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MARKETWIDE LIQUIDITY AND OPTIONS MARKET

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Abstract

In this paper, we study the relationship between marketwide liquidity and options market. Using the Chicago Board Options Exchange (CBOE) Volatility Index, VIX as a measure of overall value of the S&P 500 (SPX) options, and the CBOE SKEW Index as a measure of market crash risk premium in the options market, we study the relation among marketwide liquidity, VIX and SKEW. Empirical results show that higher the marketwide liquidity, less expensive the options and the less likely options traders anticipate a market crash.

JEL classification: G12; G13

Keywords: Marketwide liquidity; VIX; SKEW

1. Introduction

Poor liquidity in the credit derivatives market, caused by the US subprime mortgage collapse, helped to trigger the 2009 financial crisis. Liquidity is the ability of an asset to be sold with a minimum loss of value. As a result of the liquidity crisis, many financial firms wrote down large portfolios of credit derivatives known as Collateralized Debt Obligations (CDOs). Because of the large size of the derivatives market, understanding the impact of liquidity on derivatives is crucial to understanding why financial markets crash. In this paper, we study the impact of marketwide liquidity as a state variable on the pricing of derivatives, in particular index options, a popular kind of derivative.

Existing literature mainly focuses on the impact of liquidity on stock and bond markets. Pastor and Stambaugh (2003) documented that marketwide liquidity is a state variable important for pricing stocks cross-sectionally. Acharya and Pedersen (2005) develop a liquidity-adjusted capital asset pricing model under time varying liquidity, and empirically show that liquidity risk is important in the stock market. Lin, Wang and Wu's (2011) empirical results suggest that liquidity risk is an important determinant of expected corporate bond returns.

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The liquidity risk in derivatives comes from three sources: the level of underlying stock liquidity, derivative liquidity and the marketwide liquidity. Research on the impact of liquidity on derivatives markets is scarce. Brenner, Eldor and Hauser (2001) investigate the effect of nontradability on currency derivatives. Cetin et al. (2006) include liquidity into the standard Black-Scholes framework. Bongaerts, De Jong and Driessen (2011) study liquidity risk premium in Credit Default Swap market. To the best of our knowledge, the impact of marketwide liquidity on derivatives markets has never been studied in the literature. That is the focus of this paper.

2. Marketwide Liquidity and Option Expensiveness Measures

2.1 Marketwide liquidity measure

Here we describe marketwide liquidity measures and data required. We use the aggregate market liquidity measures in three markets including stock market, corporate bond market and Treasury market.

2.1.1. Stock market liquidity index

We use Pastor-Stambaugh stock market liquidity measure (PS_stock) and Sadka liquidity measures (Sadka_TF and Sadka_PV). Pastor and Stambaugh (2003) investigate whether marketwide liquidity is a state variable of stock pricing. Their study focuses on a particular dimension of liquidity associated with temporary price fluctuations induced by order flow and finds that expected stock returns are positively related cross-sectionally to the sensitivities of returns to fluctuations in aggregate liquidity. Sadka (2006) decomposes equity-based liquidity into variable and fixed components and finds that the permanent variable component is priced in stock returns. These two data sets are available in the database of WRDS. The data period of PS stock market liquidity measure is from January 1990 to December 2010. The data period of Sadka liquidity measures is from January 1990 to December 2008.

2.1.2. Corporate bond market liquidity index

The corporate bond market liquidity indexes used in the empirical analysis include Amihud corporate bond liquidity measure and PS corporate bond liquidity measure. These two measures are constructed by Lin, Wang and Wu (2010) using transaction based corporate bond data. They find that liquidity risk is priced in the cross section of expected corporate bond returns. The data period covers from March 1994 to September 2009.

2.1.3. Treasury market liquidity index

We use on-off-the-run spread (On/off spread) to measure the liquidity of Treasury market. The on-the-run yield is represented by the constant maturity five-year Treasury rate by Federal Reserve, while the off-the-run yield is the five-year generic Treasury rate reported by the Bloomberg system, which is based on the yields of non-benchmark Treasury notes. On-off-the-run spread has been used extensively in the literature as a measure of aggregate market liquidity (Longstaff, Mithal and Neis, 2005; Lin, Liu and Wu, 2011).

2.1.4 Aggregate market liquidity index

Asness, Moskowitz and Pedersen (2009) find that various liquidity measures are not very correlated to each other and construct an illiquidity index of all measures using the first principal component of all liquidity measures. Following Asness, Moskowitz and Pedersen (2009), we also construct the aggregate liquidity index, which is the first principal component of individual liquidity index, including Pastor-Stambaugh stock market liquidity measure, Sadka Transitory Fixed and Permanent Variable liquidity measure, Amihud corporate bond liquidity measure, Pastor-Stambaugh Corporate bond liquidity measure and On-off-the-run spread.

2.2. Option overall value measure

It is difficult to measure the overall value of options because options prices depend on underlying stock price, strike price and time to maturity. To eliminate the dependency along the direction of underlying stock, it is very natural to use the Black-Scholes implied volatility, which is still a function of strike price and time to maturity. In order to come up with a unique measure of options overall value, certain operation is required to aggregate the information of implied volatility surface.

In 2003, the Chicago Board Options Exchange (CBOE) adopted a new methodology to calculate a Volatility Index, VIX by using all the out-of-the-money (OTM) S&P 500 (SPX) index options.[2] It is a proxy of 30-day variance swap rate, can be used as a measure of overall value of SPX options.

In 2011, the CBOE started to publish values for the CBOE S&P 500 Skew Index (ticker symbol: SKEW), a benchmark measure of the perceived risk of extreme negative moves[3]. It is calculated as 100 minus 10 times 30-day risk-neutral skewness of SPX options. The SKEW can be used as a measure of the value of deep OTM options relative to the ATM ones. Since the deep OTM options are often used as a hedging instrument against a large market fall, the SKEW can be regarded as a measure of market crash risk premium embedded in the options market.

3. Empirical Methodology

The research is empirical. Our methodology is mainly based on single- or multiple-variable linear regressions.

3.1. The impact of liquidity on VIX and SKEW

First, we examine the relationship between marketwide liquidity and VIX by running the regression

$$VIX_t = a + b\, LIQ_t + \varepsilon_t. \qquad (1)$$

We then examine the relationship between marketwide liquidity and SKEW

$$SKEW_t = a + b\, LIQ_t + \varepsilon_t. \qquad (2)$$

Zhang, Zhao and Chang (2012) show that the third central moment (TCM) is more appropriate than skewness to measure of market crash risk premium. Therefore, we further examine the relationship between marketwide liquidity and TCM

$$TCM_t = a + b\, LIQ_t + \varepsilon_t, \qquad (3)$$

where

$$TCM_t = SKEW_t \times VIX_t^3. \qquad (4)$$

[2] See the CBOE white paper available at: http://www.cboe.com/micro/VIX/vixwhite.pdf

[3] See the CBOE white paper available at: http://www.cboe.com/micro/skew/documents/SKEWwhitepaperjan2011.pdf

3.2. The decomposition of variance

In a jump-diffusion setting, Zhang, Zhao and Chang (2012) show that the variance and TCM of stock return over the period from t to $t+\tau$, can be written as

$$Var = \sigma^2\tau + \lambda x^2\tau,$$
$$TCM = \lambda x^3\tau, \quad (5)$$

where σ is volatility coming from Brownian motion, λ is jump intensity and x is jump size. The result is derived under the assumption that σ, λ and x are constant, but we can extend the result to case that both σ and λ are stochastic with an understanding that these two formulas work for average σ and λ over the period. From this analysis, we may conclude that the variance can be decomposed into two parts. One of them comes from the risk of small change, i.e., Brownian motion, the other one comes from the risk of big change, i.e., jumps. By running the regression

$$Var_t = a + b\,TCM_t + \varepsilon_t, \quad (6)$$

The residual obtained will capture the change of variance form Brownian motion. In order to detect which of the two factors, liquidity and TCM dominates the change in variance, we can also run a regression of variance on liquidity by using TCM as a control variable

$$Var_t = a + b\,TCM_t + c\,LIQ_t + \varepsilon_t. \quad (7)$$

3.3. The impact of liquidity on Brownian motion variance

We run following regression

$$\varepsilon_t = \alpha + \beta\,LIQ_t + \eta_t, \quad (8)$$

where Brownian motion variance, ε_t, is the residual from the regression of variance on TCM

$$\varepsilon_t = Var_t - a - b\,TCM_t. \quad (9)$$

4. Empirical Results

Table 1 reports the summary statistics of variables used in the empirical analysis. For VIX, SKEW and Pastor-Stambaugh stock liquidity, we have 21 years of data. Using monthly sample, we have 252 observations[4]. For Amihud and Pastor-Stambaugh corporate liquidity, we have 187 observations, slightly shorter.

[4] Monthly VIX and SKEW are calculated by the mean of all daily value within this month.

Table 1: Summary Statistics

Variable	Sample period	Obs.	Mean	Std	Max	Min
VIX	1/1990-12/2010	252	20.42	8.00	62.64	10.82
SKEW	1/1990-12/2010	252	116.50	4.43	128.97	106.88
TCM	1/1990-12/2010	252	1.56	3.00	29.19	0.15
PS_stock	1/1990-12/2010	252	0.00	0.06	0.29	-0.27
Sadka_TF	1/1990-12/2008	228	0.00	0.00	0.01	-0.01
Sadka_PV	1/1990-12/2008	228	0.00	0.01	0.02	-0.03
Amihud_Corporate	3/1994-09/2009	187	0.00	1.00	2.21	-4.73
PS_Corporate	3/1994-09/2009	187	0.00	0.18	0.36	-1.33
On/off spreads (bps)	1/1990-12/2010	252	3.49	16.05	47.30	-35.10
ALIQ	1/1990-12/2010	252	-0.02	1.30	2.31	-9.49

Note: This table reports the summary statistics of variables used in the empirical analysis. These variables are Volatility Index (VIX), Skew Index (SKEW), the third central moment (TCM) which equals $SKEW \times VIX^3$, Pastor-Stambaugh stock market liquidity measure (PS_Stock), Sadka Transitory Fixed (Sadka_TF) and Permanent Variable (Sadka_PV) liquidity measure, Amihud corporate bond liquidity measure (Amihud_Corporate), Pastor-Stambaugh Corporate bond liquidity measure (PS_Corporate), On-off-the-run spread (On/off spreads) and aggregate liquidity measure (ALIQ). The aggregate liquidity index is the first principal component of individual liquidity index.

Table 2 reports correlation matrix of the variables. VIX and SKEW are almost independent, with a correlation coefficient -0.02. VIX is negatively correlated with all the liquidity measures. We notice that the on/off spread measures negative liquidity. Smaller the on/off spread, higher the liquidity is. SKEW is independent of liquidity, but TCM is negatively correlated with liquidity. The liquidity measures of different markets are positively correlated each other with reasonable coefficients.

Table 2: Correlation Matrix

	VIX	SKEW	TCM	PS_ stock	Sadka_TF	Sadka_PV	Amihud_ Corporate	PS_ Corporate	On/off spread	ALIQ
VIX	1.00									
SKEW	-0.02	1.00								
TCM	0.86	0.04	1.00							
PS_stock	-0.23	0.09	-0.15	1.00						
Sadka_TF	-0.14	-0.17	-0.13	0.03	1.00					
Sadka_PV	-0.27	0.09	-0.23	0.14	0.17	1.00				
Amihud_ Corporate	-0.23	-0.04	-0.33	0.26	0.17	0.26	1.00			
PS_ Corporate	-0.30	0.04	-0.35	0.11	0.06	0.24	0.33	1.00		
On/off spread	0.14	-0.08	0.10	-0.05	0.10	-0.12	-0.11	-0.02	1.00	
ALIQ	-0.40	0.04	-0.42	0.51	0.30	0.64	0.77	0.63	-0.21	1.00

Note: This table reports correlation matrix of variables used in the empirical analysis. These variables are Volatility Index (VIX), Skew Index (SKEW), the third central moment (TCM) which equals $SKEW \times VIX^3$, Pastor-Stambaugh stock market liquidity measure (PS_Stoock), Sadka Transitory Fixed (Sadka_TF) and Permanent Variable (Sadka_PV) liquidity measure, Amihud corporate bond liquidity measure (Amihud_Corporate), Pastor-Stambaugh Corporate bond liquidity measure (PS_Corporate), On-off-the-run spread (On/off spread) and aggregate liquidity measure (ALIQ). The aggregate liquidity index is the first principal component of individual liquidity index.

Table 3 reports the results of time series regressions of VIX, SKEW and TCM on different liquidity measures. The results of Panel A show that VIX is linearly related to all liquidity measures except Sadka_TF with statistical significance at 1% level. The fact that VIX is not related to Sadka_TF is consistent with Sadka's (2006) result that Transitory Fixed component is not priced in stock. The results of Panel B show that SKEW is not related to any liquidity measures except Sadka_TF. It is interesting to see that Sadka's Transitory Fixed component is picked up by SKEW. The results of Panel C show that TCM is in general linearly related to all liquidity measures, but less significant than VIX for stock and Treasury markets and more significant for corporate bond market. These regressions results are consistent with the correlation coefficients presented in Table 2.

Table 3: Time Series Regressions

Panel A. $VIX_t = a + b\,LIQ_t + \varepsilon_t$

	Liquidity index						
	Stock Market			Corporate Bond Market		Treasury Market	Aggregate
	PS_Stock	Sadka_TF	Sadka_PV	Amihud _Corporate	PS _Corporate	On/off spread	ALIQ
Intercept	20.39	20.48	20.48	20.32	20.50	19.98	20.35
	(34.36)	(33.72)	(35.13)	(34.96)	(34.98)	(32.73)	(37.30)
LIQ_t	-26.69	-672.56	-447.44	-2.55	-14.45	0.11	-2.53
	(-3.18)	(-1.57)	(-4.08)	(-4.36)	(-3.88)	(3.12)	(-2.65)
$Adj.R^2$	4.90%	0.82%	8.13%	8.83%	7.37%	4.70%	19.62%

Panel B. $SKEW_t = a + b\,LIQ_t + \varepsilon_t$

	Liquidity index						
	Stock Market			Corporate Bond Market		Treasury Market	Aggregate
	PS_Stock	Sadka_TF	Sadka_PV	Amihud _Corporate	PS _Corporate	On/off spread	ALIQ
Intercept	116.35	116.41	116.34	116.34	116.34	116.42	116.35
	(345.13)	(385.03)	(353.51)	(351.99)	(351.75)	(343.24)	(351.97)
LIQ_t	7.36	-616.69	88.98	-0.27	1.20	-0.02	0.14
	(1.58)	(-2.69)	(1.44)	(-0.79)	(0.57)	(-0.93)	(0.61)
$Adj.R^2$	0.85%	3.40%	0.60%	-0.21%	-0.38%	-0.01%	-0.36%

Panel C. $TCM_t = a + b\,LIQ_t + \varepsilon_t$, where $TCM_t = SKEW_t \times VIX_t^3$

	Liquidity index						
	Stock Market			Corporate Bond Market		Treasury Market	Aggregate
	PS_Stock	Sadka_TF	Sadka_PV	Amihud _Corporate	PS _Corporate	On/off spread	ALIQ
Intercept	1.57	1.62	1.60	1.53	1.62	1.45	1.55
	(6.43)	(6.62)	(6.71)	(6.72)	(7.00)	(5.82)	(7.05)
LIQ_t	-5.56	-355.65	-151.01	-1.28	-7.19	0.03	-1.02
	(-1.61)	(-2.07)	(-3.37)	(-5.48)	(-4.90)	(2.18)	(-6.68)
$Adj.R^2$	0.89%	1.82%	5.51%	14.08%	11.49%	2.08%	19.75%

Note: This table reports the time series regression results of VIX, SKEW and TCM on different liquidity measures. The liquidity measures used in the regressions include Pastor-Stambaugh stock market liquidity measure (PS_Stoock), Sadka Transitory Fixed (Sadka_TF) and Permanent Variable (Sadka_PV) liquidity measure, Amihud corporate bond liquidity measure (Amihud_Corporate), Pastor-Stambaugh Corporate bond liquidity measure (PS_Corporate) and On-off-the-run spread (On/off spread). Panel A, B and C report the regression results of VIX, SKEW and TCM respectively.

Table 4 reports the result of times series regressions of Variance (Var) on TCM, liquidity and jointly. As we can see from Panel C, the impact of liquidity on variance mainly comes from its impact on TCM. In other word, liquidity shocks affect variance via jump risk.

Table 4: Result of Times Series Regressions of Variance

Panel A. $Var_t = a + b\,TCM_t(LIQ_t) + \varepsilon_t$, **where** $Var_t = VIX_t^2$

	Liquidity index							
	Stock Market				Corporate Bond Market		Treasury Market	Aggregate
	TCM	PS_Stock	Sadka_TF	Sadka_PV	Amihud _Corporate	PS _Corporate	On/off spread	ALIQ
Intercept	2.47 (29.25)	4.81 (13.37)	4.87 (13.42)	4.86 (13.82)	4.76 (13.94)	4.88 (14.12)	4.59 (12.46)	4.78 (14.82)
$TCM_t(LIQ_t)$	1.52 (60.09)	-12.89 (-2.53)	-502.93 (-1.96)	-254.53 (-3.85)	-1.83 (-5.21)	-10.27 (-4.68)	0.06 (2.78)	-1.60 (-7.14)
Adj.R²	93.23%	2.96%	1.59%	7.24%	12.88%	10.56%	3.67%	22.00%

Panel B. $Var_t = a + b\,TCM_t + c\,LIQ_t + \varepsilon_t$, **where** $Var_t = VIX_t^2$

	Liquidity index						
	Stock Market			Corporate Bond Market		Treasury Market	Aggregate
	PS_Stock	Sadka_TF	Sadka_PV	Amihud _Corporate	PS _Corporate	On/off spread	ALIQ
Intercept	2.56 (25.44)	2.55 (24.08)	2.59 (24.72)	2.55 (24.05)	2.55 (23.85)	2.52 (32.73)	2.60 (24.65)
TCM_t	1.42 (50.83)	1.44 (49.05)	1.42 (48.22)	1.44 (45.94)	1.44 (46.59)	1.43 (3.12)	1.41 (43.96)
LIQ_t	-4.97 (-3.84)	8.54 (0.13)	-39.85 (-2.20)	0.02 (0.17)	0.07 (0.11)	0.02 (2.56)	-0.17 (-2.30)
Adj.R²	93.81%	93.29%	93.47%	93.29%	93.29%	93.53%	93.49%

Note: This table reports the time series regression results of Variance (Var) on TCM and different liquidity measures, where the Variance is defined as the square of VIX. The liquidity measures used in the regressions include Pastor-Stambaugh stock market liquidity measure (PS_Stock), Sadka Transitory Fixed (Sadka_TF) and Permanent Variable (Sadka_PV) liquidity measure, Amihud corporate bond liquidity measure (Amihud_Corporate), Pastor-Stambaugh Corporate bond liquidity measure (PS_Corporate), On-off-the-run spread (On/off spread) and aggregate liquidity measure (ALIQ). The aggregate liquidity index is the first principal component of individual liquidity index. Panel A reports the results of univariate regressions while Panel B reports the results of bivariate regressions.

Table 5 reports the result of time series regressions of Brownian motion variance on liquidity. As we can see most of them are not significant except PS-Stock and on/off spread. This confirms our previous finding that liquidity shocks affect variance mainly through jump risk.

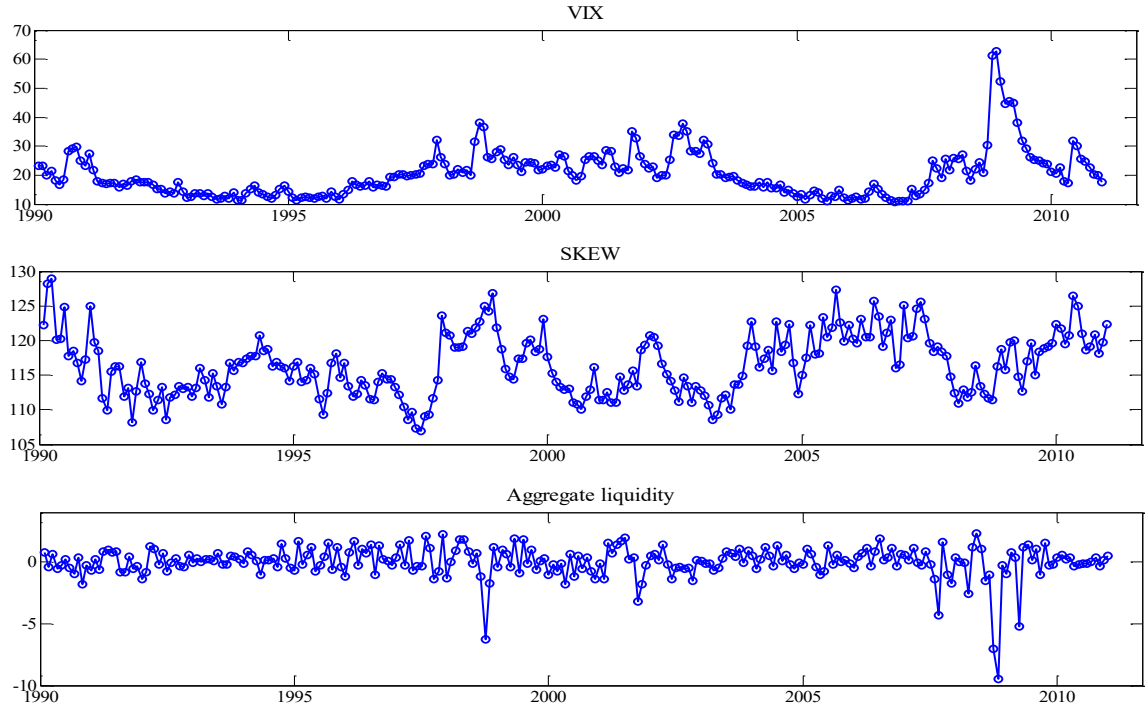
Table 5: Brownian Motion Variance on Liquidity

	Stock Market Liquidity Index			Corporate Bond Market Liquidity Index		Treasury Market Liquidity Index	Aggregate Market Liquidity Index
	PS_Stock	Sadka_TF	Sadka_PV	Amihud _Corporate	PS _Corporate	On/off spread	*ALIQ*
Intercept	-0.04	-0.04	-0.03	-0.03	-0.04	-0.08	-0.04
	(-0.41)	(-0.38)	(-0.30)	(-0.30)	(-0.38)	(-0.81)	(-0.26)
$LIQ_t(ALIQ_t)$	-0.49	34.70	-26.24	0.11	0.59	0.02	-0.06
	(-3.41)	(0.51)	(-1.46)	(1.12)	(0.97)	(2.06)	(-0.86)
Adj.R^2	5.65%	-0.42%	0.64%	0.15%	-0.03%	1.80%	-0.14%

Note: This table reports the time series regression results of Variance residuals (ε) on the different liquidity measures. The Variance residuals is from the regression of Variance on TCM. The liquidity measures used in the regressions include Pastor-Stambaugh stock market liquidity measure (PS_Stock), Sadka Transitory Fixed (Sadka_TF) and Permanent Variable (Sadka_PV) liquidity measure, Amihud corporate bond liquidity measure (Amihud_Corporate), Pastor-Stambaugh Corporate bond liquidity measure (PS_Corporate) , On-off-the-run spread (On/off spread) and aggregate liquidity measures (*ALIQ*). The aggregate liquidity index is the first principal component of individual liquidity index.

$\varepsilon_t = \alpha + \beta LIQ_t\left(ALIQ_t\right) + \eta_t$, where $\varepsilon_t = Var_t - \hat{a} - \hat{b}TCM_t$

Figure 1:



VIX, SKEW and aggregate liquidity index. This table plots the VIX, SKEW and aggregate liquidity index from 1990 to 2010. The aggregate liquidity index is the first principal component of individual liquidity index, including Pastor-Stambaugh stock market liquidity measure (PS_Stoock), Sadka Transitory Fixed (Sadka_TF) and Permanent Variable (Sadka_PV) liquidity measure, Amihud corporate bond liquidity measure (Amihud_Corporate), Pastor-Stambaugh Corporate bond liquidity measure (PS_Corporate) and On-off-the-run spread (On/off spread).

5. Conclusions

In this paper, we study the relationship between marketwide liquidity and options market. Through empirical analysis, we observe that the liquidity does have an impact on the options overall value and market crash risk premium observed in options market. Higher the marketwide liquidity, less expensive the options and the less likely options traders anticipate a market crash. The impact of liquidity on total variance is mainly through jump risk. The variance that comes from Brownian motion is almost insensitive to the change of liquidity.

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