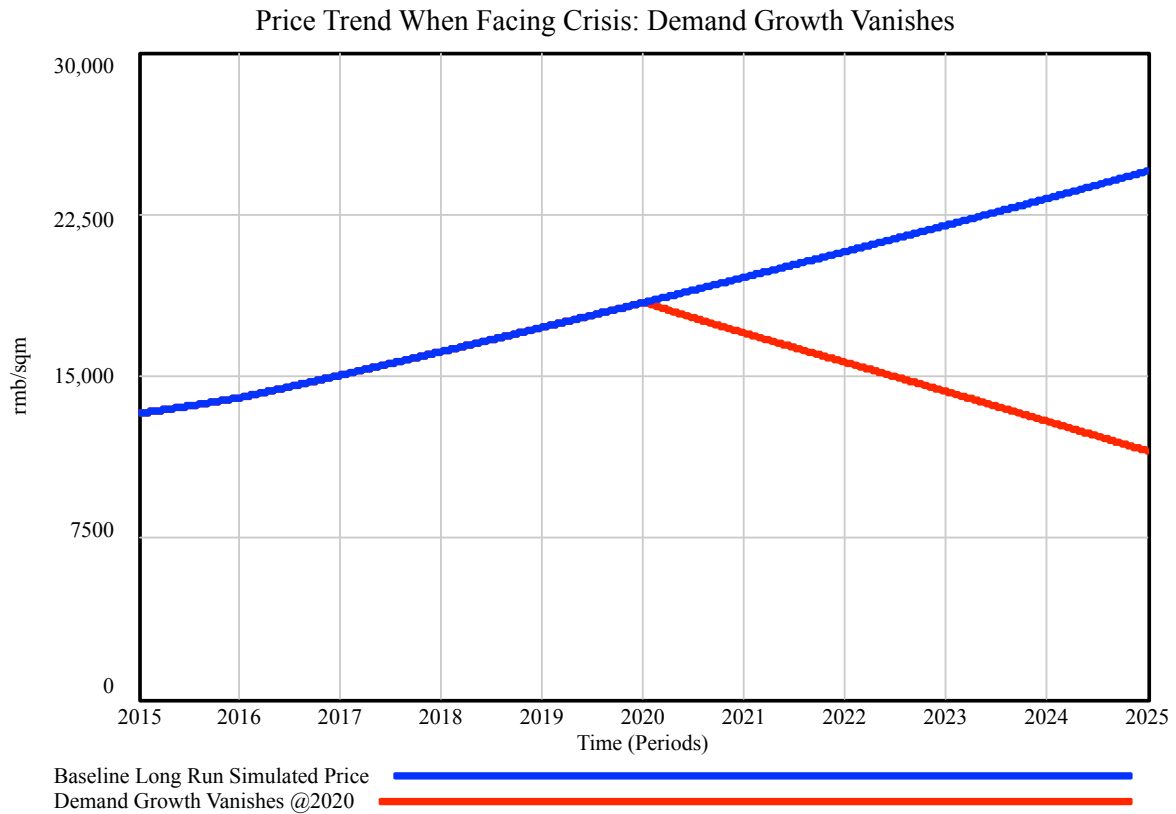


Figure 10-22 Crisis scenario four when demand growth vanishes.

The decline in price is magnified when combination of crises happens. For example, when a financial crisis hits, speculative demand vanishes, and income drops significantly, the price will experience significant drop as shown in Figure 10-23.

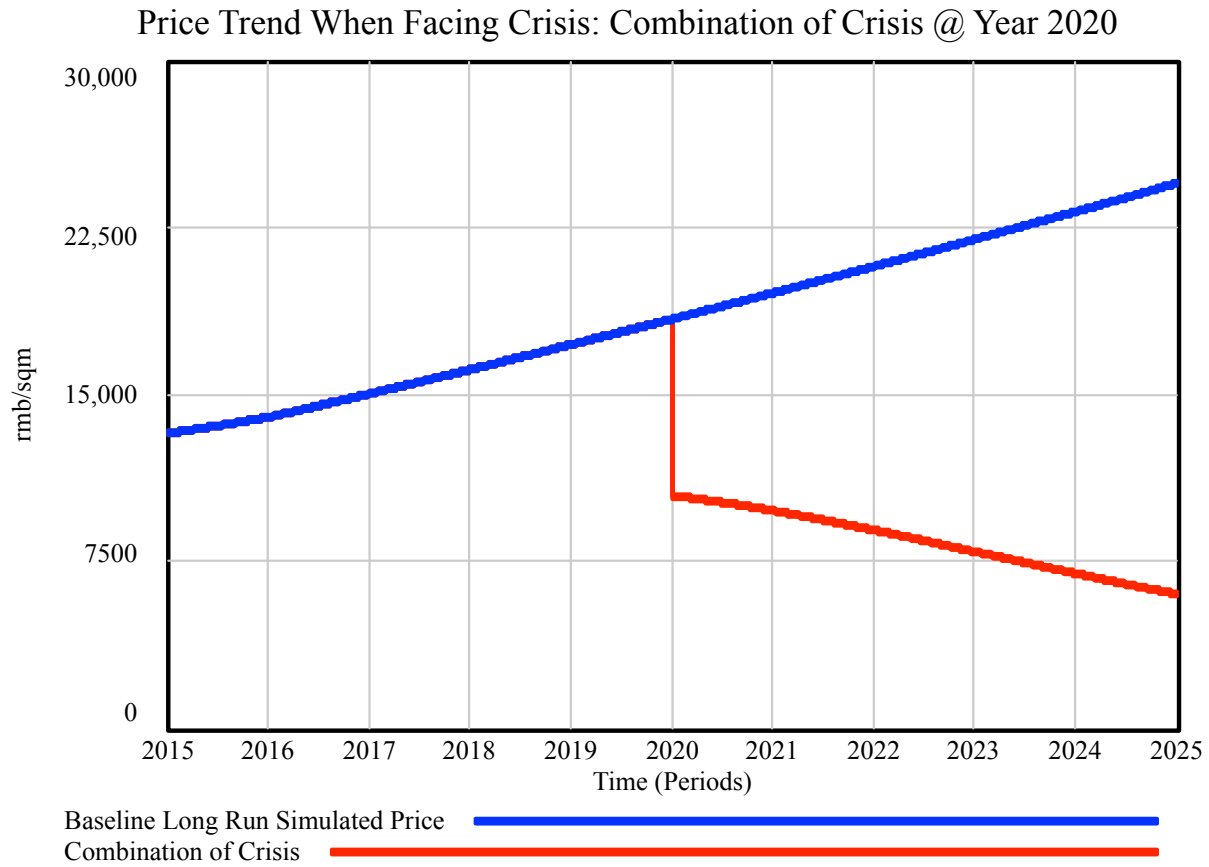


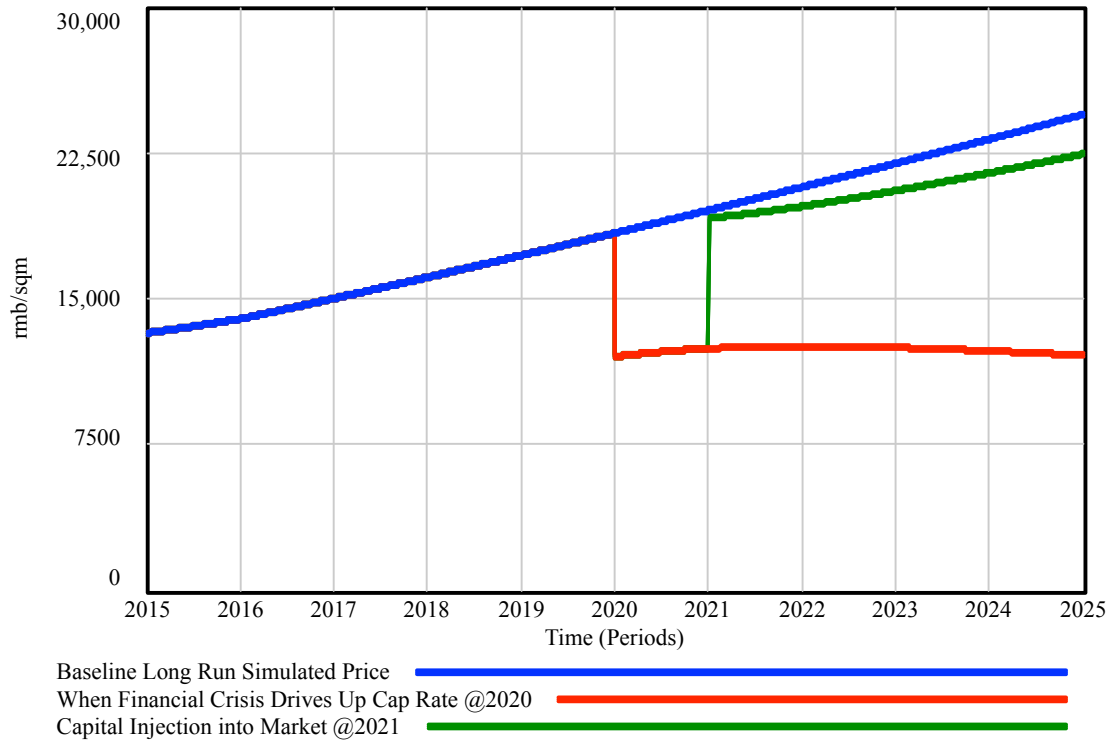
Figure 10-23 Combination of various scenarios of crises all together

**10.5.3 Market Saving Strategies when Facing Crisis**

We also found out through simulation that when one or more crises hit, the market can be saved by either (1) injecting capital into the housing sector, or (2) tightening land supply. Both strategies have been practiced in China in 2009 after the world financial crisis in 2008. In our simulation, we have assumed that the crisis happens in year 2020 and the market saving strategies are implemented in year 2021.

Strategy (1) has an immediate effect in market recovering as shown in Figure 10-24. In the upper graph, the green line (recovery line) is slightly lower than the blue line is because the price rising momentum is lost during the year between 2020 and 2021.

Financial Crisis and Saving Market By Injecting Capital



Financial Crisis and Market Saving By Tightening Land Supply

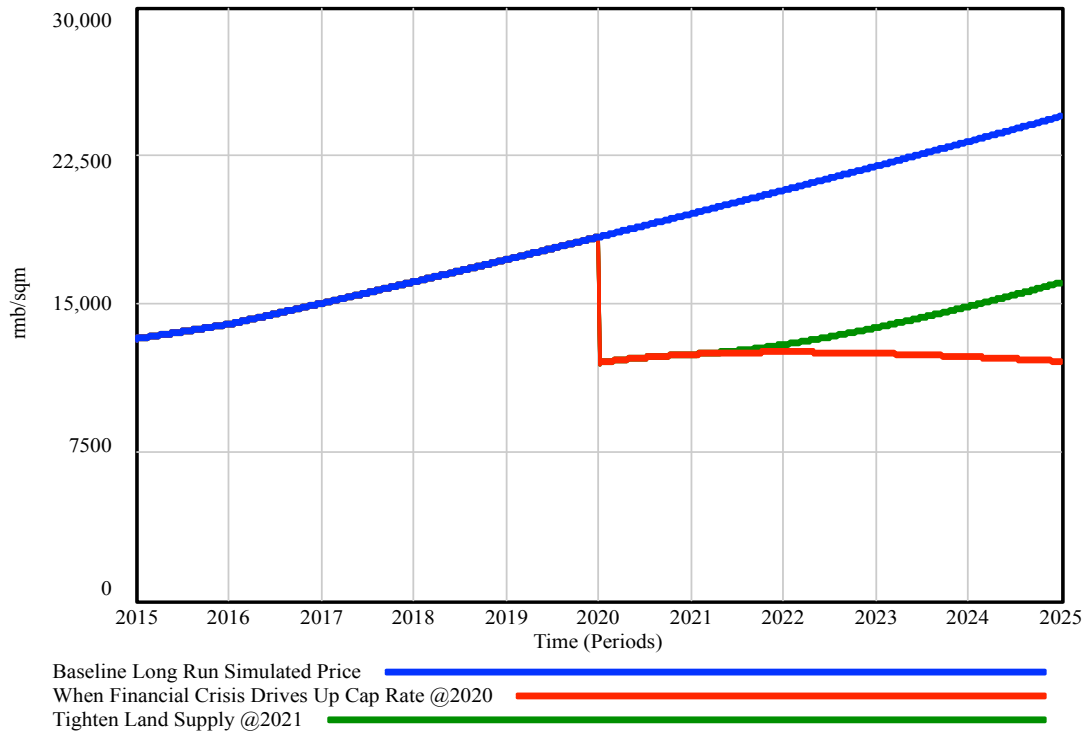


Figure 10-24 Market saving strategies injecting capital or tightening land supply

We should also notice that in strategy (1), the price bouncing back fast is also partially due to the land supply strategy. It is because when price starts to bounce back due to capital injection, the local government is in no rush to sell land as in the crisis scenario.

If strategy (2): tightening land supply is adopted, then there is the implication that the land sales income would be sacrificed. The local government however can rely on the potential property tax income. The property tax income, if implemented at 1.5% rate, would generate slightly less income than land sales, but is not subjected to the constraints on land availability and is sustainable in the long run, as shown in Figure 10-25.

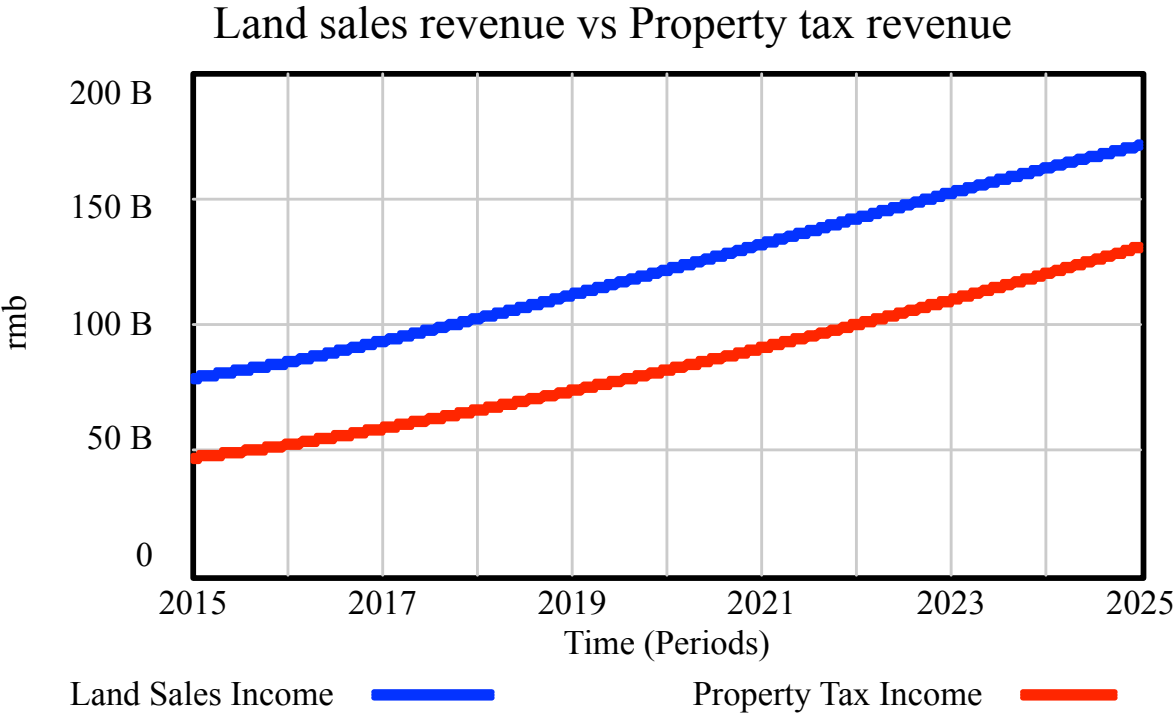


Figure 10-25 Land sales revenue vs property tax revenue

### 10.6 Simulation Results of Long-Run Price Trends (Year 2015-2045)

The long-run simulation we conducted here is more theoretical. We have set up the case for Chinese cities at two extremes: star cities vs ghost cities, and then categorize and map all Chinese cities in between. Star cities and ghost cities in China are



differentiated in terms of potential population growth, income growth, land financing reliance, and potential land reserve level. For example, star cities will have higher population and income growth, rely less on land financing scheme, but do not have much potential land reserve. On the other hand, ghost cities are exactly the opposite with abundant land reserve but no future demand growth.

Assumptions	Star City	Middle City	Ghost City
LFS ratio	0.50 and lower also low land reserve	0.60 adjustable to 0.30 (low reliance)	0.90 adjustable to 0.50 (high reliance)
Population growth	1.5%	1%	0
Income growth	Higher	Higher	Lower

Table 10-6 Comparison among Star City, Middle City, and Ghost City

It is important to point out that in order to conduct simulation for this section, we have added the “land reserve” variable to the integrated model. It is exactly as described in Model SD8: land constraint.

As shown in Figure 10-26, through simulation, we have found that star cities normally do not experience a price declining trend in the future because even at the current level, the land reserve is already very low and the demand growth is still strong. However, the housing price level will reach a plateau because the high price will hinder economic development and create a spillover effect to force people to move to other surrounding cities.<sup>75</sup>

By contrast, ghost cities will experience an oversupply of land because the local government is selling land based on promised future demand growth. However, the

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<sup>75</sup> The plateau effect was not created through simulation. We simply added a ceiling point of the price level in the model. The spillover effect is important but current not in the scope of this thesis.

projected demand growth will not materialize. As a result, such cities will continue experiencing a price decline.

The cities that fall in the middle of these two extremes may experience two price turning points, created by two land constraints: land financing scheme (Model SD12) and land reserve (Model SD8). When land financing scheme is in effect, the increase of housing stock cannot catch up with the demand increase, and the price will rise. However, when the local government supplies more land, and the demand increases at a lower rate, the housing stock increase will catch up with the demand at the first turning point. As a result, housing price will start to decline. Until the land reserve runs out, at which point housing prices will rise again.

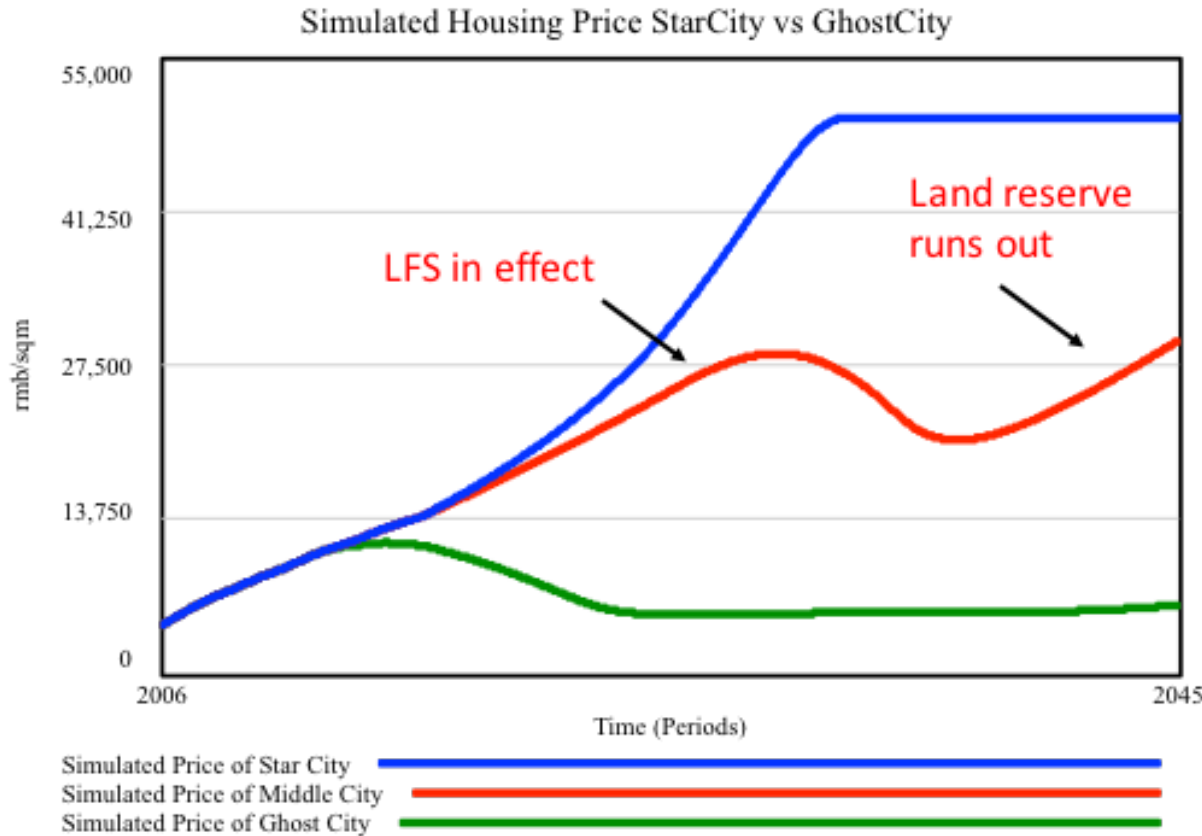


Figure 10-26 Simulated housing price of star city, ghost city, and everything in between

However, the local government has the ability to maintain housing price level by actively adjusting the land supply schedule. When price starts to drop, the local government has

the ability to tighten land supply to maintain the housing price at desirable level, as shown in Figure 10-27, where we use Middle City as an example to demonstrate. This land supply adjustment strategy can be justified in the long run because it does not consume the land reserve as fast.

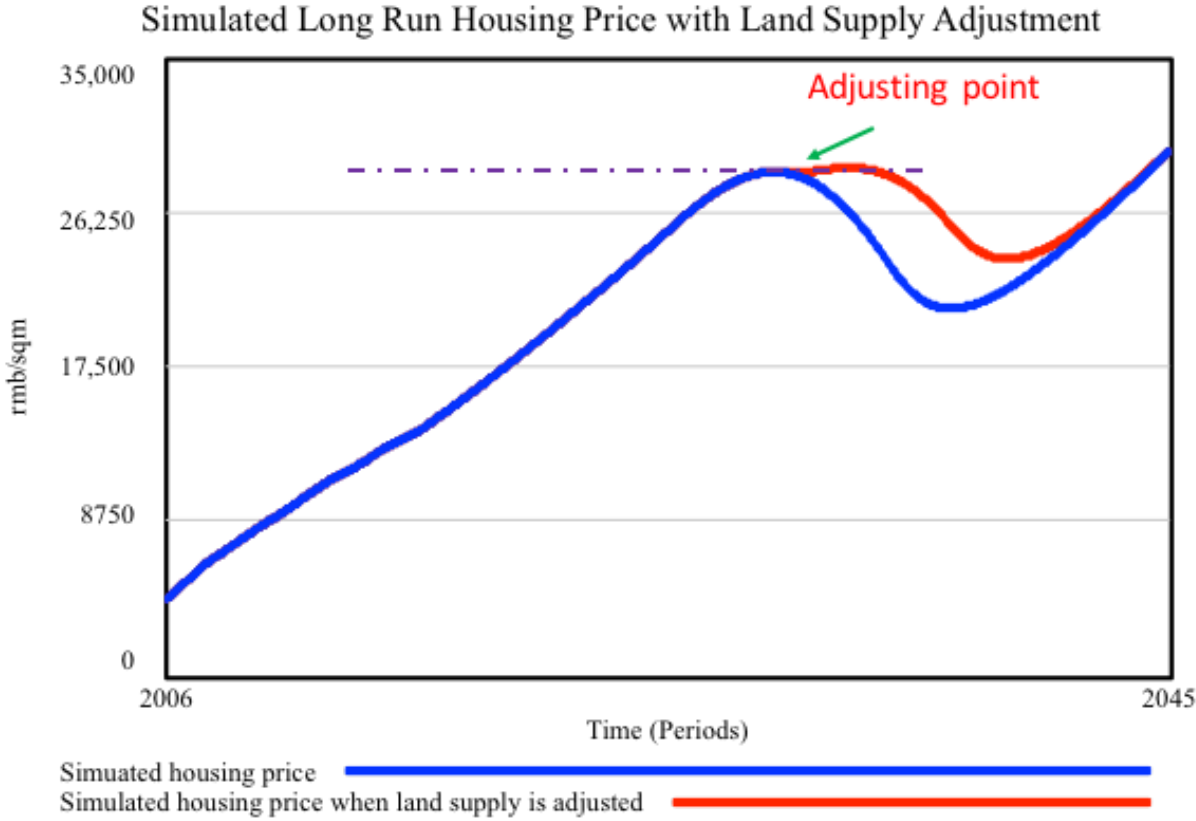


Figure 10-27 Simulated long run housing price with land supply adjustment

**10.7 Model Testing and Validation**

For the integrated model with all three features, we test the models with SD validation standards described in Chapter 3.

**1. Boundary Adequacy Tests**

The model boundary is expended in the integrated model comparing to the original stock-flow model depicted in Chapter 4. More features that we considered relevant in

determining the Chinese urban housing prices are included into the system, such as speculative demand, land financing scheme, etc.

## 2. Structure Assessment Tests

The structure assessment for the integrated models is consistent with the descriptive knowledge of the concept of the housing system. The modification made to internalize the cap rate, adding speculative demand and land financing scheme in the Chinese housing market are supported with evidence in Chapter 5 and Chapter 7.

## 3. Dimensional Consistency

The dimensional consistency, or “units checking” is performed for the integrated model. The only issue is that the parameters  $\alpha_1$  and  $\alpha_2$  are used for scaling but without actual meaning. Their definitions and equations however, makes dimensional consistency test difficult. On the other hand, all variables with real world meaning are in their common units as listed at the end of Chapter 9.

## 4. Parameter Assessment

The numerical values of the model variables and their data source are listed in details in section 10.3, Table 10-1, Table 10-2, Table 10-3, Table 10-4, and Table 10-5. For key variables with estimated value, the assessment is also conducted with the sensitivity tests through Monte Carlo simulation in Chapter 10.

## 5. Extreme Conditions

The SD models are also tested with extreme conditions, meaning each equation makes sense even when its inputs take on extreme values. For example, when demand of the integrated model is set to zero, the rent and housing price would be driven to zero. It is also important to know that the initial state of the integrated model is at equilibrium using the 2006 Nanjing data. In other words, when the demand remains unchanged (without a step jump or exponential growth), the system will remain at equilibrium stage.

## 6. Integration Error

The simulation results, at the moment, are based on years. When we reduce the time step to half a year or a quarter of year or even smaller unit the simulation result does not change.

#### 7. Behavior Reproduction

The purpose of the integrated model is not to fit data to the historical housing price point to point. We aim to firstly get the simulated price trend correct and secondly try to see if simulated price is in the range of historical housing price.

#### 8. Behavior Anomaly

There is no anomaly observed from the simulation results of integrated model.

#### 9. Family Member

So far we have tested the model with the data with one case study city, Nanjing from Jiangsu Province. We aim to expand and apply data from other cities to the model for future steps of research.

#### 10. Surprise Behavior

The surprise behavior that we observed is that the speculative demand alone actually does not affect the housing trend as much as the land financing scheme. In other words, if it were in a perfect market economy, speculations alone wouldn't drive the housing price into a continuously increasing trend to the level of what is currently happening in the Chinese market.

#### 11. Sensitivity Analysis

The sensitivity analysis is conducted with regard to key variables with estimated value. They are price related cap rate change rate, and price elasticity of speculative demand.

#### 12. System Improvement Tests

The system can be improved further, for example, when the financial market including mortgage and banking industries are modeled. However, these are beyond the focus of current thesis.

### 10.8 Policy Implications

Using Nanjing as case study and based on our various simulation results, we have identified the following policy recommendations:

1. In order to reduce the housing price, the most effective policy is to eliminate the land financing platform of the local government and increase land supply. This will have immediately effect and also bring down the housing price gradually in the long run.
2. However, the local government's land sales revenue, at least in short term, will likely to increase because of the high volume of land sales, even at a lower price. From the local government's perspective, this revenue increase is short-lived and cannot be compared to the long run land financing scheme.
3. Speculative demand plays a role in increasing the housing price. However, its effect is minimal unless combined with the effect of land financing scheme. As a result, the current policies aimed at restricting demand may have modest short term effects but are not effective for long term. From the other perspective, although not effective for long run, restricting speculative demand does not cause market price to drop drastically. It thus can serve as a compromised policy for the social stability.
4. The key external driving forces of housing price increase is the demand increase, mainly attributed by the population growth and income growth. When demand growth vanishes, housing market will collapse. In other words, the housing market is vulnerable to the overall economic conditions and labor migration.
5. The housing system is also vulnerable to the financial sector. Should a financial crisis cause a significant increase in the cap rate, the housing market will also collapse.
6. Land supply plays a dominant, amplifying role in the housing system. Land supply management strategy can be well used by local governments to manipulate housing price.

## 11 Conclusions

China's housing market, like other unconventional markets in Southeast Asia, has been experiencing rapid urbanization in recent years. This has generated a rapid increase in housing demand which, along with recent market reforms, controlled land supply, and other speculative investment factors, has affected the stability of housing market. In response, the central government has taken strict policy controls to suppress the potential housing bubble. However, the effectiveness of these policies in the housing sector or in the broader economy remains unclear.

This thesis examines the underlying issues that contribute to the ever-rising urban housing prices in China. It develops an operational model using the system dynamics (SD) platform to conduct simulation. It analyzes the Chinese urban housing market by incorporating special market features that do not exist in conventional, free-market economies. It provides insights into the complex relationships between land supply management, excessive vacancy caused by speculative investments, and increasing demand due to rapid urbanization. The insights provided by the simulation model can be used to guide policy decisions.

Traditional urban economic models such as the pedagogically efficient DiPasquale-Wheaton (D-W) model are proven to be effective in understanding and analyzing conventional free-markets such as in the United States and Europe. However, it faces limitations when being applied to the fast developing Asian markets where political economy and other non-conventional characteristics play an important role. Although numerous academic papers have applied system dynamics models to real estate markets over the past generation, the technique remains relatively unknown and little used both in the academic economics literature and, more to the point, among practitioners and educators in the real estate community.

## 11.1 Research Findings

Using actual data from the city of Nanjing as a case study, we conducted simulations with the integrated SD model developed in this thesis. We separated the analysis into three sections based on the time periods: historical simulations (2005-2015), near-term simulations (2015-2025), and long-run simulations (2015-2045).

First, we use historical data from 2005-2015 and apply it to the baseline SD model which mimics the D-W model. The results show that the traditional economic model does not fully explain the historical price. Both simulated housing price trends and scales are off from the historical data. Next, we enable each of the following three loops (one at a time) to observe the simulated price trend change: land financing loop, cap rate loop, and speculative demand loop.

When we apply the historical dataset to the integrated model with only land financing loop incorporated, the price trend shifted from cyclic behavior to an increasingly rising pattern. When we apply the same data to incorporate either speculative demand component or cap rate loop individually, minimal price effects are found. However, when we apply the data to either speculative demand loop or cap rate loop on top of land financing loop, significant price effects are found. And when all three loops are incorporated into the model simultaneously, the historical housing price of Nanjing can be explained.

Through the historical simulations, we have found that the land financing scheme or shortage of land supply is the fundamental driving force behind the drastic price increase or a potential bubble in China. The land financing scheme serves as an amplifier and can magnify the price effect of other loops. The bubble component is reflected through the price difference from simulated price with all three loops enabled and with D-W structure alone.

Based on historical data, we have projected the trend into the near term future. We use the integrated model with all three loops enabled to conduct scenario analysis, focusing



on the potential crisis scenarios. The Chinese housing market can collapse under several conditions and simulations are done assuming one of the following events happens in year 2020:

- (1) Land financing scheme is removed;
- (2) Financial crisis that drives up cap rate;
- (3) Speculative stock being pushed to usage market all at once;
- (4) Economic recession;
- (5) Simultaneous combination of (2), (3), and (4).

We have found that various degrees of price drops (or potential bubble bust) in each scenario. Scenario (3) with eliminating speculative stock has the lowest impact in bringing down housing prices. We speculate that is the reason why most of the previous housing regulation policies in China specifically target speculative demand: although it is ineffective in the long run, it does have some short term effect in reducing housing price. At the same time, it helps to avoid market collapse which may threaten the social stability.

We have found that when a significant financial crisis occurs, the housing market can be saved by either (a) injecting capital to create liquidity in the housing sector, and/or (b) tightening land supply. The former strategy can have immediate effect and bring housing price to the previous level while the latter strategy works slowly but will have a longer term impact. If strategy (b) is adopted, then there is the implication that the income from land sales income would be lost. The policy implication is that the local governments would need an alternative source of revenue to meet their financial budget needs. For example, income from the imposition of a Property Tax, if implemented at 1.5% rate, is slightly lower than the land sales income but is not subjected to the constraints on land availability and is sustainable in the long run.

The long-run simulation we conduct is more theoretical. We set up the cases for cities at two extremes: star cities vs ghost cities. We then categorize and map all Chinese cities in between: the middle cities. Star cities and ghost cities are differentiated in terms of

potential population growth, income growth, land financing income reliance, and potential land reserve level. For example, star cities will have higher population and income growth, rely less on land financing scheme, but do not have much potential land reserve. On the other hand, ghost cities are exactly the opposite.

Through simulation, we have found that star cities normally do not experience a price declining trend in the future because the land reserve is already very low and the demand growth is still strong. By contrast, ghost cities experience an oversupply of land and the projected demand growth is not materialized. As a result, such cities will continue experiencing a price decline. The cities that fall in the middle of these two extremes may experience two price turning points, caused by two land constraints imposed by land financing scheme and land reserve.

We have also found that the local government, as the key decision maker, has the ability to maintain housing price trend by adjusting the goal of land sales income and amount of land supply schedule annually. By using this process, the local governments can effectively continue to micromanage the housing price.

## 11.2 Research Contributions

Building upon the pedagogical D-W model, this research has both academic and applied contributions. The integrated SD model operationalizes the concept of housing market, and gains descriptive power by enabling a more realistic representation of the urban housing system in China. While this research was inspired by the recent housing boom in China, the model was developed with the intention to be applied to other countries with similar contextual features.

In terms of theoretical contribution, this thesis creates an integrated system dynamics model that can simultaneously model how land market, financial market, and housing speculators interact with each other and impact the housing price trend in China. By individually isolating each factor and observe its own behavior, it is shown that among various factors affecting price, the land supply under the land financing scheme is the

fundamental driver. The scheduled or manipulated land supply shortage serves as the amplifier for other driving forces coming from capital market and housing speculators. It is an important theoretical contribution to demonstrate the individual and interactive effects among seemingly important factors.

In terms of methodological contribution, the integrated overarching model developed in this thesis builds upon the proven D-W model template, and it extends and enhances the traditional urban economic theories with system dynamics methods so that the newly developed model can have the flexibility to conduct simultaneous modeling and be applied in new contexts.

This transition process between urban economics model and system dynamic model has three major innovations. First, it operationalizes a static analytical economic model into an engineering based dynamic model. The emphasis is switching from the long-run equilibrium seeking behavior to swift short-run adjustments between equilibriums. Second, the model structure is replicable and can be easily modified to address more complex issues or reduce to simple forms to analyze simplified situations. Lastly, more to the point, the system dynamics platform allows an “unpacking” of the causality links in the system, and add flexibility in modeling the system, which facilitates analysis of policy and testing of “what if” scenarios and is also helpful in communicating findings to non-economist audiences.

In terms of policy contribution, this thesis examines unique Chinese market features such as government controlled land supply scheme, as well as the phenomenon of speculative investment. These features, when integrated into the traditional urban economics model structure, provide constraints that have changed the model’s behavior, providing potentially virtuous and vicious pricing spirals that can accelerate and rapidly burst when a market bubble presents. It is proven to be different than the long-run cyclical behavior in conventional markets. For example, this thesis demonstrates how land constraint imposed during a transition period can serve as a

leverage point and amplify the effects of other housing market features and lead to bubble-like result.

The integrated model is validated with real world data through the case study of Nanjing, China. It is then used to conduct hypothetical simulations of various complex scenarios. The results of the hypothetical simulations are used to examine the impact of various policies on the Chinese housing market. The thesis provides quantitative tools to simulate the consequences of various land supply scenarios, which can be helpful for ex-ante policy evaluations and thus assist the policy makers to design the best-possible policy packages. It also helps to conduct counterfactual analysis and demonstrates how the market would behave under different crisis scenarios, and how different market saving strategies would work when introduced at a different time spot for intervention.

## References

Ahuja, Ashvin, Lillian Cheung, Gaofeng Han, Nathan Porter, and Wenlang Zhang. "Are house prices rising too fast in China?." IMF Working Papers (2010): 1-31.

Akkermans, Henk, and Nico Dellaert. "The rediscovery of industrial dynamics: the contribution of system dynamics to supply chain management in a dynamic and fragmented world." *System Dynamics Review* 21.3 (2005): 173-186.

Allen, Franklin, Jun Qian, Chenying Zhang, and Mengxin Zhao. "China's financial system: opportunities and challenges." No. w17828. National Bureau of Economic Research, (2012).

Alonso, William. *Location and land use: Toward a general theory of land rent*. Cambridge, MA: Harvard University Press, 1964.

Anderson, Edward G. "A dynamic model of counterinsurgency policy including the effects of intelligence, public security, popular support, and insurgent experience." *System Dynamics Review* 27.2 (2011): 111-141.

Angerhofer, Bernhard J., and Marios C. Angelides. "System dynamics modeling in supply chain management: research review." *Simulation Conference, 2000. Proceedings. IEEE Winter Vol. 1.* (2000): 342-351.

Aura, Saku, and Thomas Davidoff. "Supply constraints and housing prices." *Economics Letters* 99.2 (2008): 275-277.

Baddeley, Michelle. "Housing Bubbles, Herds and Frenzies: Evidence from British Housing Markets." CCEPP Policy Brief, Cambridge Centre for Economic and Public Policy No.02/05. (2005). URL: <http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.318.9169>.

Bai, Wanqi. "Analysis on land use dynamics of Shenzhen (深圳市土地利用动态趋势分析)." *Journal of Natural Resources (自然资源学报)* 15.2 (2000): 112-116.

Barlas, Yaman. "Multiple tests for validation of system dynamics type of simulation models." *European journal of operational research* 42.1 (1989): 59-87.

Barlas, Yaman. "Formal aspects of model validity and validation in system dynamics." *System dynamics review* 12.3 (1996): 183-210.

Barlas, Yaman, Birnur Özbas, and Onur Özgün. "Modeling of real estate price oscillations in Istanbul." In *Proceedings of the 2007 System Dynamics Conference*, (2007). URL: <http://www.systemdynamics.org/conferences/2007/proceed/papers/BARLA342.pdf>.

Barth, James R., Michael Lea, and Tong Li, "China's housing market: Is a bubble about to burst?" (2012). Online paper. Available at SSRN: <https://ssrn.com/abstract=2191087> or <http://dx.doi.org/10.2139/ssrn.2191087>.

Bivona, Enzo, and Giovan Battista Montemaggiore. "Understanding short- and long-term implications of "myopic" fleet maintenance policies: a system dynamics application to a city bus company." *System dynamics review* 26.3 (2010): 195-215.

Bramley, Glen. "Housing market adjustment and land-supply constraints." *Environment and Planning A* 31.7 (1999): 1169-1188.

Bucchianeri, Grace Wong. "The anatomy of a housing bubble: Overconfidence, media and politics." *Media and Politics*, (2011). Available at SSRN: <https://ssrn.com/abstract=1877204> or <http://dx.doi.org/10.2139/ssrn.1877204>.

Cao, Jerry, Bihong Huang, and Rose Neng Lai. "On the effectiveness of housing purchase restriction policy in China: A difference in difference Approach." (2015). Available at SSRN: <https://ssrn.com/abstract=2584275> or <http://dx.doi.org/10.2139/ssrn.2584275>.

Cao, Jerry, Bihong Huang, and Rose Neng Lai. "Housing bubble and government regulation: evidence from China" *Narodowy Bank Polski Workshop: Recent Trends in the Real Estate Market and Its Analysis*. NBP Working Paper 2.243 (2016). Available at SSRN: <https://ssrn.com/abstract=2841655>.

Case, Karl E., and Christopher J. Mayer. "Housing price dynamics within a metropolitan area." *Regional Science and Urban Economics* 26.3 (1996): 387-407.

Case, Karl E., and Robert A. Shiller. "Decade of boom and bust in the prices of single family homes: Boston and Los Angeles." *New England Economic Review* (1994): 40-51.

Case, Karl E., and Robert J. Shiller. "Is there a bubble in the housing market?." *Brookings Papers on Economic Activity* 2003.2 (2003): 299-342.

Chen, Jie. "Modeling Shanghai real estate market. dynamic insight into the sustaining house price growth." *System Dynamic Group, University of Bergen, Bergen, Norway*. (2005). URL:

<http://www.systemdynamics.org/conferences/2005/proceed/papers/CHEN102.pdf>.

Chen, Kaiji, and Yi Wen. "The great housing boom of China." *American Economic Journal: Macroeconomics* 9.2 (2017): 73-114.

Chen, Mingxing, Weidong Liu, and Xiaoli Tao. "Evolution and assessment on China's urbanization 1960–2010: under-urbanization or over-urbanization?" *Habitat International* 38 (2013): 25-33.

Chen, Yuehua, and Zaozhuang Liao. "Commercial housing price analysis of Wuhan based on system dynamics methods(基于系统动力学视角的武汉市商品住宅价格分析)." *Science Technology and Engineering (科学技术与工程)* 20.33 (2012): 9132-9136.

Chi, Guanghua, Yu Liu, Zhengwei Wu, and Haishan Wu. "Ghost cities analysis based on positioning data in China." arXiv preprint arXiv:1510.08505 (2015). Online see <https://arxiv.org/abs/1510.08505>.

Chow, Gregory C., and Linlin Niu. "Residential housing in urban China: demand and supply." *China's Housing Reform and Outcomes*, Lincoln Institute of Land Policy (2011): 47-59.

Clayton, Jim, David C. Ling, and Andy Naranjo. "Commercial real estate valuation: fundamentals versus investor sentiment." *The Journal of Real Estate Finance and Economics* 38.1 (2009): 5-37.

Colwell, Peter F. "Tweaking the DiPasquale-Wheaton model." *Journal of Housing Economics* 11.1 (2002): 24-39.

De Neufville, Richard, Yun S. Lee, and Stefan Scholtes. "Using flexibility to improve value-for-money in hospital infrastructure investments." Institute of Electrical and Electronic Engineers, *Journal of Infrastructure Systems* (2008).

De Neufville, Richard, Stefan Scholtes, and Tao Wang. "Real options by spreadsheet: parking garage case example." American Society of Civil Engineers, *Journal of Infrastructure Systems* 12.2 (2006): 107-111.

De Neufville, Richard, and Stefan Scholtes. *Flexibility in Engineering Design*. Cambridge, MA: MIT Press, 2011.

Dehesh, Alizera, and Cedric Pugh. "The internationalization of post-1980 property cycles and the Japanese 'bubble' economy, 1986–96." *International Journal of Urban and Regional Research* 23.1 (1999): 147-164.

Deng, Yongheng, Joseph Gyourko and Jing Wu, "Land and house price measurement in China," *Property Markets and Financial Stability*, A. Heath, F. Packer and C. Windsor (ed.), Reserve Bank of Australia, (2012), ISBN: 978-0-9873620-3-2. URL: <http://www.nber.org/papers/w18403>.

Ding, Chengri. "Land policy reform in China: assessment and prospects." *Land Use Policy* 20.2 (2003): 109-120.

Ding, Chengri. "Policy and praxis of land acquisition in China." *Land use policy* 24.1 (2007): 1-13.

DiPasquale, Denise, and William C. Wheaton. "The markets for real estate assets and space: a conceptual framework." *Real Estate Economics* 20.2 (1992): 181-198.

DiPasquale, Denise, and William C. Wheaton. *Urban Economics and Real Estate Markets*. Englewood Cliffs, NJ: Prentice Hall, 1996. DOI: 10.4018/978-1-4666-7230-7. ISBN:1466672307 9781466672307.

Dokko, Jane, Brian M. Doyle, Michael T. Kiley, Jinill Kim, Shane Sherlund, Jae Sim, and Skander Van den Heuvel. "Monetary policy and the global housing bubble." *Economic Policy* 26.66 (2011): 237-287.

Dreger, Christian, and Yanqun Zhang. "Is there a bubble in the Chinese housing market?." *Urban Policy and Research* 31.1 (2013): 27-39.

Du, Jinfeng, and Richard B. Peiser. "Land supply, pricing and local governments' land hoarding in China." *Regional Science and Urban Economics* 48 (2014): 180-189.

Du, Jing, Pin Yang, and Dezhi Li. "System dynamics analysis of the relationship between affordable housing and residential housing market (基于系统动力学的住房保障和住房市场关系研究)." *Modern Management Science(现代管理科学)* 10 (2012): 46-48.

Du, Zaichao, and Lin Zhang. "Home-purchase restriction, property tax and housing price in China: A counterfactual analysis." *Journal of Econometrics* 188.2 (2015): 558-568.

Dwenger, Nadja and Oleg V. Pavlov, "Feedback analysis of speculation in a foreign currency market." *System Dynamics Conference Proceedings* (2008). URL: <http://www.systemdynamics.org/conferences/2008/proceed/papers/PAVLO441.pdf>.

Eskinasi, Martijn, Etienne Rouwette, and Jac Vennix. "Simulating urban transformation in Haaglanden, the Netherlands." *System Dynamics Review* 25.3 (2009): 182-206.

Eskinasi, Martijn, E. A. J. A. Rouwette, and J. A. M. Vennix. "Houdini: a system dynamics model for housing market reforms." Conference paper for 2011 System Dynamics Conference, Washington D.C. (2011).

Eskinasi, Martijn. "Collected system dynamics works on recent real estate dynamics." 30th International Conference of the System Dynamics Society, St. Gallen, Switzerland. (2012). URL: <https://www.systemdynamics.org/conferences/2012/proceed/papers/P1087.pdf>.



Eskinasi, Martijn. "Towards housing system dynamics: projects on embedding system dynamics in housing policy research." Eburon Academic Publishers, Delft, the Netherlands. (2014).

Fallah-Fini, Saeideh, et al. "Optimizing highway maintenance operations: dynamic considerations." *System Dynamics Review* 26.3 (2010): 216-238.

Fang, Hanming, Quanlin Gu, Wei Xiong, and Li-An Zhou. "Demystifying the Chinese housing boom." *National Bureau of Economic Research Macroeconomics Annual* 30.1 (2016): 105-166.

Feng, Lu. "System dynamics simulation of Xi'an residential housing market (西安市住宅房地产市场系统动力学仿真研究)." MS thesis, Xi'an University of Architecture and Technology, 2008.

Feola, Giuseppe, Justus A. Gallati, and Claudia R. Binder. "Exploring behavioral change through an agent-oriented system dynamics model: the use of personal protective equipment among pesticide applicators in Colombia." *System Dynamics Review* 28.1 (2012): 69-93.

Forrester, Jay W., 1969. *Urban Dynamics*, Waltham, MA: Pegasus Communications.

Forrester, Jay W. "System dynamics and the lessons of 35 years." *A systems-based approach to policymaking*. Springer Science+Business Media New York, (1993): 199-240. DOI: 10.1007/978-1-4615-3226-2\_7. Print ISBN: 978-1-4613-6417-7.

Fu, Hongyuan, Yuhong Chen, and Huaiqing Liang. "Research on the measurement of affordable housing prices (经济适用房合理价格测度研究)." *Consumer Economics (消费经济)* 24.5 (2008): 63-66.

Gan Li. "Housing Market and Urbanization". Presentation made on February 16, 2017 at Samuel Tak Lee Lab, Massachusetts Institute of Technology. (2017). URL: <https://stl.mit.edu/news/li-gan-ghost-towns-why-50-million-housing-units-china-are-vacant>.

Gao, Shanwen, "High housing price may continue increase given the policy control (高善文：高房价在严控之下价格或许会更高", Keynote speech at "2016 海外投资嘉年华系列峰会"北京站. November 30, 2016. Beijing, China. (2016).

Gastwirth, Joseph L. "A probability model of a pyramid scheme." *The American Statistician* 31.2 (1977): 79-82.

Geltner, David, and Jianping Mei. "The present value model with time-varying discount rates: Implications for commercial property valuation and investment decisions." *The Journal of Real Estate Finance and Economics* 11.2 (1995): 119-135.

Geltner, David, Norman G. Miller, Jim Clayton, and Piet Eichholtz. *Commercial Real Estate Analysis and Investments*. 3<sup>rd</sup> Edition. Cengage Learning, 2014.

Genesove, David, and Christopher Mayer. "Loss aversion and seller behavior: Evidence from the housing market." *The Quarterly Journal of Economics* 116.4 (2001): 1233-1260.

Geng, Jijin, and Yan Li. "Policies Simulation on the Commercial Housing System of Shenzhen City (深圳市商品住宅系统政策仿真研究)." *China Land Science (中国土地科学)* 25.4 (2011): 49-56.

Georgiadis, Patroklos, and Charalampos Michaloudis. "Real-time production planning and control system for job-shop manufacturing: A system dynamics analysis." *European Journal of Operational Research* 216.1 (2012): 94-104.

Ghaffarzadegan, Navid, and Amir T. Tajrishi. "Economic transition management in a commodity market: the case of the Iranian cement industry." *System Dynamics Review* 26.2 (2010): 139-161.

Glaeser, Edward L., Joseph Gyourko, and Albert Saiz. "Housing supply and housing bubbles." *Journal of urban Economics* 64.2 (2008): 198-217.

Glaeser, Edward, Wei Huang, Yueran Ma, and Andrei Shleifer. "A Real Estate Boom with Chinese Characteristics." National Bureau of Economic Research, NBER Working Paper No.W22789, (2016). DOI: 10.3386/w22789.

Goodman, Allen C., and Thomas G. Thibodeau. "Where are the speculative bubbles in US housing markets?." *Journal of Housing Economics* 17.2 (2008): 117-137.

Green, Richard K., Stephen Malpezzi, and Stephen K. Mayo. "Metropolitan-specific estimates of the price elasticity of supply of housing, and their sources." *The American Economic Review* 95.2 (2005): 334-339.

Grenadier, Steven R. "The strategic exercise of options: Development cascades and overbuilding in real estate markets." *The Journal of Finance* 51.5 (1996): 1653-1679.

Groesser, Stefan N., and Markus Schwaninger. "Contributions to model validation: hierarchy, process, and cessation." *System Dynamics Review* 28.2 (2012): 157-181.

Guo, Feng, and Ying Sophie Huang. "Does "hot money" drive China's real estate and stock markets?" *International Review of Economics & Finance* 19.3 (2010): 452-466.

Hadjis, Andreas. "Bringing economy and robustness in parameter testing: A Taguchi methods- based approach to model validation." *System Dynamics Review* 27.4 (2011): 374-391.

- Haila, Anne. "Why is Shanghai building a giant speculative property bubble?." *International Journal of Urban and Regional Research* 23.3 (1999): 583-588.
- Han, Dongmei, Lanjuan Liu, and Kun Cao. "Empirical analysis on real estate price bubble based on state-space model (基于状态空间模型的房地产价格泡沫问题研究)." *Journal of Finance and Economics (财经研究)* 34.1 (2008): 126-135.
- Hendershott, Patric H. "Real effective rent determination: evidence from the Sydney office market." *Journal of Property Research* 12.2 (1995): 127-135.
- Hendershott, Patric H., and David Ling. "Prospective Changes in Tax Law and the Value of Depreciable Real Estate." *Journal of the American Real Estate & Urban Economics Association (AREUEA)* 12.3 (1984): 297-317.
- Hendershott, Patric H., Bryan D. MacGregor, and Raymond Tse. "Estimation of the rental adjustment process." *Real Estate Economics* 30.2 (2002a): 165-183.
- Hendershott, Patric H., Bryan D. MacGregor, and Michael James White. "Explaining Real Commercial Rents Using an Error Correction Model with Panel Data." *Journal of Real Estate Finance and Economics* 24.1&24.2 (2002b): 59-87.
- Hendershott, Patric H., and Bryan D. MacGregor. "Investor rationality: evidence from UK property capitalization rates." *Real Estate Economics* 33.2 (2005): 299-322.
- Hendershott, Patric H., Colin M. Lizieri and Bryan D. MacGregor. "Asymmetric Adjustment in the City of London Office Market." *Journal of Real Estate Finance and Economics* 41.1 (2010): 80-101.
- Hennekam, Hans, and Frank M. Sanders. "Making complex network analysis in System Dynamics." *Proceedings of the 20th International Conference of the System Dynamics Society*, July. 2002.
- Hernandez, K. "Learning in real estate: the role of the development system in creating oversupply". MS thesis, MIT Sloan School of Management, 1990.
- Holland, A. Steven, Steven H. Ott, and Timothy J. Riddiough. "The role of uncertainty in investment: An examination of competing investment models using commercial real estate data." *Real Estate Economics* 28.1 (2000): 33-64.
- Homer, Jack B. "Partial- model testing as a validation tool for system dynamics (1983)." *System Dynamics Review* 28.3 (2012): 281-294.
- Hou, Yongzhou. "Housing price bubbles in Beijing and Shanghai? A multi-indicator analysis." *International Journal of Housing Markets and Analysis* 3.1 (2010): 17-37.

Hovmand, Peter S., et al. "Victims arrested for domestic violence: Unintended consequences of arrest policies." *System Dynamics Review* 25.3 (2009): 161-181.

Hsing, You-tien. *The Great Urban Transformation: Politics of Land and Property in China*. Oxford University Press, 2010. ISBN:978-0-19-956804-8.

Hu, G. Gary, and Shih Hui Lo. "Understanding cyclical patterns of Taiwan's housing market: a system dynamics approach." 10th International System Dynamics Conference, Utrecht, the Netherlands. (1992). URL: <http://www.systemdynamics.org/conferences/1992/proceed/pdfs/hu247.pdf>

Hu, Peiyong. "Simulation of the housing quota ticket system for the affordable housing framework – using Hangzhou as case study (基于住房券政策的保障性住房体系构想及情景模拟 – 以浙江省杭州市为例)." MS thesis, Zhejiang University, 2011.

Hu, Yucun, and Qiping Shen. "A system dynamics study of the development of the housing industry in Hong Kong (香港住宅产业发展的系统动力学研究)." *Systems Engineering – Theory & Practice (系统工程理论与实践)* 7.32 (2001): 1.

Huang, Haizhou, "Discussion on China's housing market: what we know, what we don't," paper presented at the International Symposium on Housing and Financial Stability in China, Shenzhen, China, December 18-19, 2015. URL: [https://www.imf.org/external/np/seminars/eng/2015/HousingChina/pdf/Session2\\_HHuang.pdf](https://www.imf.org/external/np/seminars/eng/2015/HousingChina/pdf/Session2_HHuang.pdf).

Hui, Eddie CM, and Shen Yue. "Housing price bubbles in Hong Kong, Beijing and Shanghai: a comparative study." *The Journal of Real Estate Finance and Economics* 33.4 (2006): 299-327.

Hunter, William C. *Asset price bubbles: The implications for monetary, regulatory, and international policies*. Cambridge, MA: MIT Press, 2005.

Hwang, Sungjoo, Moonseo Park, and Hyun-Soo Lee. "Korean real estate market mechanisms and deregulation of mortgage loans: Qualitative Analysis." 27th International Conference of the System Dynamics Society. 2009.

Ibanez, Maria R., and Anthony Pennington-Cross. "Commercial property rent dynamics in US metropolitan areas: an examination of office, industrial, flex and retail space." *The Journal of Real Estate Finance and Economics* 46.2 (2013): 232-259.

Information Resources Management Association. *Open Source Technology: Concepts, Methodologies, Tools, and Applications*. Hershey, PA: IGI Publishing, 2014.

Jarsulic, Marc. *Anatomy of a financial crisis: a real estate bubble, runaway credit markets, and regulatory failure*. New York, NY: Palgrave Macmillan, 2010. ISBN: 978-1-137-03262-1.

Jiang, Xingsan, Shouying Liu, and Qing Li. "Land policy reform and national economy growth (土地制度改革与国民经济成长)." *Management World (管理世界)*. 9 (2007): 1-9.

Jiang, Zhiqiang, Weixing Zhou, Didier Sornette, Ryan Woodard, Ken Bastiaensen, and Peter Cauwels. "Bubble diagnosis and prediction of the 2005–2007 and 2008–2009 Chinese stock market bubbles." *Journal of Economic Behavior & Organization* 74.3 (2010): 149-162.

Jin, Xiaobin, Shaomei Yin, Xiaoning Yin, and Yankang Zhou. "The research on the development of urban housing industry based on system dynamics model – a case study of Nanjing city." *Journal of Nanjing University (Natural Sciences)* 40.6 (2004): 760-768.

Jin, Xiaobin, Ying Long, Wei Sun, Yuying Lu, Xuhong Yang, and Jingxian Tang. "Evaluating cities' vitality and identifying ghost cities in China with emerging geographical data." *Cities* 63 (2017): 98-109.

Keely, Louise. "The problem with ranking Chinese cities." *Fortune Insiders, Fortune*. December 5, 2015. (2015). URL: <http://fortune.com/2015/12/05/china-cities-tier-system-problem/>. Access date: Feb 13, 2017.

Kindleberger, Charles P. "Bubbles" In book "The World of Economics". Palgrave Macmillan UK, (1991): 20-22. DOI: 10.1007/978-1-349-21315-3\_3.

Kindleberger, Charles P., and Robert Z. Aliber. "Chapter 2: Anatomy of a Typical Crisis." *Manias, Panics and Crashes*. 5<sup>th</sup> edition. New York, NY: Palgrave Macmillan, 2005. Page 21-32.

Kroszner, Randall S. "Asset price bubbles, information, and public policy." *Asset Price Bubbles: The Implications for Monetary, Regulatory, and International Policies*, Cambridge MA: The MIT Press (2003): 3-13.

Kummerow, Max. "A system dynamics model of cyclical office oversupply." *Journal of Real Estate Research* 18.1 (1999): 233-256.

Kunte, Shreenivas, and Damani Om. "Exploring Harrod Domar and Solow models of economic growth." The 34<sup>th</sup> International Conference of the System Dynamics Society. Delft, the Netherlands. July 17-21, 2016. URL: <http://conference.systemdynamics.org/current/upload/tentsched.html>.

Kurebayashi, Rintaro. "A system dynamics model for analyzing bubble effects in the long distance telecom industry." Master thesis, Sloan School of Management. Massachusetts Institute of Technology, Cambridge, MA. 2004. URL: <https://dspace.mit.edu/handle/1721.1/17805>.

- Lan, Ting. "Herding behavior in China housing market." *International Journal of Economics and Finance* 6.2 (2014): 115.
- Li, Jianglin. "The measurement of the bubble of urban housing market in China." *Economic Research Journal* 6 (2010): 28-41.
- Li, Jingjing, and Shaoliang Zhang. "The study of the Housing Land Price Based on the System Dynamics (基于系统动力学的住宅用地价格研究)." *Chinese Science Paper Online(中国科技论文在线)*, Online article, 2011.
- Li, Shangpu, and Biliang Luo. "Estimation of the Size of Chinese Land Finance (我国土地财政规模估算)." *Journal of Central University of Finance & Economics*, 5 (2010): 12-17.
- Li, Wei, and Chaojian Wang. "System dynamics analysis of public affordable housing prices (基于系统动力学的公共租赁住房价格因子分析)." *Co-operative Economy & Science(合作经济与科技)* 6 (2012): 84-86.
- Li, Xuanqi, and Lizhong Hua. "Landscape aesthetic assessment based on experiential paradigm assessment technology." *Acta Ecologica Sinica* 32.10 (2012): 2965-2974.
- Li, Yan. "A study of Shenzhen's Commercial Housing System through Simulation Based on System Dynamics (房地产政策仿真研究与实践)." *Journal of Shenzhen University (Humanities & Social Sciences)*. *深圳大学学报 (人文社会科学版)* 28.4 (2011): 25-29.
- Li, Yiguang. Best days for local government finance is before tax reform (地方财政最好过的日子是分税制之前). *Sohu Finance*. Mar-9-2012. URL: <http://business.sohu.com/20120309/n337199726.shtml>.
- Liang, Yunfang, Tiemei Gao, and Shuping He. "An empirical analysis of harmonious development between the real estate industry and the national economy in transitional China." *Social Sciences in China* 3 (2006): 74-84.
- Liao, Yang. "Analysis of residence target identification during the implementation of affordable housing policy (廉租住房政策实施过程中廉租对象界定问题研究)." *Journal of Xi'an University of Architecture and Technology* (2004): 31-33.
- Liu, Hongyu, and Shen Yue. "Housing prices and general economic conditions: an analysis of Chinese new dwelling market." *Tsinghua Science & Technology* 10.3 (2005): 334-343.
- Liu, Shouying, and Xingsan Jiang. "Financial Risks of Land Financing by Local Governments—Case Study of a Developed Area in East China. (土地制度，城市化，与财政金融风险—来自东部一个发达地区的个案)" *China Land Science* 5 (2005): 1.

Liu, Weixing, and Guoqiang Zhou. "The dynamic simulation of Jilin region real estate three-level market." *Journal of Northeast Dianli University (Natural Science Edition)* 31.5 (2011): 117-123.

Liu, Ye, and Jianfa Shen. "Jobs or amenities? Location choices of interprovincial skilled migrants in China, 2000–2005." *Population, Space and Place* 20.7 (2014): 592-605.

Liu, Yonggang. "Tax Sharing System Drives Fiscal Power to Central Government and Local Governments are Forced to Sell Land to Raise Budget (分税制致大部分财权归中央 地方被迫靠卖地等找钱)." *China Economic Weekly*, 2014. URL: <http://www.chinanews.com/gn/2014/08-26/6529043.shtml>.

Liu, Yuhui, and Chucheng Zhang. *Analysis of China Local Government's Financing Platform (中国地方政府融资平台分析)*, *Banker to The World (银行家)*. 6 (2010): 48-52.

Lou, Yonghong, Guofeng Ma, Jingjing Lv, and Lei Li. "Empirical analysis of the impact factors of housing demand – case of Jiangshan county (影响住房需求因素的实证分析-以嘉善县为例)." *Shanghai Management Science* 32.6 (2010): 86-88.

Lu, Yang, and Dalu Tan. "Based on system dynamics to simulate commercial housing market in Chengdu". *Science & Technology Progress and Policy* 27.19 (2010): 89-91.

Lu, Yinqiu and Tao Sun. "Local Government Financing Platforms in China: A Fortune or Misfortune?" *IMF Working Paper No.13/243*. (2013). Available at SSRN: <https://ssrn.com/abstract=2375564>.

Lu, Yin-qiu, and Tao Sun. "Local Government Financing Platforms in China: A Fortune or Misfortune?," *International Monetary Fund Research, IMF Working Paper No.13/243*, (2013). Available at SSRN: <https://ssrn.com/abstract=2375564>.

Luna-Reyes, Luis Felipe, and Deborah Lines Andersen. "Collecting and analyzing qualitative data for system dynamics: methods and models." *System Dynamics Review* 19.4 (2003): 271-296.

Luo, Ping, Sufang He, and Huien Niu. "A case study on urban housing price by system dynamics model." *Human Geography* 16.2 (2001):57-61.

Luo, Ping, Jijin Geng, Feng Wang, and Yong Chen. "Simulation of real estate system and experiments of policies of Shenzhen." *Tropical Geography* 24.4 (2004): 371-375.

Malpezzi, Stephen, and Susan Wachter. "The role of speculation in real estate cycles." *Journal of Real Estate Literature* 13.2 (2005): 141-164.

Man, Joyce Y. "An Evaluation of China's Land Policy and Urban Housing Markets (Conference Paper)." Lincoln Land Institute. (2015). 55 pages; Inventory ID CP320-4-09; English; ISBN 978-1-55844-320-4. URL: [https://www.lincolnst.edu/pubs/3647\\_An-Evaluation-of-China-s-Land-Policy-and-Urban-Housing-Markets](https://www.lincolnst.edu/pubs/3647_An-Evaluation-of-China-s-Land-Policy-and-Urban-Housing-Markets).

Martínez-Fernández, Julia, et al. "Sustainability of Mediterranean irrigated agro-landscapes." *Ecological Modelling* 248 (2013): 11-19.

Martinez-Moyano, Ignacio J., and George P. Richardson. "Best practices in system dynamics modeling." *System Dynamics Review* 29.2 (2013): 102-123.

Mashayekhi, Ali N., Soheil Ghili, and Arash Pourhabib. "Real estate cycles: a theory based on stock-flow structure of durable goods markets", In *Proceedings of the 2009 System Dynamics Conference*, (2009). URL: <http://www.systemdynamics.org/conferences/2009/proceed/papers/P1243.pdf>.

Mayer, Christopher. "Housing bubbles: A survey." *Annual Review of Economics*. 3.1 (2011): 559-577. DOI: 10.1146/annurev.economics.012809.103822.

Mill, John Stuart. *Principles of Political Economy*. New York, NY: D. Appleton and Company, 1884.

Mills, Edwin S. *Studies in the Structure of the Urban Economy*. Baltimore, MD: The Johns Hopkins University Press, 1972.

Mrotzek, Maximilian, and Günther Ossimitz. "Catastrophe archetypes-using system dynamics to build an integrated systemic theory of catastrophes." *IDIMT-2008-Managing the Unmanageable-16th Interdisciplinary Information Management Talks* (2008): 3671-384.

Mukerji, Purba, and Khalid Saeed. "Likely causes of the US housing market crisis: A system dynamics investigation." *29th International System Dynamics Conference*, Washington DC. (2011). URL: <http://www.systemdynamics.org/conferences/2011/proceed/papers/P1419.pdf>.

Muth, Richard F. *Cities and Housing: the spatial pattern of urban residential land use*. Chicago, IL: University of Chicago Press, 1969.

Oliva, Rogelio. "Model calibration as a testing strategy for system dynamics models." *European Journal of Operational Research* 151.3 (2003): 552-568.

Ouyang, Yanqin. "Land Finance and the Difficulty of Tax Reform ("土地财政"背后的财政改革困境)." *China Economic Times* (中国经济时报). Jan 21, 2012. URL: <http://theory.people.com.cn/GB/41038/10815405.html>.



Owens, Brandon D., Nancy G. Leveson, and Jeffrey A. Hoffman. "Procedure rework: a dynamic process with implications for the "rework cycle" and "disaster dynamics"." *System Dynamics Review* 27.3 (2011): 244-269.

Özbaş, Birnur, Özgün Onur, and Barlas Yaman. "Modeling and Simulation of the Endogenous Dynamics of Housing Market Cycles" *Journal of Artificial Societies and Social Simulation* 17.1 (2014): 19. URL: <http://jasss.soc.surrey.ac.uk/17/1/19.html>. DOI:10.18564/jasss.2353.

Park, BongWon, and JaeHyeon Ahn. "Policy analysis for online game addiction problems." *System Dynamics Review* 26.2 (2010): 117-138.

Peng, Ruijue, and William C. Wheaton. "Effects of restrictive land supply on housing in Hong Kong: an econometric analysis." *Journal of housing research* 5.2 (1994): 263.

Pierson, Kawika, and John D. Sterman. "Cyclical dynamics of airline industry earnings." *System Dynamics Review* 29.3 (2013): 129-156.

Plazzi, Alberto, Walter Torous, and Rossen Valkanov. "Expected returns and expected growth in rents of commercial real estate." *Review of Financial Studies* 23.9 (2010): 3469-3519.

Pozza Jr, Clarence L., Thomas R. Cox, and Robert J. Morad. "Review of Recent Investor Issues in the Madoff, Standford and Forte Ponzi Scheme Cases, A." *The Journal of Business & Securities Law* 10 (2009): 113.

Qi, Shenjun, and Yunbo Zhang. "The impact of second-hand housing market to commercial housing market: a study of mechanisms and policy interventions using Xia'men as case study. (二手房对商品房市场的影响机理及调控政策研究-以厦门市为实证)." *Journal of Xi'an University of Architecture and Technology* 43.5 (2011): 665-671.

Qudrat-Ullah, Hassan, and Baek Seo Seong. "How to do structural validity of a system dynamics type simulation model: the case of an energy policy model." *Energy policy* 38.5 (2010): 2216-2224.

Quigley, John M. "Real Estate Price and Economic Cycles." *International Real Estate Review* 2.1 (1999): 1-20.

Ramo, Joshua Cooper. "The Shanghai Bubble." *Foreign Policy*. No.111 Summer (1998): 64-75.

Ren, Yu, Cong Xiong, and Yufei Yuan. "House price bubbles in China." *China Economic Review* 23.4 (2012): 786-800.

Ren, Zeping, and Shuangjie Song. "Why land financing scheme is still not abolished (土地财政炒高地价为何还不废除)". Sina.com.cn Special Forum, published on August 24, 2016. (2016). URL: <http://finance.sina.com.cn/zl/china/2016-08-24/zl-ifxvcsrm2353099.shtml>.

Richardson, John. "The past is prologue: reflections on forty-plus years of system dynamics modeling practice." *System Dynamics Review* 29.3 (2013): 172-187.

Riddiough, Timothy J. "The economic consequences of regulatory taking risk on land value and development activity." *Journal of Urban Economics* 41.1 (1997): 56-77.

Rosen, Kenneth. "Toward a model of the office sector." *Journal of the American Real Estate & Urban Economics Association (AREUEA)* 12.3 (1984): 161-169.

Saiz, Albert. "The geographic determinants of housing supply." *The Quarterly Journal of Economics* 125.3 (2010): 1253-1296.

Santos, Sergio P., Valerie Belton, and Susan Howick. "Adding value to performance measurement by using system dynamics and multicriteria analysis." *International Journal of Operations & Production Management* 22.11 (2002): 1246-1272.

Sargent, Robert G. "Verification and validation of simulation models." *Proceedings of the 37th conference on Winter simulation. winter simulation conference, 2005.*

Scheinkman, Jose A., and Wei Xiong. "Overconfidence and speculative bubbles." *Journal of Political Economy* 111.6 (2003): 1183-1220.

Senge, Peter M., and Jay W. Forrester. "Tests for building confidence in system dynamics models." *System dynamics, TIMS studies in management sciences* 14 (1980): 209-228.

Shang, Shengliang. "System dynamics simulation of the housing demand of Hangzhou main city district (基于系统动力学的杭州市主城区住宅需求仿真研究)". MS thesis. Zhejiang University of Technology, Hangzhou, China. 2006.

Sheng, Andrew, and Ng Chow Soon. "Bringing Shadow Banking into the Light: Opportunity for Financial Reform in China." *Fung Global Institute Asian Perspectives Global Issues (FGI report)*. March, 2015.

Shepard, Wade. *Ghost Cities of China*. Zed Books Ltd, London, UK. (2015).

Shiller, Robert J. "Diverse Views on Asset Bubbles." *Asset Price Bubbles: The Implications for Monetary, Regulatory, and International Policies*, Cambridge, MA: The MIT Press, (2003): 35-39.

Shiller, Robert J. "Before housing bubbles, there was land fever". New York Times (2013). URL: <http://www.nytimes.com/2013/04/21/business/before-housing-bubbles-there-was-land-fever.html>. Access date: February 11, 2017.

Shimizu, Chihiro, and Kiyohiko G. Nishimura. "Pricing structure in Tokyo metropolitan land markets and its structural changes: pre-bubble, bubble, and post-bubble periods." *The Journal of Real Estate Finance and Economics* 35.4 (2007): 475-496.

Shiratsuka, Shigenori. "The asset price bubble in Japan in the 1980s: lessons for financial and macroeconomic stability." *IMF-BIS Papers* 21 (2005). This paper was first prepared for the IMF-BIS conference on Real Estate Indicators and Financial Stability, held at IMF in Washington DC on October 27-28, 2003.

Smith, Felicia. "Madoff ponzi scheme exposes the myth of the sophisticated investor." *The University of Baltimore Law Review* 40 (2010): 215.

Smith, Peter, and Ann van Ackere. "A note on the integration of system dynamics and economic models." *Journal of Economic Dynamics & Control* 26 (2002): 1-10.

Sorace, Christian, and William Hurst. "China's phantom urbanization and the pathology of ghost cities." *Journal of Contemporary Asia* 46.2 (2016): 304-322.

Sterman, John D. *Business Dynamics: Systems Thinking and Modeling for a Complex World*. McGraw-Hill Education, 2000. ISBN-10: 9780072389159.

Sterman, John D. "System dynamics modeling: tools for learning in a complex world." *California Management Review* 43.4 (2001): 8-25.

Su, Teng. "Study on housing supply policy intervention model on Beijing housing price." *Journal of Urban and Regional Planning* 3.1 (2010): 124-139.

Sun, Weizeng, Siqi Zheng, David Geltner, Rui Wang. "The housing market effects of local home purchase restrictions: evidence from Beijing." *The Journal of Real Estate Finance and Economics* (2014): 1-25.

Tao, Ran, Xi Lu, Fubing Su, and Hui Wang. "China's transition and development model under evolving regional competition patterns (地区竞争格局演变下的中国转轨: 财政激励和发展模式反思)," *Economic Research Journal (经济研究)* 7.2 (2009).

Tao, Ran, Yuan Fei, and Guangzhong Cao. "Regional competition, land sales and local fiscal impact: Analysis based on Chinese city level data (1999-2003) (区域竞争, 土地出让与地方财政效应: 基于 1999-2003 年中国地级城市面板数据的分析)." *The Journal of World Economy (世界经济)* 30.10 (2007): 15-27.

Taylor, Timothy RB, et al. "Science, engineering, and technology in the policy process for mitigating natural-societal risk." *System Dynamics Review* 27.2 (2011): 173-194.

Thaler, Richard. "Toward a positive theory of consumer choice." *Journal of Economic Behavior & Organization* 1.1 (1980): 39-60.

Thornton, Liam. "Real estate development firms as learning organizations: systems thinking as a methodology for strategic planning." MS thesis, MIT Center for Real Estate, Massachusetts Institute of Technology, 1992.

Trichet, Jean-Claude. "Asset price bubbles and their implications for monetary policy and financial stability." *Asset Price Bubbles: The Implications for Monetary, Regulatory and International Policies*. Cambridge, MA: The MIT Press (2003): 15-22.

Vlachos, Dimitrios, Patroklos Georgiadis, and Eleftherios Iakovou. "A system dynamics model for dynamic capacity planning of remanufacturing in closed-loop supply chains." *Computers & Operations Research* 34.2 (2007): 367-394.

Wan, Yueya. "Analysis of property tax using system dynamics method (基于系统动力学的房产税政策传导路径研究)." MS thesis, East China Jiaotong University, 2013.

Wang, Jun. "The dynamic structure of land finance (土地财政的动力结构)." *Liao Wang (瞭望)* 37 (2005): 26-27. URL: <http://www.cqvip.com/qk/80823x/200537/20161889.html>.

Wang, Songtao, Su Hanchan, and Bohua Xu. "The estimation and determinants of the price elasticity of housing supply: evidence from China." *Journal of Real Estate Research* 34.3 (2012): 311-344.

Wang, Yourong, and Yong Tu. "Urban land supply policy, urban growth and housing prices in China." *Institute of Real Estate Studies Working Paper Series*. National University of Singapore. 2014. URL: <http://www.ires.nus.edu.sg/workingpapers/IRES2014-015.pdf>.

Wang, Zhi, and Qinghua Zhang. "Fundamental factors in the housing markets of China." *Journal of Housing Economics* 25 (2014): 53-61.

Wheaton, William C. "Real estate "cycles": some fundamentals." *Real Estate Economics* 27.2 (1999): 209-230.

Wheaton, William C. "The cyclic behavior of the national office market." *Journal of the American Real Estate & Urban Economics Association (AREUEA)* 15.4 (1987): 281-299.

Wheaton, William C. "Vacancy, search, and prices in a housing market matching model." *Journal of Political Economy* 98.6 (Dec.1990): 1270-1292.

Wheaton, William C., and Lawrence Rossoff. "The cyclic behavior of the US lodging industry." *Real Estate Economics* 26.1 (1998): 67-82.

Wheaton, William C. and Raymond Torto. "Vacancy rates and the future of office rents." *Journal of the American Real Estate and Urban Economics Association* 16.4 (1988): 430-436.

Wheaton, William C. Raymond Torto, and Peter Evans. "The cyclic behavior of the Greater London office market." *Journal of Real Estate Finance and Economics* 15.1 (1997): 77-92.

Winz, Ines, Gary Brierley, and Sam Trowsdale. "The use of system dynamics simulation in water resources management." *Water resources management* 23.7 (2009): 1301-1323.

Wu, Jing, Joseph Gyourko, and Yongheng Deng. "Evaluating conditions in major Chinese housing markets." *Regional Science and Urban Economics* 42.3 (2012): 531-543.

Wu, Jing, Joseph Gyourko, and Yongheng Deng. "Evaluating the risk of Chinese housing markets: What we know and what we need to know." *China Economic Review* 39 (2016): 91-114.

Wu, Zhenhua, Yun Li, Wenlong Gui, and Yapei Wang. "The forecast research of urban commodity residence price based on system dynamics (基于系统动力学的住宅价格预测研究)." *Technoeconomics & Management Research (技术经济与管理研究)*, 8 (2013): 101-106.

Xiang, Huaicheng. "From tax sharing system to public finance (从分税制到公共财政)." *China Reform Information Database*. October 24, 2008. URL: <http://www.reformdata.org/content/20081024/5732.html>.

Xiao, Yuan. "Making land fly: the institutionalization of China's land quota markets and its implications for urbanization, property rights, and intergovernmental politics." Ph.D Dissertation. Department of Urban Studies and Planning. Massachusetts Institute of Technology, Cambridge, MA, 2014. URL: <https://dspace.mit.edu/handle/1721.1/95581>.

Xu, Dong, and Zhiyong Han. "The herd behavior: A test based on GCAPM and the empirical evidence in China's stock market." *Journal of Financial Research* 5 (2007):13.

Yang, Wei, and Tingting Huang. "Risk analysis of Chinese local government's land financing platform (我国地方政府投融资平台风险分析)." *China Finance (中国金融)*. 6 (2010): 80-81.

Yao, Shujie, Dan Luo, and Lixia Loh. "On China's monetary policy and asset prices." *Applied Financial Economics* 23.5 (2013): 377-392.

Yu, Hong. "China's "Ghost Cities"." *East Asian Policy* 6.02 (2014): 33-43.

Yue, Guining, Lili Teng, and Chunhua Wang. "On local governments' land selling revenue in China (我国地方政府土地财政问题研究)." *China Opening Herald (开放导报)*. 3 (2009): 47-52.

Zarghami, Mahdi, and Simin Akbariyeh. "System dynamics modeling for complex urban water systems: Application to the city of Tabriz, Iran." *Resources, Conservation and Recycling* 60 (2012): 99-106.

Zhang, Gaiyan, and Hung-Gay Fung. "On the imbalance between the real estate market and the stock markets in China." *Chinese Economy* 39.2 (2006): 26-39.

Zhang, Jiazhen. "84 cities using land finance taking on debt in total of 8 trillion RMB (土地违规起底: 祸起抵押融资 84 城涉额超 8 万亿)." *China Business Journal*, August 23, 2014. URL: <http://finance.sina.com.cn/china/20140823/013920097098.shtml>.

Zhang, Li, Xianbin Wang, and Xianxiang Xu. "Fiscal incentive, political incentive and local officials' land supply (财政激励, 晋升激励与地方官员的土地出让行为)." *China Industrial Economics (中国工业经济)*. 4 (2011): 35-43.

Zhang, Xin. "An analysis of the current investment trend in the US toll road sector." Master thesis. Department of Urban Studies and Planning. Massachusetts Institute of Technology, Cambridge, MA. 2008. URL: <https://dspace.mit.edu/handle/1721.1/45620>.

Zhang, Xin, David Geltner, and Richard de Neufville. "System dynamics modeling of Chinese urban housing markets for pedagogical and policy analysis purposes." (2015). Available at SSRN: <https://ssrn.com/abstract=2600777> or <http://dx.doi.org/10.2139/ssrn.2600777>.

Zhang, Yanbing, Xiuping Hua, and Liang Zhao. "Exploring determinants of housing prices: A case study of Chinese experience in 1999–2010." *Economic Modelling* 29.6 (2012): 2349-2361.

Zhao, Simon X., and Bryane Michael. "how big is the Chinese real estate bubble and why hasn't it yet burst: A comparative study between China and world major financial crises." Lincoln Institute of Land Policy Working Paper WP16SZ2, (2016). URL: [http://www.lincolninst.edu/sites/default/files/pubfiles/zhao-wp16sz2-full\\_0.pdf](http://www.lincolninst.edu/sites/default/files/pubfiles/zhao-wp16sz2-full_0.pdf).

Zheng, Juntian, Zheng Wang, and Chaohua Tu. "How high is the vacancy rate in Chinese housing market? (中国楼市空置率到底有多高?)." May 1, 2015. (2015). URL: [http://news.xinhuanet.com/fortune/2015-05/01/c\\_1115153720.htm](http://news.xinhuanet.com/fortune/2015-05/01/c_1115153720.htm). Access date: Feb 13, 2017.

Zheng, Siqi, and Hongyu Liu. "Income elasticity of housing demand in China: Model, estimation and forecast." *China Civil Engineering Journal* 7.122.126 (2005): 122-126.

Zheng, Siqi, and Zhan Shi. "Relationship of land and housing market under land finance: analysis of local government behavior (土地财政下的土地和住宅市场: 对地方政府行为的分析)", *Social Sciences in Guang Dong (广东社会科学)*. 2 (2011): 5-10.

Zheng, Siqi, Weizeng Sun, and Matthew E. Kahn. "Investor Confidence as a Determinant of China's Urban Housing Market Dynamics." *Real Estate Economics* 44.4 (2016): 814-845.

Zheng, Siqi, Weizeng Sun, Zhen Wu, and Jing Wu. "Using land to generate revenue, using revenue to generate land – A research of the investment mode for cities with Chinese characteristics". *Economic Research Journal*. 49.8 (2014): 14-27.

Zhou, Feizhou. "10 Years After Tax Sharing System: Regulation and its Impact (分税制十年: 制度及其影响)." *Social Sciences in China (中国社会科学)*. 6 (2006): 100-115.

Zhu, Changjun. "Admit the statistical issues of GDP, and not allowing such events to be ignored (坦承 GDP 统计问题 不让造假者心存侥幸)". *China Youth Daily*. (2017). URL: <http://www.chinanews.com/gn/2017/01-19/8128817.shtml>. Access date: Feb 10, 2017.

Zhu, Xiangla, and Youliang Huang. "The system dynamics analysis of housing demand in Nanjing city." *Optimization of Capital Construction* 24.2 (2003): 6-8.