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Changes in FX liquidity: Roles of Funding Constraints and Global Risks

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Abstract

This paper investigates the measure of FX liquidity and determinants of the change in FX liquidity. Using 20 cross currency exchange rates over the spanning period of 1999 to 2016, we find that funding constraints and global risks are responsible for the change in FX liquidity. The magnitudes of both G7 and emerging volatility index are offsetting each other in all the regression models indicating that FX investors take diversification trading strategies to diversify their portfolios. The financial crisis provides evidence that the more financial constraint issues contribute to the change in FX market liquidity more than non-financial crisis period. Extending to return predictability, we find that the average variance contributes the most for currency predictability more than other explanatory variables.

KEYWORDS: Foreign Exchange, FX Liquidity, Return Predictability
JEL Classification: F30, G10, G15

1. Introduction

Investors are concerned with the liquidity issues since the change in liquidity can influence the expected returns as well as investment decisions (Pastor and Stambaugh, 2003; Acharya and Pedersen, 2005). Then, there are substantial researches regarding liquidity issues, especially in equity markets[1]. In the Foreign Exchange (FX) market, the presence of liquidity is also being considered as one factor that can influence the change in the currency excess return. The FX market, however, has a distinctively feature that is different from the equity market such that investors are more aware of newly available information and incorporate the new information to determine the investment decisions (Phylaktis and Chen, 2010; Pasquariello, 2014)[2]. Also, the FX market is considered the largest market in the world with the average trading of $5.1 trillion per day in April 2016[3] with major currencies are traded approximately 70% of daily trading. With the unique characteristics of the FX market, the factors that influence the liquidity may, however, be different from those of equity markets. Then, in this paper, we are attempting to offer various factors, namely funding constraints and global risks, to explain the change in FX liquidity.

There are several studies discussing the characteristics of the FX market. Galati, Heath, and McGuire (2007) observe the trader behavior in currency and other markets, and they find that the FX traders are taking at highly leveraged positions than participants of the other markets. Their findings provide a significant important in FX literature is that FX investors are, in fact, looking to leverage and diversify their risks than investors in equity or bond markets. Phylaktis and Chen (2010) also provide an empirical result regarding the information asymmetry in the FX market with top trading banks. The result suggests that the FX market provides private information that banks incorporate and transform the information into the adjusted price based on private information. Then, FX investors somehow are well-informed and adjust their trading behaviors according to new information in the market[4]. Pasquariello (2014) studies the effects of the FX market and reports the finding that the presence of the FX market is to provide efficiency and arbitrage parity conditions in the other markets. In sum, the characteristics of the FX market are different from the other markets such as bond and equity. Motivated by this fact, we are exploring factors that may drive the change in liquidity premium in the currency market.

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[1] See. Bessembinder (1994), Hsieh and Kleidon (1996).
[2] These studies suggest that, in the FX market, investors adjust their decisions regarding new public as well as private information before they initiate their trades.
[3] Bank for International Settlements Annual Report 2016.
[4] Their study supports the presence of the efficient market hypothesis.

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In this paper, we start off our analysis based on the market-wide liquidity measured by the bid-ask spread of 20 currencies, 10 from developed currencies, and 10 from emerging currencies. The choice of these currencies is based on the trading activities reported by the Bank for International Settlements (BIS) and data availability[5]. The series is constructed by using USD against foreign currency, i.e. USD as a numerator and foreign currency as the denominator, to be consistent with many documented literature (Banti, Phylaktis, and Sarno, 2012; Menkhoff et al., 2012; Brunnermeier et al., 2009). The sample period starts in January 1999 and ends in December 2016. The sample period is used to capture the recent financial crisis in 2008 as well as the introduction of the EURO currency[6].

We use the regression models to explain the change in FX liquidity. The predictor choices are repurchase agreements (repos), VIX, TED, JPMorgan Volatility Index G7 (JPMVXY G7), JPMorgan Volatility Index Emerging (JPMVXY EM), market return, and capital flows. These variables are proposed in both equity and currency literature and able to explain the change in liquidity for both markets. The details for each variable are presented in section 2: Data and Methodology. The result shows that the change in TED, repos (both US and UK), Volatility indexes, and market return are economically significant and support the presence of funding constraints and global risks hypotheses to the change in FX liquidity.

Then, we further test with the 5-factor model of Fama-French[7]. Using only market return as the independent variable may omit some possible explanatory and importance of individual variables to explain the change in liquidity. The result, using individual risk-factor loadings, suggests that profitability and investment factors can contribute to the change in FX liquidity. However, using all the risk-loading factors regression indicates that only the investment factor is statistically significant. The result can infer that investment factors can partially explain the need for liquidity for investors to fund their investment strategies to compensate for the higher risk from their investments.

The question still remains. Does the presence of a financial crisis change our result? We then test for the financial crisis period. The result, however, indicates that VIX now contributes to the change in FX liquidity while the change in TED does not. This result is surprising since the initial result only indicates the change in TED to be significant while VIX is not. The plausible explanation is that the change in VIX can capture the presence of global risk better than TED during the financial crisis period. Investors perceive the risk associated with the change in liquidity in the market. When the volatility is high, investors tend to slow down the investment and result in less liquid in the foreign exchange market.

We then test whether the change in liquidity can predict the change in currency returns. The study of currency predictability has been documented as Cedenese et al. (2014) test for the currency predictability using the average volatility and average correlation as the proxies for the change in the excess returns. They find that the average volatility, defined as the average variance of portfolio currency, is the factor that drives the change in currency excess returns. Furthermore, Poti and Siddique (2013) provide empirical evidence using the carry trade approach on two groups of investors, namely diversified investors and undiversified investors. They find that undiversified investors require higher liquidity then diversified investors due to capital constraints. In sum, these findings support the view that the change in liquidity can explain the change in currency returns.

Motivated by these findings, we estimate the change in liquidity based on past information to determine the change in liquidity. We conduct the DCC model to estimate the impact of the change in liquidity based on the previous information. The result shows that the impact of the lagged variables is a good indicator of the change in liquidity and these variables support the presence of return reversals as indicated by Banti et al. (2012). The funding constraints and global risks can be used to predict the change in liquidity in the FX market.

Following the Cedenese et al. (2014) approach, we use average correlation and average variance as control variables with other explanatory variables, namely the change in TED, the predictive liquidity, and the change in volatility indexes. we find that most of the independent variables are able to use for currency prediction; however, the

[5] To be included in the sample, currencies must have at least 5 years data availability and reported by Bloomberg Terminal at 16 GMT.
[6] Many literatures report the presence of EURO to affect the change in liquidity. See. Beber et al. (2008), Hua et al. (2002), De Santis (2014).
[7] The data is available at http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html.

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change in indexes cannot. The average variance provides the strongest magnitude more than other variables. The change in currency excess returns depends highly on their own risks rather than other factors indicating that currencies themselves provide substantial information to predict future returns than other factors included the change in liquidity.

The contributions of this paper are:

1. *We show that the presence of the funding constraints and global risks can explain the change in FX liquidity, especially repo rates, volatility indexes, and the change in TED spread,*
2. *During the financial crisis period, the global risks play an important role than funding constraints to explain the change in FX liquidity as the change in volatility indexes for both G7 and emerging countries can capture the change in liquidity much more than the non-crisis period,*
3. *We test for the liquidity predictability and find that the FX liquidity depends highly on the past information from the market-wide risks; however, the funding constraints seem to appear having less effect to determine the change in liquidity, and*
4. *The currency excess return predictability depends on the average variance more than other variables, including the predicted liquidity variable.*

This paper is organized as follows: Section 2 summarizes the literature related to the liquidity premium in the currency market. Section 3 explains the data and methodology used in this paper. The choice of currencies, as well as the sample period, is explained. Then, we introduce the data description of the variables used in this paper for both global risks and funding constraints in Section 4. The empirical analysis is presented in Section 5. Then, we provide a discussion based on predictability in Section 6. The paper provides a conclusion and remarks in Section 7.

2. Literature Review

2.1 Liquidity Measures

The study of the presence of a liquidity premium has been widely observed in the literature. Amihud (2002) presents measures of the illiquidity of cross-section and time-series of liquidity premium. His finding of the presence of liquidity premium provides a substantially significant contribution to the literature and to the following literature (Pastor and Stambaugh, 2003, Acharya and Pedersen, 2005, Baker and Stein, 2004, Bekaert and Harvey, 2007)[8] to observe the liquidity measure and the presence of liquidity premium in the stock and bond returns.

The common methodology used to observe the change in liquidity in financial assets is the bid-ask spread. Most of the literature (see. Stoll, 1989, Bessembinder, 1994, Hsieh and Kleidon, 1996) report a similar finding that bid-ask can be used to measure the liquidity since the methodology provides the pressure of buyers and sellers initiating in such transaction. The spread of bid-initiated and ask-initiated transaction creates the need for liquidity.

The liquidity measure is calculated using bid and asks quotes or the difference between them called 'the bid-ask spread[9]'. The spread refers to the transaction that is being initiated by buyers and sellers creating the need for liquidity (Stoll ,1989; Amihud and Mendelson, 1986; Roll, 1984; Copeland and Galai. 1983). The measure of liquidity in FX market also supports the use of bid-ask spread since the spread represents the transaction costs over the returns (Mancini, Ranaldo, and Wrampelmeyer, 2013; Corwin and Schultz, 2012; Menkhoff et al., 2012, Chen, Chien, Chang, 2012). Then, the bid-ask spread can be used as the proxy for the liquidity in the FX market since investors require to receive the higher premium to compensate for the higher bid-ask spread.

2.2 Liquidity Premium in FX Market

Mancini, Ranaldo, and Wrampelmeyer (2013) observe the liquidity in foreign exchange markets of major trading currencies. They analyze the impact of FX liquidity risk using carry trade approach, the trading technique to borrow lower interest rate currencies, and invest in high-interest-rate currencies, and their finding suggests that there is an existence of liquidity premium in the FX market. Consistent with Amihud's illiquidity measure, they conclude

[8] These papers observe the presence of liquidity in equity and bond markets. They provide a general conclusion that there is a presence of liquidity premium for investors to take a position in the market.
[9] Bid-ask spread is the spread between ask price and bid price of an asset.

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that the change in the bid-ask spread is the appropriate proxy to observe the changing liquidity and the liquidity risk in the FX market. Karnaukh, Ranaldo, and Soderlind (2015) also provide evidence of liquidity in the FX market by observing the bid and ask spread. They provide the determinants of change in FX liquidity by using demand-side hypothesis and supply-side hypothesis. Their finding indicates that FX liquidity declines when facing funding constraints. Furthermore, they find strong co-movements between liquidities in distressed markets when funding is constrained, the volatility of the market is high, and FX speculators incur losses.

The extensive study on the impact of FX liquidity is reported by Banti, Phylaktis, and Sarno (2012). They observe 20 cross currency exchange rates using a modification of Pastor and Stambaugh's liquidity approach and sorting portfolios based on the level of currency sensitivities. Using the spread between bid-quotes and ask-quotes, they find that the equity liquidity measure from Pastor and Stambaugh (2003) provides evidence of return reversals in currencies and they find that the estimated liquidity risk premium in the FX market is approximately 4.7 percent per annum. Their finding supports the point of view that investors require higher premiums when they invest in higher-risk or more sensitive currencies, and they require higher excess returns to compensate for their risks.

Banti and Phylaktis (2015) investigate the determinants of the time variation of the common component of FX liquidity using cross-currency exchange rates for both developed and emerging currencies. They argue that funding liquidity constraints and capital flows are associated with the FX market liquidity. The funding constraints using in their paper are the repos (both US and UK), and stock returns while the capital flows are the flows both inflow and outflow of bond and equity from the U.S. database. They also provide the empirical evidence that using global FX volatility (JP Morgan VXY Volatility index) be the appropriate proxy for measuring global FX volatility. Their finding shows that the funding constraints severely affect the change in FX liquidity meanwhile the volatility index depicts the significant result confirming that investors require higher returns when they are facing liquidity issues.

2.3 Liquidity Premium Factors

Bid-ask spread is the most widely used to measure liquidity in both financial assets and the FX market and most of the literature supports such methodology is appropriate to capture the change in liquidity in the foreign exchange market. Furthermore, many kinds of literature document the findings that liquidity measure in FX markets is mainly driven by the funding constraints. However, it is not well-documented whether what specific factors drive the change in FX liquidity. Then, there is a need for the study of the factors that drive the change in FX liquidity. For this reason, it motivates our interest in the measure of FX liquidity and determinants of the change of FX liquidity.

There are several studies trying to explain the liquidity premium size and factors that drive the change FX liquidity. For example, Banti, Phylaktis, and Sarno (2012) offer explanations based on the global liquidity risk that the liquidity risk is priced and the premium is approximately 4.7% per annum. Their study suggests that investors require a higher premium to compensate for their risk associated with liquidity issues in the FX market. Mancini, Ranaldo, and Wrampelmeyer (2013) use the major currencies to explain the liquidity premium in the FX market. They find that VIX spread is responsible for the change in FX liquidity. VIX is an index to measure the volatility in options or fear index for investors[10]. Then, when investors are expected to see high volatility in the market, it results in a higher premium to compensate for their returns. These studies offer the potential factors that may influence the change in the FX liquidity and support the presence of the liquidity premium in the FX market.

Karnaukh, Ranaldo, and Soderlind (2015) investigate the change in liquidity premium by using various economic factors and find that the TED spread[11], the difference between three-month Treasury bill and three-month LIBOR, is highly correlated to the change in FX liquidity premium. The pressure of money supply forces investors to evaluate the risk-return tradeoffs resulting in the greater size of the liquidity premium. Banti and Phylakts (2015) investigate the determinants of the time variation of the common component of FX liquidity using cross-currency exchange rates for both developed and emerging currencies. They argue that funding liquidity constraints and capital flows are associated with the FX market liquidity. Their results show that funding constraints, as well as the

[10] Chicago Board Options Exchange (CBOE) calculates the VIX based on the price fluctuation in the S&P 500 index options over 12-month period.
[11] TED spread sometimes can refer to the credit risk. See. Federal Reserve Bank of St. Louis (FRED) website for more details.

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volatility, severely affect the change in FX liquidity. Their results confirm that investors require higher returns when they are facing liquidity issues.

In sum, there are various factors that can be used to explain the change in FX liquidity. These factors, however, do not fulfill the picture of the FX liquidity as well as the impact of the change in FX liquidity. In this paper, we are using multiple factors, proposed by literature, and introduced new factors, to evaluate the presence of the FX liquidity. We introduce the use of global risk index, namely JPMorgan Volatility Index for G7 (JPMVXY G7) and Emerging Market (JPMVXY EM), to proxy for the risk-return tradeoffs for investors. If the volatility is high, then investors are expected to receive a higher premium to compensate for their investment decisions. We also use these indexes to see whether investors attempt to diversify their investment strategy by looking at the magnitude of these indexes. We hypothesize that if the indexes provide similar size but the different sign, then it means that the indexes are offsetting each other providing the explanation for investors to diversify their investments by taking positions in both developed and emerging currencies.

3. Data Description

Our data consists of 20 daily cross currency exchange rates spanning from December 1999 to December 2016. The primary data sources are from Bloomberg Terminal and Thompson and Reuters with the closing time of 16 GMT since it is a highly traded period in FX markets and correlated with the bid-ask measure as discussed by Karnaukh, Ranaldo, and Soderlind (2015). The total trading transactions are provided by the Bank of International Settlement (BIS). The exchange rates are defined as USD against foreign currency as it is widely used to measure the changes in US dollar value[12]. Of the 20 currencies on the sample, 10 are of developed currencies, and 10 are of emerging currencies, namely Australian Dollar (AUD), Brazilian Real (BRL), Canadian Dollar (CAD), Swiss Franc (CHF), Czech Koruna (CZK), Danish Krone (DKK), Euro (EUR), British Pound (GBP), Hungarian Forint (HUF), Japanese Yen (JPY), South Korean Won (KRW), Mexican Peso (MXN), Norwegian Krone (NOK), New Zealand Dollar (NZD), Polish Zloty (PLN), Swedish Krona (SEK), Singapore Dollar (SGD), Turkish Lira (TRY), Chilean Peso (CLP). The choice of currencies is based on the trading activities provided by the BIS database, in which these currencies are accounted for more than 70% of daily trading activities[13].

3.1 FX Liquidity Measures

The most widely accepted of measuring FX liquidity is to use bid and ask spread. The price impact of seller and buyer initiated creates the need for liquidity. Then, the bid-ask spread measures the transaction costs of buyer and seller initiated in such transactions. The higher the spread means that the higher the transaction costs and lower the liquidity level. Therefore, the bid-ask spread represents, in fact, the measure of illiquidity. Note that the illiquidity measure can be changed to liquidity by multiplying a negative sign.[14]

The bid and ask spread used as the proxy for illiquidity measure is defined as:

$$BA_{i,t} = (ask_{i,t} - bid_{i,t})/mid_{i,t}, \qquad (1)$$

where $ask_{i,t}$, $bid_{i,t}$, $and\ mid_{i,t}$ are the monthly series of the ask, bid, and mid prices of the quotes of the USD against currency i[15].

[12] The exchange rate is defined as USD against foreign currency. USD is numerator and foreign currency is denominator. This practice is used in most of the literature. See. Banti, Phylaktis, and Sarno (2012), Daniel and Maskowitz (2016).
[13] BIS 2016 provides the annual report and ranks the currencies based on the trading volumes. The trading volumes are calculated daily for both buying and selling activities. Each currency must present at least 5 years of data availability with bid and ask quotes.
[14] The bid-ask measures the illiquidity. By multiplying negative sign, it now measures the liquidity.
[15] Bid and ask spread measure can also be estimated using $BA_{i,t} = (ask_{i,t} - bid_{i,t})/2$ as suggested in literatures (See. Pastor and Stambuagh, 2003, Bekaert and Harvey, 2007).

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Table 1: Summary statistics of the bid-ask spread of 20 cross currency exchange rates from December 1999 to December 2016. The bid-ask spread is calculated from equation (1):. , are the monthly series of the ask, bid, and mid prices of the quotes of the USD against currency i. the series is taken log difference to preserve the stationary assumption in time series.

No.	Currency	Obs	Mean	Std. Dev
1	USDAUD	216	0.000549	0.000678
2	USDBRL	216	0.000890	0.000904
3	USDCAD	216	0.000427	0.000471
4	USDCHF	216	0.000636	0.000859
5	USDCZK	216	0.002084	0.001651
6	USDDKK	216	0.000361	0.000357
7	USDEUR	216	0.000239	0.000356
8	USDGBP	216	0.000264	0.000341
9	USDHUF	216	0.003417	0.002800
10	USDJPY	216	0.000369	0.000409
11	USDKRW	216	0.000842	0.001717
12	USDMXN	216	0.001260	0.001430
13	USDNOK	216	0.001362	0.001552
14	USDNZD	216	0.000863	0.000944
15	USDPLN	216	0.002543	0.003414
16	USDSEK	216	0.001012	0.000867
17	USDSGD	216	0.000884	0.001151
18	USDTRY	216	0.003623	0.007291
19	USDZAR	216	0.003588	0.003348
20	USDCLP	216	0.001205	0.005431

Table 1 presents the mean and standard deviation of the bid and asks spread. The bid-ask spreads in developed currencies, as expected, are lower in both means and standard deviations than emerging currencies. Consistent with Carrieri et el. (2013), the developed market is more integrated than the developing market. Then, the spread of the developed currencies is to be less volatile then-emerging currencies. Note that Turkish Lira[16] has the highest spread and highest standard deviation since Turkey experienced the currency crisis in the early 2000s and our sample covers during the period. The result is consistent that the higher spread, the currency is more volatile.

[16] The inclusion of Turkish Lira is to compare the change in highly exposure currency among other currencies.

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Table 2: summary statistics of regression of individual currency liquidity on market liquidity from December 1999 to December 2016. The coefficient of the regression is reported with betas. The T-test is also reported by using an adjustment of Newey-West (1987) and reported on the t-test column.

No.	Currency	beta	t-test
1	USDAUD	0.069385	10.24
2	USDBRL	0.015862	3.25
3	USDCAD	0.053835	9.58
4	USDCHF	0.073358	10.3
5	USDCZK	0.030046	4.87
6	USDDKK	0.063252	9.32
7	USDEUR	0.045564	6.01
8	USDGBP	0.041855	6.13
9	USDHUF	0.045111	7.62
10	USDJPY	0.052286	7.92
11	USDKRW	0.034407	3.4
12	USDMXN	0.072173	8.74
13	USDNOK	0.051687	10.23
14	USDNZD	0.048947	7.56
15	USDPLN	0.046705	7.14
16	USDSEK	0.048771	8.83
17	USDSGD	0.061522	9.23
18	USDTRY	0.047258	7.34
19	USDZAR	0.057443	8.69
20	USDCLP	0.057652	6.78

Following Chordia et al. (2000a) and Pastor and Stambaugh (2003), we calculate the market-wide liquidity as, where *BA* is the bid-ask spread. The market-wide illiquidity is the equally-weighted average of individual spread series for all 20 exchange rates. To see whether the market-wide liquidity can explain the change in individual currency liquidity, we regress the change in individual currency liquidity measures against the change in market-wide liquidity and the results are presented in Table 2. Consistent with the literature, we find that market liquidity can explain the change in individual currency liquidity, as reported by the T-test.

3.2 Determinants of FX Liquidity

The change in FX liquidity, as documented by many kinds of literature, is affected by the funding constraints and global risks. This section provides the determinants used in literature to determine the FX liquidity.

3.2.1 The Repo

Repo or repurchase agreement is the short-term borrowing for financing purposes. Investors enter the repo market to finance the purchase of securities (Adrian and Shin, 2010, Gorton and Metrick, 2012). The most common collateral of repo is US and UK markets which provide relatively low credit risk and high liquidity. Repo is a part of funding constraints in the FX market since repos can change the liquidity in financial markets. Banti and Phylaktis (2015) estimate using outstanding repos for both US and UK and find that repos provide the funding constraints in FX liquidity. However, they use the amount of outstanding in their estimation. In this paper, we estimate the repos using the repo closing price since the price impact of repos may significantly affect the change in liquidity as there was a huge drop in repo price for both US and UK after the financial crisis in 2008 as presented in figure 1. The repo data are collected from Bloomberg using the end of the day data. We construct using the last price of the month to determine the monthly repo price.

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Table 3: summary statistics of US and UK repo from December 1999 to December 2016. The period is included during the recent financial crisis period in 2008. The table represents the first difference to preserve the stationary assumption.

Variable	Mean	Std. Dev.	Min	Max
US Repo	-0.01084	0.264002	-1.42712	1.203973
UK Repo	-0.01586	0.090292	-0.65387	0.313503

Table 3 presents the summary statistics of both US and UK repos. As expected, US repo is more volatile than UK repo. The higher standard deviation of the US repo is due to the cumulative of the volatility period during the financial crisis. This is evident that US and UK repo be used as the funding constraint in the FX liquidity, especially during the financial crisis period.

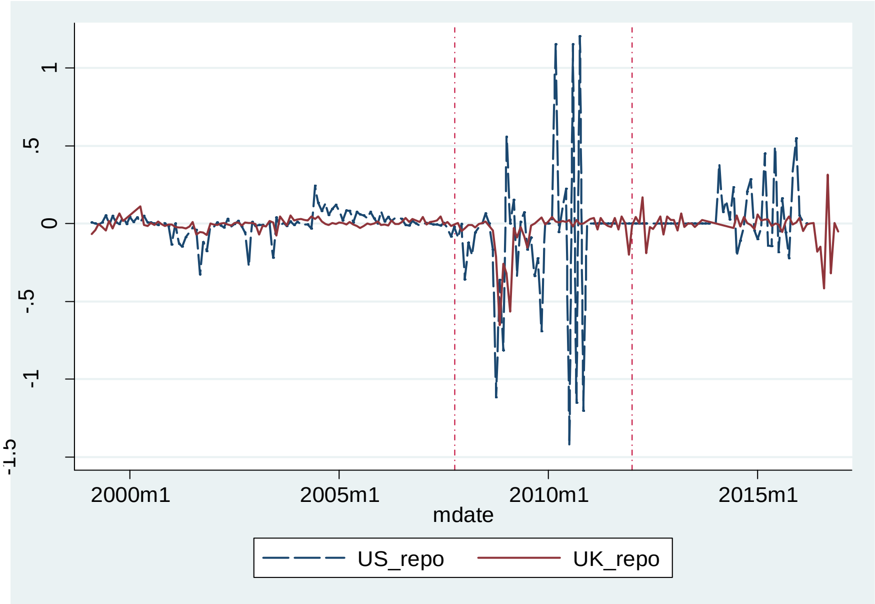

Figure 1: the US and UK Repos. The graph shows the difference at the end of the month's price of US and UK repos. US repo represents by the dashed line and the UK repo is the solid line. The vertical lines represent the financial crisis period from 2008 to 2012.

Figure 1 presents the change in repos for both US and UK repos. The stationary is satisfied by taking the difference at the end of the month's price. As shown in the figure, during the financial crisis period, the repurchase agreements were very volatile. US repo reached up to +1.2 and lowest at almost -1.5 while UK repos moved between +0.1 and -0.6. The result reflects that UK repos were less volatile than the US repo market during the financial crisis. The change in repo markets is perceived as the funding constraint issues in the financial market and they experienced a huge drop after the financial crisis for both the US and UK markets.

3.2.2 VIX and TED

VIX, defined by the Chicago Board of Options Exchange (CBOE), indicates the implied volatility of S&P500 index options. The index measures the fear or expectation of volatility in the options market. TED, on the other hand, implies the interest rates differences on interbank loans and T-bills. Both VIX and TED are used as the indicators of the funding constraints[17] that investors are facing during the volatile period. If VIX and TED can capture the change in investor's behavior regarding the change in liquidity, then we should expect to see both VIX and TED spread to have the same direction as the FX liquidity. The data for both VIX and TED are collected through the FRED website[18].

[17] Menkhoff et al. (2012) use these indexes to explain the change in the liquidity and the currency returns.
[18] The Federal Reserve Bank of St. Louis or FRED.org

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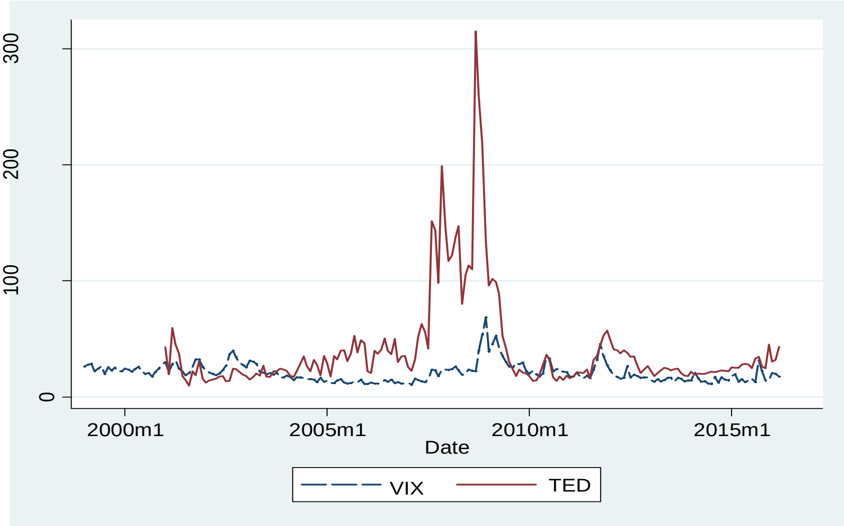

Figure 2: VIX and TED. VIX is represented by dash-line while TED is solid line. The graph shows VIX and TED from December 1999 to December 2016.

Figure 2 represents the VIX and TED spread. During the financial crisis, the explosive of the VIX and TED reached to the highest indicates that investors perceived the risks in the financial markets reflecting the need for liquidity as the funding constraints were tighter during the crisis. Karnaukh et al. (2015) explain that liquidity declines with funding constraints. Also, when VIX and TED increase, FX liquidity becomes more illiquid. Brunnermeier, Nagel, and Pedersen (2008) also suggest the TED spread as the measurement of market illiquidity.

3.2.3 Volatility Index

We include the volatility index in our analysis. The volatility index is used to control the level of uncertainty of the FX market (Menkhoff et al., 2012) as an increase in volatility can affect the riskiness of the currency exchange rates. The primary volatility index is the JP Morgan VXY volatility index[19]. We define the index into developed and emerging since these two market segments have different characteristics and different needs for liquidity[20]. The index can be used to indicate the level of riskiness of holding inventory in currency exchange.

The data are collected from Bloomberg the spanning period from December 1999 to December 2016 to be consistent with cross-currency exchange rate data. We construct the data using the end of the month volatility index for both G7 and emerging index. The reason to include both emerging (JPMVXYEM) and G7 (JPMVXYG7) in the sample is that the volatility pressure from one market should affect the volatility of the other market. For example, once the US Dollar weakens, the other currencies will be appreciated as the change in the US Dollar is now volatile. Also, FX investors tend to diversify their risk by investing in both developed and emerging currencies. Then, for diversification purposes, the change in volatility of one market will affect the change in volatility of the other market. We hypothesize that since both indexes can capture the level of riskiness in currency markets, then we should be able to observe the similar movement of the indexes and co-movement with the market liquidity.

Figures 3 and 4 show the volatility index for emerging and G7 countries, respectively. For both indexes, the market was very volatile during the financial crisis period. Consistent with what we expected, the market perceived the riskiness of currency market investment. The indexes reached almost 25 points under emerging countries and 20 points for G7 countries. The higher volatility should incorporate with higher illiquidity of FX.

[19] The JP Morgan VXY volatility indexes are based on the aggregate volatility of individual currencies and calculated with value-weighted approach.
[20] The need for liquidity of developed and emerging markets is different since emerging currencies require to have a higher premium to compensate the risks.

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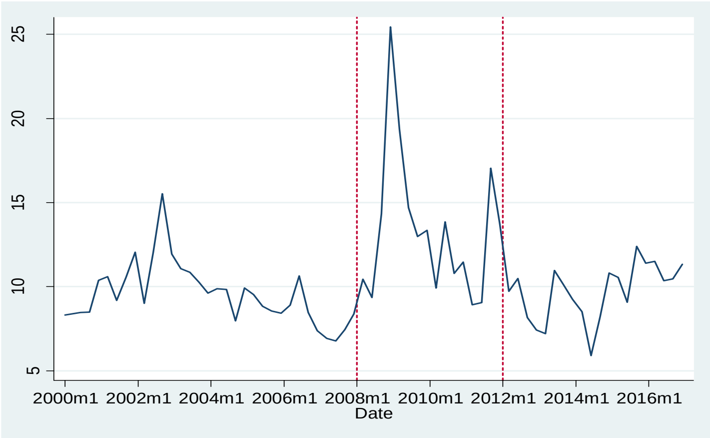

Figure 3: Volatility index of emerging countries (JPMVXY EM).
The dash lines represent the period of financial crisis from 2008 to 2012.

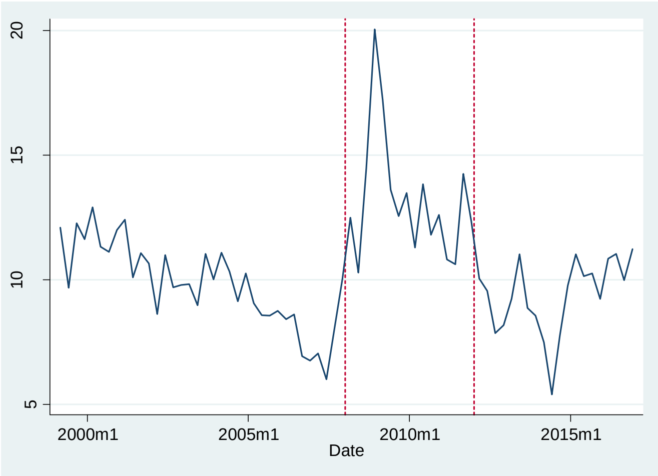

Figure 4: Volatility index for G7 countries (JPMVXY G7).
The dash lines represent the period of financial crisis from 2008 to 2012.

3.2.4 Market Returns

We also hypothesize that the market return should provide a good indicator of the amount of available capital in the market. The financial constraint can be binding when the performance of financial institutions declines. Acharya and Viswanathan (2011) suggest that less funding or tighter funding constraint can severely affect the ability to generate money for lending in the capital market. Then, we expect to see the market returns to be positively correlated with the FX market illiquidity since investors would demand higher returns during the less liquid period. The data are obtained from the Kenneth R. French Website[21].

3.2.5 Capital flows

We investigate the capital flows as part of the change in liquidity in the FX market. Banti and Phylakits (2015) measure the capital flows as the aggregated flow of international capital between the US and foreign countries and suggest that larger capital flows can improve the market liquidity since sophisticated investors are more active in the FX market and these investors are more likely to reduce the spreads due to the lower inventory risks and trade increases. The data are obtained from the U.S. Department of Treasury. We estimate the capital flows using the net flows end of the month reported by the U.S. Department of Treasury[22]. The capital flows estimation is based on the net flow of the capital between the US and other countries. We take the first difference in the capital flows to

[21] http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html
[22] The net flows are calculated using the end of the month net imports and the end of the month net exports. We aggregate the daily net flow into monthly net flows.

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preserve the stationary assumption of the time series. The capital flows may affect the change in FX market liquidity.

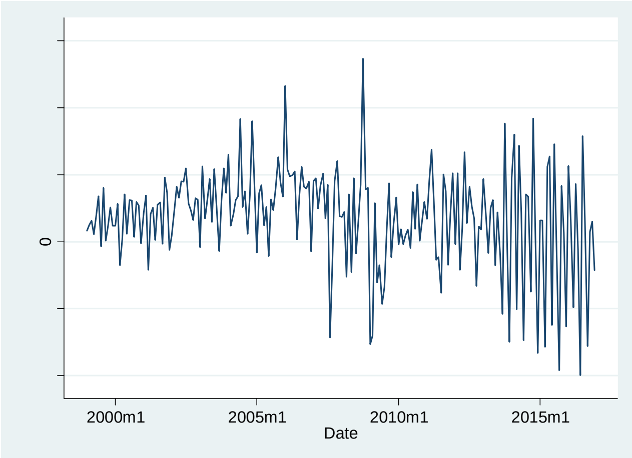

Figure 5: the change in net capital flows. The change in net capital flows is estimated by the net change in capital flows at the end of the month reported by the U.S. Department of Treasury.

Table 4: Correlation among proposed variables from December 1999 to December 2016. MKT_Liq is the market-wide liquidity. JPMVXYG7 is the volatility index for G7 countries. JPMVXYEM is the volatility index for emerging countries. UK Repo represents the UK repurchase agreement while US Repo is the US repurchase agreement. VIX is the implied volatility of S&P 500 index options measuring the fear or expectation of volatility in option markets. TED is the interest rate differences between interbank loan and T-bills. MKT_Ret is the market returns. Flows represents the net capital flows.

	MKT_Liq	JPMVXYG7	JPMVXYEM	UK Repo	US Repo	VIX	TED	MKT_Ret	Flows
MKT_Liq	1.00								
JPMVXYG7	-0.04	1.00							
JPMVXYEM	-0.05	-0.89	1.00						
UK Repo	-0.19	0.04	0.09	1.00					
US Repo	-0.04	0.03	0.03	-0.09	1.00				
VIX	0.15	-0.10	-0.08	0.06	-0.24	1.00			
TED	0.21	-0.15	-0.14	-0.02	-0.05	0.25	1.00		
MKT_Ret	0.50	-0.02	-0.02	-0.09	-0.02	0.07	0.10	1.00	
Flows	0.13	-0.20	-0.23	-0.05	-0.15	0.12	-0.10	0.06	1.00

3.3 Correlation among variables

To track the possibility of multicollinearity, we run the pairwise-correlation test among the independent variables to see whether any potential multi-collinearity, especially in US and UK repos. The result, as shown in table 4, shows that there is a weak negative relationship between US and UK repos. Banti and Phylakits (2015) track the change in the amount of outstanding US and UK repos and report the correlation of 0.26. Then, using the change in the repo price does not change the fact that the US and UK repo are not showing any collinearity issue. Other variables seem to have reasonable correlations among others. Note that JPMVXYG7 and JPMVXYEM are highly negatively correlated. This result is expected since these two volatility indexes are used to diversify the portfolio and help to rebalance the possible shocks in either developed or developing markets.

4. Methodology

We conduct the regression test to observe whether variables can explain the change in FX market liquidity. The regression is determined by the following model:

$$\Delta Iiq_{i,t} = ai + \beta'^{(\Delta X_t)} + \gamma' \Delta Vol_t + \delta' \Delta liq_{t-1} + \varepsilon_t + Fixed\ effect \quad (2)$$

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where is the change in FX market illiquidity, is the determinants that are described in the previous section? The variables are listed as following:

- ΔVIX_t – the change in VIX spread
- ΔTED_t – the change in TED spread
- $\Delta US\ Repo_t$ – the change in US repo
- $\Delta UK\ Repo_t$ – the change in UK repo
- $\Delta Mkt\ Ret_t$ – the change in market excess return
- $\Delta Flows_t$ – the change in net capital flows

$Vol_t$is the JP Morgan Volatility index (JPM) for both G7 (JPM $G7_t$) and emerging countries (ΔJPM EM_t). The change in volatility index is used as the control variable for market uncertainty or global risk. The lag of FX market liquidity (Δliqt-1) is also being used as a control variable.

We then test further to see whether when using other variables from 5-factor would have an impact on the market returns of international asset portfolios[23]. We estimate using the regression below:

$$\Delta liq_t = a + \beta'^{(\Delta X_t)} + \Psi'(FF_t) + \gamma'\Delta Vol_t + \delta'\Delta liq_{t-1} + \varepsilon_t + fixed\ effect, \quad (3)$$

where $FF_t$is the 5-factor of Fama-French? We also use and as proxies for the change in FX market illiquidity.

Brunnermeier and Pedersen (2009) suggest that liquidity dry-ups are worse during the financial crisis period. Banti and Phylaktis (2015) estimate the recent financial crisis, the collapse of Lehman Brother from September 2008 to July 2009, and their result indicates that during the financial crisis the effects of funding constraints and aggregated flows are stronger. To test for the change in liquidity during the financial crisis period, we assign the dummy variable equal to 1 indicating the financial crisis period and zero otherwise. We assign the dummy variable from March 2007 to June 2009 to be consistent with the change in volatility index for both G7 and emerging market economies. The impact of market failure can be observed from VIX and TED spread as the volatility accumulation started to increase since the beginning of 2007 and smoothed out after June 2009. The regression is estimated as follows:

$$\Delta liq_t = a + \beta'\left(\Delta X_t * Dummy_t^{crisis}\right) + \Phi'\Delta X_t * Dummy_t^{nocrisis} + \gamma'\Delta Vol_t + \delta'\Delta liq_{t-1} + \varepsilon_t + Fixed\ effect \quad (4)$$

where the dummy variable is equal to 1 if the financial crisis period, and zero otherwise.

5. Empirical Results

5.1 Regression Analysis

Table 5 reports the preliminary result based on equation (2). Under model (1), we use all the proposed variables to track the change in market liquidity. The result suggests that most of the variables are statistically significant except for ΔVIX_t and $\Delta Flows_t$. The insignificance of ΔVIX_t can partially be explained that VIX spread cannot capture the change in FX liquidity as it does for the equity market due to the differences of characteristics between equity and FX market. Unlike VIX, TED can be used to explain the change in FX market illiquidity (Karnaukh et al., 2015, Brunnermeier, Nagel, and Pedersen, 2008). Inconsistent with Banti and Phylaktis (2015), we find that the change in aggregated capital flows of US equity and bonds ($\Delta Flows_t$) is not significant. The plausible explanation is that the capital flows of equity and bond are way less than the flows of the currencies ($3.2 Trillion approximately according to Forex annual report in 2016[24]. Then, the change in capital flows does not reflect on the change in FX market liquidity. The change in repos is statistically significant for both US and UK repo in contrast to

[23] Fama and French (2016) test 5-factor model with international asset portfolios and find that these factors can depict the market returns of international asset portfolios.
[24] Annual Report is available at www.Forex.com

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Banti and Phylaktis (2015). Their measurement is to use US and UK repo outstanding, not the repo price and their results suggest that the proxies for repos are not statistically significant. The change in repo price can be interpreted that tightening the funding constraints result in an increase in transaction costs. Then, the market becomes more illiquid as the repo prices are getting higher.

Table 5: empirical result from regression equation (2): $\Delta liq_t = a + \beta(\Delta X_t) + \gamma\Delta Vol_t + \delta\Delta liq_{t-1} + \varepsilon_t + fixed\ effect$ where ΔX_t variables are: ΔVIX_t is the change in VIX spread, ΔTED_t is the change in TED spread, ΔUS $Repo_t$ is the change in US repo, ΔUK $Repo_t$ is the change in UK repo, ΔMkt Ret_t is the change in market excess return, and $\Delta Flows_t$ is the change in net capital flows. Vol_t is JP Morgan Volatility index (JPM) for both G7 (JPM $G7_t$) and emerging countries (ΔJPM EM_t), and Δliq_{t-1} is the lag of FX market liquidity. The sample period is from December 1999 to December 2016. The t-test are adjusted via Newey-West (1987) and reported in parentheses. *, ** indicate 10% and 5% level of significance.

	(1)	(2)	(3)
ΔVIX_t	0.0685		
	(1.35)		
ΔTED_t	0.3846	0.3890	0.4122
	(12.58) **	(13.44) **	(13.56) **
ΔUS $Repo_t$	-0.0835	-0.0738	0.1332
	(-3.97) **	(-3.64) **	(6.46) **
ΔUK $Repo_t$	-0.0105	-0.0104	
	(-9.35) **	(-9.32) **	
ΔMkt Ret_t	0.0154	0.0162	0.0150
	(8.75) **	(9.76) **	(9.01) **
$\Delta Flows_t$	0.0001		
	(1.12)		
ΔJPM $G7_t$	0.0279	0.0279	0.0036
	(3.57) **	(3.56) **	(0.94)
ΔJPM EM_t	-0.0268	-0.0273	
	(-4.35) **	(-4.46) **	
Δliq_{t-1}	-0.6151	-0.6175	-0.6532
	(-48.41) **	(-49.59) **	(-52.65) **
Constant	0.0093	0.0156	0.0452
	(0.23)	(0.39)	(1.12)

As demonstrated from the data and methodology section, we use the JPMorgan Volatility Indexes for both G7 and Emerging as the global risk variables to test for the change in market liquidity. The result, interestingly, suggests that the volatility index for G7 is positively correlated with the change in market liquidity while volatility index for emerging shows negative relation with market liquidity, both are statistically significant. Also, the magnitudes of these volatility indexes are almost canceling out each other (0.0279 for G7 and -0,0269 for emerging). This result indicates that, although the indexes are moving along in the same direction as suggested in Figures 3 and 4, the currency trade is a zero-sum game meaning that one currency benefits from the expense of the other. For example, USD appreciates while other currencies to be depreciated. Then, the similar magnitudes with opposite signs of G7 and EM indexes can be explained by the presence of currency gain from one country to currency loss from the other.

Next, we consider the model (2) to run regression only significant variables from the model (1). Consistent with the result from the model (1), we find that the significant variables from the model (1) are also significant in model (2). Furthermore, the G7 and emerging volatility indexes have similar magnitudes, but different signs as previously found in the model (1). The result confirms that both indexes can capture the change in market liquidity, but they provide different signs indicating that the gains from currencies are at the expense of the other currencies.

To confirm whether the presences of the severe funding constraints and global risks from developed currencies influence the change of market liquidity, we test using only the G7 volatility index and US repo. According to the volume of currency trading, G7 currencies account for more than 70% of daily trading[25], then using only these variables should be, at least partially, able to explain the change in market liquidity. Running the regression under model (3), we find, however, that the G7 volatility index becomes insignificant, which is different from the model (1) and (2). Then, to take into account for measuring FX market liquidity, using both indexes provide a clear picture than using only one index. Note that we also test for the emerging volatility index (not reported), and the index becomes insignificant as we find under model (3)[26]. Since there is no theory support the differences in the presence of the volatility index, our finding provides an important discussion of whether the result is driven by either G7 countries or emerging countries. An only plausible explanation is that investors in the FX market are well-informed to the change in price and be more sensitive to the risks involved in currency trading than investors of other markets (Galati, Heath, and McGuire, 2007). Then, they always take trading positions in both developed and emerging currencies reflecting the coefficients of these indexes to be offsetting each other.

The lag of the change in market liquidity is negatively statistically significant as suggested by documented literature (Pastor and Stambaugh, 2003, Menkhoff et al., 2012, Banti et al, 2012, Mancini et al., 2015) that the lag of market liquidity is a measure for return reversal. The market return also affects the change in FX market liquidity. The influence of the return of the equity market depicts the certain movement of the equity market along with the currency market. These variables are statistically significant for all three models.

In sum, the change in market liquidity can be explained the change in funding constraints. FX liquidity perceives the change in funding as a sign of liquidity movement. The result also suggests that the volatility indexes, or global risks, can contribute to the change in FX market liquidity.

5.2 Regression Test with the Fama-French Model

The result from the previous section suggests that the market return from the equity can influence the change in FX market liquidity. Then, we analyze further using equation (3) to see the effect of 5-factor on the change in liquidity.

The result is reported in table 6. we estimate using each 5-factor for each model: model (1)-HML, model (2)-SMB, model (3)-RMW, model (4)-CMA, and model (5)-all factors. Using one variable at a time does not show any statistical significance except for model (3) and (4). Using the comprehensive model (model (5)), only CMA is positively statistically significant while other variables in 5-factor are not significant. The result suggests that CMA, conservative investment minus aggressive investment, investors tend to be more risk-averse in the FX market than being aggressive. This can also be interpreted that sophisticated investors take positions in the FX market to provide more liquidity position in their investment strategies. Moskowitz, Ooi, and Pedersen (2012) provide empirical evidence that the hedgers and speculators take a short and long position and generate a substantial amount of the liquidity needs for the FX market. Hedgers tend to provide more stabilization to the FX market better than speculators do for the FX market.

Other variables are statistically significant as shown in the previous regression result. Also, the coefficients of the volatility index of G7 and emerging countries are, again, almost entirely offsetting each other. For example, under model (5), 0.0299 in G7 countries, and -0.0269 in emerging countries. This result suggests that these variables can contribute to the change in FX market liquidity. However, when observing individual factors of the 5-factor model, only the investment factor can contribute to the change in FX market liquidity. This finding contributes that market return, as in the previous section, can provide an insight into the change in FX liquidity; however, not all the variables of returns contribute to this change. Only the investment factor suggests the contribution of the change in FX market liquidity.

Table 6: empirical result from regression equation (3): $\Delta liq_t = a + \beta(\Delta X_t) + \Psi(FF_t) + \gamma \Delta Vol_t + \delta \Delta liq_{t-1} + \varepsilon_t + fixed\ Effect,$ where FF_t is the 5-factor as Fama-French 5-factor model: HML, SMB, RMW, and CMA. ΔX_t variables are: ΔVIX_t is the

[25] BIS annual report and Forex annual report.
[26] Testing for emerging volatility index provides similar magnitude and different sign compared to G7 volatility index.

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change in VIX spread, ΔTED_t is the change in TED spread, $\Delta US\ Repo_t$ is the change in US repo, and $\Delta UK\ Repo_t$ is the change in UK repo. Vol_t is JP Morgan Volatility index (JPM) for both G7 (JPM $G7_t$) and emerging countries ($\Delta JPM\ EM_t$), and Δliq_{t-1} is the lag of FX market liquidity. The sample period is from December 1999 to December 2016. The t-test are adjusted via Newey-West (1987) and reported in parentheses. *, ** indicate 10% and 5% level of significance.

	(1)	(2)	(3)	(4)	(5)
HML_t	0.0135				-0.0229
	(0.42)				(-0.50)
SMB_t		0.0529			0.0354
		(1.40)			(0.85)
RMW_t			-0.0547		-0.0502
			(-1.73) *		(-1.33)
CMA_t				0.0748	0.1003
				(1.96) **	(2.03) **
ΔVIX_t	0.2158	0.2232	0.2197	0.2218	0.2332
	(4.19) **	(4.34) **	(4.35) **	(4.30) **	(4.47) **
ΔTED_t	0.3541	0.3582	0.3550	0.3548	0.3585
	(13.59) **	(13.67) **	(13.76) **	(13.66) **	(13.48) **
$\Delta US\ Repo_t$	-0.0565	-0.0585	-0.0562	-0.0611	-0.0639
	(-3.18) **	(-3.12) **	(-3.09) **	(-3.40) **	(-3.46) **
$\Delta UK\ Repo_t$	-0.0843	-0.0849	-0.0859	-0.0802	-0.0808
	(-7.33) **	(-7.79) **	(-7.83) **	(-7.36) **	(-6.37) **
$\Delta JPM\ G7_t$	0.0269	0.0259	0.0297	0.0278	0.0299
	(3.51) **	(3.46) **	(3.80) **	(3.71) **	(3.78) **
$\Delta JPM\ EM_t$	-0.0243	-0.0239	-0.0264	-0.0251	-0.0269
	(-4.11) **	(-4.19) **	(-4.50) **	(-4.42) **	(-4.46) **
Δliq_{t-1}	-0.6182	-0.6191	-0.6195	-0.6181	-0.6200
	(-41.65) **	(-41.49) **	(-41.77) **	(-41.58) **	(-41.19) **
Constant	-0.0057	-0.0016	-0.0093	-0.0077	-0.0093
	(-0.15)	(-0.04)	(-0.23)	(-0.20)	(-0.24)

5.3 Financial Crisis

Table 7 provides the result of the impact of the financial crisis. Model (1) and (3) report during the non-financial crisis period while modeling (2) and (4) report during the financial crisis period. Model (3) and (4) use only significant variables from the model (1) and (2) to check the robustness of the primary results. Consistent with the previous result, the capital flows do not take an account of explaining the change in FX market illiquidity. Then, the result confirms that the capital flows have relatively no impact on the funding constraint in the FX market. This regression, however, provides an interesting result. For both financial crisis and non-financial crisis period, the change in VIX now has explanatory power and it is stronger during the financial crisis period, contradicting the main regression result in table 3 indicating that the change in VIX is not statistically significant. The change in VIX is stronger during the financial crisis period indicates that the VIX spread can capture the volatility of the FX market providing insight information that during the financial crisis period the equity market plays an important role and provides spillover effects to other markets. The FX market is also affected by the spread of spillover effects as it happens

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to bonds and commodity markets. Furthermore, the change in VIX can incorporate the information regarding future changes in the currency market[27].

Table 7: empirical result from regression equation (4): $\Delta liq_t = a + \beta(\Delta X_t * Dummy_t^{crisis}) + \Phi(\Delta X_t * Dummy_t^{nocrisis}) + \gamma\Delta Vol_t + \delta\Delta liq_{t-1} + \varepsilon_t + Fixed\ Effect,$ where ΔX_t variables are: ΔVIX_t is the change in VIX spread, ΔTED_t is the change in TED spread, ΔUS $Repo_t$ is the change in US repo, ΔUK $Repo_t$ is the change in UK repo, ΔMkt Ret_t is the change in market excess return, and $\Delta Flows_t$ is the change in net capital flows. Vol_t is JP Morgan Volatility index (JPM) for both G7 (JPM $G7_t$) and emerging countries (ΔJPM EM_t), and Δliq_{t-1} is the lag of FX market liquidity. Dummy variable is 1 during financial crisis (March 2007 to June 2009), and 0 otherwise. The sample period is from December 1999 to December 2016. Model (1) and (3) show non-crisis period while model (2) and (4) show during the crisis period. The t-test are adjusted via Newey-West (1987) and reported in parentheses. *, ** indicate 10% and 5% level of significance.

	(1)	(2)	(3)	(4)
ΔVIX_t	0.1098	0.12512	0.1137	0.1029
	(1.97) **	(13.56) **	(2.05) **	(16.97) **
ΔTED_t	0.4908	0.0393	0.4851	
	(13.36) **	(0.92)	(13.55) **	
ΔUS $Repo_t$	-0.0992	-0.0219	-0.0963	
	(-4.45) **	(-0.39)	(-4.40) **	
ΔUK $Repo_t$	-0.0210	-0.0737	-0.0211	-0.0794
	(-11.31)**	(-5.44) **	(-11.42)**	(-6.57) **
ΔMkt Ret_t	0.0253	0.0293	0.0255	0.0301
	(9.56) **	(7.98) **	(9.67) **	(8.56) **
$\Delta Flows_t$	0.0001	-0.0002		
	(0.69)	(-0.98)		
ΔJPM $G7_t$	0.0247	0.0449	0.0247	0.0401
	(2.78) **	(3.01) **	(2.78) **	(2.83) **
ΔJPM EM_t	-0.0297	-0.0318	-0.0299	-0.0286
	(-4.04) **	(-2.88) **	(-4.07) **	(-2.73) **
Δliq_{t-1}	-0.6027	-0.6622	-0.6046	-0.6626
	(-44.11)**	(-22.03)**	(-45.12)**	(-24.73)**
Constant	0.0646	-0.1526	0.0660	-0.1337
	(1.05)	(-2.45) **	(1.07)	(-2.27) **

The change in TED, however, does not show any explanatory power to explain the change in FX market liquidity. This result comes as a surprise since most of the literature (see also Mancini et al., 2015, Menkhoff et al., 2012) indicates the change in TED can be used to explain the market liquidity. The plausible explanation is that TED be observed as the supply-side factor and during the crisis period the supply for FX market liquidity is lesser than during the non-financial crisis period, indicating that less supply being funded in the FX market.

The change in US repo is not statistically significant during the financial crisis period. Only UK repo can capture the change in FX market liquidity. The funding constraint, especially in UK repo, plays a role in the impact of the change in FX liquidity (as the coefficient is negatively related to the change in FX liquidity).

Considering the change in volatility indexes for both G7 and emerging countries, the result is consistent with the preliminary result indicating that both indexes can be used to capture the change in FX market liquidity. Analyzing further, the change in volatility index for G7 countries contributes to the change in FX liquidity more during the non-financial crisis period. The coefficient of 0.0449 under model (2) or during the financial crisis period is higher than the coefficient of 0.0274 under model (1) or non-financial crisis period. This is also true for the model (3) and (4) using only significant variables from the model (1) and (2). This result suggests that G7 countries contribute to the change in FX market liquidity especially during the financial crisis period more than emerging

[27] See. Mancini et al. (2013), Menkhoff et al. (2012b), Karnaukh et al. (2015).

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countries do. Then, the level of market integration (see Carrieri at el. ,2013) of developed currencies has more impact on changing market liquidity as the developed currencies are mainly accounted for trading in the FX market than emerging currencies. Furthermore, the coefficients also indicate that the contribution of the volatility index during the financial crisis is stronger than the non-crisis period. For example, model (1) shows the coefficient of 0.0274 while during the crisis period the coefficient is 0.0449 under model (2).

In summary, the financial crisis provides evidence that the financial constraint issues contribute to the change in FX market illiquidity more than non-financial crisis period. In contrast to the preliminary result, the equity volatility index (VIX) can also capture the change in FX market liquidity strongly during the financial crisis period.

6. Predictability Discussion

6.1 Liquidity predictability

Many documented literatures report the finding of liquidity predictability (see, Pastor and Stambaugh, 2003, Chordia et al., 2000a). Poti and Siddique (2013) provide empirical evidence of the currency predictability by using the carry trade approach on diversified investors and undiversified investors. They find that undiversified investors require higher liquidity due to the capital constraint than diversified investors. Their empirical finding supports that the presence of the financial constraint can induce the change in liquidity as well as some degree of currency predictability. We estimate the liquidity predictability using modification of Poti and Siddique (2013) approach as follows:

$$\Delta LIQ_t = E(\Delta LIQ_{t-1}|I_{t-1}) \quad (5)$$

The intuition behind the methodology is that the change in liquidity is determined by the expected liquidity and information set, as described by I_{t-1}, at time t-1. The information set includes the determined variables used in the previous estimation.

The analysis is based on DCC model to analyze the predictability of the FX market liquidity. The DCC model is described as:

$$H_t = D_t^{1/2} R_t D_t^{1/2} \quad (6)$$

where H_t is covariance matrix of disturbances of market FX illiquidity, D_t is diagonal matrix conditional variances, and R_t is the matrix of conditional quasi-correlation of market FX illiquidity and control variables.

Figure 6 shows the impulse response function of the change in FX liquidity using previous information set and one-step lag of liquidity. The graph seems to support the presence of the reversals as the market FX liquidity swings between negative and positive values and gets smoothed out in the recent period. Pastor and Stambaugh (2003), and Banti et al., (2012) report similar finding as they predict the certain degree of liquidity can be predicted based on the past liquidity information.

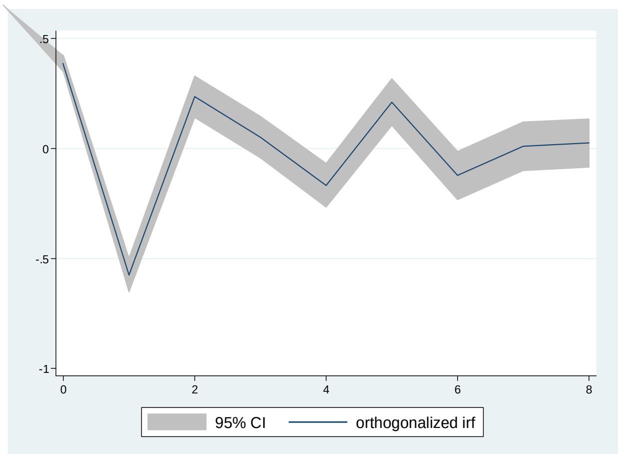

Figure 6: Impulse response function of market FX liquidity. The change in FX liquidity is estimated by the lag of FX liquidity and information set at time t-1 as described by equation (5): $\Delta LIQ_t = E(\Delta LIQ_{t-1}|I_{t-1})$.

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6.2 Return predictability

Bakshi and Panayotov (2013) and Cenedese et al. (2014) propose that the use of carrying trade portfolios to predict the return predictability. To begin our analysis, we determine the excess returns of currency based on monthly excess returns as proposed by Banti et al. (2012) that the difference between the natural log of the future's spot rate and today's forward rate[28]. Once the excess returns are determined, we follow the use of Cenedese et al. (2014) to form the conditional market variance with the decomposition form as follows:

$$MV_t = AV_t * AC_t \tag{7}$$

Where MV_t is the conditional market variance AV_t is the average of the variances of excess returns at time t, and AC_t is the average correlation of exchange rate excess returns at time t. The average variance is defined as the equally-weighted average of the variance of all currency excess returns while the average correlation is determined by the equally-weighted average pairwise correlations of all exchange rate excess returns[29].

The average variance (AV_t) and average correlation (AC_t), as presented in equation 8, are estimated as follows:

$$AV_t = \frac{1}{N}\sum_{j=1}^{N} V_{j,t} \tag{8}$$

$$AC_t = \frac{1}{N(N-1)}\sum_{i=1}^{N}\sum_{j\neq i}^{N} C_{ij,t} \tag{9}$$

Where $V_{j,t}$ is the realized monthly variance of excess return of currency j at time t, and $C_{ij,t}$ is the realized monthly correlation between the excess return of cross currencies i and j at time t.

Then, we construct the predictive regression as following model:

$$r_{i,t+1} = a_1 + b_1 AV_t + b_2 AC_t + \varepsilon_{t+1} \tag{10}$$

Where $r_{i,t+1}$, is the predictive excess return, AV_t is the average variance as defined by equation (8), AC_t is the average correlation as defined by equation (9), and ε_{t+1} is assumed to be i.i.d. and zero mean.

Table 8 reports the results using only market variance (MV) and decomposition model; the average correlation (AC) and average variance (AV). Consistent to Cenedese et al. (2014), we find that the market variance (MV) does not provide any explanatory power of explaining the change in currency excess returns. In fact, the average correlation and average variance can help explaining the change in the excess returns up to approximately 32% (28.91% + 4.2%). The average variance contributes the most to the change in excess returns.

Table 8: Predictive regression using equation (10): $r_{i,t+1} = a_1 + b_1 AV_t + b_2 AC_t + \varepsilon_{t+1}$,where $r_{i,t+1}$ is the return from time t to t+1 of the currency i, AV_t is average variance using equally weighted average of the variances of all excess returns at time t, and $AC_t$is the average correlation using equally weighted average of the pairwise correlation of all excess returns at time t. The t-test is reported using Newey-West (1987) under the parentheses. *, ** indicate 10% and 5% level of significance.

	(1)	(2)
Constant	0.0137	0.0157
	(2.36)**	(2.69)**
Market Variance (MV)	0.4631	
	(0.79)	
Average Variance (AV)		0.2891
		(3.81)**
Average Correlation (AC)		0.042
		(1.97)**
R-Squared	0.05	0.12

[28] See. Banti et al. (2012) and Banti and Phylaktis (2015).
[29] See. Cedenese et al. (2014)

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We analyze further to see whether any potential variables can be used to predict the change in return. Then, we construct the predictive regression as the following model:

$$r_{i,t+1} = a_1 + b_1 AV_t + b_2 AC_t + \gamma X_t + \varepsilon_{t+1} \quad (11)$$

Where $r_{i,t+1}$, is the predictive excess return, $X_t$is the vector of proposed variables (predictive change in liquidity, change in TED spread, and change in volatility indexes), and ε_{t+1} is assumed to be i.i.d. and zero mean.

The predictive change in liquidity is the control variable as determined from the previous section. We include the change in TED spread and volatility indexes to explain the possible change in the returns. Table 9 reports the result. As expected, the result is consistent with what Cedenese et al. (2014) report on what the average correlation and average variance can be used to predict the change in currency excess returns. The presence of average variance is strong for all the models ranging from 30% to 36% while the average correlation can partially explain the change in excess returns. The change in liquidity is positively correlated to the change in excess returns as investors require a higher premium to greater risk and return; however, it does not provide a strong magnitude as expected. The change in liquidity can be partially used to predict the future excess returns, but not as strong as the change in average variance since currency excess returns depend highly on their risks rather the other currencies. The change in volatility indexes provides an interesting result since they cannot explain or used to predict the currency excess returns. Then, in general, we find that the change in excess returns depends highly on the average variance rather than on other explanatory variables.

Table 9: Predictive regression using equation (11): $r_{i,t+1} = a_1 + b_1 AV_t + b_2 AC_t + \gamma X_t + \varepsilon_{t+1}$,where $r_{i,t+1}$ is the return from time t to t+1 of the currency i, AV_t is average variance using equally weighted average of the variances of all excess returns at time t, $AC_t$is the average correlation using equally weighted average of the pairwise correlation of all excess returns at time t, and $X_t$is predictive variable choices. Δ TED is the change in TED spread, Δ LIQ is the predictive change in liquidity, Δ JPM G7 is the change in JP Morgan volatility index for G7 countries, and Δ JPM EM is the change in JP Morgan volatility index for emerging countries. The t-test is reported using Newey-West (1987) under the parentheses. *, ** indicate 10% and 5% level of significance.

	(1)	(2)	(3)	(4)	(4)
Constant	0.0133	0.0104	0.0097	0.0108	0.0091
	(2.19) **	(2.36) **	(2.65) **	(2.25) **	(2.31) **
AV_t	0.3651	0.3087	0.3277	0.3197	0.3012
	(3.31) **	(3.15) **	(3.02) **	(3.07) **	(2.97) **
AC_t	0.0654	0.0431	0.0396	0.0412	0.0371
	(2.44) **	(2.21) **	(2.23) **	(2.25) **	(2.05) **
Δ TED_t	0.0141	0.0113			
	(6.25) **	(7.31) **			
Δ LIQ_t	0.0763		0.0817		
	(4.01) **		(4.73) **		
Δ JPM $G7_t$	0.0021			0.0032	
	(1.06)			(0.96)	
Δ JPM EM_t	-0.0063				-0.0085
	(-1.23)				(-1.01)

6.3 Robustness

We consider that the choice of the currencies in the sample may drive the estimation bias since the choice is based on Banti et al. (2012) and the most trading activities from the BIS report. For the robustness check, we include 10 more currencies, both developed and emerging currencies, into the sample, namely Greece, India, Finland, Taiwan, UAE, Malaysia, Netherlands, Saudi Arabia, Spain, and Italy. The choice[30] is also based on the trading

[30] Each currency must have data available through Bloomberg and Thompson and Reuter, and it must be at least a 5-year spanning period.

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activity and data availability through Bloomberg, and Thompson and Reuters. Then, we estimate the regression based on the equation (2), (3), and (4) to observe whether including more currencies will change the preliminary results. We exclude the capital flows in the regression model since multiple tests have indicated that capital flows do not account for the change in FX liquidity.

Table 10 reports the result. Model (1) reports the result using equation (1). Consistent with Table 4, the change in TED spread, repo for US and UK, volatility indexes for G7 and emerging countries, market returns, and lag of FX liquidity are statistically significant and they all have the same sign as in table 4. This confirms that adding more currencies does not lower the explanatory power of the factors, funding constraints, and global risks, to the change in market FX liquidity.

Table 10: Robustness check of adding more currencies into the sample. ΔVIX_t is the change in VIX spread, ΔTED_t is the change in TED spread, $\Delta US\ Repo_t$ is the change in US repo, $\Delta UK\ Repo_t$ is the change in UK repo, and $\Delta Mkt\ Ret_t$ is the change in market excess return. Fama-French 5-factor model: HML, SMB, RMW, and CMA, is included under model (2). Vol_t is JP Morgan Volatility index (JPM) for both G7 (JPM $G7_t$) and emerging countries (ΔJPM EM_t), and $\Delta illiq_{t-1}$ is the lag of FX market illiquidity. Dummy variable is 1 during financial crisis (March 2007 to June 2009), and 0 otherwise. The sample period is from December 1999 to December 2016. The t-test are adjusted via Newey-West (1987) and reported in parentheses. *, ** indicate 10% and 5% level of significance.

	(1)	(2)	(3)
HML_t		-0.0012	
		(-0.75)	
SMB_t		0.0023	
		(0.85)	
RMW_t		-0.0211	
		(-1.02)	
CMA_t		0.056	
		(1.35)	
ΔVIX_t	0.0541	0.1134	0.1231
	(1.53)	(4.12) **	(12.35) **
ΔTED_t	0.3412	0.3673	0.0145
	(12.66) **	(13.18) **	(1.35)
$\Delta US\ Repo_t$	-0.0312	-0.0457	-0.0781
	(-2.78) **	(-3.21) **	(-4.41) **
$\Delta UK\ Repo_t$	-0.0254	-0.0553	-0.0124
	(-5.96) **	(-4.73) **	(-8.83) **
$\Delta JPM\ G7_t$	0.0277	0.0281	0.0359
	(3.91) **	(3.32) **	(2.75) **
$\Delta JPM\ EM_t$	-0.0265	-0.0279	-0.0326
	(-4.36) **	(-4.89) **	(-3.78) **
$\Delta Mkt\ Ret_t$	0.0101		0.0228
	(4.67) **		(6.11) **
$\Delta illiq_{t-1}$	-0.732	-0.632	-0.682
	(-24.65)**	(-23.19)**	(-18.67)**
Constant	-0.0055	-0.0081	-0.0093
	(-0.17)	(-0.26)	(-0.23)

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In Model (2), we test with the 5-factor model; however, the result indicates that none of the factors is statistically significant. Unlike the finding in table 6 indicating the presence of the investment strategy of investors can account for the change in FX liquidity, model (2) does not provide support of the claim in the previous result. Mancini et al. (2013), Karnaukh et al. (2015), and Menkhoff et al. (2012) provide an explanation of excluding Taiwan currency is that the differences of the micro and macroeconomic structures of Taiwan currency to other currencies can drive the change in liquidity. Then, this result does not come as a surprise since the inclusion of Taiwan can omit the previous findings.

Then, we test for the financial crisis period. The result is reported in table 8 under model (3). The result is consistent with the previous finding in table 7. All variables are statistically significant to expect for TED spread. The change in VIX spread, again, becomes significant as we find in the previous regression result. The result confirms the change in VIX can capture the financial crisis shocks as resulting in the change in FX liquidity better than the change in TED spread.

Overall, the robustness check provides substantially supporting the initial results that the determinant variables of global risks and funding constraints can capture the change in FX liquidity. Testing with the 5-factor model somehow needs further research since the currency market is different from the equity market, and 5-factor is mainly used in the equity market, especially in the US stock market.

7. Conclusion and Remarks

Liquidity measure has been widely discussed and presented the importance of the literature in finance; however, the study of FX liquidity gets less attention from mainstream research. This paper provides empirical evidence of the liquidity measure in the foreign exchange market, the determinants of measuring the change in market FX liquidity, as well as the predictability of the FX liquidity.

Using 20 cross currency exchange rates both developed and emerging currencies from January 1999 to December 2016, we find that the presence of the funding constraints such as repo for both US and UK, the change in TED spread, and the global risks such as volatility indexes can play an important role of the change in market FX liquidity. However, using the famous 5-factor model, the result can only capture the investment risk factor loading affecting the change in FX liquidity. This result becomes even more puzzling when adding more currencies into the sample. The result does not hold anymore. There is a need for further research to explore the possibility of an explanation of this puzzle.

We then test the presence of the financial crisis period from 2007 to 2009. The result shows that the change in VIX plays an important role that it can capture the change in FX liquidity better than the change in TED, which is not statistically significant during the crisis period. The change in risk factor during the crisis period can contribute to the change in FX liquidity as investors face severe funding constraints and the presence of global risks. The robustness check also confirms this result.

We test further whether changing in liquidity can be used to predict the currency excess returns. Using average correlation and average variance of currency excess returns for control variables, we find that average variance contributes the most for currency predictability more than other explanatory variables.

The global risks and funding constraints play an important role in the change in FX liquidity. we, however, do not provide more variables that might contribute to the change. Moreover, the choice of currencies may depict the selection bias since there are more currencies can be added to provide a clearer picture of the change in liquidity to funding constraints and global risks.

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