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Fair valuation of mortgage insurance under stochastic default and interest rates

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ABSTRACT

Unlike most studies in the literature, in this study, we incorporate three main factors into the pricing method of mortgage insurance: interest rate, housing price, and hazard rate (default risks). The empirical analysis highlighted that the interest rate and housing price are positively correlated during July 2004 to November 2016 because of the monetary policy over this period. Subsequently, in the risk-neutral pricing framework, mortgage insurance of the fixed-rate mortgage is priced using a Monte Carlo simulation approach. The sensitivity analysis indicated that interest rate, housing price, and default rate are important factors for mortgage insurance. Moreover, because our model can measure the risks of the interest rate and hazard rate, insurance companies can use this model to price mortgage insurance to avoid a condition in which the insurance company does not have sufficient reserves to support compensation.

1. Introduction

The mortgage insurance is a contract that can indemnify the loss of mortgage bank while the borrower default and the auction income of the collateral (or the house) does not cover the loan balance. A robust mortgage insurance scheme plays an important role in the functioning of the housing market since it reduces the risk exposure of lenders and promotes the creation of secondary mortgage markets (Canner & Passmore, 1994). In the U.S., Fannie Mae and Freddie Mac, both government-sponsored agencies, require the mortgage insurance for mortgage loans that exceed 80%. The mortgage insurance is provided by two government agencies, the Federal Housing Administration (FHA) and the Department of the Veterans Affairs (VA), as well as private mortgage insurers. The need for similar risk-sharing mechanisms exists in other emerging markets as well (Bardhan, Karapandža, & Urošević, 2006).

Three main factors affect the mortgage insurance price in a fixed-rate mortgage: housing price, interest rate, and credit risks. First, geometric Brownian motion is commonly used for measuring the housing price in studies of Azevedo-Pereira, Newton, and Paxson (2003), Kau, Keenan, Muller, and Epperson (1992) and Kau and Keenan, 1995. Because houses and build-

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ings suffer from natural catastrophes (e.g., hurricanes, floods, and earthquakes), the housing price declines even if the house is destroyed. Kau and Keenan (1996) ,Kau and Keenan (1999) employ a compound Poisson process (similar to the jump diffusion process developed by Merton (1976)) to depict the effects of catastrophes on the housing price. However, Chen, Chang, Lin, and Shyu (2010) argue that global financial events affect the housing price and also use a compound Poisson process to measure the effects of these financial events on the housing price. Chang, Wang, and Yang (2012) consider macroeconomic factors to characterize the housing price. These factors can be seen as systemic risks for the house market and should be priced for mortgage insurance. Pu, Fang, and Ban (2016) categorize the total risk of the housing price into systematic and idiosyncratic factors. However, because the market prices of risks for the macroeconomic factors are difficult to determine in a risk-neutral pricing framework, we consider two factors in the housing price model (i.e., interest rate factor and noninterest rate factor); this model includes systematic and idiosyncratic factors of the housing market. The advantage of this model is that the dynamic process of the housing price can be easily measured, and the mortgage insurance price can be computed.

Second, Bardhan et al. (2006), Chang et al. (2012), Chen et al. (2010), Dennis, Kuo, and Yang (1997) and Pu et al. (2016) adopt a constant interest rate to estimate the mortgage insurance price. However, McQuinn and O'Reilly (2008) survey property prices across organizations in the economic cooperation and development (OECD) countries from 1990 to 2005 and find that interest rate plays an important role in housing price movements. In addition, Wei (2010) shows that the primary indicators of mortgage default are the interest rate and growth rate of the housing price. In other words, because of mortgage loans or mortgage insurance with a long period, mortgage banks and insurance companies face interest rate risks, which should be considered in the pricing formula. To depict the interest rate, similar to most studies, we assume that the short rate (or the instantaneous spot rate) obeys the square-root process (or the Cox, Ingersoll, & Ross, 1985), which ensures the positive level of the interest rate.

Finally, Azevedo-Pereira et al. (2003) and Kau and Keenan, 1995 develop a structural-form approach with two state variables (interest rate and housing price) to endogenously model the credit risks of mortgages. In this framework, a borrower default occurs only when the loan balance is less than the housing price. In addition, Campbell and Cocco (2015) argue that several sources of risk affect a household's decision to default on a mortgage, such as interest rate, housing price, and household income. However, the formal and extravagant structural-form approach is complicated for estimating the default probability. To simply depict the default process, Dennis et al. (1997) propose an exogenous model (or reduced-form approach) to measure the hazard rate (or credit risk). In this framework, we consider three factors in the hazard rate process (i.e., interest rate factor, housing price factor, and others). In addition, similar to short rate, we use the square-root process to depict the dynamic hazard rate process to ensure positivity.

We use the monthly sample of the 3-month Treasury bill secondary market rate, seasonally adjusted 20-City Composite Home Price Index, and S&P/Experian First Mortgage Default Index for empirical analysis and estimation of model parameters. The empirical sample encompasses the July 2004 to November 2016 period. Notably, interest rate has a positive relationship with housing price. This may be attributed to the various mortgage defaults and housing collaterals auctioned by the courts after the financial crisis in 2008, resulting in the decline in housing price. Simultaneously, the investors transfer their funds from the stock market or the credit market to the Treasury bond market, and the yield of the Treasury bond decreases. In addition, for recovery economy, the Fed adopts the quantitative easing (QE) polity in early 2009. This causes the interest rate to decline and even to approach zero. Thus, interest rate and housing price move in the same direction. Other empirical results are consistent with economic and financial intuitions.

The sensitivity analysis indicates that the mortgage insurance price is an increasing function of the following: (i) the mean-reverting force and interest rate volatility; (ii) current level, mean-reverting force, long-run mean level, volatility, and market price of the hazard rate risk; (iii) housing price volatility; and (iv) correlation between the interest rate and housing price. By contrast, the mortgage insurance price is a decreasing function of the following: (i) the current level and long-run mean level of the interest rate, (ii) correlation between the housing price and hazard rate and that between the hazard rate and interest rate, and (iii) market price of the interest rate risk.

This study provides five contributions to the current relevant literature on mortgage insurance pricing. First, we incorporate three main factors into the pricing method of mortgage insurance: interest rate, housing price, and hazard rate. As previously mentioned, we argue that the housing price risks arise from the interest rate and other systematic and idiosyncratic factors of the housing market, and the default probability is driven by the interest rate, housing price, and other systematic and idiosyncratic factors of the borrower. Second, we perform an empirical analysis of the interest rate, housing price, and hazard rate to confirm the positive correlation between interest rate and housing price. Third, according to the risk-neutral pricing framework, mortgage insurance of the fixed-rate mortgage is priced using a Monte Carlo simulation approach. The sensitivity analysis reveals the effects of each model parameter on the mortgage insurance price. Fourth, the mortgage insurance price in our model is higher than that in the model of Bardhan et al., 2006. Because our model can measure the risks of interest rate and hazard rate during the holding period, the higher mortgage insurance price can help to avoid a condition in which the insurance company does not have sufficient reserves to support compensation. Finally, unlike most studies in the literature, we introduce the auction variable into the mortgage insurance pricing model, which enables a more accurate measurement of mortgage bank losses during borrower defaults.

The remainder of the paper is organized in the following manner. Section 2 presents the setup of the model. Section 3 discuss the change of measure and the Monte Carlo simulation for pricing the mortgage insurance. Section 4 shows the result of the estimation for the model parameters using empirical data, and then conducts several numerical experiments to