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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 that deals with banks' processing time, 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 loan-to-value ratios 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.

KEYWORDS
adverse selection, banking, delay risk, financial innovation, mortgage receivable, real estate, securitization

JEL CLASSIFICATION
G1, G2, R3

1 | INTRODUCTION

While the risk and pricing of financial products provided by financial institutions have been intensively studied, recently, increasing attention has been paid to financial institutions' processing time when they are providing financial products or services. The literature has examined multiple factors that influence lenders' processing time for mortgage loan origination, including FinTech (Fuster et al., 2019), lenders' screening efforts (Choi & Kim, 2020), and loan application volumes (Fuster et al., 2017).

We study a type of securitization that deals with financial institutions' processing time, mortgage-receivable-backed securities (MRBSs). MRBSs are 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 mortgage-backed securities (MBSs) and other asset-backed securities (ABSs) in China.

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 United States, 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 1 month. Thus, both in China and the United States, 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 those in the United States.

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 originating 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 (see Figure B.1 in the Supporting Information Appendix B and detailed discussions in Section 7.1). The maturities of MRBSs are usually 1–3 years; interest is paid every 6 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.

For a large developer, house sales transactions are very frequent, generating mortgage receivables throughout the year. In contrast, MRBS issuance is much less frequent, usually two or three times a year. Therefore, on the securitization date, some receivables have already been delayed for a while (see Figure B.2 in the Supporting Information Appendix B).

Although MRBSs are related to mortgage lending, they are different from traditional MBSs in several aspects. 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

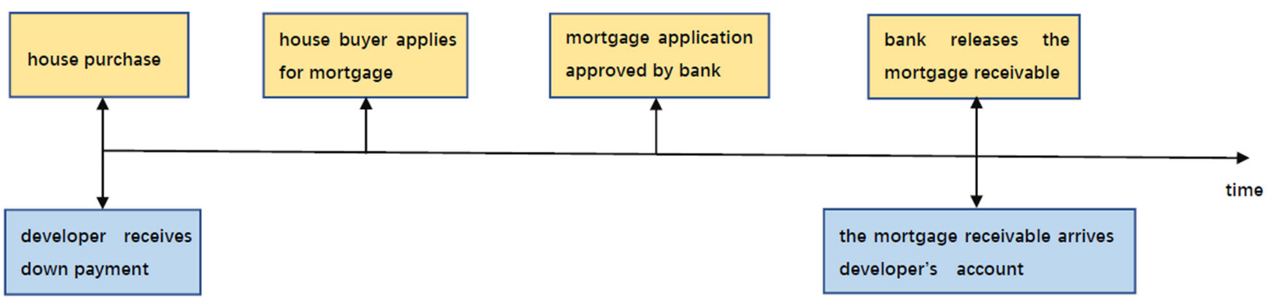

FIGURE 1 Process from house transaction to release of mortgage receivable.

security investors. Third, the underlying assets of MRBSs mainly have only delay risk and almost no default risk (see Section 2.2 for details).

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 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.[1]

Asset-backed securitization serves firms as an important financing source other than bank loans, traditional corporate bonds, and stocks. 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 instead of default risk, while the securities themselves could have default risk if a substantial proportion of the underlying assets are delayed for too long. Underlying assets with mainly delay risks are considered to be of higher quality.

Because MRBSs provide the originating developers with another substantial funding source with a lower borrowing cost compared with bank loans (see Figure B.3 in the Supporting Information Appendix B), 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 10 national real estate developers, we provide a systematic analysis regarding what factors can affect 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 an increase in house prices reduces the mortgage default risk and thereby reduces the risk of MBSs, 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 (see Fuster et al., 2017

[1]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 et al., 1997; An & Cordell, 2019; Chan et al., 2016; Cordell et al., 2015; Pence, 2006; Zhu & Pace, 2015). In the sovereign debt market, there is a very long delay between initial defaults and final negotiated restructuring (Benjamin & Wright, 2018). In the insurance market, there is a random delay between the occurrence of a claim and the settlement (Boogaert & Haezendonck, 1989; Dassios & Zhao, 2013; Waters & Papatriandafylou, 1985; Yuen et al., 2005), 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 the conversion can be forced, which affect both bondholders and shareholders' wealth (Grundy & 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 & Brunnermeier, 2002; Foucault et al., 2016; Moallemi & Sağlam, 2013; Stoll & Schenzler, 2006).

for evidence that loan application volumes can prolong processing time). Consequently, MRBSs could be an excellent financial tool to hedge against the risks of other securities (such as MBSs) in the dimension of house price fluctuations, and the introduction of MRBSs to the financial market could significantly improve the diversification of the market.

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.[2] 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 2 years after the property purchase dates. However, in the securitized asset pool, based on our simulation, only 78%–81% of receivables will be received within 2 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 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 discuss the econometric methodology (Cox proportional hazard model). In Section 6, we provide the estimation results and a systematic discussion regarding what factors from what sources and through which mechanisms affect mortgage-receivable delays. In Section 7, 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 7.1 provides an overview of MRBS designs, Section 7.2 provides the simulation procedures, and Section 7.3 discusses the pool-level simulation results and adverse selection. Section 7.4 discusses the security-level simulation results. Section 8 discusses the counterfactual analyses. Then, we conclude in Section 9.

[2]In the United States, 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 ratio).

2 | BACKGROUND

2.1 | A comparison between the real estate finance markets in China and the United States

A typical house purchase process in China is illustrated in Figure 1. A house buyer needs to first sign a purchase contract with the developer and then submits her/his mortgage application to a bank. The application documents at least should include the property purchase contract and the purchaser's proof of income. Second, the bank evaluates the application and approves it. 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 since the property purchase date 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 United States, 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 1 month. Thus, in both China and the United States, 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 those in the United States.[3]

2.2 | Risk of the underlying assets—delay risk

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 data, which cover more than 100,000 mortgage receivables from 2007 to 2015.

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, while it is possible in theory that house buyers may not be able to obtain a mortgage after signing the house purchase contract and paying the down payment or that they may regret the contract and decide not to originate a mortgage, if these mortgage receivables have already entered the underlying-asset pool and the securities backed by the pool have already been sold to investors, developers have to redeem the same amount of securities as the amount of these unqualified underlying assets. In other words, developers are obligated to use their own cash to repay investors because these underlying assets in the pool are no longer qualified. Therefore, MRBS investors are not exposed to the default risk of house buyers on mortgage originations or house purchases.

While the default risk of house buyers on mortgage originations or house purchases is borne by developers rather than by MRBS investors, this default risk itself is actually very small. First, 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. Second, 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

[3]Unlike banks in the United States and Europe, banks in China do not preapprove borrowers up to a certain loan amount before the house purchase transaction. The house purchase contract is required for a mortgage application. First, China does not have a Fair Isaac Corporation (FICO) system. Lenders evaluate borrowers' creditworthiness mainly based on income and bank statements. It is difficult for lenders' to determine a preapproved loan amount purely based on information on the borrower side. Beside borrower credit review, a larger part of risk control for mortgage lending is through the collateral (the property). Second, each bank branch faces a month-end or quarter-end lending quota. Branch managers have strong incentives to use up these quotas on time (see discussion in Section 6.3.2). Therefore, a branch manager is reluctant to preapprove a loan amount without knowing how much a borrower will finally borrow or even whether the borrower will borrow from the bank. On the other hand, even if there is a preapproved loan amount, the money will not arrive in developers' accounts before the mortgage is finalized; thus, developers still face payment delays for mortgage receivables.

buyer is rejected by a bank, developers would recommend another "less-tough" bank to the house buyer to apply for a mortgage.[4]

Moreover, developers have measures to protect themselves from losses caused by house buyers' defaults on mortgage originations or house purchases. If the property has already been occupied by the house buyer, developers can claim the properties and retain or partially retain the down payments. If the property has not been delivered to the house buyer, developers can hold the properties rather than deliver them to the house buyers, meanwhile retaining or partially retaining the down payments.[5] Many newly developed properties in China are sold through preselling; buyers may not be able to move into the properties even after the mortgages are finalized.

One may argue that if house prices decline dramatically after house purchases, house buyers may default on their monthly mortgage repayments. However, mortgage repayment 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 repayment defaults by borrowers only cause losses to banks or MBS investors (if banks securitize their mortgages into MBSs).

2.3 | Risk of the securities—default risk

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 ABSs. The underlying-asset pools are moved to a bankruptcy-remote special purpose entity (SPE). Because repayments on ABSs come from the packaged assets backing the securities and not from the originating firms, the risks associated with the ABSs are isolated from the bankruptcy risk of the originating firm; accordingly, the securities are "bankruptcy-remote," and there is less information asymmetry between originators and investors (Ayotte & Gaon, 2011). This security design helps reduce the borrowing costs for the originating firms, especially in financial markets with great imperfections.

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 originating 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 originating 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 (see Figure B.3 in the Supporting Information Appendix B).[6]

Table B.1 in the Supporting Information Appendix B summarizes the concerns about the risk of MRBSs and the corresponding explanations discussed above.

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

[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 house purchase 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 United States, lenders may still not choose to claim the deficiency judgment when the foreclosure sale proceeds cannot cover the unpaid mortgage balance.

[5]House buyers may or may not occupy a completed property before finalizing the mortgage, depending on the house purchase contract, which is negotiated between house buyers and developers. In reality, both cases exist. After a property is occupied by the buyer and before the mortgage is finalized, legally, the owner of the property is still the developer rather than the buyer.

[6]In China, there are no GSEs such as Fannie Mae and Freddie Mac to provide additional protections to investors.

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 originating 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 with the magnitude of the originating developer's bankruptcy risk will determine the discount of the MRBS interest rates relative to the interest rates of the developer's construction loans.

2.4 | 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 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 B.4 in the Supporting Information Appendix B, market concentration is increasing each year. Figure B.5 in the Supporting Information Appendix B 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 leverage. 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 depend 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 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 US 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.[7] The volumes of MBSs issued in 2014, 2015, and 2016 were 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 United States, the underlying-asset pools for issuing MRBSs are not standardized; mortgage receivables with different characteristics are pooled into the

[7]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."

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.

First, we contribute to the literature on financial institutions' processing time. Existing studies have examined multiple factors that influence lenders' processing time for mortgage loan origination, including FinTech (Fuster et al., 2019), lenders' screening efforts (Choi & Kim, 2020), and loan application volumes (Fuster et al., 2017). In contrast, we conduct a comprehensive analysis on what factors can affect the processing time and examine the securitization that deals with the processing time.

Second, we contribute to the literature on asset-backed securitization by firms. Previous studies have provided empirical evidence that the funding costs of ABSs are lower than those of comparable corporate bonds (Marques & Pinto, 2020). Previous studies have also found that asset-backed securitization can increase originating firms' abnormal stock returns and market values (Lemmon et al., 2014), reduce the probability of facing credit constraints and the costs of bank financing for nonconstrained firms (Kaya & Masetti, 2019), and increase chief executive officer compensation (Riachi & Schwienbacher, 2013). For the asset-backed securitization examined by those studies, 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 instead of default risk.

Third, a large strand of the literature has analyzed the default and prepayment risks of mortgages and the resulting risks of MBSs.[8] Unlike those papers, we analyze the delay risk of mortgage receivables and the resulting risk of MRBSs. MRBSs are a new type of securitization in the real estate market that has never been examined before.

Fourth, this study complements the literature that analyzed the risk of different forms of securitization or financial innovation, including collateralized debt obligations (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).[9] 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.

Fifth, 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 (Keys et al., 2010, 2012; Maddaloni & Peydró, 2011; Rajan et al., 2015; Vanasco, 2017) and their ex post monitoring efforts (Jiang et al., 2014; Wang & Xia, 2014), 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 et al. (2012) and Albertazzi et al. (2015) found that lenders do not adversely select 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 with other receivables (see Section 7.3 for details).

Sixth, 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

[8]For example, Kau et al. (1995), Deng et al. (2000), and Ma (2014) on mortgages; and Dunn and McConnell (1981a, 1981b) on MBSs.

[9]For example, Longstaff and Rajan (2008) on CDOs; McConnell and Singh (1994) on CMOs; Titman and Tsyplakov (2010) on CMBSs; Passmore and von Hafften (2020) on a financial innovation for fixed-rate mortgage contracts; Ayotte and Gaon (2011), Friewald et al. (2016), and Higgins and Mason (2004) on ABSs; Arentsen et al. (2015) on CDS; Acharya et al. (2013) on asset-backed commercial paper conduits; and Benmelech et al. (2012) on CLOs.

behavior and credit supply.[10] In contrast, our study examines banks' speed in transferring loan money, conditional on that they approve the lending of those loans. Banks' funding or financing behavior is also an important topic in the banking literature. Banks' delay behavior in releasing loan money 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 10 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 the property transaction date, purchase price, down payment, the 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 floor area, garden area, location, and whether the property was residential or commercial).

Bank financial data: We collect the financial reports of banks from WIND (2017), a major financial data vendor 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 and Insurance Regulatory Commission (2018). The data contain information on the number of branches of each bank in each city.

Other data: City-level unemployment rates, national-level gross domestic product (GDP) and M2 growth rates, and national average mortgage interest rates are obtained from CEIC (2019). The data on bank loans issued to publicly listed firms are obtained from CSMAR (2022). City-level average house prices and total areas sold for newly built houses are obtained from CREIS (2019), a leading national provider of real estate data.

Table 1 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 2 displays the distribution of the mortgage-receivable delays, including right-censored observations.[11] Most receivables were received within 1 year after the property purchase date.

The property transaction and mortgage-receivable payment data cover 54 cities in China. Table B.2 in the Supporting Information Appendix B compares the descriptive statistics for the city-level market condition variables between the 54 cities and all the cities in China.[12] The descriptive statistics based on the two groups of cities are not significantly different from each other.

The mortgage data also have an excellent coverage on banks. Commercial banks in China include the five national banks (the big 5), Postal Savings Bank of China, the 12 joint-stock commercial banks, and hundreds of city commercial banks and rural commercial banks. Figure B.8 in the Supporting Information Appendix B compares the shares of observations in the sample with the number of branches throughout the entire country for the big 5, Postal Savings Bank of China, and the 12 joint-stock commercial banks. Banks with more branches throughout the country have proportionally larger shares of observations in the sample. A special case is Postal Savings Bank of China, ranking first in the number of branches but fifth in the shares of observations in the sample. The reason is that the main function of the branches of Postal Savings Bank of China is providing postal services instead of banking services.

The properties in the sample have an ordinary distribution of floor areas (see Table B.3 in the Supporting Information Appendix B). Approximately 60% of the properties range from 90 to 144 m^2. The deed tax rate for a

[10]For example, see Cao et al. (2022), Acharya et al. (2011), Demirgüç-Kunt and Huizinga (2010), and Berger and Bouwman (2013).

[11]If right-censored, the delay of the observation is calculated as the days from the property purchase date to the end of the sampling period. Figures B.6 and B.7 in the Supporting Information Appendix B display the distributions of this variable for the right-censored observations and the not right-censored observation, respectively. We do not directly observe in the data whether a receivable is defaulted by the house buyer. We asked the developer from whom we obtained the data and the developer said that defaults are seldom. The statement by the developer can be partially confirmed from the data: most right-censored observations had been delayed for only less than 1 year (see Supporting Information Figure B.6) and should not be defaults; even for the observations beyond 1 year, the likelihood that they are defaults is very low because a payment delay longer than 1 year can also be observed within the received receivables in the sample (see Supporting Information Figure B.7).

[12]The descriptive statistics for the local market conditions in Table 1 are based on loan-level data matched with city-level market conditions.

TABLE 1 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 right-censored	0.9601	0.1957
Ratio of garden area to floor 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/m^2)	7649	3125
Housing area sold (million m^2)	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

Abbreviations: GDP, gross domestic product; LTV, loan-to-value ratio; ROA, returns on assets.

housing unit below 90, between 90 and 144, and above 144 m^2 is 1%, 1.5%, and 3%, respectively, on the entire property value. Housing units larger than 144 m^2 are classified as luxurious properties and are thus taxed at a higher rate. Housing units smaller than 90 m^2 are taxed at a lower rate to support homeownership of low-income households.

5 | ECONOMETRIC MODEL

We employ a Cox proportional hazard model to empirically analyze the delays of mortgage receivables.[13] 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

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

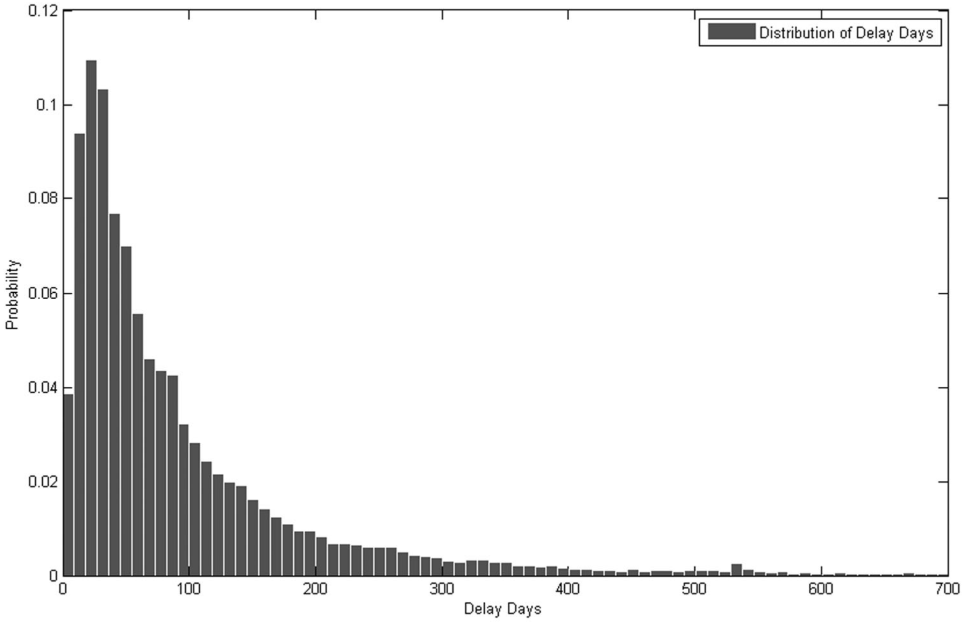

FIGURE 2 Distribution of delays in the sample

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.[14]

$$\lambda_{i,g}(\tau) = \lim_{\Delta\tau\to\infty} \frac{\Pr\left[\tau \le \tau_{i,g}^{*} < \tau + \Delta\tau \middle| \tau_{i,g}^{*} \ge \tau\right]}{\Delta\tau} = \frac{f_{i,g}(\tau)}{S_{i,g}(\tau)}.$$

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

$$S_{i,g}(\tau) = \exp\left\{-\int_0^{\tau} \lambda_{i,g}(\tau)\, d\tau\right\}.$$

Because the sampling period of our data ended on September 15, 2015, by which some mortgage receivables had not been released, the dependent variable $\tau_{i,g}^{*}$ is right censored for those observations. The full log likelihood function should be

$$\ln L = \sum_{i=1}^{n}\left[d_i \ln f_{i,g}\left(\tau_{i,g}^{*}\right) + \left(1 - d\right)\ln S_{i,g}\left(\tau_{i,g}^{*}\right)\right],$$

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

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

[14]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.

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 is 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.

6 | EMPIRICAL RESULTS

The regression results of Equation (1) are reported in Table 2. Models 1–4 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 2, 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 2, 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.[15]

6.1 | 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 of banks' liquidity. Bank liquidity is increasing in the capital adequacy ratio and is decreasing in the loan-to-deposit ratio. As shown in Table 2, the coefficient of the capital adequacy ratio is significantly positive and the coefficient of the loan-to-deposit ratio is significantly negative, which indicates that bank liquidity shortens the payment delays.

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. As shown in Table 2, the coefficient of the nonperforming loan ratio is significantly positive, which indicates that bank lending caution prolongs the payment delays.

Bank profitability: Banks' incentive to release mortgage money quickly after loan approvals also matters in determining the mortgage-receivable delays. Because banks can start to earn mortgage interest only after they release the mortgage money, the earlier the banks release the payments, the earlier they start to earn interest. As shown in Table 2, the coefficient of 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 has a significantly negative coefficient in Table 2. This is consistent with the fact that if a bank has good alternative investment opportunities (such as bonds and

[15]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.

TABLE 2 Regression results of the cox proportional hazard model

	Model 1		Model 2		Model 3		Model 4		
Parameter	**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 floor 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		

Note: $\lambda_{i,g}(\tau) = \lambda_0(\tau)\exp(x_{i,g}\beta)$. For models 1–4, 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.

***Denotes a 1% significance level, **denotes a 5% significance level, and *denotes a 10% significance level.

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.

Funding structure: The funding of banks mainly comes from two sources: deposits and wholesale funding (such as interbank borrowing). Compared with 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 (2010) found that banks' reliance on wholesale funding increases their financial fragility and worsens the performance of their stock prices. Cornett et al., (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.[16] Following the banking literature, we use the ratio of total liabilities minus total deposits to total assets as the measure of banks' funding structures.

As shown in Table 2, the coefficient of funding structure is significantly negative. 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.

6.2 | 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 (see Choi & Kim, 2020 for evidence that screening efforts can prolong processing time). In China, there is no credit score (such as FICO) that is widely used by banks to evaluate loan applications.[17] 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.[18]

However, we can observe the ratio of garden area to floor area of the property. Properties with a higher ratio of garden area to floor area are more luxurious, and thus the buyers are likely to have higher incomes. Therefore, we use this ratio as a measure of borrowers' creditworthiness. As show in Table 2, the coefficient of the ratio of garden area to floor area of the property is significantly positive.

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 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; actually, they may incur some penalties if they are unable to make that payment out of their own pocket.[19]

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[16] 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.

[17] 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.

[18] Because MRBSs are issued by developers rather than by banks, banks would not release their borrowers' creditworthiness information for developers to issue MRBSs.

[19] 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 house purchase 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.

As shown in Table 2, the coefficient of 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.

LTV and loan amount: 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 more incentive to act quickly in applying for a mortgage. 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.

As shown in Table 2, 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 face higher pressure to act fast in the 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.

Residential property versus commercial property: The mortgages for commercial properties need to go through a more complicated administrative system than the mortgages for residential properties. As shown in Table 2, the coefficient of the commercial property indicator is significantly negative.[20]

6.3 | Local market conditions

6.3.1 | Local demand for mortgages

A hot local housing market has larger housing sales volumes, which 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 (see Fuster et al., 2017). Therefore, we include city-level house prices and housing areas sold in the regressions as two measures of the hotness of local housing markets. As shown in Table 2, the coefficients of the two variables are significantly negative.[21]

6.3.2 | 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

[20]One concern is that whether the delays of mortgages from Housing Provident Fund (HPF) are different from the delays of mortgages from banks. 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. 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 C.1 in the Supporting Information Appendix C provide the evidence that HPF has longer delays than banks.

[21]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 et al., 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.

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 et al. (2022) 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.[22]

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.

Banks' market presence: Within each commercial bank, there are two layers of branches for each city: one city branch (main branch) and other branches (subbranches) 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. As shown in Table 2, the coefficient of banks' local market presence is significantly positive.

Unemployment rates: As a measure of local economic conditions, 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. As shown in Table 2, the coefficient of the local unemployment rate is significantly negative.[23]

6.3.3 | 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. As shown in Table 2, the coefficient is significantly positive; the more important the local market is to the bank, the shorter the delays are.

6.4 | Macroeconomic conditions

As shown in Table 2, the coefficient of the M2 growth rate is significantly positive at a level of 1%. This indicates that banks originate mortgages faster when the aggregate money supply growth rate is higher. The coefficient of GDP growth rate is also significantly positive.

6.5 | Further discussions and concerns

According to the rescaled hazard ratios reported in Table 2, 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.

[22]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' performances are assessed mainly based 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.

[23]Unemployment rates may also affect local housing demand and hence housing purchases and the generation of mortgage receivables. However, our study focuses on what factors, conditional on that the mortgage receivables have already been generated, can affect their delays.

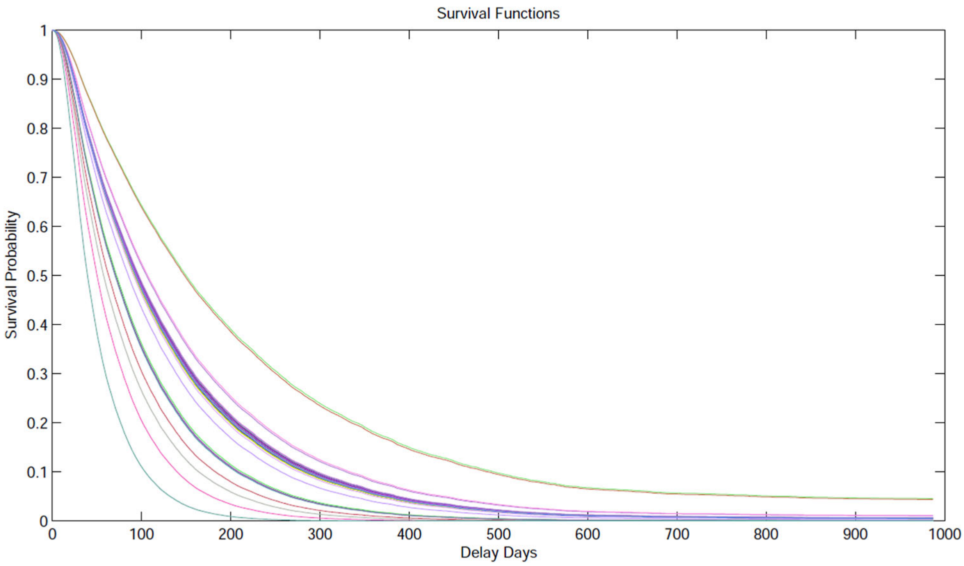

FIGURE 3 Estimated survival functions for 50 mortgage receivables randomly drawn from the sample

Figure 3 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 receivables are differentiated in the dimensions of those factors. The large heterogeneity displayed in Figure 3 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 3 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 because a receivable can rarely 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 7.3 for deeper analyses).

The pseudo-R^2 is 0.4322, which indicates that our model specification has a good in-sample fit.[24] Panel A in Table 3 separately displays the goodness of in-sample fit for the mortgage receivables associated with properties purchased in different years. Panels B–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. The pseudo-R^2 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

[24]Pseudo-R^2 is a standard measure for goodness of fit for maximum-likelihood models, because the traditional R^2 working for ordinary least squares (OLS) models cannot be constructed in maximum-likelihood models. We construct pseudo-R^2 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^2 is the pseudo-R^2 that measures the goodness of fit for the proportional hazard model.

TABLE 3 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^2	0.4322	0.2989	0.3386	0.5528	0.5744
Size of estimation sample	105,435	105,435	105,435	105,435	105,435
Size of prediction sample	105,435	10,790	27,720	34,115	16,504
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^2		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^2	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^2		0.1804	0.2435	0.3865	0.5412

Note: Panel A separately displays the goodness of in-sample fit for the mortgage receivables associated with properties purchased in different years. Panels B–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.

compositions of in-sample and out-sample. As the estimations are based on individual-level data, a 20% pseudo-R^2 is satisfactory for goodness of fit. Moreover, the simulations in Section 7 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.

A second concern is whether business expansion by a developer after issuing MRBSs could elevate the risk of the MRBSs. Although business expansion can simultaneously increase a developer's profits and bankruptcy risk, the risk of MRBSs will not be elevated. One important feature of ABSs is that they are isolated from the bankruptcy risk of the originating firms (bankruptcy remoteness). If an originating firm goes bankrupt, the underlying assets of MRBSs cannot be liquidated to repay debt holders other than the MRBS investors.[25]

A third concern is whether policies that tighten the mortgage underwriting standard will make some borrowers have to search multiple banks to obtain a mortgage and hence prolong the delays of mortgage receivables. In reality, there are two types of policies that tighten the mortgage underwriting standard. The first type is increasing the minimum down payment ratio. This policy applies to every lender. If a household cannot meet the down payment requirement, it will have to choose not to purchase a house instead of searching multiple lenders because no lender can originate a mortgage to the household. Thus, this policy will not make borrowers search more lenders.

The second type of policy is imposing limits on the total loan amount that a bank can lend to mortgage borrowers, which was implemented in January 2021. This policy could make borrowers search more lenders to obtain a mortgage. Because our mortgage-receivable data end in 2015, we cannot directly examine the impact of this policy. However, this policy would be associated with decreases in the money supply. As can be seen from Figure B.9 in the Supporting Information Appendix B, the year-on-year M2 growth rate fell in 2021 immediately after the implementation of this policy. We include the M2 growth as a regressor in the regression of mortgage-receivable delays. Based on the estimate, we conduct a sensitivity analysis in Section 8 to quantify the impact of a 25%-standard-deviation decrease in the M2 growth on the shortfall probability and expected return of senior tranches.

7 | MONTE CARLO SIMULATIONS FOR MRBSS

7.1 | Overview of MRBS structures

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 RMB of mortgage receivables and the buffer size is set to 25%, then only 0.75 billion RMB of MRBSs are issued. However, the coupon and principal payments to the investor of those 0.75 billion RMB 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 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 1–3 years.

The redistribution of arriving cash flows among those tranches follows the "waterfall" rule. Panels A and B in Figure B.1 in the Supporting Information Appendix B 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.

7.2 | 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[26]; this pool is composed of 4933 mortgage receivables. Assuming this pool is securitized on September 1, 2015, for

[25]In addition, business expansion by developers who issued MRBSs will not increase the risk of the entire industry because the land supply is completely determined by the government in China. All the land parcels in China are sold by the government through public auctions, with the floor-to-area ratio limit of each land parcel predetermined by the government before the auction. Business expansion by developers with MRBSs can only reduce the market shares of other developers and will not increase the housing supply of the entire real estate development industry.

[26]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%.

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).[27] 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.

From the estimates in Section 6, 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, $S_{i,g}(\tau)$, that is, 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 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, $F_{i,g}\left(\tau|\tau_{i,g}^* > t_{0,i,g}\right)$, 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 $F_{i,g}\left(\tau|\tau_{i,g}^* > t_{0,i,g}\right)$ can be obtained from the unconditional survival functions based on our estimates.

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

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 $\boldsymbol{1}_{\{\cdot\}}$ is the indicator function and $A_t \in [0, p]$. Suppose the MRBSs have an 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, that is,

[27]For simplicity, we simulated for two-layer MRBSs rather than three-layer MRBSs. Two-layer MRBSs are enough to illustrate all the important properties.

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

We provide the proof of Proposition 1 in Appendix A.

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

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

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

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

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 originating 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 with the magnitude of the originating 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 simulations, 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 originating 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.

7.3 | Pool-level simulation results and adverse selection

The simulation results based on the underlying-asset pool appear to be puzzling. Figure 4 displays the histograms of the number of receivables, the amount of money, and the proportion of the pool in terms of the monetary amount that has been received by the maturity date of the security (2 years) over the 10,000 simulated paths. The

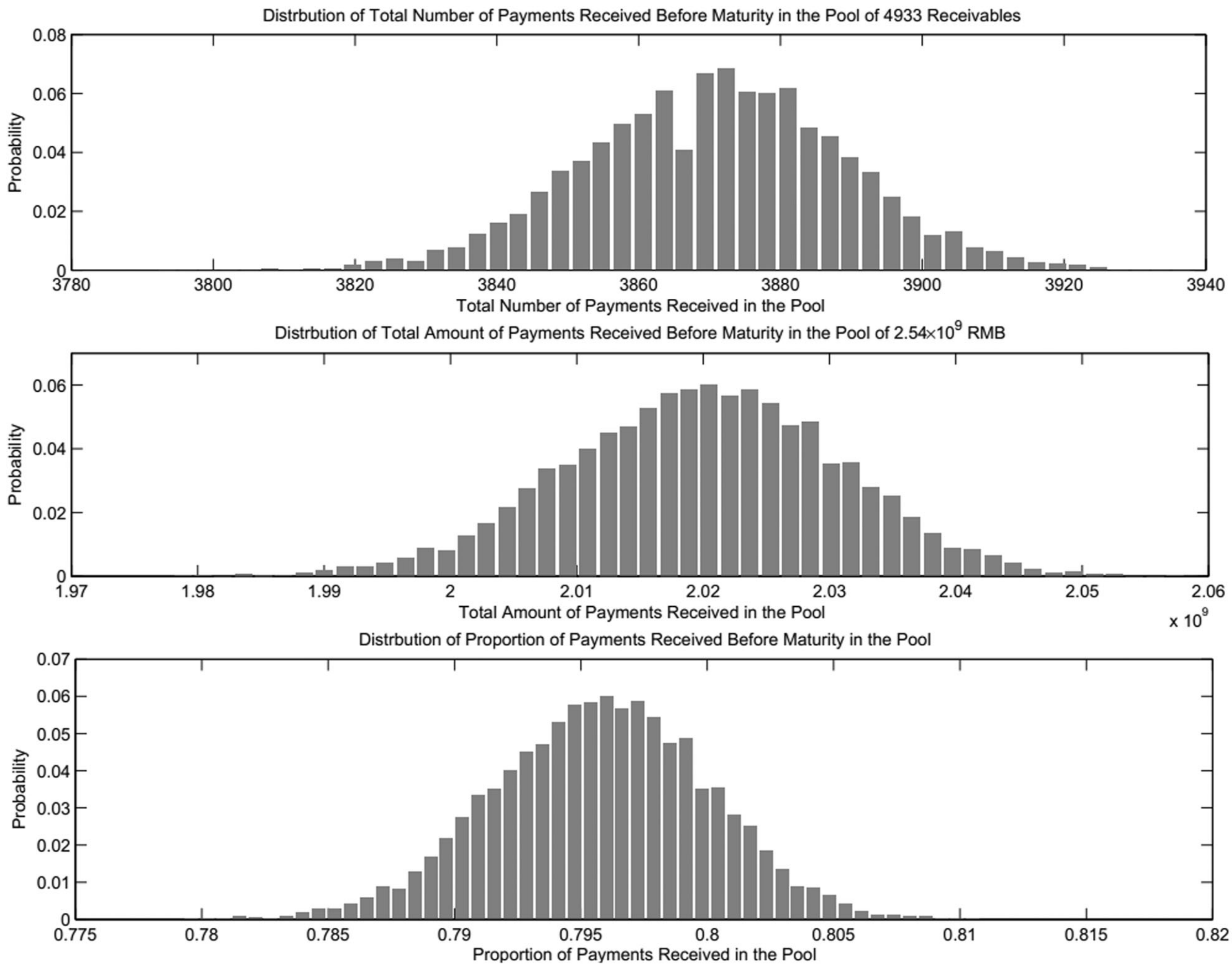

FIGURE 4 Simulated distributions of the cash received in the securitized receivable pool by maturity date

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 2 years after the property purchase dates. Why will only approximately 80% of mortgage receivables in the securitized pool be received within 2 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 (see Figure B.2 in the Supporting Information Appendix B). 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* $F(x)$, *that is, for any* t, $\Pr(y > t) > \Pr(x > t)$.

We provide the proof in Appendix A.

Proposition 2 only indicates that receivables entering the securitization pool tend to have longer delays since the property purchase dates compared with the entire population. However, Figure 4 focuses on the delay since the securitization date rather than the delay since the property purchase date because it is the delay of receivables since the securitization date that affects the shortfall risk of MRBSs. The puzzling distribution in panel 3 of

Figure 4 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 domains, as displayed in Figure 3 in Section 6.5. 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 $F(x)$, that is, for any t, $\Pr(z > t) > \Pr(x > t)$.*

We provide the proof for Proposition 3 in Appendix A.

Note that the convexity of the survival function obtained from the estimation (see Figure 3) 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.

7.4 | Security-level simulation results

7.4.1 | Three typical security designs

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 5 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.

1. Design 1: buffer size = 27% and senior coupon rate = 8%;
2. Design 2: buffer size = 28% and senior coupon rate = 8%;
3. 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

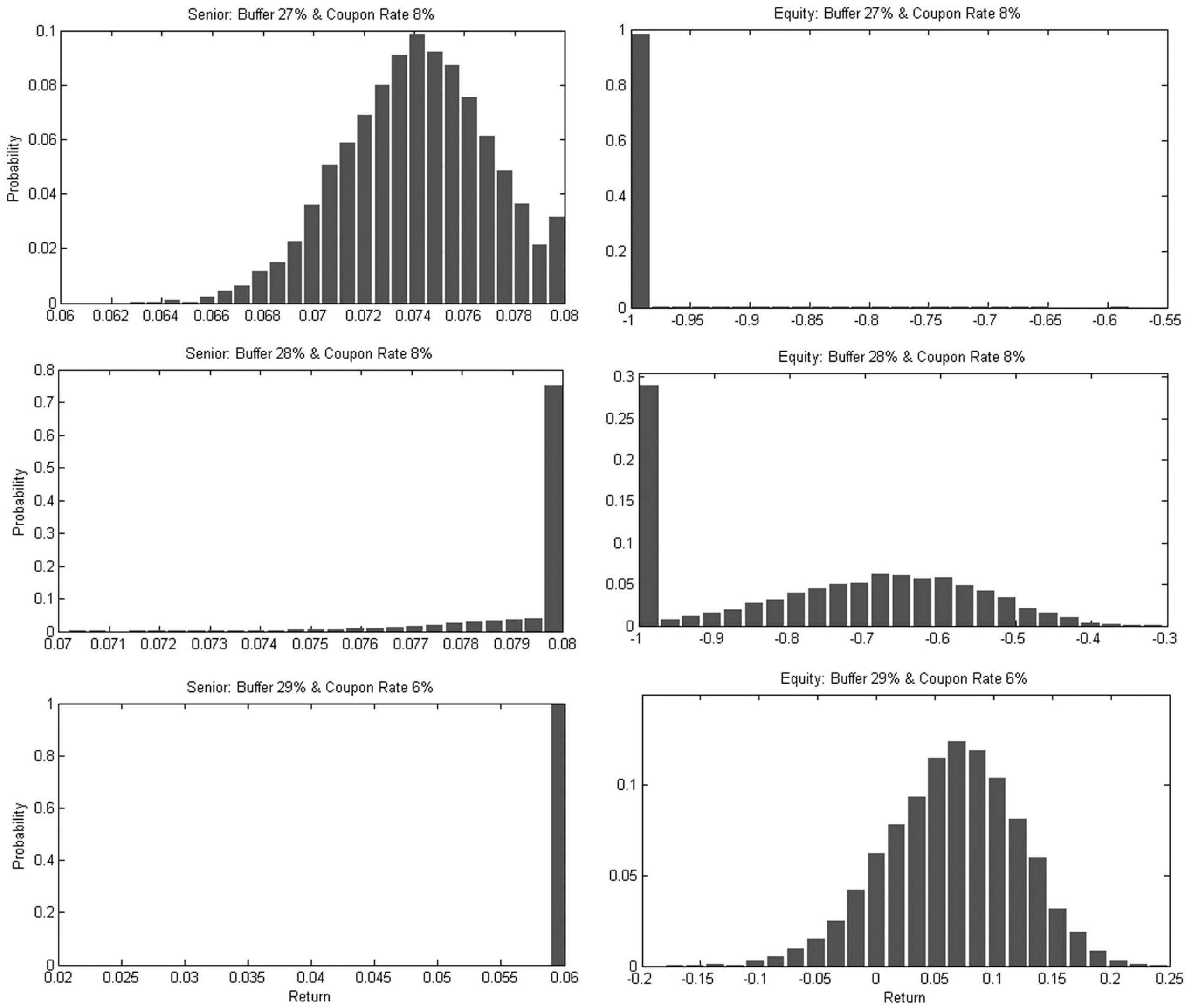

FIGURE 5 Simulated expected returns at maturity for senior and equity tranches under different security designs. Each row represents a security design. The focus is the distribution of returns at maturity for senior tranches on the left because equity tranches are held by developers to resolve the moral 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%.

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 5 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.

7.4.2 | 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 6, 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 small (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. In other words, given the same underlying-asset pool, the decrease in the buffer size does not change the total cash that will be received by senior tranche holders at maturity but only increases the money that the originating firm raises at issuance. Correspondingly, the expected return at maturity on equity tranches remains at −100%.

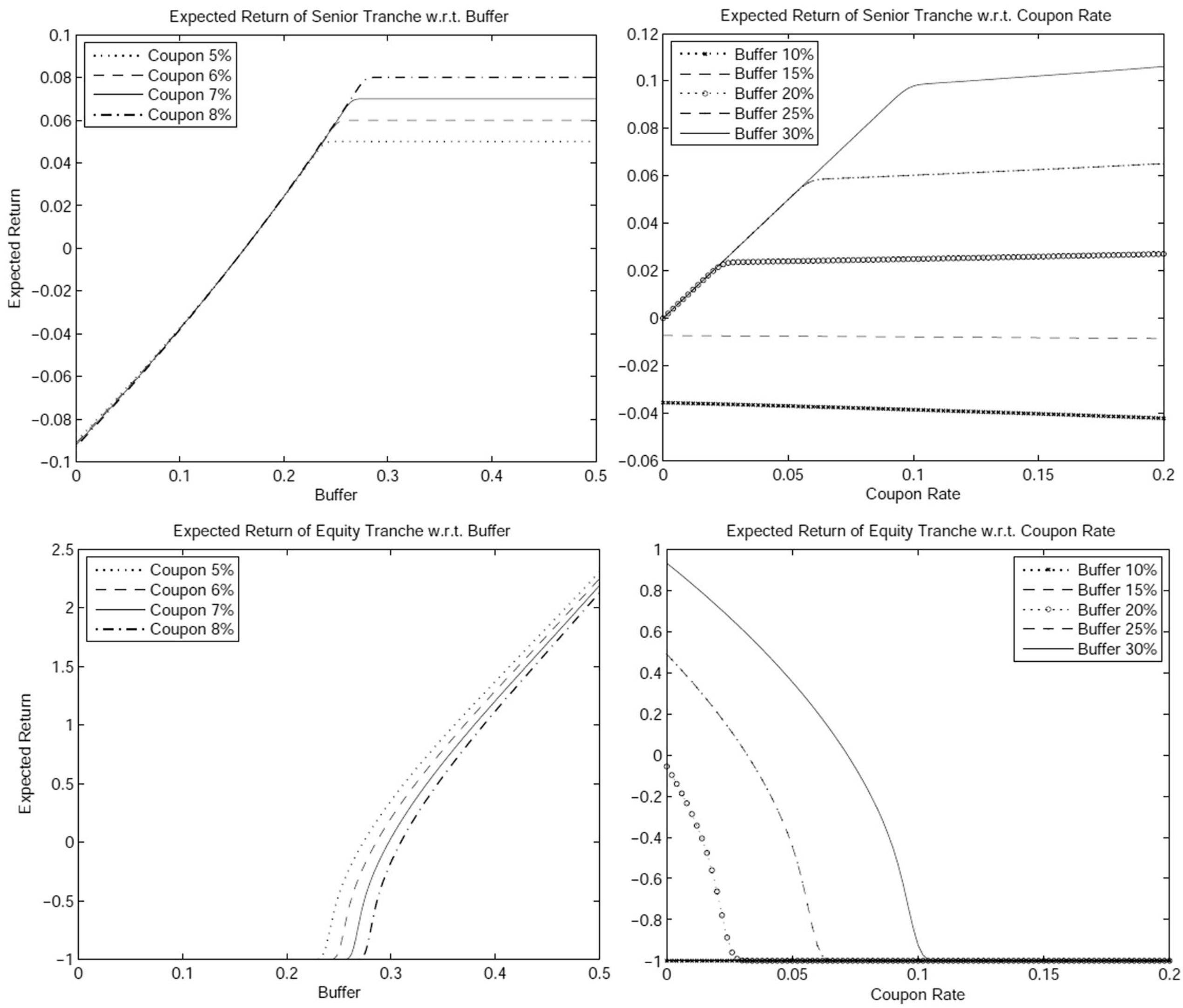

FIGURE 6 Simulated relationship among expected returns at maturity, buffer size, and coupon rate

When the buffer size is large (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.

The turning domain between the linearly increasing domain and the constant domain is dramatically narrow because the distribution of the portion of receivables received in the pool by the maturity date is spread over a narrow range (mainly from 78% to 81%, see Figure 4), given that pooling thousands of receivables together could accomplish diversification to a certain extent. In the linearly increasing domain, senior tranche holders bear substantial shortfall risk. In the constant domain, the originating firm can raise more money by reducing the buffer size without increasing the shortfall risk borne by senior tranche

TABLE 4 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

Note: 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.

holders. Therefore, one important step for the security design on the underlying-asset pool is to numerically find the narrow turning domain and then pin down the optimal buffer size in that domain.

7.4.3 | Relationship between returns at maturity and senior coupon rates

The upper-right diagram of Figure 6 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 larger 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 small 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.[28]

7.4.4 | Further discussion

Table 4 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 deviations of returns at maturity are also reported in Table 4. Given the coupon rate, as the buffer size increases, the standard deviation of returns at maturity on senior tranches is decreasing.[29,30]

[28] In the Supporting Information Appendix B, Figure B.10 employs three-dimensional 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 B.11 plots the two surfaces in the same diagram and zooms in on a smaller domain.

[29] 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 small, 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 large 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.

[30] 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 originating developers may have an incentive to select new receivables in lower quality to enter the underlying-asset pool. However, the selection criteria are predetermined for all the receivables that will enter the underlying-asset pool; and developers are required to hold all the equity tranches to resolve the moral hazard concern. Therefore, succeeding receivables should have similar quality as initial receivables. Lemmon et al. (2014) have conducted a thorough discussion on covenants in ABS agreements to resolve the potential agency problem for securitizations involving revolving funding.

TABLE 5 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

Note: We counterfactually increase the house prices (HPs) of all the cities by 10%, 25%, 50%, and 100% of the standard deviation. 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 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%.

8 | COUNTERFACTUAL ANALYSES

The estimation results of the Cox proportional hazard model in Table 2 quantitatively 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 quantitatively 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 10,000 times. We compute the average proportion of the underlying assets that can be received by the maturity date (2 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 5, 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 5 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 7 displays how much the distribution of returns at maturity for senior tranches will be shifted leftward in the four counterfactual scenarios compared with the baseline case.

We also perturb other risk factors and conduct counterfactual analyses at the security level. In each row of Table 6, 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 keeping all other factors unchanged. The corresponding probability of shortfalls and the average return at maturity for senior tranches are reported.

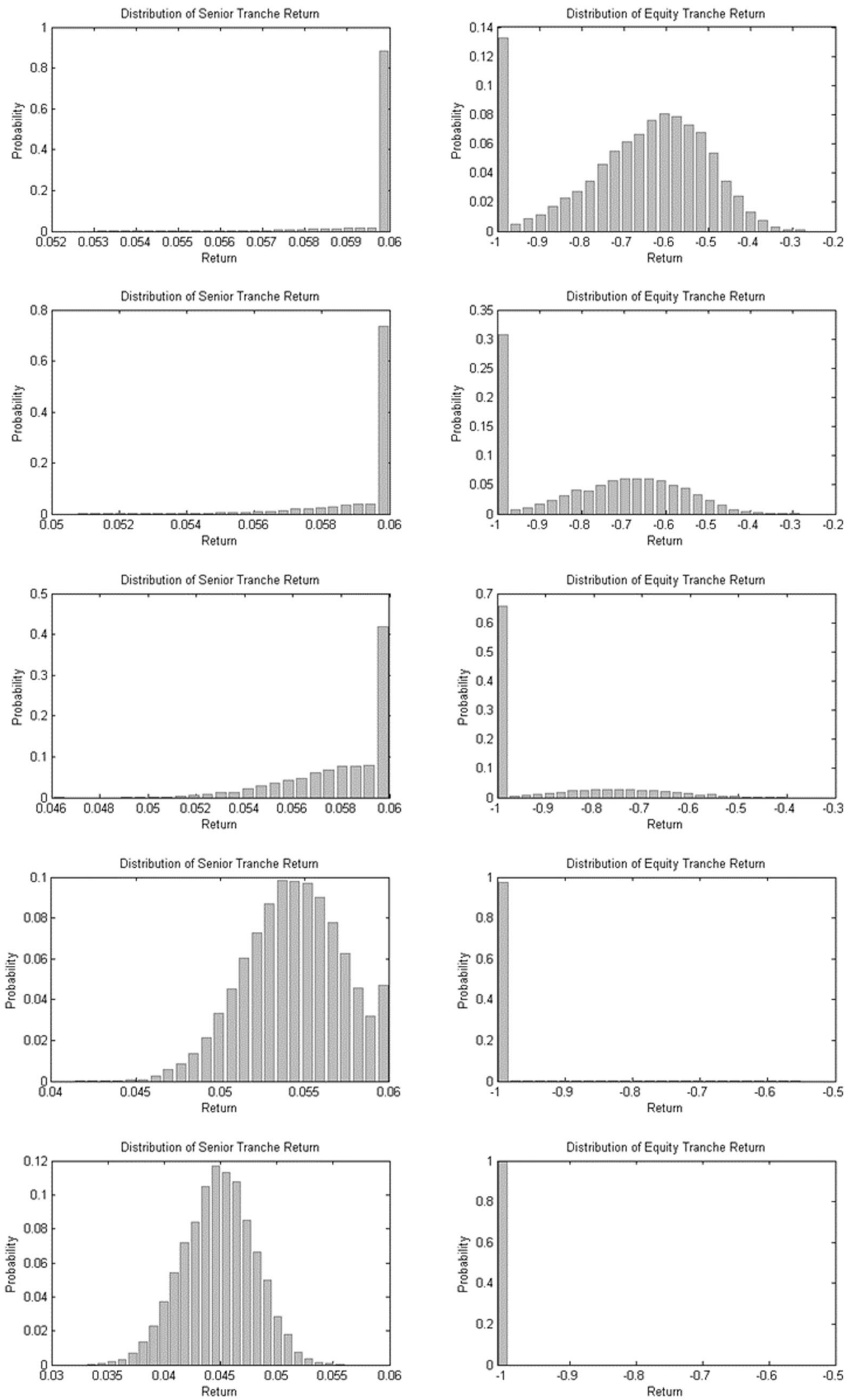

FIGURE 7 Counterfactual analyses for house price changes. *Notes*: Given that overcollateralization rate = 25.5% and senior coupon rate = 6%, the left and right columns display the distributions of returns at maturity for senior and equity tranches, respectively. The first row shows the baseline results. In the second through fifth rows, the house prices in all the cities are increased by 10%, 25%, 50%, and 100%, respectively, of the standard deviation.

TABLE 6 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 floor 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

Note: 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 keeping all other factors unchanged. That is, if the coefficient of the factor in the estimation result shown in Table 2 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 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.

Abbreviations: GDP, gross domestic product; LTV, loan-to-value ratio.

9 | CONCLUSION

While the risk and pricing of financial products provided by financial institutions have been intensively studied, we examine financial institutions' processing time when they are providing financial products or services. The uncertainty of processing time can generate delay risk. 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 10 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. On the basis of 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 originating 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) in the dimension of house price fluctuations, 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.

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DATA AVAILABILITY STATEMENT

The property transaction data and mortgage-receivable payment data are confidential data obtained from an anonymous developer in China and cannot be shared. Restrictions apply to the availability of the bank financial report data from WIND, the city-level and national-level macroeconomic data from CEIC and CREIS, and the data on bank loans issued to publicly listed firms from CSMAR, which were used under license for this study. The bank branch data are posted on the websites of China Banking and Insurance Regulatory Commission.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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APPENDIX A

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

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

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

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

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, that is,*

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

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 1th 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

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

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, that is, $C_1 = c_S$ 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, that is, $C_1 < c_S$ 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

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

Then, the accumulated deficit at t_2 is

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

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

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

Then, the accumulated deficit at t_3 is

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

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

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

□

Proposition 2. *Suppose that the time length from the property transaction 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 $F(x)$, that is, for any t, $\Pr(y > t) > \Pr(x > t)$.*

Proof.

$$G(t) = F(t|t > t_0) = \begin{cases} 0 < F(t) & \text{if } t \le t_0, \\ \frac{F(t) - F(t_0)}{1 - F(t_0)} = \frac{F(t)(1 - F(t_0)) + F(t)F(t_0) - F(t_0)}{1 - F(t_0)} < F(t) & \text{if } t > t_0. \end{cases}$$

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 $F(x)$, that is, 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

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

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

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. □