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Volatility morphology of asset value and credit spread puzzle

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Abstract

Merton model has provided a classic theoretical framework for explaining credit spreads. This paper extends Merton model by introducing morphology factor of asset value volatility in the model, and conducts empirical studies on the effect of asset volatility morphology on credit spreads in China's bond market. The results show that asset volatility morphology is economically important and can explain credit spreads well. Furthermore, this paper analyzes the asymmetric influences of monetary policy on credit spreads and asset volatility morphology. This paper points out that the responses of credit spreads and asset volatility morphology to monetary policy are consistent in the tight liquidity environments. To this end, monetary policy and liquidity, which are two factors that have been ignored by classic Merton model but proved to have significant influences on credit

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spreads, play roles in influencing credit spreads by changing volatility morphology of asset value. Since asset volatility morphology can reflect the change of investors' expectation on the default probability of asset, the argument mentioned in the credit spread puzzle that the fundamentals related to bond default probability cannot explain credit spreads needs to be reexamined.

Keywords: Bond market; credit spread puzzle; Merton model; monetary policy; volatility morphology.

1. Introduction

Credit spreads are the differences in yield between a risk-free bond and another bond with the same maturity but higher credit risk, and can reveal a wealth of important information to investors. On the micro-level, credit spreads show the expected default risk of a specific bond issuer. Whereas on the macro-level, credit spreads index constructed based on the credit spreads of a large amount of representative bonds can reflect the systematic risk of the overall economy to some extent.

Numerous studies have explored the determinants of credit spreads either theoretically or empirically. Most theoretical models belong to diffusion-based structural models. The core assumption of these models is that default occurs the first time asset value drops below the face amount of debt. Merton (1974) builds an early structural model based on the idea that the value of a corporate bond can be expressed as the value of a risk-free bond minus that of a put option on the assets, and then calculates the theoretical bond value and credit spreads by using the option pricing model of Black and Scholes (1973). Afterward, many scholars have made modifications to this classical Merton model. Black and Cox (1976) relax the assumption that default would only occur on the maturity date of bonds, and indicate that default would be triggered if the asset value falls below a certain default boundary. Anderson and Sundaresan (1996) conclude that even if the asset value falls below the default boundary, a bond issuer may not choose to default immediately because the default timing is determined by a game between shareholders and creditors. Mella-Barral and Perraudin (1997) follow the idea and obtain the analytical solution of bond value. The works of Kim *et al.* (1993), Shimko *et al.* (1993) and Longstaff and Schwartz (1995) modify the assumption that yield curve is flat in Merton model, and assume that interest rates follow a mean-reverting CIR model or Vasicek model. Since asset value is continuous in classical Merton model, when asset value is far from the default boundary, the default probability is almost zero, which is inconsistent with the actual change of credit spreads. To account for this, Zhou (2001) uses a Poisson process to describe the abrupt change of enterprise value, and simulates credit spreads through the Monte Carlo method.

Along with structural models that are established well, many empirical studies are conducted to examine the explanation of these models for credit spreads. One of the earliest studies is that of Jones *et al.* (1984), which empirically explores the difference between the credit spreads estimated from Merton model and the real credit spreads in the bond market. Delianedis and Geske (2001) indicate that credit factors related to default probability proposed by structural models only has an explanatory power of about 20% for credit spreads. Huang and Kong (2003) conclude that the default probability could explain no more than 20% of the change in the credit spreads of corporate bonds. In addition, more and more scholars find that there are significant effects of noncredit factors such as taxation, liquidity, monetary policy on credit spreads (Elton *et al.*, 2001; Boss and Scheicher, 2002; Ohyama and Sugimoto, 2007; Gao and Zou, 2015). This creates a phenomenon described by Amato and Remolona (2003) as the credit spread puzzle.

Some studies have provided explanations for the credit spread puzzle. For instance, Avramov *et al.* (2007) point out that investors' attitudes towards default risk vary with their preferences of bonds with different credit quality; accordingly, the explanatory power of default probability of bonds with low credit ratings is much higher than that of bonds with high credit ratings. Amato (2005) proposes that the insufficient explanatory power of default probability on credit spreads might be attributed to the negative skewness of the yield distribution and the difficulty in diversifying credit risks. According to Feldhütter and Schaefer (2018), the distribution of the historical default rate is skewed, meaning that the observed historical default rate is likely to be below the *ex-ante* default probability, so when testing a structural model that is calibrated to the historical default rate, predictions of the spread are likely to appear too low relative to the actual spread. Bai *et al.* (2020) indicate that the large market price of risk brought by securities that have significant exposure to downside tail risk implying that structural models of default are misspecified, and thus provide an explanation for why these models significantly underestimate credit spreads. However, many of these explanations haven't derived from structural models themselves, so they offer little insights to the fundamental issue, that is the incongruence between theories and empirical evidences related to credit spreads. More meaningful work should be conducted on the reasons behind the inefficiency of the structural models and to increase their explanatory power by extending the models.

In this paper, we first extend classic Merton model by using Asymmetric Exponential Power Distribution (AEPD) to introduce morphology factor of asset value volatility in the model. We then find empirical supports to the extended Merton model by confirming the explanatory power of the newly added factor of asset volatility morphology for credit spreads. After analyzing the expected default probability of investors implied in asset volatility morphology, this paper further explores how monetary policy and liquidity which are two noncredit factors excluded in classic Merton model influence credit spreads by changing asset volatility morphology, and attempts to answer why fundamentals related to default probability always fail in explaining credit spreads.

2. The Extended Merton Model

Classic Merton framework suggests that risk-free rate, leverage ratio and asset volatility are the main factors influencing the probability of default. In terms of asset volatility, a higher volatility rate of asset value would widen credit spreads. But the real story is that asset volatility by itself does not necessarily increase the default probability, and there is an asymmetric response of default probability to the positive and negative changes of asset value. Specifically, when the asset value of a company occurs positive fluctuation in consequence of good news, the probability of default would not increase. To acquire a better understanding of the mechanism by which asset volatility influences credit spreads, we argue that asset volatility factor includes not only volatility rate but also volatility morphology. Classic Merton model only covers asset volatility rate which has been proven by prior empirical studies to have little explanatory power for credit spreads. However, it doesn't mean that asset volatility morphology lacks explanatory power as well. As a matter of fact, asset volatility morphology provides far richer information than volatility rate. Let's take a simple numerical example. Suppose that for one company, 9 out of 10 fluctuations in asset value are 1%, and only one is −9%, while for another company, asset value changes by −1% on 9 of these 10 fluctuations and by 9% on 1 fluctuation. Although the volatility rates of the two companies have same mean value and variance, the morphology of asset volatility is drastically different. In this paper, we extend classic Merton model based on that.

Merton (1974) believes that the equity portion of a company can be modeled as a European call option written on the value of the assets (V) with a strike price equal to the face value of the debt (D). Assuming the equity does not receive dividends and the debt is in the form of a zero coupon bond with maturity at time T, the implied credit spreads can be calculated as follows:

$$\mathrm{CS}(L, \sigma_v, T) = -\frac{1}{T}\ln\left[N(d_2) + \frac{1}{L}N(-d_1)\right], \tag{1}$$

$$d_1 = \frac{1}{2}\sigma_v\sqrt{T} - \frac{\ln(L)}{\sigma_v\sqrt{T}}, \tag{2}$$

$$d_2 = d_1 - \sigma_v\sqrt{T}, \tag{3}$$

where σ_v is the volatility of the assets; T is the term to maturity of the debt; $L = De^{-rT}/V_0$ is the leverage ratio when the risk-free rate is r and the current value of assets is V_0.

The dynamics for the value of the assets V through time can be described by a diffusion-type stochastic process:

$$\mathrm{d}V = \mu_v V \mathrm{d}t + \sigma_v V \mathrm{d}z, \tag{4}$$

where $\mathrm{d}z$ is a standard Wiener process and z_t follows the normal distribution; μ_v is the instantaneous expected rate of return on the assets per unit time.

We modify Eq. (4) by letting z_t follow the asymmetric exponential power distribution (AEPD) instead of the normal distribution. The AEPD could better describe financial time series' distribution characteristics of leptokurtosis, fat-tail and asymmetry (Zhu and Zinde-Walsh, 2009). The AEPD density has the following form:

$$f_{\mathrm{AEP}}(y|\beta)\begin{cases} \left(\dfrac{\alpha}{\alpha^*}\right)\dfrac{1}{\sigma}K_{\mathrm{EP}}(p_1)\exp\left(-\dfrac{1}{p_1}\left|\dfrac{y-\mu}{2\alpha^*\sigma}\right|^{p_1}\right) & \text{if } y \le \mu \\ \left(\dfrac{1-\alpha}{1-\alpha^*}\right)\dfrac{1}{\sigma}K_{\mathrm{EP}}(p_2)\exp\left(-\dfrac{1}{p_2}\left|\dfrac{y-\mu}{2(1-\alpha^*)\sigma}\right|^{p_2}\right) & \text{if } y > \mu, \end{cases} \tag{5}$$

where $\beta = (\alpha, p_1, p_2, \mu, \sigma)^{\mathrm{T}}$ is the parameter vector. $\mu \in R$ and $\sigma > 0$ represent location and scale, respectively. $\alpha \in (0, 1)$ is the skewness parameter. $p_1 > 0$ and $p_2 > 0$ are two parameters controlling the thickness of left and right tail, respectively. α^* and $K_{\mathrm{EP}}(p)$ are defined as follows:

$$\alpha^* = \frac{\alpha K_{\mathrm{EP}}(p_1)}{\alpha K_{\mathrm{EP}}(p_1) + (1-\alpha)K_{\mathrm{EP}}(p_2)}, \tag{6}$$

$$K_{\mathrm{EP}}(p) = \frac{1}{2p^{1/p}\Gamma(1+1/p)}, \tag{7}$$

where Γ is the Gamma function and analytically $\Gamma(x) = \int_0^\infty y^{x-1}\mathrm{e}^{-y}\mathrm{d}y$.

The expectation and variance of the AEPD are as follows:

$$E(x) = \frac{1}{B}\left[(1-\alpha)^2\frac{p_2\Gamma\left(\frac{2}{p_2}\right)}{\Gamma^2\left(\frac{1}{p_2}\right)} - \alpha^2\frac{p_1\Gamma\left(\frac{2}{p_1}\right)}{\Gamma^2\left(\frac{1}{p_1}\right)}\right], \tag{8}$$

$$\begin{aligned}\mathrm{Var}(x) = \frac{1}{B^2}\Bigg\{&\left[(1-\alpha)^3\frac{p_2^2\Gamma\left(\frac{3}{p_2}\right)}{\Gamma^3\left(\frac{1}{p_2}\right)} + \alpha^3\frac{p_1^2\Gamma\left(\frac{3}{p_1}\right)}{\Gamma^2\left(\frac{1}{p_1}\right)}\right] \\ &- \left[(1-\alpha)^2\frac{p_2\Gamma\left(\frac{2}{p_2}\right)}{\Gamma^2\left(\frac{1}{p_2}\right)} - \alpha^2\frac{p_1\Gamma\left(\frac{2}{p_1}\right)}{\Gamma^2\left(\frac{1}{p_1}\right)}\right]^2\Bigg\},\end{aligned} \tag{9}$$

where $B \equiv \alpha K_{\mathrm{EP}}(p_1) + (1-\alpha)K_{\mathrm{EP}}(p_2)$.

Let $z = (x - E(x))/\sqrt{\mathrm{Var}(x)}$, the standard AEPD density $(\mu = 0, \sigma = 1)$ has the following form:

$$f_{\mathrm{AEP}}(z|\alpha, p_1, p_2) = \begin{cases} \delta \dfrac{\alpha}{\alpha^*} K_{\mathrm{EP}}(p_1) \exp\left(-\dfrac{1}{p_1}\left|\dfrac{w + z\delta}{2\alpha^*}\right|^{p_1}\right) & \text{if } z \le 0 \\ \delta\left(\dfrac{1-\alpha}{1-\alpha^*}\right) K_{\mathrm{EP}}(p_2) \exp\left(-\dfrac{1}{p_2}\left|\dfrac{z}{2(1-\alpha^*)}\right|^{p_2}\right) & \text{if } z > 0, \end{cases} \tag{10}$$

We then use the standard AEPD to define the uncertainty of the asset value. The value of assets at time t is equal to

$$V_t = V_0 e^{\mu_v t + \sigma_v \sqrt{t} Z_t - t\phi\left(\frac{\sigma_v}{t}\right)}, \tag{11}$$

where V_0 and V_t represent the value of assets at the present time and time t, respectively, μ is the discount rate, μ_v is the expected rate of return on the assets. z_t follows the AEPD, ϕ denotes the logarithm of the eigenfunction of the AEPD.

Taking logarithms of both sides of Eq. (11), the value of assets can be described by the following equation:

$$\ln(V_t) = \ln(V_0) + \left(\mu_v - \phi\left(\frac{\sigma_v}{t}\right)\right)t + \sigma_v \sqrt{t} z_t. \tag{12}$$

It should be noted that when the parameters $\alpha = 0.5$, $p_1 = 2$, $p_2 = 2$, z_t follows the standard normal distribution. At this time, the logarithmic eigenfunction $\phi(\sigma_v/t)$ equals to $\frac{1}{2}\sigma_v^2$, we get the following equation which can also be derived from classical Merton model:

$$\ln(V_t) = \ln(V_0) + \left(\mu_v - \frac{1}{2}\sigma_v^2\right)t + \sigma_v \sqrt{t} z_t. \tag{13}$$

Based on Eq. (13), the credit spreads can be defined as follows:

$$\mathrm{CS} = \mathrm{CS}(h, \sigma_v, T, p_1, p_2, \alpha). \tag{14}$$

Compared to classical Merton framework, credit spreads under the extended Merton model taking a more complicated form to capture richer information related to default probability. α is the most important parameter since it decides the skewed direction the asset volatility is. Theoretically, negative skewness of asset volatility implies constant negative earnings on the asset, which may change investors' confidence in the company and then impair its financing ability. To this end, as α gets larger, the credit spreads get smaller.

3. Empirical Analysis

3.1. Asset volatility morphology and credit spreads

We conduct an empirical study on the explanatory power of asset volatility morphology for credit spreads in China's bond market. Our research only involves companies that issue both stocks and bonds at the same time. Moreover, many companies have several outstanding bonds during the same period. In order to avoid the excessive influence of a single company on the overall sample, we only use the bond with largest issuing scale of a company as our research sample,[1] resulting in a sample of 6,948 bond-quarter observations before December 2019. The main reason for choosing the quarterly data is that the stock price volatility rate is quite large, we may not obtain robust estimators for the model parameters by using monthly data or data of a higher frequency. Besides, the leverage ratio is disclosed quarterly by companies.

We use fixed effect model to examine the impacts of quarterly yield, leverage ratio, asset volatility rate and asset volatility morphology on credit spreads. The explained variable, credit spreads are calculated by taking the difference between the quarter-end China Bond yield of focal bond and the yield of the same-term treasury bond. In terms of the explanatory variables, leverage ratio is calculated by using the financial data in the quarterly report, and yield and asset volatility rate, respectively, are measured by the stock return rate and price volatility obtained from the quarterly stock trading data. We then estimate the quarterly time series of the parameter α based on the extended Merton model and real bond and stock data. To conveniently describe the results, we use $-\alpha$ as the proxy for asset volatility morphology. Furthermore, according to the existing literatures, we control the quarterly slope of yield curve of bond issuer, firm fixed effect and time fixed effect in the regression model. The slope of term structure often represents investors' expectation of economic growth, inflation and so on (Hardouvelis, 1988; Mishkin, 1990), and can be estimated from Nelson and Siegel (1987) model as follows:

$$R(t,m) = \theta_1(t) + \theta_2(t)\frac{\tau}{m}\left[1 - \exp\left(-\frac{\tau}{m}\right)\right] + \theta_3(t)\left\{\frac{\tau}{m}\left[1 - \exp\left(-\frac{\tau}{m}\right)\right] - \exp\left(-\frac{\tau}{m}\right)\right\}, \tag{15}$$

where $R(t,m)$ is the bond yield, m represents term to maturity, coefficient $\theta_1(t)$ is the asymptote of the long-term yield, and coefficient $\theta_2(t)$ measures how steep the

[1]If a company's two bonds have the same issuing scale, we keep the one with longer term to maturity so as to have more observations.

Table 1. Regression results for various factors on credit spreads.

	Credit spreads	
	(1)	(2)
Yield	−0.02	−0.05
	(0.06)	(0.07)
Asset volatility rate	−2.03***	−0.28***
	(0.10)	(0.09)
Asset volatility morphology ($-\alpha$)		0.32**
		(0.15)
Leverage ratio	0.05***	0.05***
	(0.04)	(0.04)
Slope of yield curve	−0.30**	−0.23**
	(0.18)	(0.19)
Firm fixed effect	Yes	Yes
Time fixed effect	Yes	Yes
Constant	−0.24*	−0.19
	(0.13)	(0.12)
Observation	6,948	6,948
R-square	0.45	0.53

Notes: Standard errors are reported in parentheses under the estimation coefficient.
***, **, * indicate the significance level of 1%, 5% and 10%, respectively.

yield curve is. Generally, $\theta_2(t)$ has a negative value, and as the absolute value of $\theta_2(t)$ gets larger, the curve gets steeper. coefficient $\theta_3(t)$ describes the curvature while τ describes the speed and degree that the long-term yield converges to its asymptote. As τ gets larger, the measure has more information about forward rate. In this case, we give τ a lower bond of 1 to focus more on the short-term rate.

The empirical results are shown in Table 1. Models (1) and (2) show that the effect of leverage ratio on credit spreads is significantly positive ($p < 0.01$), which can be predicted by classic Merton model. However, the coefficient of yield is not significant, and the coefficient of asset volatility rate is significantly negative ($p < 0.01$), that is, when asset volatility rises, credit spreads narrow. Overall, explanatory power of yield and asset volatility rate for credit spreads is limited, which is inconsistent with that implied by classic Merton model. According to Model (2), asset volatility morphology has strong explanatory power for credit spreads ($p < 0.05$), which is consistent with the theoretical implications of the extended Merton model. We improve classical Merton framework by depicting the asset volatility factor more accurately.

3.2. The influences of monetary policy and liquidity under the extended Merton model

Although a large number of empirical studies have revealed that monetary policy and liquidity have significantly higher explanatory power for credit spreads than fundamental factors (Driessen, 2005; Wu and Zhang, 2008), but they often attribute the influences of these factors to their own characteristics, and completely separate them from the possibility of default. We argue that monetary policy and liquidity do not directly affect credit spreads, and some of their effects still play roles by affecting the possibility of default.

When the liquidity environment is loose, companies face less fund constraint, so the marginal changes in monetary policy have less impact on companies' activities. In this circumstance, the influence of monetary policy shock is usually temporary, and investors' expectation for defaults caused by monetary policy is relatively small. On the contrary, monetary policy in the tight liquidity environments is more likely to exert continuous impacts on business operation. If investors realize the constraints of tight liquidity environments, they may increase the fear of the default probability. Here is a simple example to illustrate the relationship between the continuity of monetary policy's influence and asset volatility morphology. Assuming that the asset price conforms to a normal distribution with a mean value of 0. When a shock comes, if the impact is continuous, it is assumed that the asset price will drop to the position of the mean value of -2 and continue to fluctuate following the normal distribution. Conversely, if the impact is short-term, it is assumed that the asset price will first fluctuate at the position where the mean value is -2 for a short time and then quickly return to fluctuate at the position where the mean value is 0. Fig. 1 shows that the volatility morphology of asset price under continuous and noncontinuous impacts is obviously different.

Based on the argument, we propose that asset volatility morphology may play a mediating role in the transmission mechanism of the effect of monetary policy on credit spreads. Smooth transition vector auto-regression (STVAR) is used to examine the impacts of monetary policy on credit spreads and asset volatility morphology. We calculate the credit spreads between China Bond Corporate Bond Yield Curve (AAA rating) and China bond Government Bond Yield Curve from March 2003 to December 2019, and then take the arithmetic mean of the credit spreads for different maturities to obtain the credit spreads series of AAA rated bonds. The credit spreads series of AA+, AA and AA− rated bonds are generated in the same way. We then use the parameter $-\alpha$ estimated from the extended model to measure asset volatility morphology. The monthly average of the weighted seven-day repo rate from March 2003 to December 2019 is used as the proxy variable for monetary policy. The reasons are as follows. First, common

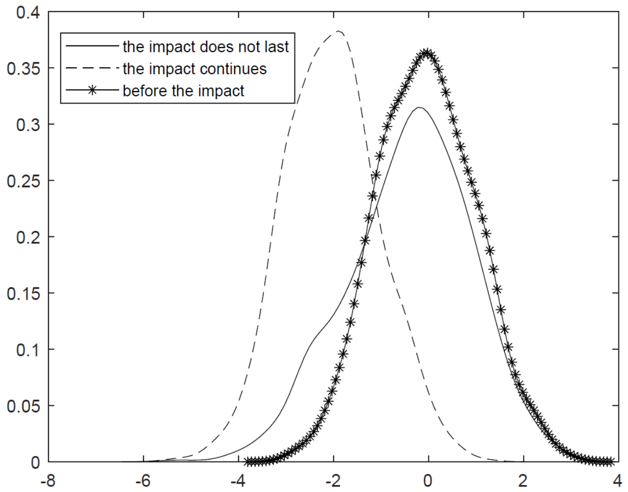

Fig. 1. An example to compare the distributions of return after continuous and noncontinuous impacts of monetary policy.

proxy variables such as loan growth and M2 have flaws in studying the effect of monetary policy on the bond market. Bonds and loans both appear on the asset side of banks' balance sheet, the rapid growth of loans often means the shrinking of banks' allocation of bond assets, so the easing monetary policy measured by the loan growth rate sometimes represents the tight bond market. In addition, loan growth and M2 are often the result of the asset allocation and capital expenditure of banks and residents, which may lag behind investors' allocation of bonds. Second, because interbank repurchase is the financial product with the largest transaction volume, compared with other deposit and loan benchmark interest rates, the daily seven-day repo rate can quickly reflect the short-term cost of funds of financial institutions. Third, many scholars indicate that the monetary authority should pay more attention to use short-term interest rates to guide changes of long-term interest rates. The seven-day repo rate is an ideal proxy variable for short-term interest rates.

Since all data series except the credit spreads are stationary, we take the natural logarithm of the original credit spreads series and the new series have passed the stationary test. Given the limited space, we only show the results related to AA+ rating bonds below. The results for other rated bonds are consistent. Before running STVAR, we set the lag order of the transition variables is 1, and iterate the threshold value and smoothing coefficient to obtain the two-dimensional graphs of the likelihood function LR p-value (as shown in Fig. 2) and then select the transition available for tests. It is not difficult to find that large areas of LR p-value less than 0.1 appear on both sides of the threshold from 3 to 4, so the range of available

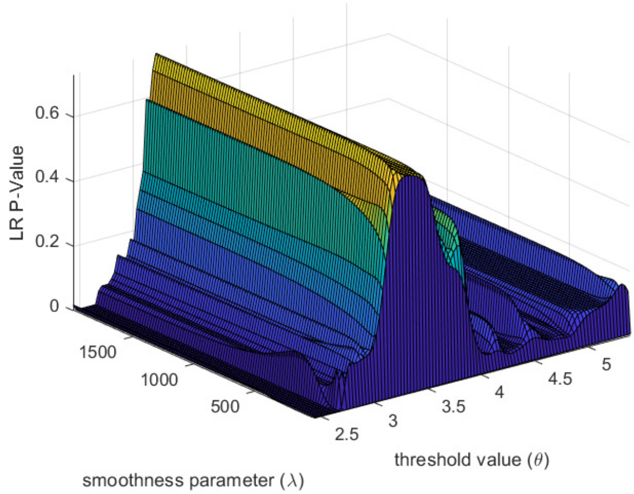

Fig. 2. Two-dimensional graph of the likelihood function LR.

transition variable is relatively wide. In this paper, we define the loose and tight liquidity environments by using the threshold value of (<3, >4). The selection criterion of the smoothing coefficient is to make the LR p-value as small as possible under the existing parameters.

Figure 3 reflects the impulse response of credit spreads to monetary policy under the conditions of [loose (<3), tight (>4)]. The result shows that the impact

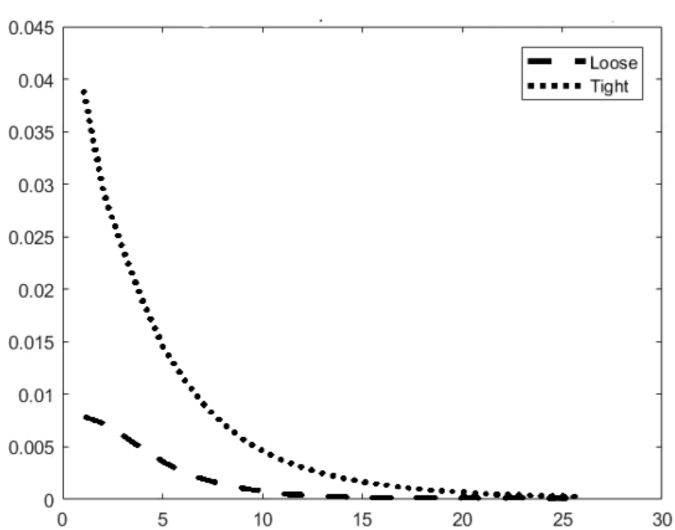

Fig. 3. Impulse response of credit spreads to monetary policy in loose or tight liquidity environments.

Table 2. Granger tests for examining the effect of monetary policy on credit spreads.

Null hypothesis	F-test
Monetary policy does not Granger cause credit spreads in loose liquidity environments	3.06
Monetary policy does not Granger cause credit spreads in tight liquidity environments	5.02**

Note: ** represents the significance level of 5%.

Table 3. Granger tests for examining the mediating effect of asset volatility morphology.

Null hypothesis	F-test
Panel A: in loose liquidity environments	
Monetary policy does not Granger cause volatility morphology	2.05
Monetary policy does not Granger cause credit spreads	1.26
Panel B: in tight liquidity environments	
Monetary policy does not Granger cause volatility morphology	6.12***
Monetary policy does not Granger cause credit spreads	5.57***

Note: ***represents the significance level of 1%.

of monetary policy has a significant asymmetric effect on credit spreads, that is, monetary policy expands credit spreads in tight liquidity environments more than that in loose liquidity environments. Table 2 also indicates that monetary policy Granger causes credit spreads in tight liquidity environments, while monetary policy is not the Granger reason for credit spreads in loose environments. This is basically consistent with the analysis of the theoretical part.

We further add asset volatility morphology into the STVAR model to examine its mediating effect on the relationship between monetary policy and credit spreads. Panel A in Table 3 shows that in loose liquidity environments, monetary policy does not Granger cause credit spreads and asset volatility morphology. While according to Panel B in Table 3, in tight liquidity environments, monetary policy is the Granger reasons for credit spreads and asset volatility morphology. At the same time, compared with Fig. 4 and Table 2, Fig. 5 and Table 3 show that the magnitude of the impulse response of credit spreads to monetary policy and the significance of the corresponding Granger reason both increases when asset volatility morphology is added. The results indicate that one of mechanisms that how monetary policy and liquidity influence credit spreads is through changing the volatility morphology of asset value.

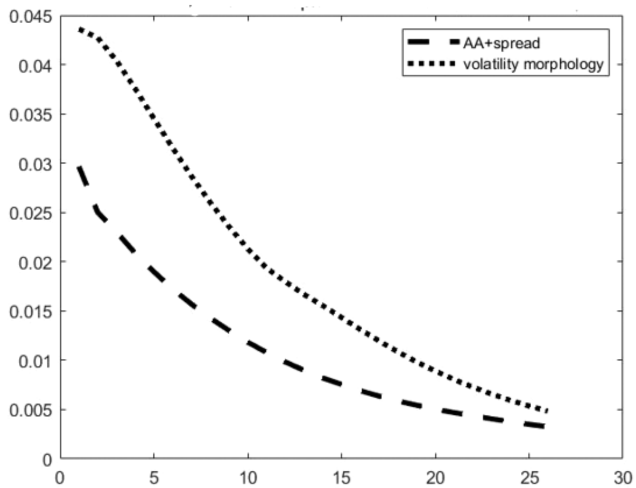

Fig. 4. Impulse response of credit spreads and asset volatility morphology to monetary policy in loose liquidity environments.

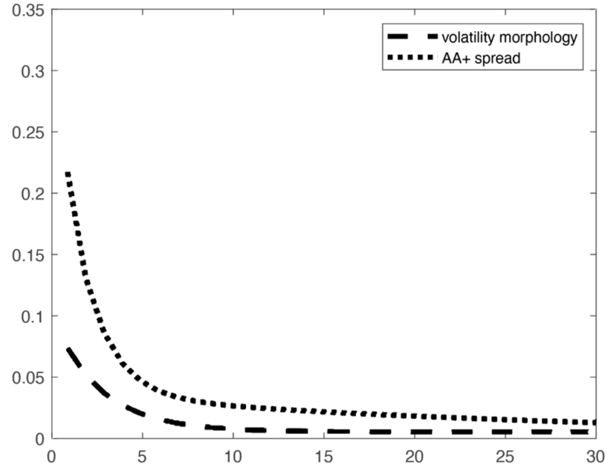

Fig. 5. Impulse response of credit spreads and asset volatility morphology to monetary policy in tight liquidity environments.

4. Conclusions

This paper extends classic Merton model by introducing morphology factor of asset value volatility and uses empirical studies to reveal the explanatory power of the extended mode. Based on the extended model, we further argue that there are two reasons why classical Merton framework is inconsistent with empirical evidences in explaining credit spreads. First, classical Merton model ignores some fundamental factors like volatility morphology of asset value. When the neglected factors reflect investors' fears of default, the explanatory power of classical Merton model become limited. Second, classical Merton framework only considers the factors that are directly related to companies' default risks. However, some non-credit factors such as monetary policy and liquidity may be reflected in the expectations of investors on the default risks though they have not direct relations with the default probability of companies. In conclusion, it may be inappropriate to simply regard the phenomenon that the factors related to default probabilities proposed by the theoretical models fail to explain credit spreads as the credit spread puzzle.

Our paper also sheds new light on the understanding of China's bond market. In essence, credit spreads are the capitalization of default probability. Because the rigid payment phenomena exist at times, many scholars believe that China's bond market is still immature and the credit spreads are more of a function of liquidity and investor psychology. Accordingly, the credit spread puzzle is often regarded as the evidence of the inefficiency and irrationality of China's bond market. Based on the research on China's bond market, our paper provides estimates of the risk premium of expected default implied in asset volatility morphology and document that it can be a key driver of credit spreads. This means that China's bond market has a degree of pricing capability and allocation efficiency.

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