Securitization of Assets with Payment Delay Risk: A Financial Innovation in the Real Estate Market*

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Abstract

We study a new type of securitization, mortgage-receivable-backed securities (MRBSs) issued by real estate developers. Unlike traditional mortgage-backed securities (MBSs), the major risk of underlying assets of MRBSs is payment delay instead of default and prepayment. Using unique loan-level data, we estimate proportional hazard models and detect factors that affect the risk of underlying assets of MRBSs, including bank characteristics, property-loan-household characteristics, local market conditions, and macroeconomic conditions. Especially, we find that the effects of house prices and LTVs on MRBS risk are the opposite of those on traditional MBS risk. Based on the estimates, we simulate cash flows of an underlying-asset pool and analyze the shortfall risk of the corresponding security tranches. We find that the securitization process imposes a natural adverse selection on the underlying assets. Our analyses provide a benchmark for conducting appropriate security designs based on the composition of the underlying asset pool, increase the transparency for investors on the risk pattern of MRBSs, and provide implications for pricing and regulation.

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1. Introduction

Asset-backed securitization serves firms as an important financing source other than bank loans, traditional corporate bonds, and stocks. Firms can package part of their assets that are short dated, of high quality, and transparent to investors (e.g., receivables) as underlying asset pools to issue Asset-Backed Securities (ABSs). The underlying asset pools are moved to a bankruptcy-remote special purpose entity (SPE). Because repayment on ABSs comes from the packaged assets backing the securities and not from the issuing firms, the risks associated with the ABSs are isolated from the bankruptcy risk of the issuing firm; accordingly, the securities are "bankruptcy-remote", and there is less information asymmetry between issuers and investors (Ayotte and Gaon, 2011). This security design helps reduce the borrowing costs for the issuing firms, especially in financial markets with great imperfections.[1]

For the asset-backed securitization examined by previous research, the major risk of the underlying assets is default risk. In contrast, we study a form of asset-backed securitization for which the major risk of the underlying assets is payment delay risk. This type of underlying assets is supposed to be of higher quality.

Default risk is associated with scheduled payments with clear due dates specified by the contract; after defaults, the entitled payments may not be able to be received or fully received. The underlying assets of traditional ABSs include credit cards, auto loans, student loans, equipment leases, firm receivables, and mortgages, which have clearly specified payment due dates and thus default risks. In contrast, delay risk is associated with entitled future payments

[1] Previous studies have provided empirical evidence that the funding costs of ABSs are lower than those of comparable corporate bonds (Marques and Pinto, 2020). Previous studies have also found that asset-backed securitization can increase insuring firms' abnormal stock returns and market values (Lemmon, Liu, Mao and Nini, 2014), reduce the probability of facing credit constraints and the costs of bank financing for non-constrained firms (Kaya and Masetti, 2019), and increase CEO compensation (Riachi and Schwienbacher, 2013).

or scheduled future actions without a clearly specified due date; the uncertainty is how long it takes to receive the entitled payments. Delay risk is another important type of risk that exists in various parts of the financial market.[2]

In this paper, we study mortgage-receivable-backed securities (MRBSs), a financial innovation that appeared in 2015 in the real estate finance market of China, and they have grown rapidly along with the development of MBSs and other ABSs in China. The issuing volumes of MRBSs issued in 2015, 2016, 2017, and 2018 are 0.6, 14.50, 18.32, and 48.96 billion RMB, respectively. The MRBS market in China is believed to have a potential of hundreds of billions of RMB per year.

Unlike MBSs, MRBSs are issued by real estate developers rather than mortgage lenders. After a new property transaction, the property purchaser pays the down payment to the real estate developer. The difference between the property purchasing price and the down payment will be financed through a mortgage. However, developers do not receive the mortgage immediately. As shown in Figure 1, after the property transaction date, the house buyer first submits her/his mortgage application to a bank; second, the bank evaluates the application and approves it; and third, there is a delay from the date on which the bank approves the mortgage application to the date on which the bank releases the money to the developer. The entire process can last several months or even more than a year; the average is approximately 90 days, and the standard deviation is approximately 100 days. In the U.S.,

[2] For example, in the mortgage market, there is a random delay between default and foreclosure; lenders can obtain proceeds and partially recover losses only after foreclosure; therefore, in addition to foreclosure losses, the delays affect the value of MBSs to investors (Ambrose, Buttimer and Capone (1997); Pence (2006); Zhu and Pace (2015); Cordell, Geng, Goodman and Yang (2015), Chan, Haughwout, Hayashi and Van der Klaauw (2016); An and Cordell (2019)). In the sovereign debt market, there is a very long delay between initial defaults and final negotiated restructuring (Benjamin and Wright (2018)). In the insurance market, there is a random delay between the occurrence of a claim and the settlement (Waters and Papatriandafylou (1985); Boogaert and Haezendonck (1989); Yuen et al. (2005); and Dassios and Zhao (2013)), especially for car accidents with bodily injuries; this delay is valuable to insurance companies because they only need pay proceeds after settlement. There are also delays by firms in calling their convertible bonds when conversion can be forced, which affect both bondholders and shareholders' wealth (Grundy and Verwijmeren (2016)). In high-frequency trading, there are delays from a trading decision to the resulting trade execution and the reporting of the trade, which affect the trading strategies and the profitability of dealers, high-frequency traders, and low-frequency traders (Abreu and Brunnermeier (2002); Stoll and Schenzler (2006); Moallemi and Saglam (2013); Foucault, Hombert and Rosu (2016)).

there is also a contract-to-close period after ratifying a house purchase contract: the contract-to-close period for house purchases with mortgages is usually 30-60 days; the contract-to-close period for cash-only house purchases is usually within one month. Thus, both in China and the U.S., after a house purchasing transaction, the difference between the property purchasing price and the down payment becomes a receivable to a seller; the payment delays of those receivables are longer in China than in the U.S.

The time it takes for developers to obtain these mortgage receivables from banks is a random variable and is affected by a number of factors. Real estate developers dislike the delay and the uncertainty of how long the delay is going to be. First, developers' profitability heavily depends on their turnover rates, which can be reduced by delays of cash inflows. Second, as developers usually have high financial leverage, delays of cash inflows will increase their financial distress to repay their construction debt; and the uncertainty of the delay length will increase the requirement on developers' costly cash holding in working capital management. Consequently, real estate developers seek to issue MRBSs through security companies to institutional investors, using a pool of numerous mortgage receivables as the underlying assets.

The issuing developer will immediately obtain cash inflows from the sales of MRBSs; the receivables received later will be used as the principal and interest payments to the MRBS investors. The maturities of MRBSs are usually 1-3 years; interest is paid every six months, and the principal is paid at maturity. If at maturity, the receivables that have arrived are not enough to cover the principal due, there will be shortfalls in the payments to investors. The delay is thereby transferred from the developer to the MRBS investors; the cost the developer needs to pay the investors is the MRBS yield. Currently, MRBSs can only be purchased by institutional investors.

Although MRBSs are related to mortgage lending, they are different from traditional MBSs in several aspects. Table 1 displays the comparison between MRBSs and MBSs in several dimensions. First, the cash flows entering the underlying asset pool backing MBSs are mortgage borrowers' monthly principal and interest payments, whereas the cash flows entering the underlying asset pool backing MRBSs are the release of mortgage receivables from banks to real estate developers. Second, through MBSs, it is mortgage lenders who obtain liquidity for new lending activities and transfer the default and prepayment risks to government sponsored enterprises (GSEs, such as Fannie Mae and Freddie Mac) and the secondary market investors; in contrast, through MRBSs, it is real estate developers who obtain liquidity for developing activities and transfer the mortgage receivable delays to the security investors. Third, the underlying assets of MRBSs mainly have only delay risk and have almost no default risk (see Section 2.1 for details).

Because MRBSs provide the issuing developers another substantial funding source with a lower borrowing cost compared to bank loans (see Figure 2), the introduction of MRBSs had a dramatic impact on the real estate development industry in China. Using the land auction data and the firm securitization data, which are publicly available, Ma (2020a) conducted difference-in-difference analyses and found that after securitization, developers become more aggressive in purchasing land and entering new cities, and engage more in strategic alliances with other developers in a construction project to expand their businesses.

In this paper, using unique proprietary data from one of the top ten national real estate developers, we provide a systematic analysis regarding what factors can affect the mortgage receivable delays. We estimate a Cox proportional hazard model, and the empirical results indicate that bank characteristics, property-loan-household characteristics, local market conditions, and macroeconomic conditions all matter in affecting the mortgage receivable delays. Regarding bank characteristics, the length of delays is decreasing in bank liquidity and loan-deposit interest spreads and is increasing in banks' lending caution, returns on assets (ROA), and reliance on wholesale funding. Regarding property-loan-household characteristics, the length of delays is decreasing in borrowers' creditworthiness and incentive to act quickly in applying for mortgages; commercial properties experience longer delays than residential properties. Regarding local market conditions, the length of delays is decreasing in the bank's local market presence and is increasing in the local house prices and unemployment rates. Regarding macroeconomic conditions, the length of delays is decreasing in the monetary supply.

Based on the estimates, we conduct Monte Carlo simulations for the cash flow of a mortgage receivable pool and risk analyses for MRBS tranches. These analyses provide the benchmark for developers and underwriters (security companies) in designing MRBSs, for investors in making investment decisions, and for the regulator in making regulatory policies. Unlike many previous studies that used the security-level returns and default events to analyze the risk of ABSs and MBSs, we use a "bottom-up" approach to analyze MRBSs: first, estimate and simulate the risk of individual underlying assets; second, aggregate up to the security-level risk.

The empirical results have several important implications. To begin with, while the effects of some important factors on mortgage default risk and thereby on the risk of MBSs are well known, the effects of these factors on mortgage receivable delay risk and thereby on the risk of MRBSs could be either in the opposite direction or in the same direction but through different mechanisms. Our study provides empirical evidence for these factors, including house prices, local unemployment rates, loan-to-value ratios (LTV), and borrowers' creditworthiness. Consequently, MRBSs could be an excellent financial tool to hedge against the risks of other securities (such as MBSs), and the introduction of MRBSs to the financial market could significantly improve the diversification of the market.

Table 2 summarizes the comparison between the effects of these factors on MBSs and on MRBSs. First, an increase in house prices reduces the mortgage default risk and thereby reduces the risk of MBSs; in contrast, an increase in house prices can be associated with prolonged mortgage receivable delays by banks because banks need to deal with more mortgage applications and face a higher demand of money, which tends to increase the risk of MRBSs. Second, an increase in local unemployment rates raises the probabilities of illiquidity-triggered default for mortgages; in contrast, regarding the effect on MRBSs, an increase in local unemployment rates can prolong the mortgage receivable delays by banks because unemployment can reduce the supply of deposits from the household sector, a major funding source for banks. Third, a higher LTV is associated with a high probability of strategic default for mortgages because of a lower home equity; in contrast, a higher LTV can shorten homebuyers' delays in mortgage application because of a greater incentive to act fast.

Fourth, mortgage borrowers with higher creditworthiness have lower default risk, which reduces the risk of MBSs; in contrast, regarding the effect on the risk of MRBSs, mortgage receivables associated with these borrowers may have shorter delays because banks take less time in screening and selecting for these borrowers.

The second implication of our empirical results is for the regulator. Although the underlying assets of MRBSs mainly have only delay risk and almost no default risk and are thus supposed to be high-quality assets, we find that there are large heterogeneities in delays across different mortgage receivables. Moreover, we find that many factors from multiple sources (banks, homebuyers, and local markets) can significantly affect individual mortgage receivable delays; consequently, in contrast to MBSs, it is difficult to standardize the underlying asset pools for issuing MRBSs.[3] Therefore, for investors to accurately analyze the risk of MRBSs, the security level characteristics (e.g., overcollateralization rate, equity tranche proportion, unsophisticated criteria for mortgage receivables to enter the asset pool) currently released by developers to investors are far from sufficient. The regulator should require developers to release information on the composition of the asset pool (i.e., the distribution of all the individual-level characteristics that can significantly affect the delay risk of an individual mortgage receivable) to investors and bring more transparency to the financial market.

Third, our estimation and simulation results imply a natural adverse selection effect of securitization on the quality of underlying assets. In the estimation sample (including both securitized and nonsecuritized receivables), 95% of receivables were received within two years after the property purchase dates. However, in the securitized asset pool, based on our simulation, only 78% to 81% receivables will be received within two years after the securitization date. The reason is that securitized receivables are those that have not been received by the securitization date since the property transaction dates. Conditional on having not been received by the securitization date, those receivables tend to have longer delays than

[3] In the U.S., the underlying asset pools for issuing MBSs are highly standardized; mortgages in the same pool are similar in several major characteristics that affect default and prepayment risks (e.g., credit score, loan-to-value (LTV) ratio, and debt-to-income (DTI) ratio).

usual. Therefore, even if developers do not intentionally select low-quality receivables to securitize, the securitization process itself will impose a natural adverse selection on the underlying assets of MRBSs.

In contrast, traditional mortgage-backed securitization (of which the major risk of underlying assets is default risk) does not have this problem. Although securitized mortgages are those that have not been defaulted by the securitization date since the origination dates (usually ranging from several months to several years), conditional on having not been defaulted by the securitization date, those mortgages tend to stay alive for a longer period and hence make more monthly principal and interest payments.

Correspondingly, there could be two policy implications regarding how to mitigate this adverse selection effect for MRBSs. First, in current practice, only receivables that have not been delayed for more than 12 months since the property purchase dates can enter the underlying asset pool for securitization. The regulator can consider tightening this criterion. Second, increasing overcollateralization rates of securitization can help reduce the risk exposure of security investors.

To the best of our knowledge, this study is the first to formally examine MRBSs, a financial innovation in the real estate market. We provide thorough analyses regarding what factors from what sources through which possible mechanisms affect the delay risk of mortgage receivables and thereby the shortfall risk of MRBSs. Moreover, little previous research has studied securitization of assets with mainly delay risk in general.

The remaining portion of this paper is organized as follows. In Section 2, we provide the industry background. In Section 3, we review the relevant literature and discuss our contribution to the literature. In Section 4, we describe the data used in this paper. In Section 5, we provide a systematic discussion regarding what factors from what sources and through which mechanisms could affect mortgage receivable delays. In Section 6, we discuss the econometric methodology (Cox proportional hazard model). In Section 7, we provide the estimation results. Based on the estimates of the model governing the probability distributions of individual mortgage receivable delays, we conduct Monte Carlo simulations and risk analyses for MRBSs. Section 8 provides an overview of MRBS designs and the simulation procedures. Section 9 discusses the pool-level simulation results and adverse selection. Section 10 discusses the security-level simulation results. Section 11 discusses the counterfactual analyses. Then, we conclude in Section 12.

2. Background

2.1. Risk of the Underlying Assets

The major risks of the underlying assets for MBSs are the default and prepayment risks of mortgage borrowers, whereas the major risks of the underlying assets for MRBSs are the payment delay risks of banks and house buyers. There are almost no default observations in our mortgage receivable data.

On the one hand, because banks do not default on their payment obligations unless they go into bankruptcy, the default risk from banks is not a major concern for mortgage receivables, especially in China, in which banks are backed by the government.

On the other hand, the default risk from house buyers is also not a major concern for mortgage receivables. First of all, the house buyers have incentives to do their best to apply for mortgage loans. If they fail to obtain mortgages, they are obligated to pay the remaining house prices to developers from their own pockets. Meanwhile, the possibility that a house buyer cannot obtain any mortgage is very low. Developers usually conduct some preliminary screening when selling properties; if developers highly doubt the house buyer's ability to obtain a mortgage, they will not sell the property to the buyer. Furthermore, if a house buyer is rejected by a bank, developers would recommend another "less-tough" bank to the house buyer to apply a mortgage.[4]

[4] Although there is a due date of the full payment of the property price specified in purchasing contracts, developers seldom punish buyers immediately if the developers do not receive the full payment on the due date, as there are many other factors (such as factors from banks) that can cause the delays. Developers specify the full payment due date in purchasing contracts mainly for imposing some pressures on buyers to apply for mortgages quickly. If a mortgage application cannot be approved by a bank, developers would recommend another bank to the buyer. This flexibility in practice is in some sense similar to the fact that in recourse states in the U.S., lenders may still not choose to claim the deficiency judgment when the foreclosure sale proceeds cannot cover the unpaid mortgage balance.

One may argue that if house prices decline dramatically after house purchases, house buyers may default on their mortgages. However, mortgage defaults do not generate risk to MRBSs. Once mortgages are originated by banks, developers have already received the money and will use the money to pay the coupon and principal to MRBS investors. Mortgage defaults by borrowers only cause losses to banks or MBS investors (if banks securitize their mortgages into MBSs).

Another concern is that if house prices dramatically decline after house purchase transactions (when down payments are paid) but before mortgage applications, house buyers may neither apply for mortgages nor pay the remaining house prices from their own pockets. In this case, however, developers can claim the properties and retain or partially retain the down payments; another possibility is that as many new properties in China are sold through preselling, developers can hold the properties rather than deliver them to the house buyers, meanwhile retaining or partially retaining the down payments. Unlike the U.S., many cities in China require the down payment percentage to be above 50%. Consequently, the default risk from house buyers due to house price declines is very low.

Even if some house buyers cannot obtain a mortgage or regret on the house purchase contract and decide not to originate a mortgage, MRBS investors can redeem part of their securities corresponding to the monetary amount of these receivables. Therefore, MRBS investors are not exposed to the risk from house buyers.

2.2. Risk of the Securities

Although the underlying assets of MRBSs are unlikely to default, in principle, MRBSs might default because if many mortgage receivables in an underlying asset pool have delays longer than the term to maturity of the MRBS, the pool will not have enough cash to pay the coupon and principal to the MRBS investors at the maturity date. However, in this case, the receivables in the pool that arrive after the maturity date of the security must be used to repay the investors to cover the previous shortfall. If banks go bankrupt and cannot deliver the money to the developer at all (which is unlikely to happen), the developer is obligated to use its own free cash to repay the investors.

Therefore, in principle, the final protection to MRBSs is the issuing developers' solvency, which is also the major protection to firm loans. However, because there is a "firm-bankruptcy-remote" underlying asset pool supporting the MRBSs and the underlying asset risk is much lower than the developers' bankruptcy risk, the probability that MRBSs investors need to resort to the issuing developers' solvency is almost zero. Correspondingly, the risk of MRBSs mainly depends on the underlying asset risk and is not affected by the developers' bankruptcy risk; and the interest rates of MRBSs are much lower than those of developers' construction loans.[5]

In this paper, we first estimate the delay risk of underlying assets using a developer's mortgage receivable data during 2007-2015 and obtain the probability distribution of the delay length for each receivable given its characteristics. Based on these distributions, we conduct simulations for an MRBS backed by a mortgage receivable pool constructed in 2015. We simulate the shortfall risk that the underlying asset pool does not have enough cash to pay the coupon and principal to the MRBS investors at the maturity date.

This shortfall risk can be viewed as a proxy for the entire risk of an MRBS because the underlying asset pool is "bankruptcy remote" and the issuing developer's bankruptcy risk has little effect on the MRBS risk. If the MRBS is designed appropriately (i.e., the term to maturity of the MRBS can cover the delays of most receivables in the underlying asset pool and the overcollateralization rate is set appropriately), the shortfall risk should be much lower than the developer's bankruptcy risk. The magnitude of the shortfall risk of an MRBS compared to the magnitude of the issuing developer's bankruptcy risk will determine the discount of the MRBS interest rates relative to the interest rates of the developer's construction loans.

2.3. Why MRBSs emerged in China

There are two major reasons why MRBSs emerged in China and have great potential. First, in China, there exist many large real estate developers with massive sales each year. Because

[5] In China, there are no Government Sponsored Enterprises (GSEs) such as Fannie Mae and Freddie Mac to provide additional protections to investors.

issuing MRBSs incurs a large fixed cost, it is only profitable for large developers with a substantial amount of mortgage receivables. On the one hand, the Chinese real estate development market is large. China is experiencing a rapid urbanization process with a large migration from rural areas to urban areas and a dramatic transformation of rural areas into urban areas. Cities are growing in population and expanding in size at an extremely high speed, which generates a massive new housing demand. Consequently, a large proportion of house transactions each year are new houses sold directly from developers rather than existing houses sold by previous individual owners. With the strong housing demand in the emerging economy of China, together with a huge amount of hot money rushing into the real estate market because of the lack of other good investment opportunities in the highly regulated emerging financial system of China, house prices in most cities grow rapidly. On the other hand, the Chinese real estate development industry is relatively concentrated. The market shares of the top 10 and top 100 developers in 2016 were 18.6% and 40.8%, respectively. As shown in Figure A.1 in the Online Appendix, market concentration is increasing each year. Figure A.2 in the Online Appendix shows the average annual profits and sales of the top 100 developers. In 2016, there were 131 developers with sales of more than 10 billion RMB.

The second reason for the emergence and great potential of MRBSs in China is that most real estate developers have high financial leverages. As the real estate developing industry is a capital-intensive industry and China's real estate market is growing at an extremely high speed, the profitability and growth speed of a real estate developer heavily depends on its debt availability, funding costs, liquidity, and turnover rates. A break in the cash flow chain is crucial to a developer expanding its business. Therefore, developers have a strong desire to issue MRBSs in order to access the money as soon as possible and reduce the uncertainty of payment delays, even at the expense of paying yields to MRBS holders.

The first MRBSs in China were issued on December 16, 2015. Subsequently, the market continued to grow rapidly. The volumes of MRBSs issued in 2015, 2016, 2017, and 2018 were 0.6, 14.50, 18.32, and 48.96 billion RMB, respectively. The MRBS market in China is believed to have a potential of hundreds of billions of RMB per year. The rapid growth of the MRBS market accompanied the development of the ABS and MBS markets in China. As an emerging country, China launched asset securitization in 2005. The first two MBSs were issued in 2005 and 2007 with small volumes. After the 2007 U.S. financial crisis, both the government and the financial sectors adopted a conservative attitude toward asset securitization. Consequently, no MBS was issued until 2014. After 2012, the ABS practice resumed and grew gradually. In 2014 and 2015, due to a series of policy changes that significantly simplified the process of issuing ABSs and MBSs, the securitization markets started to grow at a dramatically higher speed.[6] The volumes of MBSs issued in 2014, 2015, and 2016 are 6.81, 32.95, and 139.86 billion RMB, respectively.

Although MRBSs play a very important role in the Chinese real estate market and the transaction volume is growing rapidly, the MRBS market is still far from mature. Unlike MBSs in the U.S., the underlying asset pools for issuing MRBSs are not standardized; mortgage receivables with different characteristics are pooled into the same packages. There have not been thorough analyses regarding what factors from what sources through which mechanisms could affect the risk of the underlying assets and thereby the backed securities. The financial investment market also lacks transparencies of the compositions of mortgage receivables in the underlying asset pools along the dimensions of those factors.

3. Literature

To the best of our knowledge, this study is the first to formally analyze MRBSs, a financial innovation in the real estate market. Moreover, little previous research has studied securitization of assets with mainly delay risk in general. However, our study complements several important strands of literature.

[6] In 2013, the China Securities Regulatory Commission issued Administrative Rules for Asset Securitization by Security Companies, followed by the Shanghai Stock Exchange and Shenzhen Stock Exchange issuing more detailed instructions. In 2014, the regulation procedure for ABS issuing was changed from "Examine and Approve" to "Put on File", which significantly accelerated the ABS issuing process. In 2015, the regulation procedure was further changed to "Register at the Central Bank".

First, a large strand of literature has analyzed the default and prepayment risks of mortgages and the resulting risks of MBSs.[7] Unlike those papers, we analyze the delay risk of mortgage receivables and the resulting risk of MRBSs. MRBSs is a new type of securitization in the real estate market that has never been examined before.

Second, this study complements the literature that analyzed the risk of different forms of securitization or financial innovation, including CDOs, collateralized mortgage obligations (CMOs), commercial mortgage-backed securities (CMBSs), financial innovations for fixed-rate mortgage contracts, ABSs, credit default swap (CDS), asset-backed commercial paper conduits, and collateralized loan obligations (CLOs). [8] While the major risks of the underlying assets of the forms of securitization examined by previous studies are default risks, the major risks of the underlying assets of the form of securitization examined in our study are delay risks.

Third, this study also contributes to the literature on the adverse effect of securitization on underlying asset qualities. It has been documented that mortgage-backed securitization had a negative effect on lenders' ex ante screening efforts (Maddaloni and Peydro (2011); Keys, Mukherjee, Seru and Vig (2010); Keys, Seru and Vig (2012); Rajan, Seru and Vig (2015); Vanasco (2017)) and their ex post monitoring efforts (Wang and Xia (2014) and Jiang, Nelson and Vytlacil (2013)), which is believed to be one of the major driving forces that caused the 2007 financial crisis. Demiroglu and James (2012) found that a mortgage originator's affiliation with the sponsor of a securitization (having "skin in the game") can mitigate this adverse effect. Agarwal, Chang and Yavas (2012) and Albertazzi, Eramo,

[7] For example, Kau, Keenan, Muller and Epperson (1995), Deng, Quigley and Order (2000), Clapp, Goldberg, Harding and LaCour-Little (2001), Clapp, Deng and An (2006), Kau, Keenan and Li (2011), Bajari, Chu, Nekipelov and Park (2013), Ma (2014), Corbae and Quintin (2015), Campbell and Cocco (2015), and Fang, Kim and Li (2016) on mortgages; and Dunn and McConnell (1981a and 1981b), Schwartz and Torous (1989), Stanton (1995), Boudoukh, Whitelaw, Richardson and Stanton (1997), Longstaff (2005), Lugo (2014), and Piskorski, Seru and Witkin (2015) on MBSs.

[8] For example, Coval, Jurek and Stafford (2009), Longstaff and Rajan (2008), and Chernenko (2017) on CDOs; McConnell and Singh (1994) on CMOs; Titman and Tsyplakov (2010) and An, Deng and Gabriel (2011) on CMBSs; Passmore and von Hafften (2020) on a financial innovation for fixed-rate mortgage contracts; Ayotte and Gaon (2011), Friewald, Hennessy and Jankowitsch (2016), and Higgins and Mason (2004) on ABSs; Arentsen, Mauer, Rosenlund, Zhang and Zhao (2015) on CDS; Acharya, Schnabl, and Suarez (2013) on asset-backed commercial paper conduits; Benmelech, Dlugosz, and Ivashina (2012) on CLOs.

Gambacorta and Salleo (2015) found that lenders do not adversely selected mortgages with higher default risk to securitize, which indicates that lenders care about their reputation for not selling lemons. In contrast, we find that for MRBSs (a new type of securitization in the real estate market), the securitization process itself will impose a natural adverse selection on the underlying assets. The reason is that securitized receivables are those that have not been received by the securitization date since the property purchase dates. Conditional on having not been received by the securitization date, those receivables tend to have longer delays compared to other receivables.

Fourth, as banks' characteristics play important roles in affecting their payment delays on mortgage receivables, this paper is also related to the general banking literature. Many papers have studied the factors affecting banks' lending behavior and credit supply.[9] In contrast, our study examines banks' speed in transferring the monies of loans, conditional on that they approve to lend those loans. Banks' funding or financing behavior is also an important topic in the banking literature. Banks' delay behavior in releasing the monies of loans in our study plays a role that is similar to funding activities in increasing banks' liquidities.

4. Data

Property Transaction Data and Mortgage Receivable Payment Data. We collect proprietary data about property transactions and mortgage receivable payments from one of the top ten real estate developers in China. This developer's total sales in 2016 were more than 100 billion RMB. The data contain more than 100,000 property transactions, covering all the major markets of this developer during 2007-2015, including nine provincial level areas (Tianjin, Anhui, Fujian, Guangdong, Jiangsu, Hubei, Hunan, Shandong, and Sichuan). The data contain information on property transaction date, purchase price, down payment, the

[9] For example, Cao, Fisman, Lin and Wang (2018); Acharya, Shin and Yorulmazer (2011); Berger and Bouwman (2009); Demirgüç-Kunt and Huizinga (2010); Berger and Bouwman (2013); Brei, Gambacorta and von Peter (2013); Cornett, McNutt, Strahan and Tehranian (2011); Distinguin, Roulet and Tarazi (2013); Francis and Osborne (2012); Gambacorta and Mistrulli (2004); Ivashina and Scharfstein (2010); Meh and Moran (2010); Shim (2013); VanHoose (2007); and Wu (2015).

bank originating the mortgage, the date on which the bank made the mortgage receivable payment to the developer, and a number of property characteristics (such as living area, garden area, location, and whether the property was residential or commercial).

Bank Financial Data. We collect the financial reports of banks from WIND, a major financial data vender in China. The data contain information on banks' liabilities, assets, profits, and a number of financial ratios.

Bank Branch Data. We collect bank branch data from the China Banking Regulation Commission. The data contain information on the number of branches of each bank in each city.

5. What Factors Can Affect Mortgage-Receivable Delays?

We classify the potential factors that can affect mortgage-receivable delays into four groups: bank characteristics, property-loan-household characteristics, local market conditions, and macroeconomic conditions.

5.1. Bank Characteristics

Bank Liquidity: A low liquidity level may make a bank delay its payments for a longer time. Following the banking literature, we use the capital adequacy ratio and loan-to-deposit ratio as measures for banks' liquidity. Bank liquidity is increasing in the capital adequacy ratio and is decreasing in the loan-to-deposit ratio.

Lending Caution: Banks that are more cautious in lending may use longer procedures and take more time to evaluate mortgage applications before approval. Furthermore, after approval, more cautious banks may take a longer time to release the mortgage receivable payment. Following the banking literature, we use the nonperforming loan ratio as a measure of banks' lending caution. The more cautious a bank is in lending, the better loan performance results the bank will obtain, and thus the lower the nonperforming loan ratio of the bank will be.

Bank Profitability: Banks' incentive to release mortgage monies quickly after approvals of loans also matters in determining the mortgage receivable delays. Because banks can start to earn mortgage interests only after they release the mortgage monies, the earlier the banks release the payments, the earlier they start to earn interest. On the one hand, banks with higher loan-deposit interest spreads have more incentive to release loan monies quickly after approvals of loans; banks' average loan-deposit interest spreads and average deposit interest costs are available in their annual financial reports. On the other hand, if a bank has good alternative investment opportunities (such as bonds and mutual funds), it will have less incentive to release loan monies quickly after approvals of loans; ROAs of a bank are available as a measure of the average profitability of all the investments of the bank; if banks' average loan-deposit interest spreads are already controlled for, ROAs will capture the effect of variations in returns of bank businesses other than loans. Banks' ROAs also affect their payment delays through another channel: higher-profitability banks have higher operational efficiency and thus should have shorter delays in making payments. Therefore, the sign of ROA is undetermined.

Funding Structure: The funding of banks mainly comes from two sources: deposits and wholesale funding (such as interbank borrowing). Compared to deposits, wholesale funding is more costly and less stable. Banks' reliance on wholesale funding to finance the expansion of their credit supplies plays an important role in the buildup of systemic risks and the propagation mechanism. Demirgüç-Kunt and Huizinga (2009) found that banks' reliance on wholesale funding increases their financial fragility and worsens the performance of their stock prices. Cornett, McNutt, Strahan and Tehranian (2011) found that the liquidity of banks with more stable funding structures is less likely to dry up relative to other banks during the global financial crisis.[10] Following the banking literature, we use the ratio of total liabilities minus total deposits to total assets as the measure of banks' funding structures. We expect that this variable is positively related to the delays of mortgage receivable payments. Banks' reliance on wholesale funding increases their interest costs and thus can reduce their incentive to release loan monies quickly. In addition, banks' reliance on wholesale funding increases their financial fragility and thus can cause more payment delays. The instability of

[10] In September 2017, Moody's downgraded their credit rating of Bank of Communications (the fifth largest bank in China) from Baa3 to Ba1 because of its heavy reliance on wholesale funding.

the funding source will also make banks less willing to engage in long-term lending, such as mortgages.

5.2. Property, Loan, and Household Characteristics

Household Creditworthiness and Mortgage Risks: It takes a shorter time for households with higher creditworthiness to obtain mortgages after the house sales transaction. First, households with lower creditworthiness may need to search for multiple banks, as their mortgage applications may be rejected by some banks. Second, it may take a longer time for banks to evaluate mortgage applications by households with lower creditworthiness. In China, there is no credit score, such as FICO, that is widely used by banks to evaluate loan applications.[11] Usually, banks assess borrowers' creditworthiness based on their income and banking account transactions. The proprietary data from the real estate developer do not contain house buyers' income and banking account transaction information. While banks collect those data when households apply for mortgages and systematically use this information to evaluate the mortgage default risk, the real estate developer only informally asks for this information at the property transaction date and does not systematically record and use it.[12]

However, we can observe the ratio of garden area to living area of the property. Properties with a higher ratio of garden area to living area are more luxury, and thus the buyers are likely to have higher income.

In addition to borrowers' creditworthiness, the risk-related characteristics of mortgage loans may also affect the time banks spend evaluating loan applications and the probability of rejection. Both the loan amount and LTV in the data are related to mortgage risks. The higher the loan amount or LTV ratio, the riskier the mortgage.

[11] There are some credit scoring systems developed and used by E-commerce platforms, such as "Sesame Credit" developed by Ant Financial Services Group, an affiliate of the Chinese Alibaba Group.
[12] Because MRBSs are issued by developers rather than by banks, banks would not release their borrowers' creditworthiness information for developers to issue MRBSs.

Incentive to Act Quickly in Applying for Mortgages: The more quickly households act in applying for mortgages, the earlier they will get their mortgage applications approved by banks, and thus the earlier the developer will obtain the mortgage receivables from the banks. One measure of households' incentive to act quickly in applying for mortgages is the number of days from the property transaction date to the due date of the full purchasing payment. After a household signs the contract with the developer at the transaction date, that household needs to pay the down payment at the transaction date and make the remaining payment through mortgages before the due date specified in the contract. If the household fails to obtain a mortgage before the due date, legally, they are obligated to make the payment out of their own pocket; and actually, they may incur some penalties if they are unable to make that payment out of their own pocket.[13] The mortgage loan amount and LTV are also related to households' incentive to act fast in applying for mortgages. The higher the loan amount or LTV is, the larger the amount of money the household is legally obligated to pay out of their own pocket to the developer after the due date. The direction of the effect of the loan amount or LTV on delays through this channel is the opposite of that through the channel that a higher loan amount or LTV makes banks spend more time evaluating the mortgage applications and have higher rejection probabilities. Therefore, the sign of the loan amount or LTV is undetermined, depending on which channel is dominant.

Residential Property vs. Commercial Property: The mortgages for commercial properties need to go through a more complicated administrative system than the mortgages for residential properties. Therefore, the mortgage receivable delay of commercial property mortgages is expected to be longer than that of residential property mortgages.

5.3. Local Market Conditions

[13] Although there is a due date of the full payment of the property price specified in purchasing contracts, developers seldom punish buyers immediately if the developers do not receive the full payment on the due date, as there are many other factors (such as factors from banks) that can cause the delays. Developers specify the full payment due date in purchasing contracts mainly for imposing some pressures on buyers to apply for mortgages quickly. If a mortgage application cannot be approved by a bank, developers would recommend another bank to the buyer.

5.3.1. Local Demand for Mortgages

Larger housing sales volumes in a city could make banks have longer delays to approve a mortgage because banks need to deal with more mortgage applications and face a higher demand of money. Therefore, we include city-level house prices and housing areas sold in the regressions. The two variables are expected to prolong the delays.

5.3.2. Local Funding Supply for Banks

Many banks in China have branches in multiple cities. Therefore, a city branch of a bank does not completely rely on deposits from the city to make loans to the city. In the Chinese banking system, the central bank controls the total money supply and allocates lending quotas to each commercial bank. The headquarters of each commercial bank then allocates its lending quotas to each of its city branches as month-end or quarter-end quotas.

However, how much money a city branch of a bank can lend is mainly determined by the deposits the branch absorbs from the city. First, the amount of quotas allocated to each city branch by the headquarters is related to the city branch's ability to absorb deposits from the local market. Second, if a city branch has already used up its quota but finds additional good lending opportunities, it can negotiate with the headquarters to temperately increase its quota if the city branch has a strong ability to absorb deposits.

Cao, Fisman, Lin and Wang (2018) found that in city branches with a tight quota constraint for a period, in the middle of the period, branch managers often delay loan originations to wait for higher-quality loan applications. At the end of the period, if the branch managers have not accomplished the quota, they will originate lower-quality loans to meet the target.[14]

[14] City branch managers cannot lend beyond the quota, and they also would not like to lend below the quota. Most commercial banks conduct monthly or quarterly evaluations on the performance of their city branch managers. The evaluation results will affect city branch managers' bonuses and future promotions. City branch managers' performance are assessed mainly base on the quality and quantity of loans they lend. Conditional on the lending quality, the evaluation score is increasing in the lending quantity as long as it does not surpass the quota. At the end of each month or each quarter, if a city branch manager cannot accomplish its quota, the remaining quota will be reallocated to other city branches by the headquarters, and the future quotas may also be reduced.

Therefore, a city branch of a bank with a lower deposit supply from the city could have longer delays in approving mortgages. Accordingly, we add two variables that are related to a bank's local deposit supply in the regressions: the bank's local market presence and the city unemployment rate. The explanations of the two variables are as follows.

Banks' Market Presence: Within each commercial bank, there are two layers of branches for each city: one city branch (main branch) and other branches (sub-branches) under the control of the city branch. All the branches can absorb deposits and many branches can also receive loan applications, but the final approvals on loan applications are usually determined by the city branch. Using the bank branch data from the China Banking Regulation Commission, we create the share of bank i's branches in city m during year g as follows:

$$Market\_presence_{i,m,g} = \frac{\#\ of\ branches\ of\ bank\ i\ in\ city\ m\ in\ year\ g}{\#of\ branches\ of\ all\ the\ banks\ in\ city\ m\ in\ year\ g}$$

A bank with a larger presence in a local market has an advantage in absorbing deposits from the local market and thus may originate loans faster to the local market.

Unemployment rates: A high unemployment rate in a city can decrease deposits from the household sector and thus reduce the city branch's funding supply and cause longer delays for the bank's loan origination.

5.3.3. Other Local Market Factors

Market Importance to a Bank: We use the share of a bank's branches in a city over all its branches in the entire country as the measure of the importance of the local market to the bank. We expect that banks have shorter payment delays in more important markets.

We also control for city fixed effects in the regressions.

5.4. Summary

Table 3 provides a summary of the expected signs for those factors. Table 4 displays the descriptive statistics. There are 105,435 mortgage receivables in the sample, with the property purchase dates ranging from 2007 to 2015. By the end of the sampling period, 3.99%

of those receivables had not been received by the developer (right-censored observations). The property purchase dates of those right-censored observations are mainly in 2015. Figure 3 displays the distribution of the mortgage receivable delays, including censored observations.[15] Most receivables were received within one year after the property purchase date.

6. Econometric Model

We employ a Cox proportional hazard model to empirically analyze the delays of mortgage receivables.[16] For property i sold in year g, $F_{i,g}(\tau)$ denotes the cumulative distribution function (CDF) of the days from the house purchase to the release of the mortgage receivable by the bank, $\tau_{i,g}^{*}$, which is the delay; $f_{i,g}(\tau)$ denotes the probability density function; and $S_{i,g}(\tau) = 1 - F_{i,g}(\tau)$ denotes the survival function, which is the probability that the mortgage receivable has not been released by time τ. The hazard function $\lambda_{i,g}(\tau)$ is the instantaneous probability that the mortgage receivable is paid conditional on it not having been paid by τ.[17]

$$\lambda_{i,g}(\tau) = \lim_{\Delta\tau \to \infty} \frac{\Pr[\tau \leq \tau_{i,g}^{*} < \tau + \Delta\tau | \tau_{i,g}^{*} \geq \tau]}{\Delta\tau} = \frac{f_{i,g}(\tau)}{S_{i,g}(\tau)}$$

The relation between $S_{i,g}(\tau)$ and $\lambda_{i,g}(\tau)$ is

$$S_{i,g}(\tau) = \exp\{-\int_{0}^{\tau} \lambda_{i,g}(\tau) d\tau\}$$

Because the sampling period of our data ended on Sep 15, 2015, by which some mortgage receivables had not been released, the dependent variable $\tau_{i,g}^{*}$ is right censored for

[15] If censored, the delay of the observation is calculated as the days from the property purchase date to the end of the sampling period.

[16] Cox proportional hazard models have been widely used in empirical studies involving duration data, such as studies on mortgage default and prepayment (Deng, Quigley and Order (2000)), bank failures (Wheelock and Wilson (1995)), start-up firm behavior (Hellmann and Puri (2002)), purchase timing (Jain and Vilcassim (1991) and Seetharaman and Chintagunta (2003)), unemployment duration (Meyer (1990), and feedback trading (Pearson, Yang and Zhang (2017)).

[17] Although the statistical terminology of $\lambda_{i,g}(\tau)$ and $S_{i,g}(\tau)$ are hazard function and survivor function, respectively, the termination of a duration is favorable and the prolonging of a duration is unfavorable in our empirical scenario, which is similar to unemployment duration. In other empirical scenarios, such as the default of mortgages and the death of patients, the termination of a duration is unfavorable and the prolonging of a duration is favorable, which is consistent with the statistical terminology.

those observations. The full log likelihood function should be

$$lnL = \sum_{i=1}^{n}[d_i lnf_{i,g}(\tau_{i,g}^*) + (1-d)lnS_{i,g}(\tau_{i,g}^*)]$$

where $d_i = 1$ if the observation is not censored and $d_i = 0$ if censored. In fact, the model is estimated using the partial likelihood estimation method developed by Cox (1975), in which the right censoring problem is still taken into consideration.

Assume that the hazard function $\lambda_{i,g}(\tau)$ takes the form

$$\lambda_{i,g}(\tau) = \lambda_0(\tau)\exp(x_{i,g}\beta) \quad (1)$$

where $\lambda_0(\tau)$ is the baseline hazard rate, and $x_{i,g}$ denotes the vector of covariates that proportionally shift the baseline hazard. A positive coefficient means that an increase in the covariate will accelerate the payments and thus shorten the delays. Following the partial likelihood estimation methodology developed by Cox (1975), β are estimated parametrically in the first step; in the second step, $\lambda_0(\tau)$ is estimated nonparametrically. Because $\lambda_0(\tau)$ is estimated nonparametrically, there is no need to assume a parametric functional form for the baseline hazard rate $\lambda_0(\tau)$.

The covariates $x_{i,g}$ can be classified into three groups: individual property-loan-household characteristics, the characteristics of the bank originating the mortgage for property i in year g, and the local market conditions in year g. In addition, we also control for bank-fixed effects and city-fixed effects.

7. Empirical Results

The regression results of equation (1) are reported in Table 5. Models 1 through 4 gradually add bank characteristics, property, loan, and household characteristics, local market conditions, and macroeconomic variables. The results are very robust. For each model of Table 5, the first column reports the estimates (a positive coefficient means an increase in the covariate will accelerate the payments and thus shorten the delays); the second column reports the standard errors. For model 4 of Table 5, we also add the third column to report the rescaled hazard ratio, which measures the importance of a covariate in determining the delays.

For the dummy variable “Commercial property”, the rescaled hazard ratio indicates the extent to which the hazard rate will be shifted if the dummy variable changes from 0 (residential property) to 1 (commercial property); for the other covariates, the rescaled hazard ratio indicates the extent to which the hazard rate will be shifted if there is a one-standard-deviation increase of the covariate from the mean. A hazard ratio above one means the covariate will shift the hazard rate upward, while a hazard ratio below one means the covariate will shift the hazard rate downward. The more the rescaled hazard ratio deviates from one, the more important is the covariate.

The dependent variable $\tau_{i,g}^{*}$ is the days from the property purchase transaction to the arrival of the mortgage money to the developer. This time length constitutes the delay risk to developers and MRBS investors. In fact, this time length consists of two parts: the days from the property purchase transaction to the mortgage application (determined by the individual house buyer) and the days from the mortgage application to the arrival of the mortgage money to the developer (determined by the originating banks). In the data, we only observe the length of the total delay but do not observe the length of each part. However, in the covariates $x_{i,g}$, we include both factors affecting the first part (individual characteristics) and factors affecting the second part (mainly bank characteristics), as well as factors affecting both parts. Moreover, it is the length of the total delay that matters for the delay risk of the underlying assets and the shortfall risk of MRBSs.

7.1. Bank Characteristics

Regarding bank characteristics, first, as measures of bank liquidity, the capital adequacy ratio is significantly positive and the loan-to-deposit ratio is significantly negative, which indicates that bank liquidity shortens the payment delays.

Second, as a measure of bank lending caution, the non-performing loan ratio is significantly positive, which indicates that bank lending caution prolongs the payment delays.

Third, the loan-deposit interest spread is significantly positive, and the average deposit interest rate is significantly negative, which indicates that banks with higher lending profitability from loans act faster in releasing loan payments. As a measure of a bank’s overall profitability from all its investments, ROA is significantly negative. This is consistent with the fact that if a bank has good alternative investment opportunities (such as bonds and mutual funds), it will have less incentive to release a loan fast. However, this is inconsistent with the fact that a bank with higher ROA and thus higher operational efficiency may have shorter delays in making payments. Thus, the former channel of the ROA effect dominates the latter one.

Fourth, the coefficient of funding structure (the ratio of total liabilities minus total deposits to total assets) is significantly negative. Compared to deposits, wholesale funding (such as interbank borrowing) is more costly and less stable. Banks' reliance on wholesale funding increases their interest costs and thus reduces their incentive to release loans quickly. In addition, banks' reliance on wholesale funding increases their financial fragility and thus causes more payment delays. The instability of the funding source also makes banks less willing to engage in long-term lending, such as mortgages.

7.2. Property, Loan, and Household Characteristics

Regarding property, loan, and household characteristics, to begin with, the ratio of garden area to living area of the property is significantly positive. The explanation is that properties with a higher ratio of garden area to living area are more luxury, and thus the buyers are likely to be of higher creditworthiness. On the one hand, households with lower creditworthiness may need to search for multiple banks, as their mortgage applications may be rejected by some banks. On the other hand, banks may take more time in screening and selecting borrowers with lower creditworthiness.

As a measure of house buyers' incentive to act quickly in applying for mortgages, the number of days from the property transaction date to the due date of the full purchasing payment is significantly negative. This indicates that the pressure on house buyers to make payments on time significantly shortens the payment delays.

As discussed in Section 5, the loan amount or LTV can affect delays through two channels. The first channel is that a higher loan amount or LTV makes the mortgage riskier; thus, banks may need to spend more time evaluating the application and have a higher rejection probability. If the application is rejected, the house buyer has to search for another lender, which further delays the payment to the developer. The second channel is that house buyers with a higher loan amount or LTV have a larger incentive to act quickly in applying for a mortgage, because if they fail to obtain a mortgage before the due date, legally, they are obligated to make the payment out of their own pocket; and actually, they may incur some penalties if they cannot make the payment out of their own pocket, although developers seldom execute the penalties. The coefficient of loan amount is significantly negative, which indicates that the first channel dominates the second one with respect to the effect of the loan amount; the coefficient of LTV is significantly positive, which indicates that the second channel dominates the first one with respect to the effect of LTV. One possible explanation for why the second channel dominates for LTV but not for the loan amount is that a borrower choosing a large loan amount may not necessarily have higher pressure to act fast in mortgage application because the borrower may also have high income and purchase an expensive house; however, a borrower with high LTV is likely to have a high loan amount relative to her/his income.

The coefficient of the commercial property indicator is significantly negative, which is consistent with the fact that mortgages for commercial properties need to go through a more complicated administrative system than mortgages for residential properties and thus experience longer delays.[18]

7.3. Local Market Conditions

Regarding the local market conditions, first, the measure of banks' local market presences is significantly positive. As discussed in Section 5.3, a bank with a larger presence in a local market has an advantage in absorbing deposits from the local market and thus may face a

[18] One concern is that whether the delays of mortgages from Housing Provident Fund (HPF) are different from the delays of mortgages from banks. HPF have much longer delays than mortgage from banks because HPF has a more complicated administrative and regulatory process. Developers usually do not securitize mortgage receivables from HPF. The regression analysis above only includes mortgages from banks. The results of the regression using both mortgages from banks and mortgages from HPF reported in Table A.1 in the Online Appendix provide the evidence that HPF has longer delays than banks.

more flexible lending quota constraint; therefore, it may have shorter delays in mortgage originations to the local market. In addition, the market importance is significantly positive. The more important the local market is to the bank, the shorter the delays are.

Second, the local unemployment rate is significantly negative. The explanation is that a bank may face a low deposit funding supply in a city experiencing a high unemployment rate and thus have longer delays in mortgage originations.

Third, the city-level house prices and the housing areas sold are significantly negative. The explanation is that larger housing sales volumes in a city could make banks have longer delays to approve a mortgage because banks need to deal with more mortgage applications and face a higher demand of money.[19]

7.4. Macroeconomic Conditions

The M2 growth rate is significantly positive at a level of 1%. This indicates that banks originate mortgages faster when the aggregate monetary supply growth rate is higher. The GDP growth rate is also significantly negative.

7.5. Further Discussions and Concerns

Based on the rescaled hazard ratios, covariates including days from the transaction date to the payment due date, commercial property indicator, bank liquidity, lending caution, ROA, and local house prices and unemployment rates are relatively more important in determining the payment delays than other covariates.

Figure 4 displays the survival functions of 50 mortgage receivables randomly drawn from the sample. There is a large heterogeneity of delay risks among them, because many factors can significantly affect the delay of an individual mortgage receivable and those

[19] Theoretically, house price growth could have two effects on housing sales. First, it can make households form a higher expectation for future house price appreciations and thus invest more money in housing assets (see Case, Shiller and Thompson (2012) for evidence of adaptive house price expectations and see Ma (2020b) for evidence of house price expectations diverging from fundamentals). Second, it can make houses become less affordable to low-income households and reduce their housing purchases. Ma and Zhang (2020) found that overall, a faster house price growth is associated with a faster housing sales growth.

receivables are differentiated in the dimensions of those factors. The large heterogeneity displayed in Figure 4 indicates that, unlike MBSs, it is difficult to standardize the underlying asset pools for issuing MRBSs. Therefore, when analyzing the risk of MRBSs, the security level characteristics (e.g., overcollateralization rate, equity tranche proportion, unsophisticated criteria for mortgage receivables to enter the asset pool) currently released by developers to investors are far from sufficient; developers should release information on the composition of the asset pool (i.e., the distributions of all the factors that can significantly affect the delay risk of an individual mortgage receivable) to investors and bring more transparency to the financial market.

Figure 4 also exhibits an important pattern: the survival functions are convex in most of the domain (only slightly concave at the beginning of the domain). The probability that a mortgage receivable has been paid is increasing at a decelerating speed in general because conditional on the receivable having not been paid for a while, the payment would be slower in the future. The probability is increasing at an accelerating speed at the beginning as it is rare that a receivable can be received within the first several days after the property purchase date. This convexity of survival functions implies a natural adverse selection effect of securitization on the quality of underlying assets. Conditional on having not been received by the securitization date, those receivables tend to have longer delays further (see Section 9 for deeper analyses).

The pseudo R squared is 0.4322, which indicates that our model specification has a good in-sample fit.[20] Panel A in Table 6 separately displays the goodness of in-sample fit for the mortgage receivables associated with properties purchased in different years. Panels B, C and D display the goodness of out-sample fit. In panel B, the observations in the prediction year are excluded from the estimation sample; in panel C, a 50% random sample of

[20] Pseudo R squared is a standard measure for goodness of fit for maximum likelihood models, because the traditional R squared working for OLS models cannot be constructed in maximum likelihood models. We construct pseudo R squared using the following procedure: first, based on the maximum-likelihood estimates of the proportional hazard model, we construct the CDF of the payment delay for each mortgage receivable; second, based on the CDF, we simulate the payment delay for each mortgage receivable, with right censoring at the end of the sample period; third, we run an OLS regression of the actual delay on the simulated delay, and the resulting R squared is the pseudo R squared that measures the goodness of fit for the proportional hazard model.

observations in the prediction year and all the observations after the prediction year are excluded from the estimation sample, and the 50% random sample of observations in the prediction year becomes the prediction sample; in panel D, the observations in and after the prediction year are excluded from the estimation sample. The pseudo R squared in most of those cases is above 0.20; this indicates that the out-sample performance of the model is satisfactory in many scenarios that are differential in the compositions of in-sample and out-sample. As the estimations are based on individual-level data, a 20% pseudo R squared is satisfactory for goodness of fit. Moreover, the simulations in the next section are conducted for the risk analyses of a mortgage pool containing thousands of mortgage receivables. The level of goodness of fit obtained from the estimation based on the individual mortgage data is more than sufficient to conduct accurate risk assessments at the pool level.

One concern is whether the dependent variable (length of delay for a mortgage receivable) could drive the bank-level covariates, which may generate a reverse causality issue. For example, payment delays by banks may improve their liquidity measures. First, we use individual-mortgage-level data in the regression, and the length of delay for a mortgage receivable would not affect bank-level covariates. Second, in addition to mortgage lending, banks engage in many other types of lending, such as firm loans, credit cards, auto loans, and student loans.

8. Monte Carlo Simulations for MRBSs

8.1. Overview of MRBSs

MRBSs are issued based on the underlying pool of mortgage receivables with a certain buffer size (magnitude of overcollateralization) as a way to better protect investors. For example, if the underlying pool has one billion dollars of mortgage receivables and the buffer size is set to 25%, then only 0.75 billion dollars of MRBSs are issued. However, the coupon and principal payments to the investor of those 0.75 billion dollars of MRBSs are covered by the cash flows of the entire underlying pool. Similar to MBSs, MRBSs are divided into different layers of tranches. Some MRBSs have two layers: senior tranches and equity tranches; other MRBSs have three layers: senior tranches, middle tranches (mezzanine tranches), and equity tranches (subordinated tranches). Equity tranches are held by developers themselves in order to resolve the moral hazard concern; otherwise, developers will have more incentive to securitize low-quality assets, and rational investors would require a higher return for MRBSs. The maturities of MRBSs are usually 1 to 3 years.

The redistribution of arriving cash flows among those tranches follows the "waterfall" rule. Panels A and B in Figure 5 illustrate the cash flow redistribution of three-layer MRBSs. Each mortgage receivable in the asset pool is received at a random time. The cash balance of the pool gradually accumulates. At the end of each half year before maturity, the cash in the pool will first be used to pay the coupon of senior tranches; if there is still money left, it will then be used to pay the coupon of middle tranches. At the maturity date, the cash in the pool will first be used to pay the coupon and principal of senior tranches; if there is still money left, it will then be used to pay the coupon and principal of middle tranches; if there is still money left, it will then belong to equity tranche holders.

8.2 Simulation Procedures and Contributions

Based on the criteria set by the developer for the mortgage receivables to enter the underlying asset pool for securitization, we select a pool of mortgage receivables that had not been received by the developer by September 1, 2015;[21] this pool is composed of 4,933 mortgage receivables. Assuming this pool is securitized on September 1, 2015, for each receivable, we simulate the date on which the receivable is released by the bank and arrives in the developer's account.

We assume that senior tranches and equity tranches backed by the pool are issued (two-layer MRBSs).[22] Let p, p_S, and p_E denote the face values of all the receivables in the pool, the senior tranches, and the equity tranches, respectively. Then, $p_S + p_E = (1 - b)p$, where b is the buffer size (overcollateralization rate). Based on the simulations, we conduct risk analyses on the MRBS senior and equity tranches.

[21] The criteria set by the developer include that the receivable had not been delayed for more than 12 months since the property purchase date and that the LTV ratio should be lower than 75%.
[22] For simplicity, we simulated for two-layer MRBSs rather than three-layer MRBSs. Two-layer MRBSs are enough to illustrate all the important properties.

From the estimates in Section 7, for each receivable i in the pool, we can determine the unconditional probability that it has not been paid by τ days since the property transaction, $S_{i,g}(\tau)$, i.e., the survival function. Because it is the days from the securitization date to the receivable arrival date for each receivable that affects the shortfall risk of MRBSs rather than is the days from the property purchase date to the receivable arrival date, what truly matters is the conditional CDF conditional on that the receivable has not been received by the securitization date, $F_{i,g}(\tau|\tau_{i,g}^* > t_{0,i,g})$, where $t_{0,i,g}$ is the days from the property purchase date to the securitization date. As shown in equation (2), the conditional CDF $F_{i,g}(\tau|\tau_{i,g}^* > t_{0,i,g})$ can be obtained from the unconditional survival functions based on our estimates.

$$F_{i,g}(\tau|\tau_{i,g}^* > t_{0,i,g}) = 1 - \Pr(\tau_{i,g}^* > \tau|\tau_{i,g}^* > t_{0,i,g}) = 1 - \frac{S_{i,g}(\tau)}{S_{i,g}(t_{0,i,g})} \qquad (2)$$

Using the conditional CDF, we simulate $\tau_{i,g}^*$ and obtain the delay after being securitized, $\tilde{\tau}_i = \tau_{i,g}^* - t_{0,i,g}$, for each mortgage receivable i in the pool. Then, we obtain the path of cash flows of the entire pool and the rates of returns of the tranches backed by the pool. We conduct the simulation 10,000 times and then obtain the expected rates of returns and the risk measures for those tranches.

The accumulated number of payments entering the whole pool up to time t after the securitization date is

$$N_t = \sum_{i=1}^{n} \mathbf{1}_{\{\tilde{\tau}_i \leq t\}} ,$$

and the accumulated (aggregated) amount of payments up to time t for the whole pool is

$$A_t = \sum_{i=1}^{n} \mathbf{1}_{\{\tilde{\tau}_i \leq t\}} ,$$

where $\mathbf{1}_{\{\cdot\}}$ is the indicator function and $A_t \in [0, p]$. Suppose the MRBSs have a m-period maturity (one period is half a year) and the total amount of coupon promised to pay senior tranches at the end of each period is c_S. The cash-flow structure of senior and equity tranches exhibits a property stated in the following proposition:

Proposition 1. *The payoff functions at the coupon payment times* $\{t_k\}_{k=1,\ldots,m}$ *for the senior tranches are specified by*

$$C_k = \min\{A_{t_k}, kc_S\} - W_{k-1}, \quad k = 1,2, m-1;$$

$$C_m = \min\{A_T, p_S + mc_S\} - W_{m-1};$$

the payoff function at maturity for the equity tranches is specified by

$$C^E = A_T - W_m;$$

where W_k *is denoted as the accumulated payoff, i.e.,*

$$W_k := \sum_{j=1}^{k} C_j, \qquad k \in \{1,2,\dots,m\}, \qquad W_0 = 0.$$

We provide the proof of Proposition 1 in Appendix III.

The annualized return at maturity on senior tranches in a simulated path, Y_R^S, can be numerically solved from the following equation:

$$p_S = \sum_{k=1}^{m} \frac{C_k^S}{(1 + Y_R^S/2)^k}$$

The annualized return at maturity on equity tranches in a simulated path, Y_R^E, can be solved from the following equation:

$$p_E = \frac{C^E}{(1 + Y_R^E)^{\frac{m}{2}}}$$

Averaging Y_R^S and Y_R^E across the 10,000 simulated paths yields the estimates for the expected returns at maturity on senior tranches and equity tranches, respectively. We can also calculate the standard deviations of Y_R^S and Y_R^E across the 10,000 simulated paths.

The (expected) return at maturity is not the same as the final (expected) return. In the case of shortfall (i.e., the cash in the underlying asset pool at the maturity date is not enough to pay the interest and principal of senior tranches), senior tranche investors will receive whatever the underlying asset pool has, which constitutes the return at maturity for senior tranches. However, the receivables in the pool that arrive after the maturity date of the security must be used to repay the shortfall. Because banks will finally pay these receivables anyway, the final return on senior tranches will almost always be equal to the coupon rate, though it may not always be realized on time.

This shortfall risk can be viewed as a proxy for the entire risk of an MRBS because the underlying asset pool is "bankruptcy remote" and the issuing developer's bankruptcy risk has little effect on the MRBS risk. If the MRBS is designed appropriately (i.e., the term to maturity of the MRBS can cover the delays of most receivables in the underlying asset pool and the overcollateralization rate is set appropriately), the shortfall risk should be much lower than the developer's bankruptcy risk. The magnitude of the shortfall risk of an MRBS compared to the magnitude of the issuing developer's bankruptcy risk will determine the discount of the MRBS interest rates relative to the interest rates of the developer's construction loans. The reduction in borrowing costs resulting from "bankruptcy-remote" collaterals is the purpose of asset securitization.

For senior tranches, the expected return at maturity and the standard deviation of the return at maturity both serve as measures for the shortfall risk. The lower the expected return at maturity relative to the coupon rate, the higher the shortfall risk; if there is no shortfall risk, the expected return should be equal to the coupon rate. The greater the standard deviation of the return at maturity, the higher the shortfall risk; if there is no shortfall risk, the standard deviation of the return at maturity should be zero.

Based on the simulation, we will analyze how the shortfall risk of senior tranches varies according to the security-design parameters (overcollateralization rate and coupon rate). Our analyses provide a benchmark for conducting appropriate security designs based on the composition of the underlying asset pool such that the shortfall risk is small enough relative to the issuing firm's bankruptcy risk, through which should the borrowing-cost-reduction purpose of asset securitization be achieved. Our analyses for the shortfall risk also increase the transparency for investors on the risk pattern of MRBSs and provide implications for the pricing of MRBSs.

9. Pool-level Simulation Results and Adverse Selection

The simulation results based on the underlying asset pool appear to be puzzling. Figure 6 displays the histograms of the number of receivables, the amount of money, and the proportion of the pool in terms of monetary amount that have been received by the maturity date of the security (2 years) over the 10,000 simulated paths. The distribution of the portion of receivables received in the pool by the maturity date is spread over mainly from 78% to 81%. However, in the sample used for the estimations in Section 6 (including both securitized and nonsecuritized receivables), 95% of mortgage receivables were received within two years after the property purchase dates. Why will only approximately 80% of mortgage receivables in the securitized pool be received within two years after the securitization date?

The reason is that receivables that enter the underlying asset pool for securitization are those that have not been received by the securitization date since the property purchase dates. Conditional on having not been received for a while, those receivables tend to have longer delays. We provide a mathematical illustration for this phenomenon by the following proposition:

Proposition 2: Suppose that the time length from the property purchase date for a mortgage receivable to the securitization date is t_0. The CDF for the payment delay since the property purchase date is $F(x)$. The conditional CDF for the payment delay is $G(y) = F(y|y > t_0)$. Then, $G(y)$ first-order stochastically dominates $F(x)$, i.e., for any t, $\Pr(y > t) > \Pr(x > t)$.

We provide the proof in Appendix III.

Proposition 2 only indicates that receivables entering the securitization pool tend to have longer delays since the property purchase dates compared to the entire population. However, the horizontal axis in Figure 6 is the delay since the securitization date rather than the delay since the property purchase date. The puzzling distribution in panel 3 of Figure 6 implies that even the further delays of securitized receivables after the securitization date tend to be longer than the total delays since the property purchase dates of the population on average. The reason for this phenomenon is that the survival function for a receivable obtained from the estimation is convex in most of the domain, as displayed in Figure 4 in Section 6. By the following proposition, we provide a mathematical illustration regarding why a convex survival function will cause a receivable's further delay after securitization to be even longer.

Proposition 3: Denote z as the further delay of a securitized receivable since the securitization date, conditional on that the receivable has been securitized and that the time length from the property purchase date to the securitization date is t_0. The CDF of z is $H(z) = \frac{F(z+t_0)-F(t_0)}{1-F(t_0)}$. If the survival function $S(x) = 1 - F(x)$ is convex, then there exists a $\underline{t}_0$ such that for any $t_0 \geq \underline{t}_0$, $H(z)$ first-order stochastically dominates $F(x)$, i.e., for any t, $\Pr(z > t) > \Pr(x > t)$.

We provide the proof for Proposition 3 in Appendix III.

Note that the convexity of the survival function obtained from the estimation (see Figure 4) is not due to the functional form of the proportional hazard model. The reason is that the baseline hazard function $\lambda_0(\tau)$ in equation (1) is estimated nonparametrically, which provides enough flexibility to capture the true convexity or concavity of the survival function. The parametric component in equation (1), $\exp(x_{i,g}\beta)$, only proportionally shifts the hazard function and the survival function and does not change the convexity or concavity.

Correspondingly, there could be two policy implications regarding how to mitigate this adverse selection effect for MRBSs. First, in the current practice, only receivables that have not been delayed for more than 12 months since the property purchase dates can enter the underlying asset pool for securitization. The regulator can consider tightening this criterion. Second, increasing overcollateralization rates of securitization can help reduce the risk exposure of security investors.

In contrast, traditional mortgage-backed securitization (of which the major risk of underlying assets is default risk) does not have this problem. Although securitized mortgages are those that have not been defaulted by the securitization date since the origination dates (usually ranging from several months to several years), conditional on having not been defaulted by the securitization date, those mortgages tend to stay alive for a longer period and hence make more monthly principal and interest payments.

10. Security-Level Simulation Results

10.1. Three Typical Security Designs

Figure 6 above display the distributions for the entire underlying asset pool. The next two figures will display the distributions for the tranches backed by the pool, given the parameters of a security design. Following most industrial practices, we set the proportions of senior and equity tranches to be 95% and 5%, respectively. The focus is the distribution of the return at maturity for senior tranches because equity tranches are held by developers to resolve the moral hazard problem, but we also compute the distribution of the return at maturity for equity tranches for comparison. Figure 7 displays the distribution of annualized returns at maturity for senior and equity tranches in the following three security designs. We choose these three designs to exhibit because they are quite representative of three different patterns of simulated distributions.

Design 1: buffer size = 27% and senior coupon rate = 8%;

Design 2: buffer size = 28% and senior coupon rate = 8%;

Design 3: buffer size = 29% and senior coupon rate = 6%.

In Design 1, most of the time the pool will have shortfalls in cash to repay the principal and interest to senior tranches at maturity; thus, the returns at maturity on senior tranches cannot reach the coupon rate (8%). Correspondingly, the returns at maturity on equity tranches will be bunching at -100% because equity tranches can claim nothing if there are shortfalls in repaying senior tranches.

In Design 2, the buffer size is increased to 28%, and thus, both senior and equity tranches become safer. Most of the time the pool will have enough cash to repay the principal and interest to senior tranches at maturity. Even if there is extra cash in the pool, the returns at maturity on senior tranches will still be capped at the coupon rate. Thus, there is a large bunching at the coupon rate (8%) for the returns at maturity on senior tranches. Correspondingly, once the pool has enough money to repay senior tranches, equity tranches can claim the residuals and have at-maturity returns higher than -100%. Occasionally, the pool has shortfalls in repaying senior tranches; thus, their returns at maturity cannot reach the coupon rate, and there is a small tail to the left of the bunching at the coupon rate. Correspondingly, there is a small bunching of returns at maturity on equity tranches at -100%. Comparing Design 2 with Design 1, the 1% increase in the buffer size leads to a significant change in the distribution pattern for at-maturity returns on senior tranches, and the expected return at maturity for senior tranches is increased from 7.40% to 7.95%.

In Design 3, the buffer size is further increased to 29%, and the senior coupon rate is reduced to 6%. The pool always has enough money to repay senior tranches in the 10,000 simulated paths, and thus, senior tranches become almost riskless assets. Correspondingly, equity tranches always have residuals to claim.

Figure 7 displays a nice duality between senior and equity tranches. A bunching of returns at maturity on senior tranches at the coupon rate corresponds to a distribution of returns at maturity on equity tranches to the right of -100%; a bunching of returns at maturity on equity tranches at -100% corresponds to a distribution of returns at maturity on senior tranches to the left of the coupon rate.

10.2. Relationship between Returns at Maturity and Overcollateralization Rates

Next, we average the returns at maturity on senior and equity tranches, respectively, over the 10,000 simulated paths and obtain the expected returns at maturity.

In Figure 8, the upper-left diagram shows the relationship between buffer sizes and expected returns at maturity given coupon rates for senior tranches, while the lower-left diagram shows that relationship for equity tranches.

When the buffer size is low (below 20%), there are always shortfalls in repaying senior tranches. Because the face value of the security issued is constrained by one minus the buffer size, the expected return at maturity on senior tranches is increasing linearly in the buffer size. Correspondingly, the expected return at maturity on equity tranches remains at -100%.

When the buffer size is high (above 30%), the pool always has enough money to repay senior tranches, but the returns on senior tranches are capped by the coupon rate; therefore, the expected return at maturity on senior tranches holds constant as the buffer size increases. Correspondingly, the expected return at maturity on equity tranches is increasing in the buffer size, as the larger the buffer size, the more residuals to be claimed by equity tranches.

Around the turning point, there are both a positive probability that the pool has enough money to repay senior tranches and a positive probability of shortfalls, and the former probability is increasing in the buffer size while the latter probability is decreasing in the buffer size; therefore, the line is turning gradually rather than sharply. The higher the coupon rate is, the higher the turning point is in terms of the buffer size because senior tranches with a higher coupon rate need a larger buffer size to fully repay the principal and interest.

10.3. Relationship between Returns at Maturity and Senior Coupon Rates

The upper-right diagram of Figure 8 shows the relationship between senior coupon rates and expected returns at maturity given the buffer sizes for senior tranches, while the lower-right diagram shows that relationship for equity tranches.

First, in the cases of higher buffer sizes (20%, 25%, or 30%), the pool will always have enough cash to repay the principal of senior tranches; thus, their expected return at maturity is always positive. When the coupon rate is low, the pool can also repay the interest of senior tranches; thus, the expected return at maturity on senior tranches is increasing linearly in the coupon rate. Correspondingly, the expected return at maturity on equity tranches is decreasing in the senior coupon rate, given that the higher the coupon rate paid to senior tranches, the less residual there is to be claimed by equity tranches.

When the coupon rate is high, the pool will not have enough cash to fully repay the interest, although it can fully repay the principal; therefore, the expected return at maturity on senior tranches is almost constant as the coupon rate increases. The increase in the coupon rate does not change the total cash that can be paid to senior tranches but only alters the time of the cash flow to senior tranches: the higher the coupon rate is, the more cash will be paid in periods before the maturity date and the less cash will be paid at the maturity date. Therefore, the line of the expected return at maturity on senior tranches in this domain is slightly upward sloping. The expected return at maturity on equity tranches in this domain is always -100% because there is no residual to be claimed.

Second, in the case of low buffer sizes (10% or 15%), the pool does not have enough cash to repay the principal of senior tranches; thus, its expected return at maturity is negative. The increase in the coupon rate does not change the total cash that can be paid to senior tranches; it only alters the time of the cash flow to senior tranches: the higher the coupon rate is, the more cash will be paid in periods before the maturity date and the less cash will be paid at the maturity date. However, because the expected return at maturity on senior tranches is negative, its line is slightly downward sloping. The expected return at maturity on equity tranches is always -100% because there is no residual to be claimed.[23]

10.4. Further Discussion

Table 7 displays the statistics of returns at maturity on senior and equity tranches over the 10,000 simulated paths for different security designs. The standard errors of the estimates of expected returns are very small, indicating that a total of 10,000 simulations is large enough to generate accurate estimates for expected returns at maturity. The standard deviation of returns at maturity are also reported in Table 7. Given the coupon rate, as the buffer size increases, the standard deviation of returns at maturity on senior tranches is decreasing.[24] [25]

One import implication for the security design on the underlying asset pool is that the shortfall risk could change continuously according to the change of the overcollateralization rate in certain domains (see Figure 8 and Table 7). The reason is that although pooling

[23] In the Online Appendix, Figure A.3 employs 3D plots to display how the expected returns at maturity on senior tranches and equity tranches are determined by the coupon rates and buffer sizes. Figure A.4 plots the two surfaces into the same diagram and zooms in on a smaller domain.

[24] For equity tranches, given the coupon rate, as the buffer size increases, the standard deviation of returns at maturity is first increasing and then decreasing. When the buffer size is very low, the principal and interest of senior tranches cannot be fully covered and equity tranches always have zero residual to claim; therefore, the return at maturity on equity tranches always equals -100%, and thus the standard deviation is always zero. When the buffer size reaches a certain point, equity tranches start to have positive residuals to claim and bear more uncertainty of the cash flow in the underlying asset pool; therefore, the standard deviation is increasing in the buffer size. When the buffer size is high enough, the pool always has enough funding to cover senior tranches; because returns at maturity on senior tranches are capped at the coupon rate, all the uncertainty of the underlying asset pool is borne by equity tranches; consequently, their standard deviation is decreasing in the buffer size.

[25] Some MRBSs have a rollover investment design: if some receivables are received before a certain time point in the security term, the money can be used to purchase new receivables. Our simulation framework is extendable to the shortfall risk analyses of these MRBSs. We can first simulate the proportion of receivables that arrives before the cutoff time point and then simulate the delays of new receivables starting from the arrival dates of those preceding receivables. One concern is that issuing developers may have an incentive to select new receivables in lower quality to enter the underlying asset pool. However, the selection criteria is predetermined for all the receivables that will enter the underlying asset pool; and developers are required to hold all the equity tranches in order to resolve the moral hazard concern. Therefore, succeeding receivables should have similar quality as initial receivables. Lemmon, Liu, Mao and Nini (2014) have conducted a thorough discussion on covenants in ABS agreements to resolve the potential agency problem for securitizations involving revolving funding.

thousands of receivables together could accomplish diversification to a certain extent, the distribution of the portion of receivables received in the pool by the maturity date is still spread over mainly from 78% to 81% (see Figure 6). Therefore, pinning down an appropriate overcollateralization rate corresponding to the coupon rate is important in ensuring the fairness for MRBS investors, who obtain MRBS returns that are lower than the interest rates of developers' construction loans.

11. Counterfactual Analyses

The estimation results of the Cox proportional hazard model in Table 5 quantitively show only how the delays of individual mortgage receivables change according to bank factors, individual factors, local market conditions, and macroeconomic conditions. In this section, we conduct counterfactual analyses to quantitively show how the returns at maturity of MRBSs change according to these factors.

First, we assume that the house prices in all the cities increase by 10%, 25%, 50%, and 100% of the standard deviation, respectively. In each of these four scenarios, based on the estimates of the Cox proportional hazard model, we simulate the delay of each receivable in the underlying asset pool for 10,000 times. We compute the average proportion of the underlying assets that can be received by the maturity date (two years). Given a typical security design (overcollateralization rate = 25.5% and senior coupon rate = 6%), we compute the probability of shortfalls and the average return at maturity for senior tranches.

As shown in Table 8, when the house prices in all the cities increase by 10%, 25%, 50%, and 100% of the standard deviation, the average returns at maturity for senior tranches will be reduced from 5.98% (baseline) to 5.94%, 5.82%, 5.43%, and 4.48%, respectively; the probability of shortfalls for senior tranche payments will be increased from 13.10% (baseline) to 30.58%, 65.67%, 97.26%, and 100.00%, respectively. The lower part of Table 8 shows that an increase in house prices by 10% of the standard deviation will only reduce the quantiles below the 50%. More increases in house prices will reduce the higher quantiles. Figure 9 displays how much the distribution of returns at maturity for senior tranches will be shifted leftward in the four counterfactual scenarios compared to the baseline case.

We also perturb other risk factors and conduct counterfactual analyses at the security level. In each row of Table 9, we counterfactually change the factor of the row by 25% of its standard deviation for all the mortgage receivables in the underlying asset pool toward the direction that prolongs the delays while keep all other factors unchanged. The corresponding probability of shortfalls and the average return at maturity for senior tranches are reported.

12. Conclusion

Different from default risk, delay risk is associated with entitled future payments or scheduled future actions without a clearly specified due date.

In this paper, we study a form of securitization that deals with underlying assets with mainly delay risk, MRBSs. As a financial innovation that appeared in 2015 in China's real estate finance market, MRBSs are growing rapidly along with the development of MBSs and other ABSs in China. It has been documented that MRBSs have a dramatic impact on the real estate development industry in China. Developers who issue MRBSs expand much faster in their businesses.

Using unique proprietary data from one of the top ten national real estate developers in China, we provide a systematic analysis regarding what factors from what sources through which mechanisms can affect mortgage receivable delays. We estimate a Cox proportional hazard model. The empirical results indicate that regarding bank characteristics, the length of delays is decreasing in bank liquidity and loan-deposit interest spreads and is increasing in banks' lending caution, ROAs, and reliance on wholesale funding. Regarding property-loan-household characteristics, the length of delays is decreasing in borrowers' creditworthiness and incentives to act quickly in applying for mortgages; commercial properties experience longer delays than residential properties. Regarding local market conditions, the length of delays is decreasing in the bank's market presence and is increasing in the local unemployment rate and housing market performance.

Based on the estimates, we conduct Monte Carlo simulations for the cash flow of a mortgage receivable pool and the shortfall risk of MRBS tranches. Unlike many previous studies that used the security-level returns and default events to analyze the risk of ABSs and

MBSs, we use a "bottom-up" approach to analyze MRBSs: first, estimate and simulate the risk of individual underlying assets; second, aggregate up to the security-level shortfall risk. Based on the simulation, we analyze how the shortfall risk of senior tranches varies according to the security-design parameters (overcollateralization rate and coupon rate).

Our analyses provide a benchmark for conducting appropriate security designs based on the composition of the underlying asset pool such that the shortfall risk is small enough relative to the issuing firm's bankruptcy risk, through which the borrowing-cost-reduction purpose of asset securitization should be achieved. Our analyses for the shortfall risk also increase the transparency for investors regarding the risk pattern of MRBSs and provide implications for the pricing of MRBSs.

Moreover, our estimation and simulation results have several important implications. First, high local house prices and low LTVs tend to prolong the mortgage receivable delays and thus increase the shortfall risk of MRBSs, although it is well known that increases in house prices and decreases in LTVs reduce mortgage default risk and thereby the risk of MBSs. Consequently, MRBSs could serve as an excellent financial tool to hedge against the risks of other securities (such as MBSs), and the introduction of MRBSs to the financial market could significantly improve the diversification of the market.

Second, although the underlying assets of MRBSs mainly have only delay risk and almost no default risk and are thus supposed to be high-quality assets, we find that there are large heterogeneities in delays across different mortgage receivables. Moreover, we find that many factors from multiple sources (banks, homebuyers, and local markets) can significantly affect individual mortgage receivable delays; consequently, in contrast to MBSs, it is difficult to standardize the underlying asset pools for issuing MRBSs. Therefore, for investors to accurately analyze the risk of MRBSs, the security level characteristics (e.g., overcollateralization rate, equity tranche proportion, unsophisticated criteria for mortgage receivables to enter the asset pool) currently released by developers to investors are far from sufficient. The regulator should require developers to release information on the composition of the asset pool (i.e., the distribution of all the individual-level characteristics that can significantly affect the delay risk of an individual mortgage receivable) to investors and bring more transparency to the financial market.

Third, the securitization process of MRBSs imposes a natural adverse selection on the quality of underlying assets. The reason is that conditional on having not been received by the securitization date, receivables tend to have longer delays. Correspondingly, there could be two policy implications regarding how to mitigate this adverse selection effect for MRBSs. The first one is to tighten the criterion that receivables that have been delayed for more than a certain time length by the securitization date cannot enter the securitization pool. Second, increasing overcollateralization rates of securitization can help reduce the risk exposure of security investors.

To the best of our knowledge, this study is the first to formally analyze a form of securitization that mainly deals with delay risk of underlying assets. The framework established in this paper for MRBSs can also be applied to the designs and analyses of other potential delay derivatives, such as delay swaps (an analogy to default swaps), which are currently being conceived by the financial market in China. After the market for delay swaps is well developed, more delay derivatives (e.g., delay index products and options on delay spreads) can further be constructed in practice. Because the formation mechanism of delay risk is fundamentally different from other risks (such as default and prepayment risks), financial instruments dealing with delay risk have great potential for diversifying the overall risk of investors' portfolios.

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Table 1. Comparison between MBSs and MRBSs

	Mortgage-Backed Securities	Mortgage-Receivable-Backed Securities
Underlying asset pool	Mortgage payment from borrowers to lenders	Mortgage receivable from lenders to real estate developers
Sellers	Lenders	Real estate developers
Term	Long	Short, usually 1 - 3 years
Cash flow schedule	Certain if not default or prepay	Uncertain
Risk	Defaults and prepays by borrowers	Delays by homebuyers and lenders, almost no defaults
Cash flow distribution	Waterfall	Waterfall

Table 2. Different Effects of Risk Factors on MBSs and MRBSs

	Mortgage-Backed Securities	Mortgage-Receivable-Backed Securities
House price	decreases mortgage default risk because of more home equity	increases receivable delays because banks face more demand of mortgages
Unemployment rate	increases illiquidity-triggered default risk	increases receivable delays because banks face lower deposit supplies from the city
LTV	increases strategic default risk because of lower home equity	decreases homebuyers' delays in mortgage application because of more incentive for them to act fast
Homebuyer's creditworthiness	decreases mortgage default risk	decreases banks' delays in approving mortgage applications

Table 3. Expected Signs of Covariates

Variable	Expected sign of coefficients in the proportional hazard model	Effects on payment delays
Bank factors		
capital adequacy ratio	+	-
loan-to-deposit ratio	-	+
nonperforming loan ratio	+	-
loan-deposit interest spreads	+	-
deposit interest rate	-	+
ROA	+-	-+
funding structure (the ratio of total liabilities minus total deposits to total assets)	-	+
Individual factors (Property, Loan, and Household Characteristics)		
ratio of garden area to living area	+	-
the number of days from the property transaction date to the full payment due date	-	+
loan amount	+-	-+
LTV	+-	-+
commercial property indicator	-	+
Local market conditions		
market presence	+	-
market importance	+	-
city-level house prices (RMB/square meter)	-	+
housing area sold (million square meters)	-	+
unemployment rate	-	+
Macroeconomic conditions		
M2 growth	+	-

Note: A positive (negative) coefficient in the proportional hazard model means that an increase in the covariate will accelerate (decelerate) the payments and thus shorten (prolong) the delays. A “+-” or “-+” means that theories or stories with positive predictions and those with negative predictions both exist.

Table 4. Descriptive Statistics

Variable	Mean	S.D
Bank factors		
capital adequacy ratio	0.1279	0.0166
loan-to-deposit ratio	0.6282	0.1214
nonperforming loan ratio	1.6402	2.6161
loan-deposit interest spread (%)	2.8122	0.3447
average deposit interest rate (%)	1.3618	0.2662
ROA (%)	1.0767	0.2637
funding structure	0.1477	0.0543
Individual factors (Property, Loan, and Household Characteristics)		
days of delay	86.6461	99.8269
observations not censored	0.9601	0.1957
ratio of garden area to living area	0.1729	0.3781
days from property transaction date to mortgage due date	41.4160	48.5555
loan amount (100,000 RMB)	5.0429	5.2607
LTV	0.6173	0.1200
commercial property indicator	0.0207	0.1425
Local market conditions		
market presence	0.1322	0.0718
market importance	0.0250	0.1316
city-level house prices (RMB/square meter)	7649	3125
housing area sold (million square meters)	0.5078	0.3911
unemployment rate	0.0249	0.0235
Macroeconomic conditions		
M2 growth (quarterly)	0.0340	0.0169
GDP growth (quarterly)	0.0278	0.1129

Table 5. Regression Results of the Cox Proportional Hazard Model

Parameter	Model 1		Model 2		Model 3		Model 4		
	Estimate	Std Err	Estimate	Std Err	Estimate	Std Err	Estimate	Std Err	Rescaled Hazard Ratio
Bank factors									
capital adequacy ratio	11.1992***	0.5912	12.7322***	0.5919	13.0478***	0.5964	12.9155***	0.5994	1.2392
loan/deposit ratio	-1.9402***	0.1757	-2.2195***	0.1764	-2.1520***	0.1810	-2.1424***	0.1809	0.7716
nonperforming loan ratio	0.2247***	0.0153	0.1957***	0.0152	0.1575***	0.0155	0.1511***	0.0155	1.4810
loan-deposit interest spread (%)	0.1440***	0.0251	0.2059***	0.0252	0.1295***	0.0259	0.1430***	0.0260	1.0503
deposit interest rate (%)	-0.4715***	0.0252	-0.3869***	0.0256	-0.3016***	0.0263	-0.2566***	0.0272	0.9343
return on asset (%)	-2.4836***	0.0777	-2.5894***	0.0776	-2.5893***	0.0785	-2.5678***	0.0786	0.5103
funding structure	-1.5776***	0.2769	-2.0724***	0.2772	-1.7719***	0.2815	-1.9377***	0.2825	0.8974
Individual factors (property, loan, and household characteristics)									
ratio of garden area to living area			0.0678***	0.0111	0.0744***	0.0112	0.0737***	0.0112	1.0283
days from house purchase to mortgage due date			-0.0047***	0.0001	-0.0047***	0.0001	-0.0047***	0.0001	0.7753
loan amount (100 K RMB)			-0.0075***	0.0008	-0.0080***	0.0008	-0.0081***	0.0008	0.9586
LTV			0.0835***	0.0274	0.0864***	0.0277	0.0851***	0.0277	1.0103
commercial property			-0.5255***	0.0245	-0.5154***	0.0246	-0.5188***	0.0246	0.5952
Local market conditions									
market presence					1.1251***	0.1072	1.1188***	0.1072	1.0837
market importance					0.4914***	0.1581	0.5043***	0.1581	1.0686
local house price					-0.7235***	0.0430	-0.7024***	0.0433	0.8029
housing areas sold					-0.3766***	0.0210	-0.3795***	0.0215	0.8620
unemployment rate					-3.7379***	0.7191	-3.7151***	0.7192	0.9165
Macroeconomic conditions									
M2 growth							1.5948***	0.2420	1.0273
GDP growth							0.1301***	0.0351	1.0148
Fixed effects									
bank fixed effects	Yes		Yes		Yes		Yes		
city fixed effects	Yes		Yes		Yes		Yes		

$$\lambda_{i,g}(\tau) = \lambda_0(\tau)\exp(x_{i,g}\beta)$$

For models 1 through 4, column 1 reports the estimates of β in the Cox proportional hazard model above using a partial likelihood method. A positive (negative) coefficient means that an increase in the covariate will accelerate (decelerate) the payments and thus shorten (prolong) the delays. Column 2 reports the standard errors. For model 4, column 3 reports the rescaled hazard ratio, which measures the importance of a covariate in determining the delays. For the dummy variable "Commercial property", the rescaled hazard ratio indicates the extent to which the hazard rate will be shifted if the dummy variable changes from 0 (residential property) to 1 (commercial property); for the other covariates, the rescaled hazard ratio indicates the extent to which the hazard rate will be shifted if there is a one-standard-deviation increase of the covariate from the mean. A hazard ratio above one means the covariate will shift the hazard rate upward, while a hazard ratio below one means the covariate will shift the hazard rate downward. The more the rescaled hazard ratio deviates from one, the more important is the covariate. Model 2 adds macroeconomic variables on top of model one and obtains similar results. * denotes a 10% significance level. ** denotes a 5% significance level. *** denotes a 1% significance level.

Table 6. Goodness of Fit

Panel A: in-sample fit					
Estimation sample	2007-2015	2007--2015	2007--2015	2007--2015	2007--2015
Prediction sample	2007-2015	2012	2013	2014	2015
Pseudo R squared	0.4322	0.2989	0.3386	0.5528	0.5744
Size of estimation sample	105435	105435	105435	105435	105435
Size of prediction sample	105435	10790	27720	34115	16504
Observations not censored in prediction sample	96.01%	99.98%	99.58%	95.62%	83.44%
Panel B: out-sample fit (1)					
estimation sample		2007-2011 and 2013-2015	2007-2012 and 2014-2015	2007-2013 and 2015	2007-2014
Prediction sample		2012	2013	2014	2015
Pseudo R squared		0.2845	0.3025	0.5446	0.5505
Panel C: out-sample fit (2)					
estimation sample	A 90% random sample in 2007-2015	2007-2012 excluding a 50% random sample in 2012	2007-2013 excluding a 50% random sample in 2013	2007-2014 excluding a 50% random sample in 2014	2007-2015 excluding a 50% random sample in 2015
Prediction sample	A 10% random sample in 2007-2015	a 50% random sample in 2012	a 50% random sample in 2013	a 50% random sample in 2014	a 50% random sample in 2015
Pseudo R squared	0.4273	0.2094	0.3240	0.5380	0.5707
Panel D: out-sample fit (3)					
estimation sample		2007-2011	2007-2012	2007-2013	2007-2014
Prediction sample		2012	2013	2014	2015
Pseudo R squared		0.1804	0.2435	0.3865	0.5412

Panel A separately displays the goodness of in-sample fit for the mortgage receivables associated with properties purchased in different years. Panels B, C and D display the goodness of out-sample fit. In panel B, the observations in the prediction year are excluded from the estimation sample; in panel C, a 50% random sample of observations in the prediction year and all the observations after the prediction year are excluded from the estimation sample, and the 50% random sample of observations in the prediction year becomes the prediction sample; in panel D, the observations in and after the prediction year are excluded from the estimation sample.

Table 7. Expected Returns at Maturity and Standard Deviations

	Senior			Equity		
Buffer %	Expectation	Standard Error	Standard Deviation	Expectation	Standard Error	Standard Deviation
	Coupon Rate 6%			*Coupon Rate 6%*		
20.00%	2.42%	0.00%	0.28%	-100.00%	0.00%	0.00%
21.00%	3.08%	0.00%	0.28%	-100.00%	0.00%	0.00%
22.00%	3.76%	0.00%	0.28%	-100.00%	0.00%	0.00%
23.00%	4.44%	0.00%	0.28%	-100.00%	0.00%	0.00%
24.00%	5.14%	0.00%	0.28%	-100.00%	0.00%	0.25%
25.00%	5.80%	0.00%	0.22%	-92.70%	0.13%	12.52%
26.00%	6.00%	0.00%	0.02%	-54.33%	0.14%	14.07%
27.00%	6.00%	0.00%	0.00%	-28.24%	0.08%	8.27%
28.00%	6.00%	0.00%	0.00%	-9.43%	0.07%	6.55%
29.00%	6.00%	0.00%	0.00%	6.43%	0.06%	5.63%
30.00%	6.00%	0.00%	0.00%	20.57%	0.05%	5.03%
	Coupon Rate 8%			*Coupon Rate 8%*		
20.00%	2.46%	0.00%	0.29%	-100.00%	0.00%	0.00%
21.00%	3.13%	0.00%	0.29%	-100.00%	0.00%	0.00%
22.00%	3.82%	0.00%	0.29%	-100.00%	0.00%	0.00%
23.00%	4.51%	0.00%	0.29%	-100.00%	0.00%	0.00%
24.00%	5.22%	0.00%	0.29%	-100.00%	0.00%	0.00%
25.00%	5.94%	0.00%	0.29%	-100.00%	0.00%	0.00%
26.00%	6.67%	0.00%	0.29%	-100.00%	0.00%	0.00%
27.00%	7.40%	0.00%	0.29%	-99.71%	0.02%	2.47%
28.00%	7.95%	0.00%	0.12%	-76.77%	0.18%	18.09%
29.00%	8.00%	0.00%	0.00%	-39.58%	0.10%	10.48%
30.00%	8.00%	0.00%	0.00%	-16.89%	0.07%	7.38%

Under the assumption that the proportions of senior and equity tranches are 95% and 5%, respectively, three statistics of returns at maturity on senior and equity tranches over the 10,000 simulated paths for different combinations of coupon rates and buffer sizes are reported. The three statistics are: the expected return at maturity, the standard error of the estimate for the expected return at maturity, and the standard deviation of the return at maturity.

Table 8. Counterfactual Analyses for Perturbations of House Prices

	Baseline	**10% Std. HP increase**	**25% Std. HP increase**	**50% Std. HP increase**	**100% Std. HP increase**
Proportion of the pool received at maturity	79.74%	79.48%	79.10%	78.44%	77.05%
Senior shortfall probability at maturity	13.10%	30.58%	65.67%	97.26%	100.00%
Senior average return at maturity	5.98%	5.94%	5.82%	5.43%	4.48%
Senior yield quantile					
0%	5.31%	5.07%	4.60%	4.13%	3.31%
5%	5.84%	5.68%	5.40%	4.94%	3.95%
25%	6.00%	5.95%	5.69%	5.24%	4.27%
50%	6.00%	6.00%	5.88%	5.44%	4.49%
75%	6.00%	6.00%	6.00%	5.64%	4.70%
95%	6.00%	6.00%	6.00%	5.92%	4.99%
100%	6.00%	6.00%	6.00%	6.00%	5.60%

We counterfactually increase the house prices of all the cities by 10%, 25%, 50%, and 100% of the standard deviation, respectively. In each of these four scenarios, based on the estimates of the Cox proportional hazard model, we simulate the delay of each receivable in the underlying asset pool for 10,000 times. Then, we aggregate to the pool level and obtain the distribution of senior returns at maturity, given the security design that overcollateralization rate = 25.5% and senior coupon rate = 6%.

Table 9. Counterfactual Analyses for Perturbations of Risk Factors

Parameter	Proportion of the pool received at maturity	Senior shortfall probability	Senior average return	Senior yield quantile						
				0%	5%	25%	50%	75%	95%	100%
Baseline	**79.74%**	**13.10%**	**5.98%**	**5.31%**	**5.84%**	**6.00%**	**6.00%**	**6.00%**	**6.00%**	**6.00%**
Bank factors										
capital adequacy ratio	79.11%	63.56%	5.82%	4.62%	5.41%	5.70%	5.90%	6.00%	6.00%	6.00%
loan/deposit ratio	78.97%	75.24%	5.76%	4.47%	5.32%	5.61%	5.80%	6.00%	6.00%	6.00%
nonperforming loan ratio	78.58%	94.49%	5.52%	4.39%	5.03%	5.33%	5.54%	5.74%	6.00%	6.00%
loan-deposit interest spread (%)	79.59%	21.87%	5.96%	5.02%	5.74%	6.00%	6.00%	6.00%	6.00%	6.00%
deposit interest rate (%)	79.54%	26.02%	5.95%	5.07%	5.71%	5.99%	6.00%	6.00%	6.00%	6.00%
return on asset (%)	77.71%	99.94%	4.94%	3.62%	4.43%	4.73%	4.94%	5.15%	5.44%	6.00%
funding structure	79.42%	35.50%	5.93%	4.98%	5.63%	5.91%	6.00%	6.00%	6.00%	6.00%
Individual factors (property, loan, and household characteristics)										
ratio of garden area to living area	79.66%	17.85%	5.97%	5.11%	5.80%	6.00%	6.00%	6.00%	6.00%	6.00%
days from house purchase to mortgage due date	78.99%	73.71%	5.77%	4.45%	5.32%	5.62%	5.82%	6.00%	6.00%	6.00%
loan amount (100 K RMB)	79.38%	38.23%	5.93%	5.07%	5.63%	5.90%	6.00%	6.00%	6.00%	6.00%
LTV	79.70%	15.14%	5.98%	5.03%	5.82%	6.00%	6.00%	6.00%	6.00%	6.00%
commercial property	73.02%	100.00%	1.64%	0.08%	1.01%	1.39%	1.65%	1.90%	2.25%	2.98%
Local market conditions										
market presence	79.50%	27.93%	5.95%	5.08%	5.69%	5.98%	6.00%	6.00%	6.00%	6.00%
market importance	79.54%	25.65%	5.95%	5.05%	5.71%	5.99%	6.00%	6.00%	6.00%	6.00%
local house price	79.10%	65.67%	5.82%	4.60%	5.40%	5.69%	5.88%	6.00%	6.00%	6.00%
housing areas sold	79.30%	46.23%	5.90%	4.79%	5.54%	5.83%	6.00%	6.00%	6.00%	6.00%
unemployment rate	79.48%	30.39%	5.94%	5.02%	5.67%	5.96%	6.00%	6.00%	6.00%	6.00%
Macroeconomic conditions										
M2 growth	79.66%	17.90%	5.97%	5.15%	5.78%	6.00%	6.00%	6.00%	6.00%	6.00%
GDP growth	79.69%	15.62%	5.98%	5.11%	5.81%	6.00%	6.00%	6.00%	6.00%	6.00%

In each row except commercial property, we perturb the factor of the row by 25% of its standard deviation for all the mortgage receivables in the underlying asset pool toward the direction that prolongs the delays while keep all other factors unchanged. That is, if the coefficient of the factor in the estimation result shown in Table 5 is positive (negative), we decrease (increase) the factor by 25% of its standard deviation. Then, we simulate the delay of each receivable in the underlying asset pool for 10,000 times and aggregate to the pool level to obtain the distribution of senior returns at maturity, given the security design that overcollateralization rate = 25.5% and senior coupon rate = 6%. For commercial property, we counterfactually let all the properties in the pool become commercial properties.

Figure 1. Process from House Transaction to Release of Mortgage Receivable

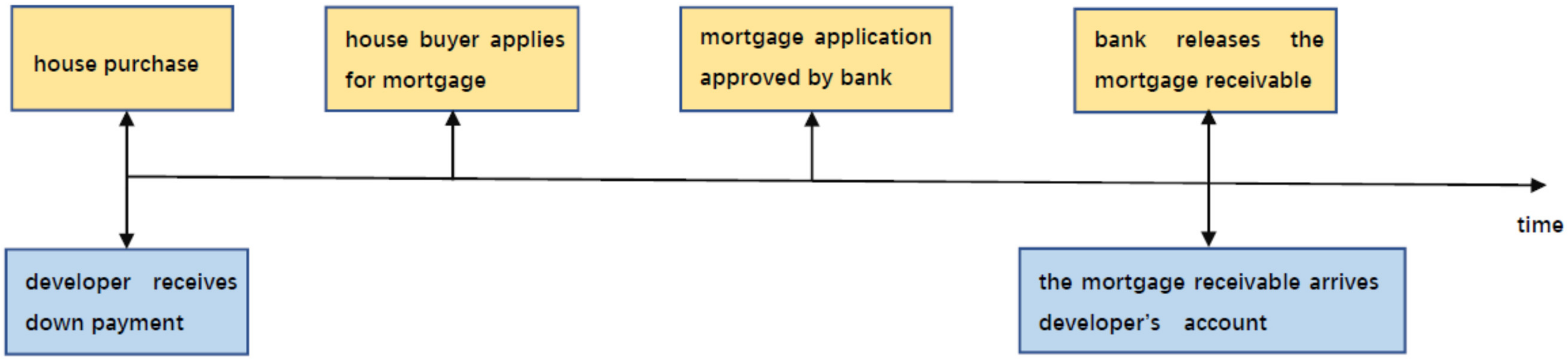
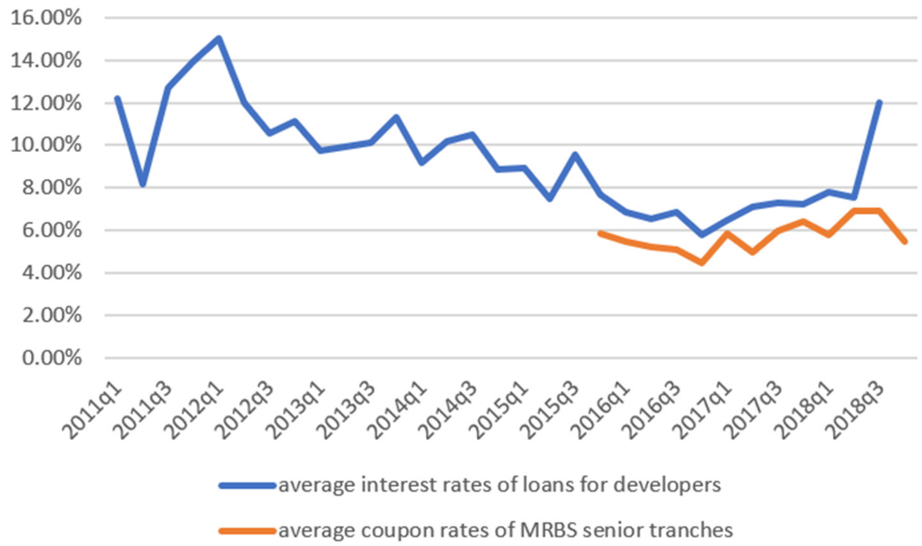


Figure 2. Comparison of interest rates between MRBSs and loans to developers



The blue line represents the quarterly average of interest rates of bank loans to publicly listed developers. The interest rates are extracted from the data set provide by WIND for bank loans to all publicly listed firms. The orange line represents the average of interest rates of MRBS senior tranches issued in a quarter. The data are also extracted from WIND.

Figure 3. Distribution of Delays in the Sample

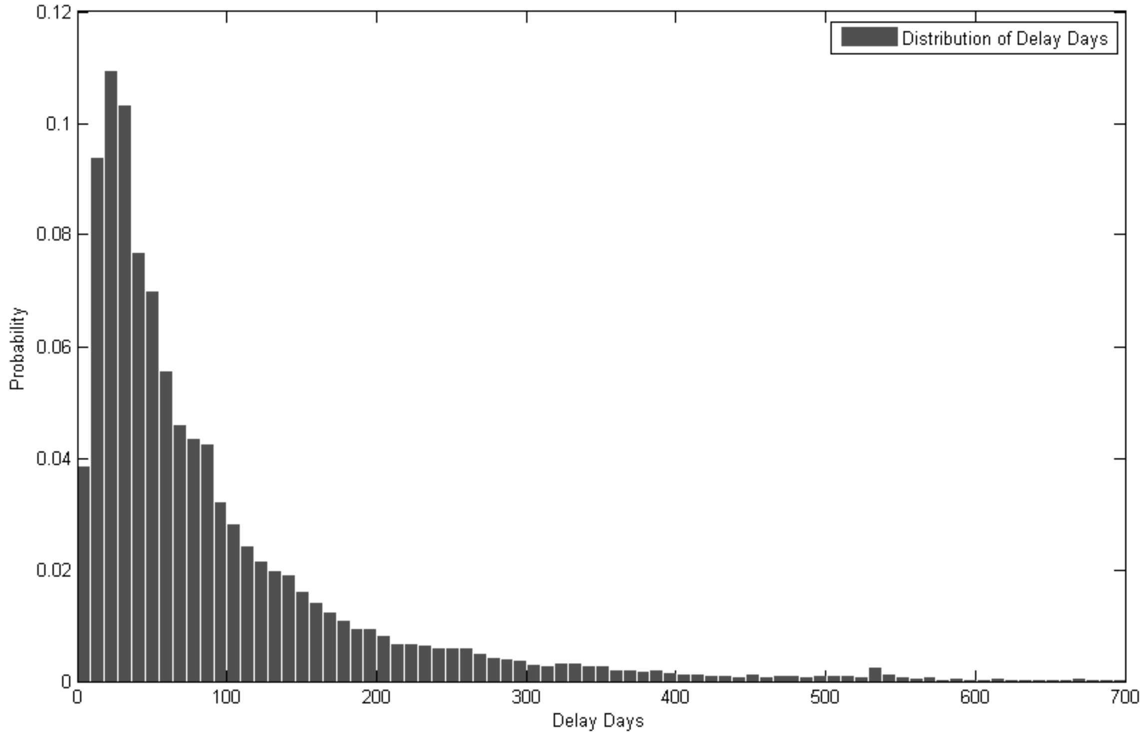


Figure 4. Estimated Survival Functions for Some Mortgage Receivables

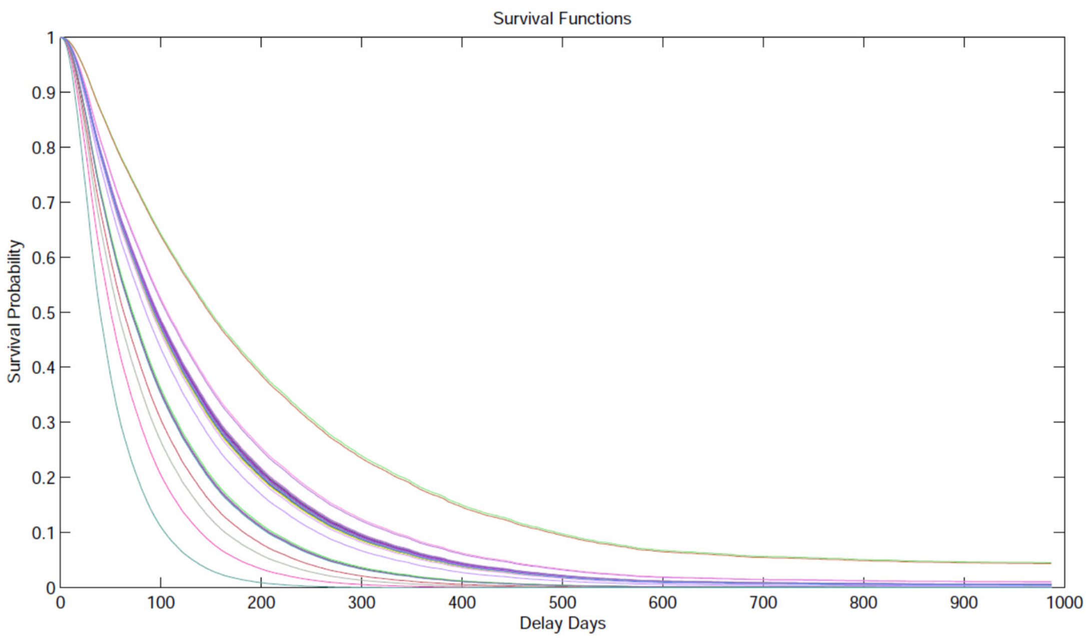
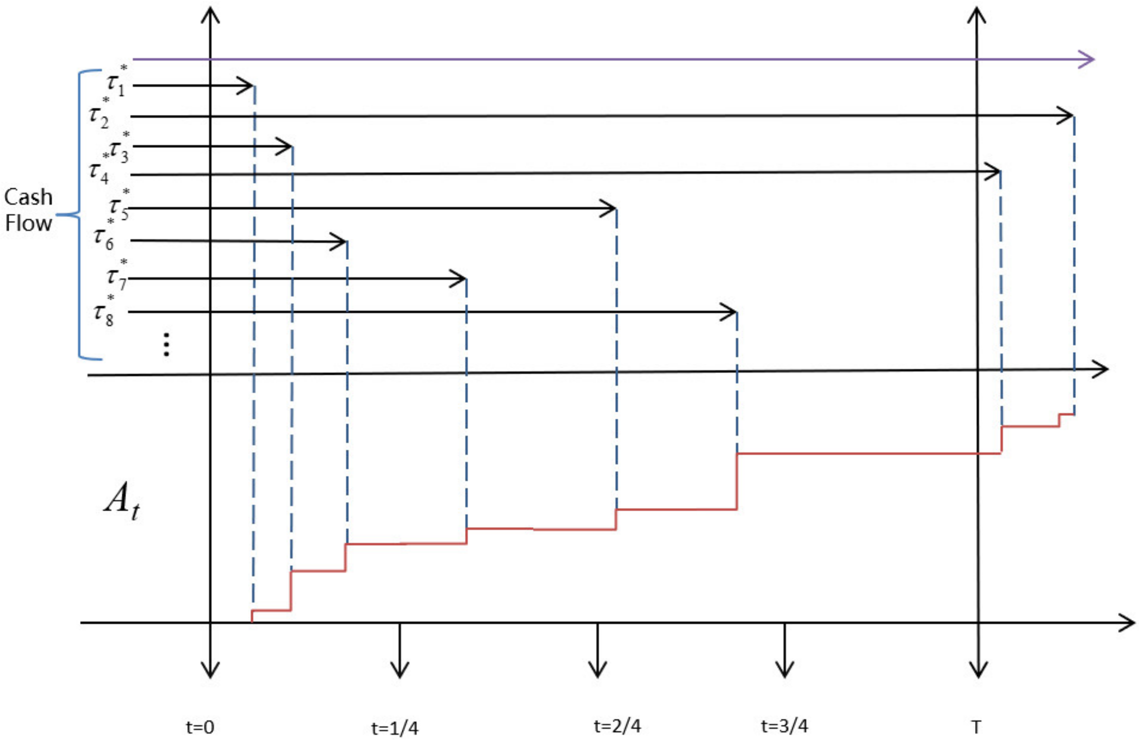


Figure 5. Cash Flow Structures of the Underlying Asset Pool and the Tranches for MRBSs

Panel A



Panel B

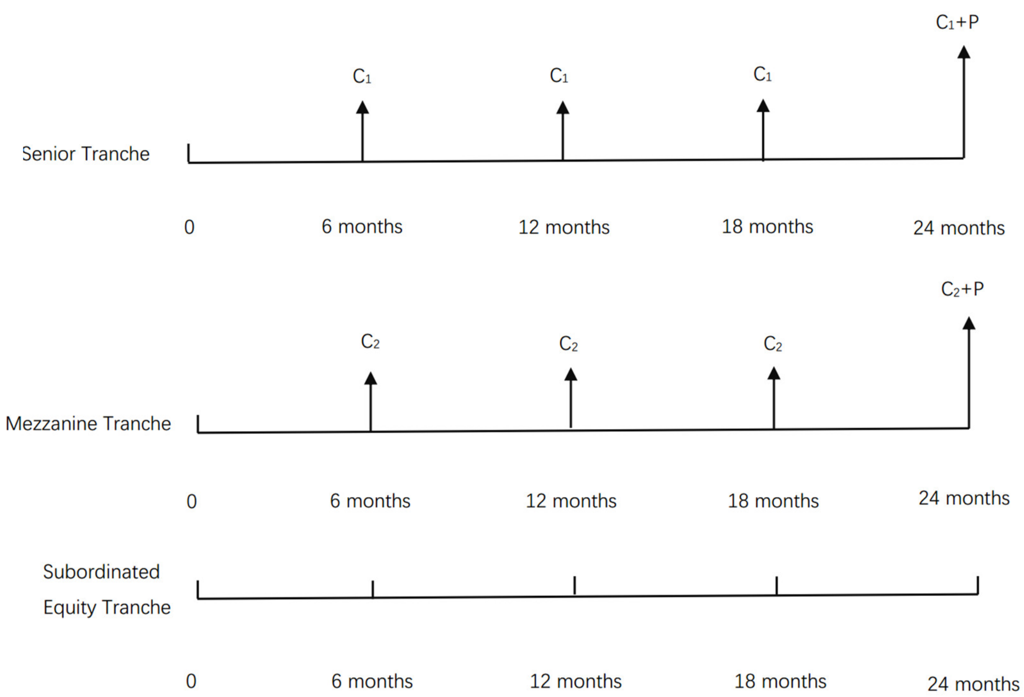


Figure 6. Simulated Distributions of the Cash Received in the Pool by Maturity Date

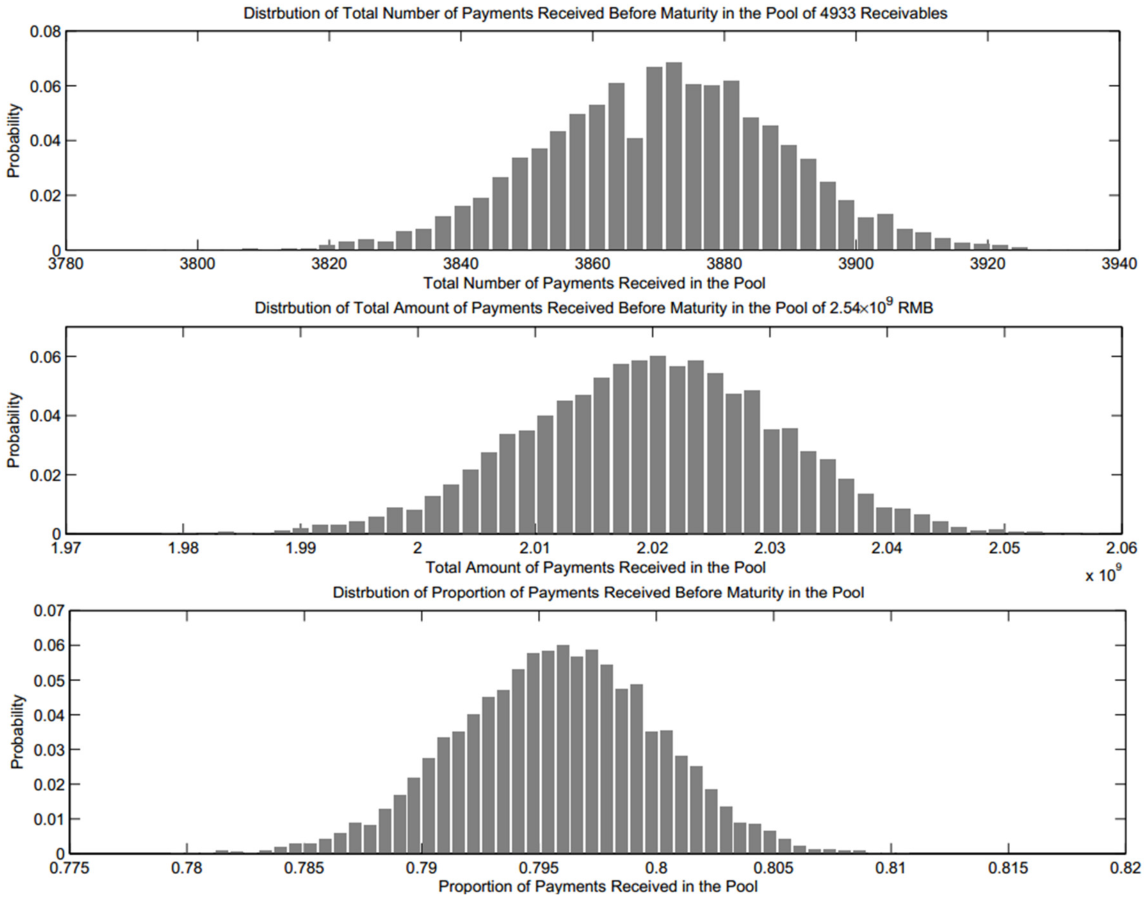
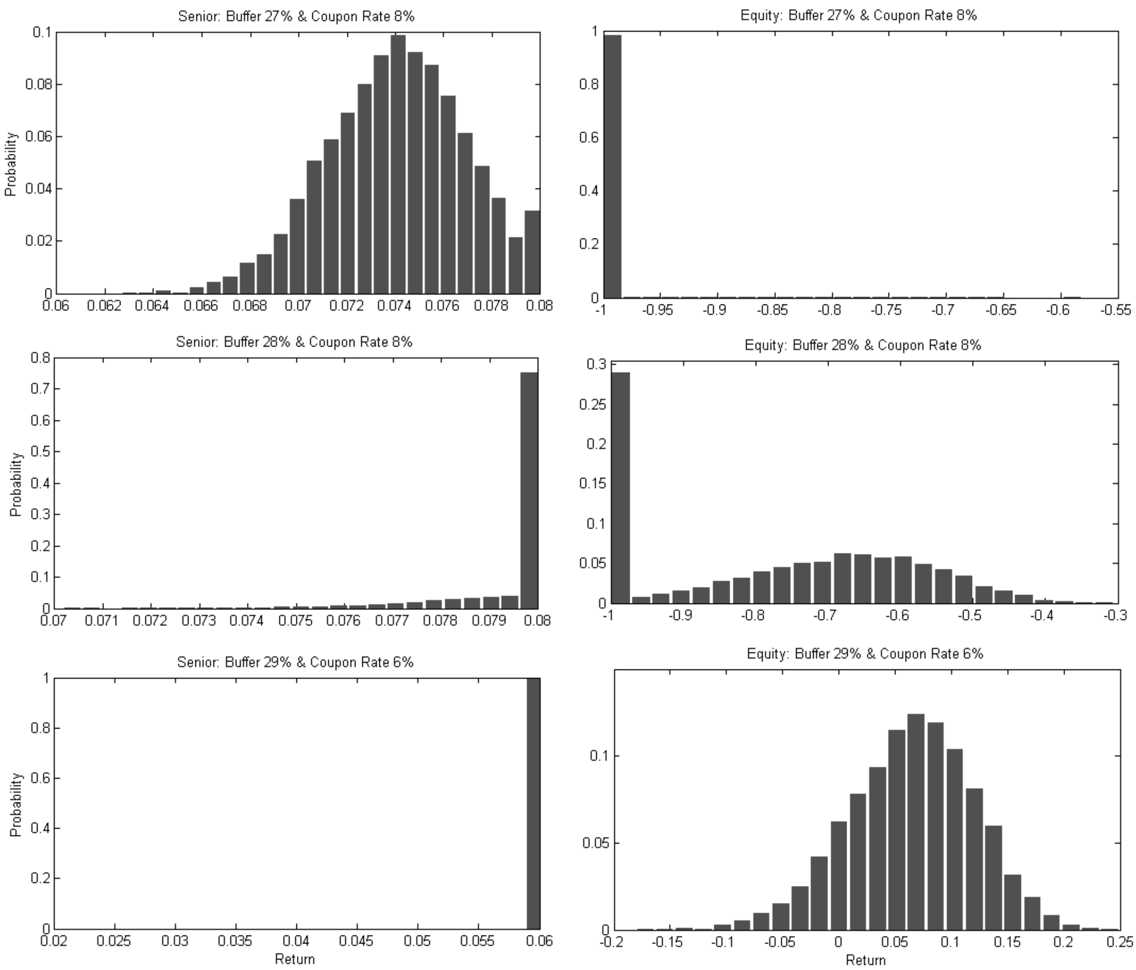


Figure 7. Simulated Expected Returns at Maturity for Senior and Equity Tranches under Different Security Designs



Each row represents a security design. The focus is the distribution of returns at maturity for senior tranches on the left because equity tranches are held by developers to resolve the moral hazard problem, but we also display the distribution for equity tranches on the right for comparison. We choose these three security designs to exhibit because they are quite representative of three different patterns of simulated distributions. Comparing Design 2 with Design 1, the 1% increase in the buffer size leads to a significant change in the distribution pattern of returns at maturity for senior tranches, and the expected return at maturity for senior tranches is increased from 7.40% to 7.95%.

Figure 8. Simulated Relationship among Expected Returns at Maturity, Buffer Size, and Coupon Rate

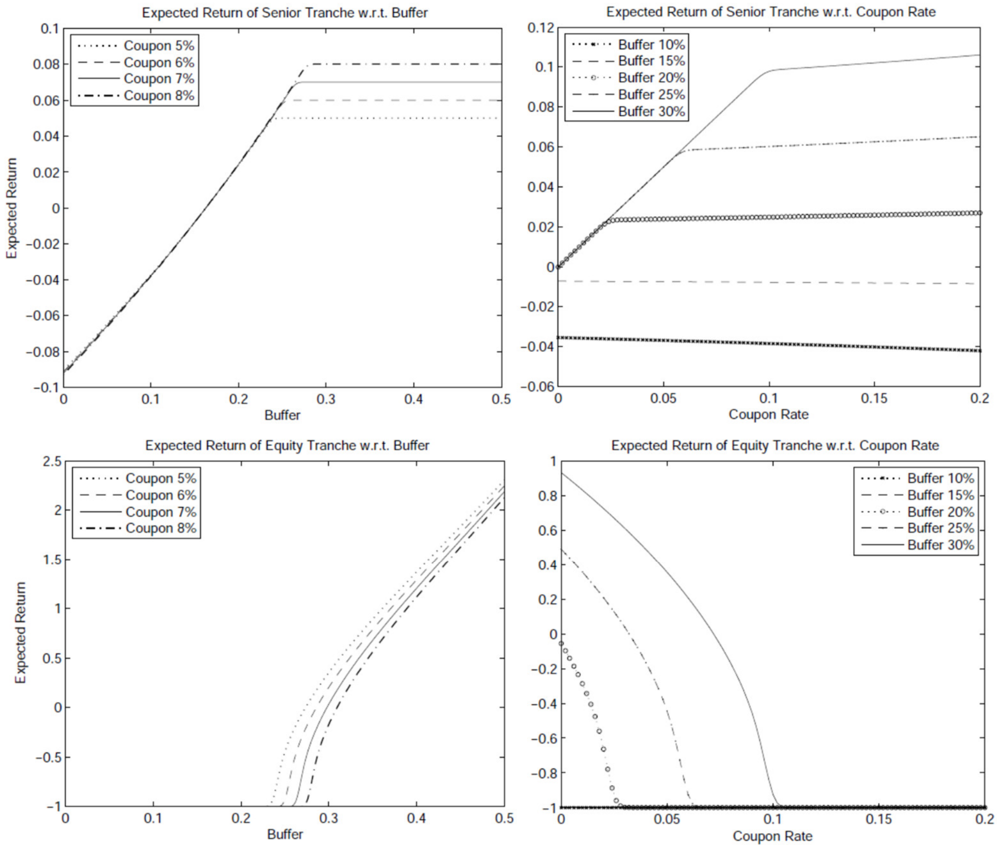
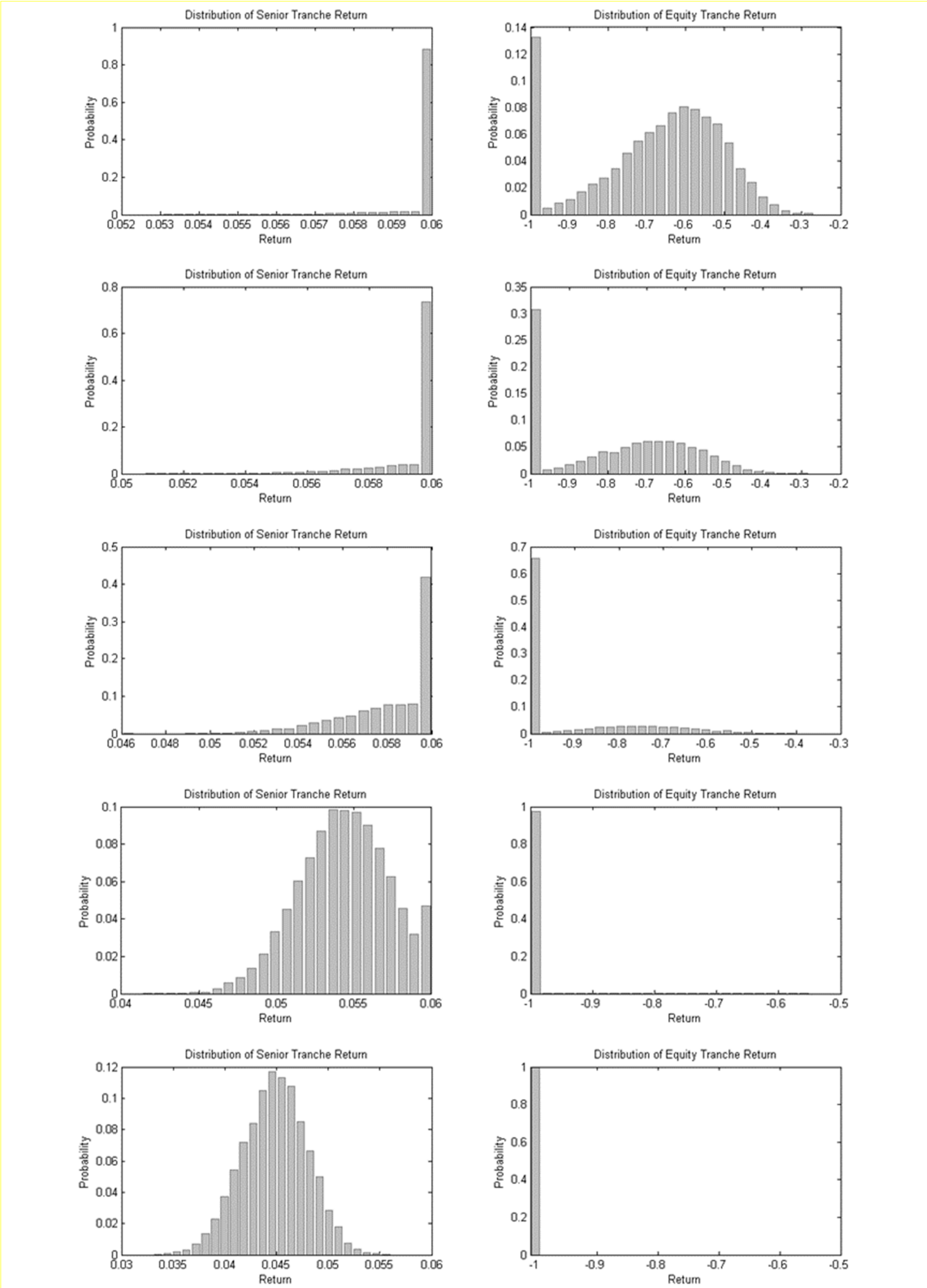


Figure 9. Counterfactual Analyses for House Price Changes

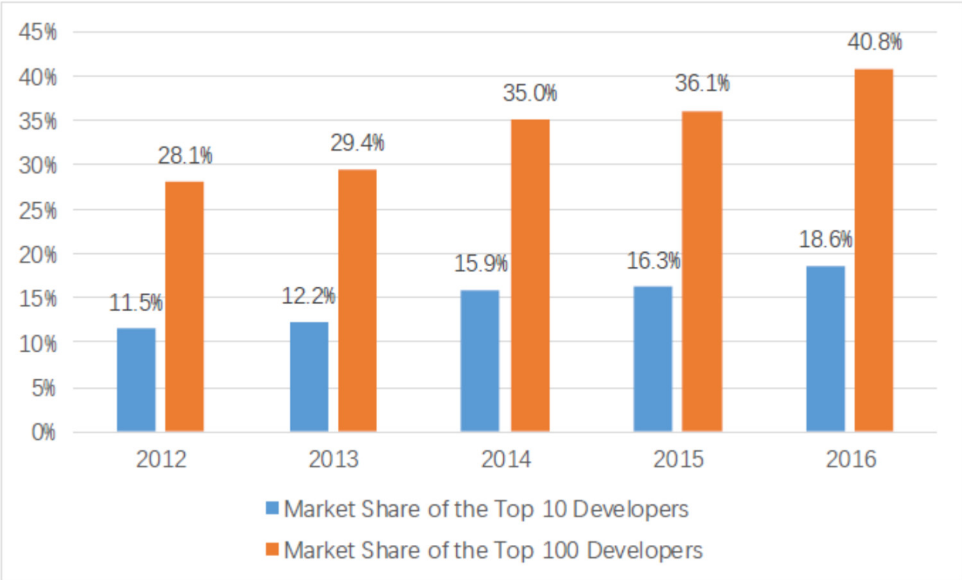


Notes: Given that overcollateralization rate = 25.5% and senior coupon rate = 6%, the left and right columns display the distributions of returns at maturity for senior and equity tranches, respectively. The first row shows the baseline results. In the second through fifth rows, the house prices in all the cities are increased by 10%, 25%, 50%, and 100% of the standard deviation, respectively.

Online Appendix

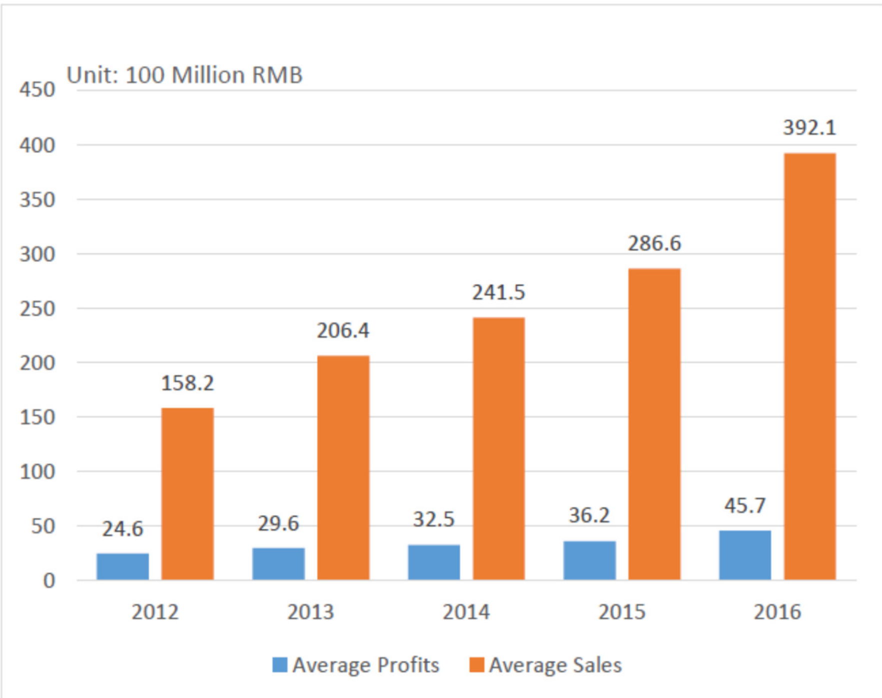
Appendix I

Figure A.1. Average Market Shares of the Top Real Estate Developers in China



(Data Source: TOP10 Research Group)

Figure A.2. Average Profits and Sales of the Top 100 Developers



(Data Source: TOP10 Research Group)

Figure A.3. Simulated Relationship among Expected Returns at Maturity, Buffer Size, and Coupon Rate – 3D Plot (1)

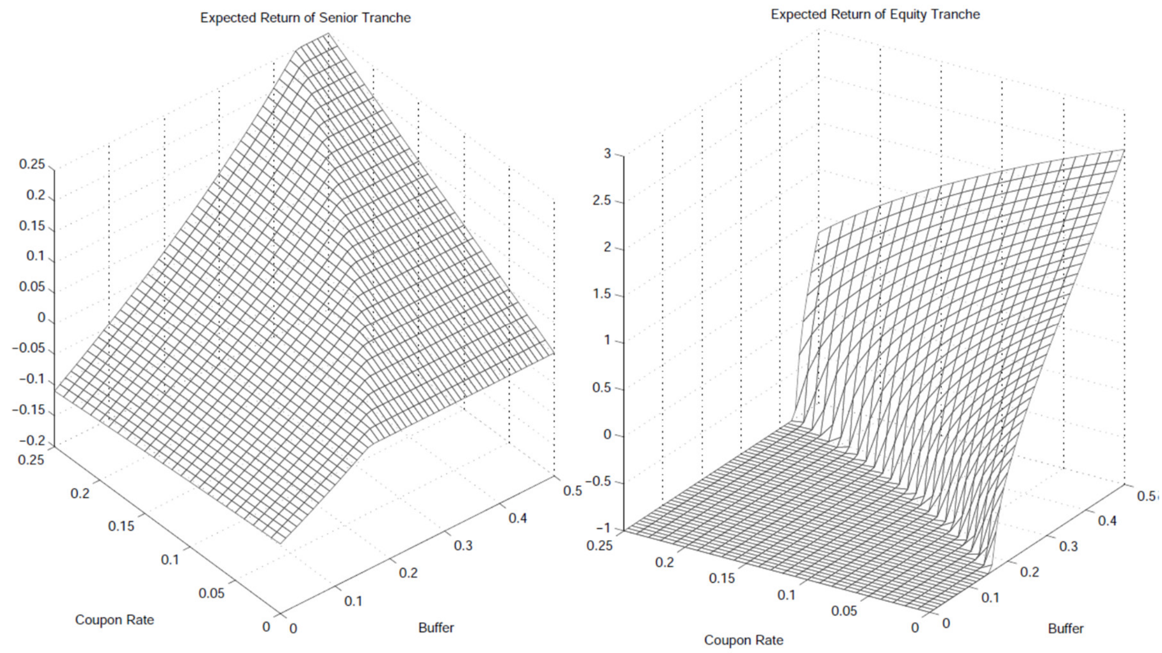
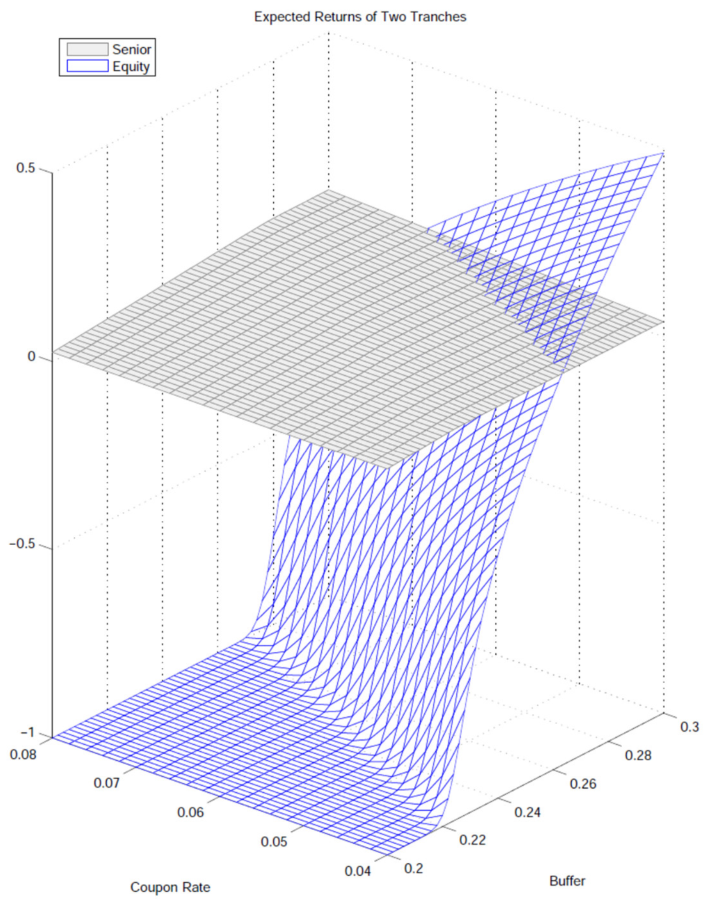


Figure A.4. Simulated Relationship between Expected Returns at Maturity, Buffer Size, and Coupon Rate – 3D Plot (2)



Appendix II. Mortgages from Banks vs. Mortgages from Housing Provident Fund (HPF):

The HPF policy is implemented by the Chinese government to help low-to-moderate income employees build homeownership. It requires both employees and employers to contribute to a pool every month; the money in the pool can be used later to make mortgage loans to employee participants. We estimate a proportional hazard model using both mortgages from banks and mortgages from HPF. As shown in Table A.1, the coefficient of the HPF indicator is -0.7740, significantly negative with a rescaled hazard ratio highly deviated from one. This result is consistent with the reality that mortgages from HPF have much longer delays than mortgages from banks because HPF has a more complicated administrative and regulatory process. Developers usually do not securitize mortgage receivables from HPF.

Table A.1

Parameter	Estimate	Std Err	Rescaled Hazard Ratio
ratio of garden area to living area	0.3537***	0.0089	1.1431
days from house purchase to mortgage due date	-0.0046***	0.0001	0.7811
loan amount (100 K RMB)	-0.0147***	0.0007	0.9259
LTV	0.3556***	0.0239	1.0437
commercial property indicator	-0.3756***	0.0204	0.6869
house provident fund indicator	-0.7740***	0.0196	0.8809
city fixed effects	Yes		

$$\lambda_{i,g}(\tau) = \lambda_0(\tau)\exp(x_{i,g}\beta)$$

The sample includes both mortgages from banks and mortgages from HPF. Column 1 reports the estimates of β in the Cox proportional hazard model above using a partial likelihood method. A positive (negative) coefficient in the proportional hazard model means that an increase in the covariate will accelerate (decelerate) the payments and thus shorten (prolong) the delays. Column 2 reports the standard errors. Column 3 reports the rescaled hazard ratio, which measures the importance of a covariate in determining the delays. For the dummy variable "house provident fund", the rescaled hazard ratio indicates the extent to which the hazard rate will be shifted if the dummy variable changes from 0 (mortgages from banks) to 1 (mortgage from HPF); for the dummy variable "Commercial property", the rescaled hazard ratio indicates the extent to which the hazard rate will be shifted if the dummy variable changes from 0 (residential property) to 1 (commercial property); for the other covariates, the rescaled hazard ratio indicates the extent to which the hazard rate will be shifted if there is a one-standard-deviation increase of the covariate from the mean. A hazard ratio above one means the covariate will shift the hazard rate upward, while a hazard ratio below one means the covariate will shift the hazard rate downward. The more the rescaled hazard ratio deviates from one, the more important is the covariate. * denotes a 10% significance level. ** denotes a 5% significance level. *** denotes a 1% significance level.

Appendix III. Proof of Propositions 1, 2, and 3

Proposition 1. *The payoff functions at the coupon payment times* $\{t_k\}_{k=1,\ldots,m}$ *for the senior tranches are specified by*

$$C_k = \min\{A_{t_k}, kc_S\} - W_{k-1}, \quad k = 1,2, m-1;$$

$$C_m = \min\{A_T, p_S + mc_S\} - W_{m-1};$$

the payoff function at maturity for the equity tranches is specified by

$$C^E = A_T - W_m;$$

where W_k *is denoted as the accumulated payoff, i.e.,*

$$W_k := \sum_{j=1}^{k} C_j\,, \qquad k \in \{1,2,\ldots,m\}, \qquad W_0 = 0.$$

Proof:

Without loss of generality, we provide the proof of Proposition 1 in the case of 4-period maturity. It is straightforward to extend to the general case of any number of periods $m \in N^+$.

Payoff at First Period: Let C_1 denote the payoff (or cash flow) to senior tranches at the end of the first period t_1, which is a random number contingent on the following two situations:

- If $A_{t_1} < c_S$, then it partially receives the coupon with amount A_{t_1};
- If $A_{t_1} \geq c_S$, then it receives the 1^{th} coupon in full with amount c_S.

Therefore,

$$C_1 = \min\{A_{t_1}, c_S\},$$

which implies a short position of one put option with strike c_S. Then, the deficit at t_1 is

$$D_{t_1} = c_S - C_1 = \left(c_S - A_{t_1}\right)^+ \geq 0.$$

Payoff at Second Period: Conditional on the realization of C_1, the payoff (or cash flow) at the end of the second period t_2, C_2, is contingent on the following two subcases:

- If there is no deficit in the first period, i.e., $C_1 = c_S$ with accumulated deficit amount $D_{t_1} = 0$, then it receives $\min\{A_{t_2} - C_1, c_S\}$ at t_2;
- If there is deficit in the first period, i.e., $C_1 < c_S$ with accumulated deficit amount $D_{t_1} = c_S - C_1$, the cash flow received at t_2 should be used to first pay the deficit and then pay the coupon. Thus, $C_2 = \min\{A_{t_2} - C_1, c_S + D_{t_1}\}$ at t_2.

Therefore, the payoff at time t_2 conditional on the realization of C_1 is

$$C_2 = \min\left\{A_{t_2} - C_1, c_S + D_{t_1}\right\} = \min\left\{A_{t_2} - C_1, 2c_S - C_1\right\} = \min\left\{A_{t_2}, 2c_S\right\} - C_1$$

Then, the accumulated deficit at t_2 is

$$D_{t_2} = 2c_S - C_1 - C_2 = \left(2c_S - A_{t_2}\right)^+ \geq 0.$$

Payoff at Third Period: Similar to the situation in the second period, conditional on the realization of C_1 and C_2, the payoff at the end of the third period t_3 is:

$$\begin{aligned} C_3 &= \min\left\{A_{t_3} - C_1 - C_2, c_S + D_{t_2}\right\} \\ &= \min\left\{A_{t_3} - C_1 - C_2, 3c_S - C_1 - C_2\right\} \\ &= \min\left\{A_{t_3}, 3c_S\right\} - C_1 - C_2 \end{aligned}$$

Then, the accumulated deficit at t_3 is

$$D_{t_3} = 3c_S - C_1 - C_2 - C_3 = \left(3c_S - A_{t_3}\right)^+ \geq 0.$$

Payoff at Maturity: Finally, conditional on the realization of C_1, C_2 and C_3, investors receive the principal together with the last coupon paid at time T. The payoff is:

$$\begin{aligned} C_4 &= \min\left\{A_T - C_1 - C_2 - C_3, p_S + c_S + D_{t_3}\right\} \\ &= \min\{A_T - C_1 - C_2 - C_3, p_S + 4c_S - C_1 - C_2 - C_3\} \end{aligned}$$

$$= \min\{A_T, p_S + 4c_S\} - C_1 - C_2 - C_3$$

Proposition 2: Suppose that the time length from the property transaction data for a mortgage receivable to the securitization date is t_0. The CDF for the payment delay since the property purchase date is $F(x)$. The conditional CDF for the payment delay is $G(y) = F(y|y > t_0)$. Then, $G(y)$ first-order stochastically dominates $F(x)$, i.e., for any t, $\Pr(y > t) > \Pr(x > t)$.

Proof:

$$G(t) = F(t|t > t_0)$$

$$= \begin{cases} 0 < F(t) & if\ t \le t_0 \\ \dfrac{F(t) - F(t_0)}{1 - F(t_0)} = \dfrac{F(t)\big(1 - F(t_0)\big) + F(t)F(t_0) - F(t_0)}{1 - F(t_0)} < F(t) & if\ t > t_0 \end{cases}$$

Therefore, for any t, $\Pr(y > t) > \Pr(x > t)$.

Proposition 3: Denote z as the further delay of a securitized receivable since the securitization date, conditional on that the receivable has been securitized and that the time length from the property purchase date to the securitization date is t_0. The CDF of z is $H(z) = \frac{F(z+t_0)-F(t_0)}{1-F(t_0)}$. If the survival function $S(x) = 1 - F(x)$ is convex, then there exists a $\underline{t}_0$ such that for any $t_0 \ge \underline{t}_0$, $H(z)$ first-order stochastically dominates $F(x)$, i.e., for any t, $\Pr(z > t) > \Pr(x > t)$.

Proof:

$$H(z) = F(z + t_0|t_0) = \frac{F(z + t_0) - F(t_0)}{1 - F(t_0)}$$

To show that for any z, $H(z) < F(z)$, we only need to show that

$$\frac{F(z + t_0) - F(t_0)}{1 - F(t_0)} < F(z),$$

$$F(z + t_0) - F(t_0) < F(z)\big(1 - F(t_0)\big),$$

or

$$F(z + t_0) - F(t_0) - F(z) + F(z)F(t_0) < 0$$

Denote

$$A(z) = F(z + t_0) - F(t_0) - F(z) + F(z)F(t_0)$$

We have

$$A(0) = F(t_0) - F(t_0) - F(0) + F(0)F(t_0) = 0$$

$$A'(z) = f(z + t_0) - f(z) + f(z)F(t_0)$$

Taking first-order Taylor approximation to $f(z + t_0)$ at z, we have

$$A'(z) \approx f(z) + f'(z)t_0 - f(z) + f(z)F(t_0) = f'(z)t_0 + f(z)F(t_0)$$

If the survival function $S(x) = 1 - F(x)$ is convex, $F(x)$ is concave and $f'(z) < 0$. Because $F(t_0)$ is bounded by 1, when t_0 is large enough, $f'(z)t_0 + f(z)F(t_0) < 0$ for any z. Therefore, $A(z) < 0$ for any z.