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Abstract This study investigates urban housing supply in China by focusing on the development strategies of real estate developers. In a dynamic and volatile market, developers face great challenge determining the optimal development time in order to ride the boom-bust cycles. We follow Titman (1985) to model this "option to develop" in a real option framework and examine the effect of policy uncertainty on real estate development. A two-step identification strategy is developed based on the policy implementation gap between the central government and the local government in China. Our empirical evidence shows that the development delay caused by price uncertainty eases off as local government's reliance on land revenue increases. This effect is stronger for state-owned developers who are better shielded from policy uncertainty than non-state-owned developers. These findings extend our understanding of the impact of government interventions and policy uncertainty on real estate market.

Key words Uncertainty, Real option, Government policy, Urban housing supply, Hazard model

JEL Classification D81, R31, R38, G31

1. Introduction

Empirical investigations of housing supply have been lagging behind that on housing demand. In response to Dipasquale (1999)'s call, "why don't we know more about housing supply", there was a wave of studies focusing on issues surrounding urban housing supply. For example, a group of scholars centred on the impact of land use planning systems and confirmed a negative relationship between regulatory stringency and urban housing supply (e.g., Mayer and Somerville, 2000; Green et al., 2005; Glaeser et al., 2005; Glaeser and Ward, 2009; Kok et al., 2014). However, there is still much to learn about the behaviours of players on the supply side of the housing market. This study follows this line of research to investigate regulations and new housing supply in China by focusing on development strategies of real estate developers.

Given sufficient land supply, real estate developers should respond to growing demand by building more. However, this does not seem to be true in China, where peoperty prices have been climbing for more than a decade. Specifically, only 64% of the purchased urban land parcels were developed during the period between 2000 and 2010 (Tang and Wang, 2017). Mak et al. (2007) also found an extended time lag between construction and completion in China, which may explain why an increase in residential investments did not always lead to more housing supply in the short run. Titman (1985) proposed a call option model to understand the rationale behind holding back development when investigating similar phenomenon in Los Angeles three decades ago. He argued that because real estate development is irreversible, the option to develop becomes valuable when market conditions are uncertain. This results in land being held undeveloped until more information is available.

Titman's (1985) seminal work has inspired a large body of real option research in the real estate sector (e.g., Holland et al., 2000; Sivitanidou and Sivitanides, 2000; Capozza and Li, 2001, 2002; Cunningham, 2006; Bulan et al., 2009; Grovenstein et al., 2011; McMillen and O'Sullivan, 2013; Yao and Prretorius, 2014; Wrenn and Irwinn, 2015). The general consensus is that there is a negative relationship between uncertainty and the rate of new construction. How to reliably estimate the level

of uncertainty embedded within the development process, however, is still an open question. We contribute to the literature by investigating the effect of a particular source of uncertainty, i.e., policy uncertainty, on the development decision of developers.

It has been established that policy uncertainty and corporate investment are negatively related (e.g., Julio and Yook, 2012; Gulen and Ion, 2015; Baker et al., 2016; Kelly et al., 2016). The effect of policy uncertainty on real estate development, on the other hand, have not been thoroughly interagated. Existing literature, albeit small, suggests a negative effect by the uncertainty of real estate development regulations on the land and housing markets. For example, Mayo and Sheppard (2001) examined the effect of stochastic development controls on distorting new housing supply and Cunningham (2007) explored how growth controls (i.e., density limits) reduce the option value of land development. Zax and Skidmore (1994), Hassett and Metcalf (1999), and Groves (2009) documented consistent evidence showing that unanticipated increases in tax rates applied to residential property market slow down development.When the timing, content, and impact of government intervention is uncertain, it would increase the uncertainty related to the development's future profitability. Will real estate developers hold back development, and subsequently reduce immediate supply to the market? The answer to this question has significant implication to local and central governments who intend to regulate the housing market effectively. This paper sets off to address this important policy issue by using data from China.

China's highly regulated real estate market provides a natural setting to test the policy influences on real estate development in a real option framework. As it has been significantly influenced by the central government's counter-cyclical interventions, the risk associated with housing price uncertainty is prominent. To curb the rapidly rising house prices, the central government imposes a wide range of interventions on both the demand and supply side (i.e., restrictions on bank lending, land leases, home mortgage loans, and home purchases), often without sufficient consultation or warning. This practice introduced a considerable level of uncertainty to the market and may have encouraged developers to wait and see. This makes China an ideal setting to test our hypotheses.

One important innovation in this study is the reliable measurement of policy uncertainty, without which the conclusions drawn could be invalid. Specifically, the inconsistency and instability of the interventions by the Chinese government makes the measurement of policy uncertainty very challenging. Previous studies usually use a binary variable to indicate the onset of a single policy event (e.g., Cunningham, 2007) or the variation of market indicators surrounding a particular type of policies (e.g., Mayo and Sheppard, 2001). These two methods are too rudimentary to the overall policy uncertainty that a Chinese developer is facing when making development decisions, because developers need to look both backward and forward to assess the overall level of uncertainty.

Our treatment of this issue is to use the policy implementation gap between the central government and the local government. Though China is centrally controlled, local governments are responsible for the implementation of central policies and the formation of local real estate policies (Xu, 2011; Liu et al., 2016). The incentives and interests of local governments are not always aligned with those of the central government. As a result, local governments can selectively implement central polcies. Local governments with greater reliance on land leasing revenues will be more interested in keeping local housing prices high in order to extract more revenue from land leasing. Consequently, they will not be very keen to follow the central government's counter-cyclical regulations. This will amileorate the negative effect of policy-related uncertainty on the supply in local housing markets. Based on this assumption, we developed a two-step identification strategy. First, we measure the overall uncertainty faced by developers based on the variation of local housing prices. Second, we isolate the effect of policy uncertainty by examining the variation of the local government's reliance on land revenues.

We expect the negative relationship between price uncertainty and real estate development, a reliable real option prediction, to decrease with local governments' reliance on land revenues.

By way of comparison, we also employ the Economic Policy Uncertainty (EPU) Index for China as developed by Davis et al. (2019) through text mining in mainstream newspapers. The advantage of the EPU Index is that it covers multiple economy policies over time. Nevertheless, the EPU Index measures uncertainty caused by policy changes in the whole economy, including the real estate sector. It is also a national measure, which cannot reflect local variations in policy uncertainty.

Our sample consists of over 1,300 residential developments completed by 90 listed real estate firms between 2007 and 2016 in 17 major cities. By utilizing a parametrtic hazard model, the empirical results show that our two-step identification strategy performs better than the economic policy uncertainty index. We found that the development delay caused by price uncertainty eases off as local government's reliance on land revenue increases. This effect is stronger for state-owned developers who are better shielded from political uncertainty than non-state-owned developers. In contrast, the use of the EPU Index shows no delaying impact on the development rate, which is indistinguishable between state-owned and non-state-owned developers.

By testing the influence of policy uncertainty on real estate development, this study makes several contributions to the literature. First, it provides empirical evidence that government interventions affect the developer's development decision through the channel of uncertainty. In this respect, it is closely related to the recent study by Wang et al. (2016), which also considers the uncertainty caused by policy changes in China. They quantified the policy uncertainty by taking the variance of monetary measures and documented a delaying effect on the rate of development when the expected policy is positive. However, regulatory policies in China's real estate market are complicated and may not be effectively captured in a single monetary measure. Our study improves their work by using information from local housing market to measure policy uncertainty. This approach enables us to take into account the heterogeneity of local housing market, which is important in studies of real estate market.

In addition, our findings also extend the land finance literature that are focused on the consequences of the increasing reliance on land revenues in China (e.g., Fu, 2015; Pan et al., 2015; Wu et al., 2015). While the land finace strategy is criticized for driving up China's housing prices, our finding suggests that it also can accelerate new housing supply by reducing the policy uncertainty. Finally, the study also contributes to the broader literature of housing supply. Previous studies that discuss the determinants of housing supply are mainly focused on developed markets, particularly in the United States (e.g., Goodman, 2005; Glaeser et al., 2005; Glaeser and Ward, 2009). We complement the literature with micro-level empirical evidence in a rapidly urbanising developing market, where the housing shortage is a serious issue.

We proceed as follows with the rest of the paper. The next Section introduces the background of China's real estate market. Section 3 describes data and variables for the empirical analysis. Section 4 introduces the empirical model. Empirical findings are reported in Section 5. The final section concludes.

2. China's real estate market

2.1 The institutional background

The institutional background is key to understanding the policy initiatives of the government in China's real estate market. Though China is politically centralized, the national economy is delegated to local municipal governments. In simple term, under the supervision of the central government, local governments are responsible for initiating reforms, providing public services, and making and enforcing local policies (Xu, 2011). This decentralized setting gives local officials substantial discretion to intervene the real estate market where they have played pivotal roles. As the representative of the "state", local governments are not only the *de facto* owner and the monopoly supplier of urban land for development, but the local real estate manager responsible for the implementation of the central government's policies and the formation of local policies governing the real estate market (Liu et al., 2016).

Local governments can make use of their discretion in urban land development to achieve their fiscal and political goals. Their thirst for fiscal revenues has been rooted in the restructuring of the fiscal decentralization since the mid-1990s when the tax-sharing reform was first launched (Han and Kung, 2015). The central government has gained increasing shares in major taxes, such as the consumption tax and customs duties, diverting more fiscal revenues from local governments. Local governments, on the other hand, found it difficult to meet the increasing fiscal obligations given the shrunk tax share. In return, the tax-sharing reform has empowered local officials with large discretion in the way they operate local development, among others, the exclusive right to grant land use rights and enjoy the "extra-budgetary[1]" revenue (Wang and Hui, 2017). This results in a strong incentive for local governments to promote the real estate sector so as to maximize the revenue from land leases, which is usually referred as land finance (Fu, 2015; Pan et al., 2015; Wu et al., 2015).

A second reason that motivates local governments to rely on land finance is the underlying political and personnel control system. In China's system, land revenue maximization is not only consistent with the local government's fiscal incentive, but supportive for local officials' political incentive. The cadre promotion in China is primarily based on a GDP-centered evaluation criterion, that is, the likelihood of cadre promotion depends on the local economic performance (Li and Zhou, 2005). Land leases can spur local GDP growth through short-term increases in extra-budgetary revenue and long-term benefits from attracting investment, thus enhancing the career prospects of local officials (Chen and Kung, 2016).

From the perspective of fiscal expansion and economic development, local governments become increasingly reliant on land leases to collect conveyance fees. Accompanied by the skyrocketed demand for commercial land since the took off of urbanisation in the early 2000s, land leases through the market-oriented method (i.e., tender, auction, and listing) become extremely profitable and manageable (Lichtenberg and Ding, 2009). This results in an extraordinary rise in the share of extra-budgetary revenues. While accounting for less than 10% of the local budgetary revenue before 2000, revenues from leasing land grew dramatically to constitute nearly 60% in 2013 (Wang and Hui, 2017). To the extent that land revenue plays a pivotal role in local fiscal revenue, it is criticized that the local government's land finance strategy is a driving force for China's soaring housing prices (Pan et al., 2015; Wu et al., 2015).

2.2 The central government interventions

As one of the most important emerging economies in the world, China's real estate market has been experiencing rapid and unprecedented growth. The total size of developed urban area soared from 22,439 km^2 in 2000 to 52,102 km^2 in 2015, with an average annual growth rate of about 6% (NBSC, 2016). Along with this rapid urbanization, real estate has been a key engine to China's economic

[1] The extra-budgetary category means that local governments will not share it with upper-level authorities.

growth, with housing prices and land prices skyrocketing. Real estate investment grew rapidly from about 5% of GDP in 2000 to 14% of GDP in 2015 (NBSC, 2016). At the same time, the real house price growth and land price growth have averaged over 10% per annum (Wu et al., 2016). Housing has become less affordable because the average growth rate of housing prices far exceeds that of the household income in most cities. For example, Beijing, the capital city, was the least affordable with a price-to-income ratio at 14.5 in 2015[2]. The housing price surges in China have led to substantial interventions from the central government, which complicate the housing market with significant uncertainty due to frequent policy changes.

The central government's intervention influences the market mainly through three channels: land administration, credit regulation, and purchase restrictions (see Table 1 for overview). In the land market, the intervention mainly takes the form of direct control over land supply. To supply, local governments can draw a parcel of land from their urban land bank or from rural collectives through rural-urban land conversion (Lichtenberg and Ding, 2009). However, after the spate of tightening land supply policies to curb the property booms in 2004, the amount of rural land that can be converted into urban uses is subjected to mandatory quotas. It is also stipulated that all land used for commercial and residential purposes onwards had to be supplied by the local government through tender, auction or listing and existing urban land users are no longer allowed to supply land to developers. The central government also tightened the credit conditions as an important supply-side constraint to dampen developers' speculative investment, which led to the exclusion of some types of developers (e.g., non-state-owned firms) by the state-owned banks in the credit allocation (Cull et al., 2015).

[Insert Table 1 here]

On the demand side, a series of counter-cyclical policies on home mortgage loans and home purchases were implemented. Since 2004, (tightening and loosening) regulations were issued in almost every couple of months. In March 2005, the State Council issued the "National 8 Rules", first proposing the establishment of an accountability system in regulating the real estate market. Since then, several official documents had reiterated to stabilize the housing market. This round of tightening policies was only loosened in 2008 due to the burst of the financial crisis. Followed were stricter regulations in 2010. On 30 April, the State Council issued the home purchase restriction (HPR) policy, for the first time, to curb the speculative housing demand for owning more than one property. The HPR policy was upgraded several times to express the central government's firm attitude in regulating the real estate market. The effect of HPR was salient and housing prices cooled down (Sun et al., 2017; Li et al., 2017). The central government began loosening policies again in mid-2012 before further crashes of the housing price. Again, a new spate of home purchase restrictions were announced in 2013 and 2016, respectively.

2.3 The localized implementation of the central government's policies

It is important to note that there are two sources of interventions in China: from the central government and from the local government. The policies introduced above are from the central government applicable to the entire country. Because the central government has given much authority to local officials, retaining only weak control over policy implementation, local officials can implement the central government's policies selectively (Ran, 2013). As the agent for the central government, local governments assigned with different tasks will prioritize the task that favours themselves most (Wu et al., 2015). Maintaining the real estate boom is one of such prioritized task. Because revenues from the real estate market have emerged as a main contributor to the local fiscal

[2] Data from the E-House report which is published annually.

income, cooling down the market would threaten the local fiscal sustainability. Therefore, while the central government strongly calls for curbing the rampant housing prices over concerns about housing bubbles and affordability, it would be no surprise if some local governments fail to make sufficient effort in regulating the real estate market. The divergence of local governments' interest from that of the central government would result in substantial implementation gap between the central and local policies, which brings more uncertainty to policies (Wang et al., 2016).

3. Data and variables

The data for empirical analysis come principally from the CREIS database which contains detailed records of parcels and developments that occurred across China. The descriptions include, among others, transaction date of the land parcel, size of the structure built on it, and the developer and the date of open sale. The CREIS database also provides city-level market information including the monthly sales prices and volumes, as well as land transactions and prices. The multi-city housing price index was obtained from the Real Estate Institute in Tsinghua University and the method is introduced in Wu et al. (2014). It is based on the newly-built housing market which can better describe the Chinese housing market that concentrates in the newly-built sector. The prefecture data mainly comes from official Chinese publications: land transaction data are from China Land and Resources Statistical Yearbook, and government budgetary records and economic data are from China City Statistical Yearbook. Our sample consists of a total of 1,355 newly-built residential projects that are developed on land parcels transacted between 2006 and 2015, and one-tenth of them remain unlisted on the market at the end of 2016. These developments come from 17 cities by 90 listed real estate firms.

3.1 Timing of development

We use the trackable records to identify the start and the end of each land parcel as undeveloped. In theory, developers can start the development once completing the purchase of a parcel from the local government. Yet, around a one-year lag is needed to allow developers to go through the necessary administrative approvals (Wang et al., 2016). Therefore, we measure the start of the duration by one year after the parcel transaction date recorded. Regarding the duration end, we abandon the construction start but use the open sale date, that is, when the development project built on the parcel is first listed on the market for sale. On the one hand, in the context of China, neither construction starts nor completions can accurately reflect developer's timing of development. Realizing the problem of strategically holding developable land vacant, the government imposes regulations requiring developers to start and complete the construction within a certain period[3]. However, with the connivance by the local government, developers can play many tricks, such as starting construction as required and then suspend the work, which caused the implementation of the regulations ineffective in deterring land hoarding (Wei et al., 2014). Developers retain valuable flexibility to change the following implementation schedule, when to list for sale and when to complete the construction, among others. Due to the possibility of presale, that is, sell before completion, we also abandon the completion date as the end of the development duration. On the other hand, the open sale decision can be largely treated as irreversible. Developers are not only required to list all the housing units after receiving the sale permit, but stick to the sales price that have been registered in advance with the local authority (Wu et al., 2014). Therefore, in a dynamic

[3] According to Article 26 of the Urban Real Estate Management Laws of China, an idle land fee less than 20% of the lease fees for land use will be charged if the development start is delayed by one year, and the right to use the land will be taken back without compensation if it is delayed by two years. The exceptions include delays caused by force majeure, actions of government, or the needed perparation for starting the development (Wei et al., 2014).

market with short market cycles, it is fairly important to choose the right date for the development's open sale.

The duration of undeveloped time is then calculated from the date when a parcel is bought by a real estate developer postponed by one year until the structure built upon it is first listed for sale. In total, the 1,355 residential projects are transformed into over 40,000 observations, as the time-span records of a single project is split into monthly records. As displayed in Figure 1, majority projects were listed for sale within 40 months and fewer projects remain unlisted as time goes by.

[Insert Figure 1 here]

3.2 Policy uncertainty

The policy uncertainty measures in the literature usually focus on a particular type of policy, which are not applicable to a market with complicated regulations such as China. In this study, we adopt a two-step strategy to identify the effect of policy uncertainty that can incoporate the policy intensity and complexity in China's real estate market. The intuition is that, considering the salient effect of policies on housing prices in China, the price uncertainty measure should reflect the influence of policy changes. Taking the city of Shanghai as an example, Zhou (2016) found evidence showing that the real estate market overreacted to policy changes with increased short-term volatility. Then our strategy is to separate the effect of the price uncertainty that results from policy changes.

We start with measuring the local price uncertainty faced by developers by time series changes in the volatility of housing prices. It is computed using a GARCH (1,1) model as applied in Cunningham (2006) and Miles (2009), which estimates the variance of residuals from an autoregressive model of price returns on lagged returns. We first calculate the annualized housing price return $R_{j,t}$ for city *j* at time *t* by:

$$R_{j,t} = 12log\left(\frac{P_{j,t}}{P_{j,t-1}}\right), \quad (1)$$

We then specify the following equations, in which $R_{j,t}$ is regressed on its lagged terms, and the conditional variance $\sigma_{j,t}^2$ follows a GARCH (1, 1) process with a one-month-lagged squared residual ($e_{j,t-1}^2$) and a one-month-lagged conditional variance ($\sigma_{j,t-1}^2$).

$$R_{j,t} = \alpha_{0j} + \sum_{\tau=1}^{3} \alpha_{\tau,j} R_{j,t-\tau} + e_{j,t}, \text{ and} \quad (2)$$

$$\sigma_{j,t}^2 = \gamma_{0j} + \gamma_{1j} e_{j,t-1}^2 + \delta_{1j} \sigma_{j,t-1}^2 , \quad (3)$$

where $e_{j,t} \sim N\left(0, \sigma_{j,t}^2\right)$. The price volatility $vol_{j,t}$, which represents the price uncertainty risk for city *j* at time t, is calculated by:

$$vol_{j,t} = \sqrt{\widehat{\sigma_{j,t}^2}}. \quad (4)$$

We generate 17 price uncertainty estimates, one for each of the cities included in our analysis. The price uncertainty estimates are noted with significant differences across cities. Higher vol represents greater difficulty to predict the future housing prices. According to the standard real option theory, we expect a delaying impact of the price uncertainty estimate on the likelihood of development.

Since vol is a combination of policy and market uncertainties, in the second step, we isolate the delaying impact of the price uncertainty attributable to policy changes. Specifically, we make use of the distinctive institutional feature in China—the policy implementation gap between the central government and the local government. Considering the different objective from the central government, we suppose that local governments with greater reliance on revenues from the housing market would stick to the objective of maintaining the real estate sector rather than implemennting the central government's counter-cyclical policies, which reduces the impact of the policy-related uncertainty. Given no property taxes in China, land leasing revenues are the main income of the local government from the housing market. We then follow the literature to measure the local government's reliance on the housing market as the ratio of land leasing revenues divided by local budgetary fiscal revenues (*landrev*)[4]. The higher the land revenue ratio, the greater reliance on land revenue the local government is, as well as a weaker impact of policy uncertainty. Thus, provided with a higher ratio of land revenue, we expect a decline in the negative relationship between price uncertainty and real estate development, that is, a positive crossing effect between price uncertainty and the land revenue ratio.

It is particularly important to verify the resulted decline in delaying real estate development is being driven by policy uncertainty changes. To this end, we sort out another exogenous aspect that can alter the influence of the land revenue ratio in reducing policy uncertainty, that is, whether the developer of the development is state-owned. Because of their special connections to the government, state-owned developers are deemed with greater protection from the government, among others, financial and political support, against policy changes than non-state-owned developers (e.g., Poncet et al., 2010; Cull et al., 2015). This leads us to argue that state-owned developers would suffer less from policy changes than non-state-owned firms. We test the difference between state-owned and non-state owned developers by the interaction of the three variables, namely, the state-owned developer dummy, the price uncertainty measure, and the land revenue ratio. The expectation is a positive interactive estimate.

Alternatively, we measure the policy uncertainty by a monthly Economic Policy Uncertainty (EPU) Index for China which is developed by Davis et al. (2019). They rely on two mainstream newspapers in China—the Renmin Daily and the Guangming Daily—to quantify concepts related to economy policy uncertainty and then scale the monthly EPU counts by the number of total articles for the same newspaper and month. This method is first proposed by Baker et al. (2012) and has been applied worldwide to measure the uncertainty related to each aspect of government policies, such as taxation, government spending and debt, monetary policy, tarrif, and legislation. Likewise, we interact the EPU Index with the the state-owned developer dummy to capture the differences, if any, in the responses of state-owned and non-state-owend developers to changes in the general economy policy uncertainty. Despite its advantage in measuring the overall policy uncertainty, the use of the EPU Index in the underlying study suffers limitations. First, it is not specific to the real estate market but measures the policy uncertainty related to the general economy which may not affect the real estate market or the profitability of real estate developments. We graphed the EPU Index in Figure 3 with important central regulations in the real estate market. The EPU Index appears very volatile and its reponses to real estate regulations are mixed. For example, the series of strict land and housing purchase restrictions between late 2009 and early 2010 were associated with both ups and downs in the EPU Index, while regulations in late 2010 were followed by radical increases. Second, the EPU Index cannot reflect the local variations in policy uncertainty. Given the local government's authority in

[4] It is important to note that the *Landrev* variable reflects revenues obtained from urban land leases but not the net profits made by local governments due to the lack of information on the cost of acquiring and preparing land. Liu et al. (2016) estimated that the profit margin of land sales was around 40% of the gross traded price, with the rest 60% spent on land expropriation and land developments.

policy implementation in China's real estate market, it is natural to expect different levels of policy uncertainty depending on how central government policies were implemented locally.

[Insert Figure 3 here]

3.3 Control variables

Following Wang et al. (2016) and Li et al. (2017), control variables are divided into three broad categories: (i) hedonic variables for the development project, including phasing strategy (*phasing*), building area (*fBuidArea*), and class (*luxury*), (ii) firm characteristics, including firm size (*firmsize*) and year-on-year growth (*firmgrowth*), and (iii) variables on market characteristics representing both the local supply and demand sides. On the supply side, we describe the local housing market by the level of competition. According to the literature, the exercise of one developer' development option may affect the housing price faced by other developers in a competitive market and therefore influence their exercise strategies (Schwartz and Torous, 2007; Bulan et al., 2009; Wang et al., 2016). We follow Wang et al. (2016) to count the number of units from competing projects within a 1-km radius from the site of the target project and indicate the competition with a dummy variable (denoted by *competition*), which is equal to 1 if the development project faces above-average competition and 0 otherwise. The higher the competition is, the earlier the development will start. We also include the ratio of the land price to the housing price (*lp_hp*) and the 9-month Shanghai interbank offered rate (*shibor*). Both land price and interest rate can affect the development cost to a large extent. We expect developers that face higher land cost or financing cost will be more likely to develop to accelerate capital turnover.

We use the local population (*population*) and per capita GDP (*pergdp*) to control for local demand changes. To capture expectations about future house market conditions, we also include the historical average housing price returns in the shorter run ($avgyield_S$) and longer run ($avgyield_L$)[5], referring to the previous 6 and 18 months, respectively. Developers are expected to delay the development in anticipation of price increases in the near future. On the other hand, future expected price increases can lead to a greater hazard rate of development (Bulan et al., 2009). The intuition is that rising prices can provide capital gains that allow developers to overcome liquidity constraints, enabling them to pursue more profitable projects. The independent effect of $avgyield_S$ and $avgyield_L$ therefore remains an empirical question. In addition, in case we ignore some important fixed impacts, the developer fixed effects, seasonal fixed effects, and district fixed effects, referring to the local district of the land within the city, were added as further control.

The definition and summary statistics of the above variables are presented respectively in Table 2 and Table 3.

[Insert Table 2 and Table 3 here]

4. Empirical model

The hazard function provides appropriate tools for analysing the determinants of the time to the occurrence of an event, which in our context, is land development. Unlike the use of aggregate data in a reduced form supply equation (e.g., Holland et al., 2000), both property characteristics and

[5] The two variables can also deal with the concern that our price uncertainty measure is picking up factors related to periods of rapidly increasing or decreasing prices that may have an independent effect on development timing.

developer features can be well captured in the hazard function. This enables us to test the net effect of risk associated with policy uncertainty. We estimate a parametric hazard model in which a purchased land parcel is regarded as a "living" subject, and it "dies" once the development occurs on it. We specify the hazard (or probability) of "death" in a basic hazard model as follows:

$$h(t) = \exp(X'\beta)h_0(t) \quad (5)$$

and

$$X'\beta = \gamma_1 Policy\ uncertainty + controls \quad (6)$$

where $h(t)$ measures the conditional probability of development occurring at time *t,* which is routinely called the hazard rate, *X* (in the basic specification) compromises the policy uncertainty measure and control variables defined above. $h_0(t)$ is the baseline hazard[6] that defines the hazard rate when all explanatory variables are equal to 0. Developments that remain unlisted at the end of our sample period are treated as right censored.

The real option hypothesis predicts a negative relationship between policy uncertainty and the likelihood of development, that is, $\gamma_1<0$. To perform the two-step identification strategy, we expand the baseline hazard specification (equation (6)) into equation (7) by replacing the policy uncertainty measure with the price uncertainty measure and its interaction with the land revenue ratio. Interacting two continuous variables may complicate the interpretation of the results, then we turn the continuous land revenue ratio into three category variables: the land revenue ratio that falls in the first 25% quantile is categorised as the regime of low reliance on the land revenue, denoted by $landrev_l$, with the last 25% quantile categorised in the regime of heavy reliance on the land revenue (denoted by $landrev_h$); the land revenue ratio falling between the first and last 25% quantiles is categorised as the average land revenue reliance and is defaulted in the hazard model. Then $Landrev_H$ and $Landrev_L$ are interacted with the price uncertainty measure (vol), respectively, in equation (7). Because we argue that the higher the land revenue regime, the lower the policy uncertainty it is, π_2 is expected to be positive and π_3 to be negative to support the impact of the policy uncertainty. Lastly, we interact the state-owned developer dummy (soe) with each of the two interactive terms to further test whether the impact of policy uncertainty manifests itself heterogeneously between state-owned and non-state-owned firms. We also replace the policy uncertainty measure with the natural logarithm of the EPU Index and repeat Eq.(7) with the same control variables.

$$X'\beta = \pi_1 vol + \pi_2 vol * landrev_H + \pi_3 vol * landrev_L + \pi_4 vol * landrev_H * soe + \pi_5 vol * landrev_L * soe + controls \quad (7)$$

5. Empirical results

5.1 Baseline results

[6] We assume a Weibull baseline hazard which has the function form of $h_0(t)=\lambda p(pt)^{p-1}$, where p is the shape parameter to be estimated. The hazard of new project sale should increase with time because either keeping the land uncompleted or completed projects vacant would generate additional costs, such as financing and inventory expenses. Therefore, we expect $h_0(t)$ to increase monotonically with time, that is, $p>1$.

Table 4 presents the baseline regression results of the relationship between price uncertainty and real estate development. First of all, the hazard model is statistically significant, as indicated by the value of the Weibull parameter estimate, p. Specifically, p>1 at all standard significance levels. This outcome suggests a strongly increasing hazard of development over time that is consistent with theories and empirical observations. As shown in column (1), the price uncertainty measure alone shows negative but insignificant impact on the likelihood of development, inconsistent with the real option prediction. Likewise, Wang et al. (2016) find no delaying impact of the price uncertainty measure using a sample of developments in the Hangzhou city of China, which is also covered in our sample. Their explanation is that developers in China focus more on policy uncertainty rather than market uncertainty in exercising their real options. However, we find their excuse to be problematic because the price uncertainty measure they have used results from a combination of factors, which should include policy changes. Even if they have used the volatility of interest rates and money supply to proxy the policy uncertainty, the price uncertainty measure should include uncertainty resulting from policies other than monetary policies, such as land supply regulations. If the policy uncertainty remains a primary component of the price uncertainty, the absence of the delaying impact of price uncertainty in Wang et al. (2016) is likely to be caused by the counteractive effect of the local government's reliance on land leasing revenues. The credence of the argument could be checked by the following tests.

[Insert Table 4 here]

Among the control variables, we find no significant impact of the state-owned developer dummy and the size of the developer firm, while firms that grow fast adopts a fast development plan. At the expansion stage, it is wise for the developer to accelerate development so as to speed up capital return and occupy more market shares. On the demand side, increases in the short-term historical price return, population, and per capita GDP are associated with development accelerations. Likewise, the supply variables including the ratio of land price to housing price, interest rate, and competition from other developments are positively correlated to the likelihood of development. The three variables measuring development attributes show consistent delaying impact on development. That is, a luxury development, a phased development, or a large-size development is associated with significant development delays. One possible explanation is that these types of developments need longer periods of construction before listed on the market for sale.

5.2 The impact of policy uncertainty

Our interest mainly lies on the variable of price uncertainty and its interaction with the two land revenue variables. Column (1) of Table 5 reports the results interacting the price uncertainty measure with the two category variables of the land revenue ratio. The coefficient estimate on vol turns significant at the 1% significance level, while the interaction term on vol and $landrev_H$ registers a positive and significant coefficient estimate. This suggests that the impact of price uncertainty on the probability of development turns positive in the regime of a substantially high land revenue ratio, which supports the offsetting effect of heavy reliance on the land revenue on the uncertainty caused by policy changes. Ideally, the estimated coefficient on the interactive term of vol and $landrev_L$ should be significantly negative; it reports to be insignificant, however. Therefore, in the low and average regimes of land revenue ratio, price uncertainty shows similar delaying impacts on the likelihood of development. This provides evidence for the delaying impact of price uncertainty on the likelihood of development as predicted by the standard real option theory.

[Insert Table 5 here]

In column (2) of Table 5, we distinguish the impacts of price uncertainty not only in different regimes of land revenue ratio, but between state-owned and non-state-owned developers. Overall, we find similar results for non-state-owned developers as shown in column (1), while, in comparison, state-owned developers show expectedly greater sensitivity to changes in the land revenue ratio. The coefficient estimate on vol × soe is negative and significant at the 10% significance level, showing that state-owned developers in the average regime of land revenue reliance react to price uncertainty with delayed developments. The negative impact of price uncertainty is even stronger for state-owned developers in the regime of the least reliance on land revenue, which is supported by the significantly negative coefficient estimate on vol × $landrev_L$ × soe. Meanwhile, the positive and significant coefficient estimate on vol × $landrev_H$ × soe turns the delaying impact of price uncertainty into the impact of acceleration for state-owned developers in the high regime of land revenue reliance.

State-owned and non-state-owned developers differ not only in their close relationships with local officials, but in the access to loans, in particular when the government tightens its credit policy (Cull et al., 2015). Developing a housing project is a lengthy and costly exercise, and the financial cost adds additional cost to the exercise price of a real estate development, thus contributing to a lower estimated value of the development option (Marseguerra and Cortelezzi, 2009). If it is the financial advantage of state-owned developers that causes their greater sensitivity to policy-related uncertainty, such impact may not be exclusive to state-owned developers but other financially-rich firms. To differentiate the channels of the state-owned impact, we include a dummy variable (i.e., *hdebt*), which is equal to 1 if it is larger than the average value of the debt-to-asset ratio and 0 otherwise, to indicate developers with high financial pressure and interact it with the price uncertainty measure and the land revenue ratios. As reported in the last column of Table 5, though we find a significantly positive crossing impact between the high debt-to-asset variable and the price uncertainty measure, this impact is not distinguishable across local goverments in different regimes of land revenue reliance. Meanwhile, results on the varibles interacted with the state-owned dummy remain stable, which suggests that the sensitivity differences between state-owened and non-state-owned developers to policy uncertainty changes is unlikely to be caused by their financial advantages but other protections from the local government.

To sum up, the higher the regime of the land revenue reliance, the weaker the delaying impact of price uncertainty. The local government's reliance on the land leasing revenue reduces the impact of policy uncertainty on the rate of development in particular when the developer is state-owned, which contributes to a substantial decline in development delays in the face of uncertainty. On the one hand, the inclusion of the developer type reassures us that we have extracted a policy-related component from the overall price uncertainty, which is orthogonal to market forces. On the other hand, it provides us the predicted delaying impact of price uncertainty on land development, which Wang et al. (2016) failed to obtain with part of our sample.

Table 6 presents the results with the EPU Index. As shown in column (1), the coefficient on the EPU Index is positive and significant at the 10% significance level. Specifically, a 1% increase in the EPU index is associated with an increase in the likelihood of development equivalent to 0.15% of the average development rate in the sample. That means, the greater the future economic policy uncertainty, the higher the development rate will be, inconsistent with the real option prediction. In column (2) with the inclusion of the interaction term between the EPU Index and the state-owned dummy, both the interaction estimate and the coefficient estimate register insignificant signs. This suggests that the impact of the EPU Index on the rate of development is negligible and indistinguishable between state-owned and non-state-owned developers. One possibility is that the EPU Index is not measuring the type of uncertainty that is considered by a real estate developer in making their development decisions. In the future study, it may be considered to repeat the way of

building the EPU Index to create a real estate specific policy uncertainty index that can guide the developer in real estate development.

[Insert Table 6 here]

6. Conclusion

In this study, we analyse the impact of policy-related uncertainty on real estate development of China. We pay close attention to the way this impact manifests itself differently across cities and firms. To do so, we first utilize the local municipal government's reliance on land leasing revenues to isolate the impact of policy uncertainty from that of price uncertainty in the real estate market. Then we further identify the impact of policy uncertainty by distinguishing between state-owned and non-state-owned developers. The two steps allow us to extract variations in uncertainty resulting from policy changes that are not endogenous to market changes. Utilizing a parametric hazard model, we document a negative relationship between policy uncertainty and the likelihood of real estate development, which decreases with the local government's reliance on land revenues and the state-owned developer's political connections. In so doing, we provide empirical support for the existence of a causal link going from policy-related uncertainty to the developer's decision of real estate development.

Our results bring some insights to policy makers. While the motive of the government to stabilize the surging property prices should be welcomed by users who bought properties for consumption, the inconsistent and short-run policies have in fact brought an opposite result-that is, an increase in the volatility of future housing prices. This uncertainty increase contributes to development delays at least in the short run which does no good to drag down the housing price surges. Furthermore, it is interesting to note an unintended consequence of the land finance strategy. We find that local government's reliance on land revenues could accelerate the development by reducing the uncertainty associated with policy changes. Overall, for policies designed to increase housing supply, one has to ensure that the land is not simply added to the developer's land bank but is actually developed and the property is sold within a reasonably period of time. Though there are written regulations, our results show limited evidence for their effectiveness in performing the task.

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Table 1■ The central policy changes in China's housing market between 2003-2016

Date	Policy name	Tools	Direction
Jun 2003	121 Directives: Directives to further improve the management of real estate credit	Credit control House purchase: MR-2, DP-2	Tighten
Mar 2004	The Regulation on Transferring the Use Right of State-Owned Construction Land by Tender, Auction, and Listing	Land: all land lease transactions must go through the tender/auction/listing system	Tighten
Sep 2004	Guidance for commercial banks to improve risk management of real estate lending	Credit control	Tighten
Oct 2004	Decision on Deepening Reform and Tightening Land Management	Land: RUC	Tighten
Mar 2005	National 8 Rules	House purchase	Tighten
Apr 2005	New National 8 Rules	House purchase	Tighten
Sep 2005	Directive to improve the risk management of trusts investment	Credit control	Tighten
May 2006	National 6 Rules, National 15 Rules	House purchase: T-RS, DP-1	Tighten
Sep 2007	927 New Policy	House purchase: DP-2, MR-2	Tighten
Sep 2007	Directive to Improve the management of the commercial real estate credit	Credit control	Tighten
Jul 2008	Directives to use financial approaches to improve economical and intensive land use	Credit control	Tighten
Oct 2008	1022 Rules	House purchase: DP, MR	Relax
Dec 2008	National 13 Rules	House purchase: T-RS, DP-2, MR-2, T-O	Relax
Feb 2009	Directives to improve the healthy development of the real estate industry		Tighten
Sep 2009	Directives to further improve credit management	Credit control	Tighten
Dec 2009	National 4 Rules	House purchase: T-RS	Tighten
Dec 2009	Directives of Land and Resources Ministry on Strengthening the Supply of and Supervisions on Property Land Use	Land: TR	Tighten
Jan 2010	National 11 Rules	House purchase: DP-2, T-RS	Tighten
Jan 2010	Interim measures for the administration of working capital loans	Credit control	Tighten
Apr 2010	New National 10 Rules	House purchase: DP-1, DP-2, MA-3, MR-2, MA-NSH	Tighten
Sep 2010	929 Rules	House purchase: DP-1, MA-3	Tighten
Sep 2010	Notification on Further Strengthening Control on Property Land Use and Construction Management by State Land and Housing Ministries	Land: DEV	Tighten
Jan 2011	New National 8 Rules	House purchase: T-RS, DP-2	Tighten
Feb 2013	National 5 Rules	House purchase	Tighten
Sep 2014	930 New Policy	House purchase: MR-1, DP-2, MR-2	Relax
Mar 2015	330 New Policy	House purchase: DP-2, DP-PFL-1, DP-PFL-2	Relax

DP: Down payment (all houses); MR: Mortgage rate (all houses); DP-1: Downpayment (first house); MR-1: Mortgage rate (first house); DP-2: Downpayment (second house); MR-2: Mortgage rate (second house); DP-PFL-1: Ceiling of the ratio of PFL to total value (first house); DP-PFL-2: Ceiling of the ratio of PFL to total value (second house); T-RS: Tax on resale; T-O: Other taxes; MA-NSH: Mortgage availability (without hukou); TR: Land transfer fee; DEV: development schedule; RUC: rural-urban land conversion

Table 2■ Variable definition

Variables	Definitions
vol	Monthly variance estimate of the city from Generalized Autoregressive Conditional Heteroskedasticity (GARCH(1,1)) model
EPU	The Economic Policy Uncertainty Index for China built by Davis et al. (2019) through text mining on mainstream newspapers
landrev	The ratio of the annual total granted land revenue to local government's annual total fiscal revenue/expenditure
$landrev_L$	1 if the land revenue ratio falls in the first 25% quantile; otherwise, 0
$landrev_H$	1 if the land revenue ratio falls in the last 25% quantile; otherwise, 0
soe	1 if the project is developed by a state-owned developer; otherwise, 0
firmsize	The natural logarithm of the total asset value of the developer lagged by one year (10^8 RMB)
firmgrowth	The year-on-year percentage change in asset value
population	The natural logarithm of the population in the city
pergdp	The natural logarithm of per capita GDP in the city
$avgyield_S$	Average monthly housing price return in previous 6 months in the city
$avgyield_L$	Average monthly housing price return in previous 18 months in the city
competition	1 if the project faces above-average competition from competing projects within a 1km-circle; otherwise, 0
shibor	The 9-month Shanghai Interbank Offered Rate
lp_hp	The ratio of the average land price to the average housing price in the city
phasing	1 if the project has multiple phases; otherwise, 0
fBuildArea	The natural logarithm of building floor area within the project
luxury	1 if the project is a villa; otherwise, 0

Table 3■ Summary statistics

Variables	Mean	Max	Min	S.D.
vol	2.835	11.196	0.685	1.056
logEPU	4.683	5.724	3.843	0.270
landrev	0.627	2.220	0.018	0.331
$landrev_H$	0.247	1	0	0.431
$landrevl_L$	0.224	1	0	0.418
soe	0.433	1	0	0.495
firmsize	6.788	9.511	-3.045	1.289
firmgrowth	0.260	7.038	-0.725	0.413
$avgyields_S$	0.065	0.792	-0.449	0.144
$avgyield_L$	0.081	0.416	-0.111	0.114
polulation	0.005	0.526	-0.043	0.019
pergdp	2.375	3.898	0.368	0.441
lp_hp	0.352	1.066	0.074	0.159
shibor	4.120	5.247	1.638	0.905
competition	0.187	1	0	0.390
phasing	0.347	1	0	0.476
fBuildArea	3.453	6.215	-0.343	1.019
luxury	0.072	1	0	0.258

See Table 2 for detailed variable definitions.

Table 4■ Policy uncertainty and real estate development: first-stage

	(1)	
Dependent variable: the hazard rate at time t for property i		
vol	-0.066	(-0.25)
Control variables		
soe	-0.105	(-0.23)
firmsize	-0.080	(-0.91)
firmgrowth	0.138*	(1.65)
$avgyield_S$	0.962***	(4.58)
$avgyield_L$	0.197	(0.57)
polulation	2.003***	(6.23)
pergdp	2.756***	(8.35)
lp_hp	0.349*	(1.60)
shibor	0.103***	(3.08)
competition	0.136****	(3.25)
phasing	-0.184***	(-3.46)
fBuildArea	-0.183***	(-7.16)
luxury	-1.013***	(-9.95)
Constant	-25.360***	(-8.60)
Weibull parameter ρ [standard error]	1.866 [0.023]	
Log likelihood	-8009	
No. of Events	1,355	
Observation	41,458	
Firm fixed effects	Yes	
Season fixed effects	Yes	
District fixed effects	Yes	

The estimated hazard model is $h(t)=\lambda\rho(\lambda t)^{\rho-1}exp(X'\beta)$. Coefficients are reported in real form (β) and a standard deviation change in X leads to a $[exp(1*\beta*\rho)]-1$ percent change in the hazard rate $h(t)$. Z-statistics are reported in parenthesis (except for where noted).

* Significant at 10%; ** Significant at 5%; *** Significant at 1%

Table 5■ Policy uncertainty and real estate development: second stage

	(1)		(2)		(3)	
Dependent variable: the hazard rate at time t for property i						
vol	-0.905***	(-2.74)	-0.732**	(-2.08)	-0.146	(-0.36)
vol × $landrev_H$	2.739***	(5.41)	2.093***	(3.43)	2.372***	(3.36)
vol × $landrev_L$	-0.878	(-1.48)	0.806	(1.12)	0.439	(0.46)
vol × $landrev_H$ × soe			2.617**	(2.60)	2.435**	(2.49)
vol × $landrev_L$ × soe			-3.337**	(-3.33)	-3.400***	(-3.33)
vol × soe			-1.257*	(-1.94)	-1.371**	(-2.11)
vol × $landrev_H$ × hdebt					-0.763	(-0.98)
vol × $landrev_L$ × hdebt					0.483	(0.54)
vol × hdebt					0.770***	(2.87)
$landrev_H$ × soe			-0.645*	(-1.95)	-0.590*	(-1.84)
$landrev_L$ × soe			0.539*	(1.87)	0.595**	(2.03)
$landrev_H$ × hdebt					0.313	(1.15)
$landrev_L$ × hdebt					0.124	(0.49)
Weibull parameter ρ [standard error]	1.862 [0.023]		1.887 [0.023]		1.894 [0.023]	
Log likelihood	-7976		-7951		-7943	
No. of Events	1,355		1,355		1,355	
Observation	41,458		41,458		41,458	
Control variables	Yes		Yes		Yes	
Firm fixed effects	Yes		Yes		Yes	
Season fixed effects	Yes		Yes		Yes	
District fixed effects	Yes		Yes		Yes	

The estimated hazard model is $h(t)=\lambda\rho(\lambda t)^{\rho-1}exp(X'\beta)$. Coefficients are reported in real form (β) and a standard deviation change in X leads to a $[exp(1*\beta*\rho)]-1$ percent change in the hazard rate $h(t)$. Z-statistics are reported in parenthesis (except for where noted).

* Significant at 10%; ** Significant at 5%; *** Significant at 1%

Table 6■ Policy uncertainty and real estate development: EPU

	(1)		(2)	
Dependent variable: the hazard rate at time t for property i				
logEPU	0.138*	(1.95)	0.104	(1.16)
logEPU × soe			0.082	(0.62)
Weibull parameter ρ [standard error]	1.880 [0.023]		1.873 [0.023]	
Log likelihood	-7888		-7862	
No. of Events	1,355		1,355	
Observation	41,458		41,458	
Control variables	Yes		Yes	
Firm fixed effects	Yes		Yes	
Season fixed effects	Yes		Yes	
District fixed effects	Yes		Yes	

The estimated hazard model is $h(t)=\lambda\rho(\lambda t)^{\rho-1}exp(X'\beta)$. Coefficients are reported in real form (β) and a standard deviation change in X leads to a $[exp(1*\beta*\rho)]-1$ percent change in the hazard rate $h(t)$. Z-statistics are reported in parenthesis (except for where noted).
* Significant at 10%; ** Significant at 5%; *** Significant at 1%

Figure 1■ The distribution of the duration of undeveloped time (in months)

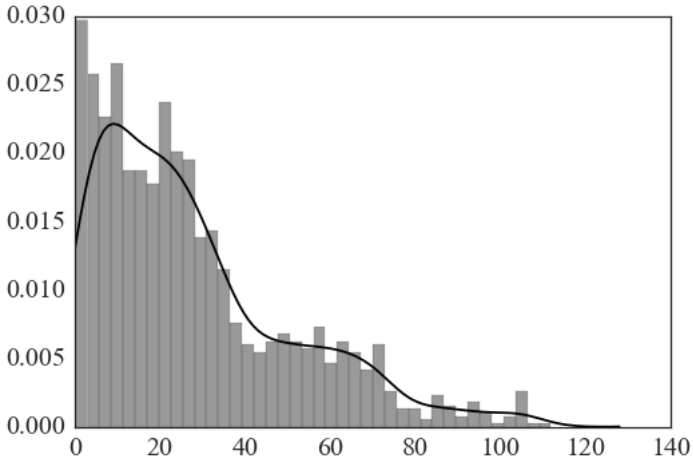

Figure 2■ The EPU Index for China and central government regulations in China's real estate market: 2006-2017