ILLIQUIDITY IN THE STOCK AND FX MARKETS: AN INVESTIGATION OF THEIR CROSS-MARKET DYNAMICS

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Abstract

In this paper, I investigate the illiquidity channel linking stocks and currencies and provide evidence of important illiquidity dynamics, especially during crisis episodes. I show that the stocks of small firms more exposed to funding constraints also exhibit greater linkages with foreign exchange (FX) illiquidity. Furthermore, the currencies that are common targets of carry trades are more intertwined with stock illiquidity. Regarding potential determinants, the liquidity demand by institutional investors and liquidity provision by dealers are potential triggers of systemic illiquidity spirals. Importantly, these dynamics are not exclusive of the recent financial crisis but were also present during the dotcom bubble crisis.

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I. Introduction

The subprime mortgage market turbulence in the summer of 2007 was characterized by sharp drops in asset prices, increasing volatility and episodes of liquidity dry-ups. Most of the literature focuses on the dramatic reactions of the stock and bond markets. However, the crisis has been systematic from its very beginning and has severely affected the foreign exchange (FX) market. Indeed, Melvin and Taylor (2009) extensively document the large losses in currency trading strategies, especially the carry trade, from August 2007. They also show that the dynamics of currency bid-ask spreads during the crisis were largely affected by factors originating outside the FX market. The literature has established returns and volatility linkages between currencies and stocks, but the illiquidity linkage has received little attention.

In this paper, I investigate the illiquidity channel linking currencies and stocks. Illiquidity is a broad concept that comprises different aspects. I focus on bid-ask spreads and study how shocks to transaction costs are transmitted across markets and what factors may trigger these dynamics. Understanding illiquidity dynamics is especially important when liquidity is scarce. Indeed, a large body of literature emerged following the recent financial crisis to study illiquidity and identify its determinants (e.g., Brunnermeier and Pedersen 2009). I follow the literature and analyze illiquidity dynamics during the recent financial crisis (2007-09). Moreover, I investigate whether these dynamics are exclusive of this crisis or they are common in market turbulence, focusing on two other episodes: the dotcom crisis (2000-01) and the European sovereign debt crisis (2010-14).

The cross-market linkages between stock and currency returns originate from a variety of factors. For instance, commonality in stocks and currencies may originate from international investors rebalancing their portfolios (e.g., Hau and Rey 2005; Hau, Massa and Peress 2010). Moreover, popular trading strategies link the two markets. For instance, “global macro” and "multistrategy" are strategies that involve simultaneous trading in stocks and currencies.[2] Additionally, arbitrageurs may exploit price mismatches between cross-listed stocks. There is evidence of co-movement between FX and stock liquidity (Mancini, Ranaldo and Wrampelmeyer 2013; Karnaukh, Ranaldo and Söderlind 2015). To the best of my knowledge, this paper is the first investigation of the dynamics of the illiquidity mechanisms linking stocks and currencies, with particular attention to illiquidity spirals. The focus is on the NASDAQ and the major FX electronic trading platforms (Reuters and EBS). These segments are representative of significant portions of trading in stocks and currencies and share important similarities in their structure (see Section II).

The identification of the illiquidity channel linking stocks and currencies is relevant in different respects. As a measure of frictions, illiquidity affects market efficiency. Hence, the identification of interdependencies in the illiquidity of financial markets contributes to the understanding of the processes towards market efficiency (Chordia, Roll and Subrahmanyam 2008). Furthermore, the presence of illiquidity spillovers across markets has implications for asset management. Asness, Moskowitz and Pedersen (2013) find a significant correlation between the returns of trading strategies in stocks and currencies, determined by their exposure to liquidity risk. In addition, liquidity risk is priced in the cross-section of both asset returns (Pastor and Stambaugh 2003; Banti, Phylaktis and Sarno 2012). Thus understanding the sources of these linkages is relevant for asset pricing. The systemic dimension of liquidity also has important policy implications, given the severe costs and negative externalities associated with its sudden dry-ups. These have been particularly severe during the recent financial crisis.

I identify cross-market illiquidity dynamics between stocks and currencies by conducting a vector autoregression (VAR) analysis of daily transaction costs from 1999 to

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[2] According to the 2015 FCA survey on hedge funds, these strategies account for 16% and 17% of hedge funds in the UK, respectively.

2014. The observed illiquidity linkages depend on certain asset characteristics. In particular, I find that, during the recent financial crisis, stocks of smaller firms (also called small caps) are more strongly related to currencies than stocks of larger firms (large caps). In turn, I find that the relationship between the illiquidity of currencies and small caps depends on currencies' role in the carry trade. The carry trade is a popular leveraged cross-currency trading strategy that involves borrowing in low-yield currencies (so-called funding currencies) to invest in high-yield currencies (so-called investment currencies). In this respect, I find that investment currencies are more intertwined with small caps than funding currencies. Interestingly, small caps and investment currencies are also relatively more vulnerable to shifts in the availability and costs of external financing for dealers or traders, the so-called funding constraints. An influential study by Brunnermeier and Pedersen (2009) identifies the key dynamics between market liquidity and funding constraints. Albeit to different degrees depending on the venue, dealers are important liquidity providers in financial markets, and they rely on external financing to operate. When financing availability is low as in a crisis, increasing global risk and risk aversion may trigger greater capital requirements (or haircut, i.e., the difference between the value of a security and the collateral, financed with dealers' own capital) and margin calls (i.e., requests by financiers for additional collateral to secure financing). These funding shocks may force dealers to cut down their liquidity supply in all of the markets in which they operate. Small caps that are more volatile and less liquid than large caps on average are also more capital-intensive and exposed to margin calls. According to Brunnermeier, Nagel and Pedersen 2008, investment currencies are sensitive to crash risk, that is, the risk of a sudden unwinding of carry trade positions by funding-constrained traders. Hence, their exposure to funding constraints coupled with severe distress in funding markets may explain the linkage between small caps and investment currencies during the recent financial crisis. However, this finding cannot be generalized to other crisis episodes. Indeed, I find greater illiquidity linkages between stocks and funding currencies during the dotcom crisis, whereas I find no clear pattern in the analysis of the European sovereign debt crisis.

To clarify these findings, I explicitly investigate the role of the supply and demand side factors identified in the literature. In addition to dealers' liquidity supply, I consider the role of the demand for liquidity by institutional investors (e.g., Kamara, Lou and Sadka 2008). I find that the behavior of these key market players implies that shifts in funding constraints and institutional correlated trading may dry up systemic liquidity, providing empirical evidence for the theoretical models of illiquidity spirals by Brunnermeier and Pedersen (2009) and Acharya and Viswanathan (2011). An illiquidity shock in one market may lead to a higher liquidity demand by institutional investors, in addition to lower liquidity provision by funding-constrained dealers. These reactions may trigger further illiquidity shocks, precipitating illiquidity spirals. Importantly, I show that the role of currencies in such events is not uniform across crises. Illiquidity spirals are a feature of investment currencies during the recent financial crisis, but they mostly relate to funding currencies during the dotcom bubble crisis. This suggests different mechanisms at work. During the dotcom bubble, carry traders were only starting to build up their positions after the 1998 crisis (Galati and Melvin 2004). The liquid and less risky funding currencies are generally used in short-term money markets. Hence, an illiquidity shock to this set of currencies may impair funding markets and lead to tighter funding constraints (Mancini, Ranaldo and Wrampelmeyer 2013). Conversely, traders held large carry positions at the onset of the recent financial crisis (Hattori and Shin 2009). Liquidation of these positions resulted in dramatic unwinding episodes (Melvin and Taylor 2009). The subsequent price pressure on investment currencies may have caused illiquidity problems in the presence of funding constraints (Plantin and Shin 2014). Indeed, given their riskiness, illiquidity shocks to investment currencies may fuel expectations of further losses on carry trades (Brunnermeier, Nagel, and Pedersen 2008). As the credit risk of leveraged carry traders worsens, banks may curtail funding further, triggering an illiquidity spiral. Finally, there is no evidence of illiquidity spirals across markets during the European debt crisis. At this time, "official" liquidity provision from the policy responses to the previous financial crisis may have reduced the impact of "private" funding constraints. Along these lines, I document that illiquidity is responsive to unexpected changes in US monetary policy, especially stocks.

II. The Institutional Framework

The FX market is characterized by a variety of trading venues. Due to data availability, I focus on trading activity in the major currency pairs that occurs on the largest FX electronic platforms (Reuters and EBS). These account for $738bn of the $5.3tn average daily turnover in the global FX market (BIS 2013). These trading platforms operate with automatic order matching. The NASDAQ is a centralized electronic market with the automatic execution of trades. Although historically quote-driven, it has features of an order-driven market (i.e., it displays all bid and ask quotes) with the presence of market makers for the sample period of this study.

Despite the changes in the composition of traders over time, dealers play an important role in both markets. On the NASDAQ, dealers, or market makers, are required to post quotes on both sides (bid and ask). Because they are not required to post inside the spread, the aggressiveness of their quotes, and their liquidity provision, varies across time and stocks (Chung and Zhao 2004). As a multi-dealer market, each stock has 17 registered dealers on average (NASDAQ website). Dealers are not the sole liquidity providers, and they are subject to competition from their customers' limit orders (which they are required to post and execute before their proprietary orders) and from electronic communication networks (ECNs). ECNs are open-limit order books that can connect directly to the NASDAQ network and account for a large share of trading (40% of trading in 2002 according to Hendershott (2003)).

Turning to FX, the electronic trading platforms have been traditionally interdealer markets. Following the introduction of prime brokerage arrangements in 2004-05, they have experienced an increasing presence of non-dealer financial institutions (BIS 2013). Indeed, trading between dealers and financial institutions was 17% higher than interdealer trading in April 2013 (Rime and Schrimpf 2013). These institutions include institutional investors (such as mutual funds and pension funds) and hedge funds, each accounting for 11% of trading in April 2013 (BIS 2013).[3] Moreover, in both markets, changes in the market structure and technology have encouraged the development of high-frequency trading and have led to a decline in transaction costs over time.

Differences in regulation are also noteworthy. The FX market is unregulated, whereas the NASDAQ falls under the Financial Industry Regulatory Authority (FINRA) framework. Indeed, behaviors and practices that are illegal in the NASDAQ may be discouraged by conventions and best practices but are nevertheless legal in the FX market (King, Osler and Rime 2012). It is important to note that the unregulated nature of the FX market is currently being challenged by the regulatory responses to the recent scandals in currency trading.[4]

III. Data

Measuring Illiquidity: Transaction Costs

Liquidity is a broad concept. It generally relates to the ease of placing large trades quickly and at low cost. Although several measures have been developed to study liquidity in the stock market, limitations on data availability have restricted the number of proxies employed in the analysis of the FX market. In this study, I estimate illiquidity in the two markets by their

[3] Even if unable to trade directly on these platforms, financial institutions traded with dealers in the costumer-dealer segment of the FX market for the first part of the sample period of this work and, in part, throughout the entire sample. Thus, their presence and trading activity affect the dynamics of interdealer trading. For a model of FX trading across segments, see Lyons (1997).

[4] The FEMR of the Bank of England has issued a consultation document on this issue that was presented by Deputy Governor Sharik during a speech at the LSE on October 27, 2014.

transaction costs.[5] As a result, I restrict the definition of illiquidity to the cost of obtaining immediacy (Demsetz 1968). I measure transaction costs by the percentage bid-ask spreads, that is, the difference of ask and bid prices scaled by the mid. Doing so improves comparability across stocks and currencies.

The stock market dataset comprises the bid and ask quotes of NASDAQ ordinary common shares (CRSP share code 10 or 11) for the sample period of 1999 to 2014.[6] The ask and bid are the closing inside quotes (highest bid and lowest ask) for each trading day, where closing time is 16:00 EST.[7] The data are from CRSP and are adjusted for errors and outliers. In detail, when the value of the spread is zero or the percentage spread is higher than half the mid-price in any given year, I exclude the quotes from the dataset in that year. Additionally, when the stock price in any year is higher than $999, I exclude the stock from the analysis to avoid extremely large share prices that would drive the measures. These omissions are in line with the adjustments performed by Chordia, Roll and Subrahmanyam (2001) and Hameed, Kang and Viswanathan (2010). To build the measures, I sort stocks according to their market capitalization at the beginning of each year and divide them into five groups, with the first group containing smaller cap stocks and the fifth containing larger cap stocks. I then calculate the individual illiquidity measures for each market capitalization quintile as the cross-sectional average of the bid-ask spreads in the group. In the analysis, I focus on the illiquidity of the smallest and largest market capitalization quintiles because the two groups are characterized by important differences. On one hand, trading in small caps is more capital-intensive and sensitive to changes in financing availability (Brunnermeier and Pedersen 2009). On the other

[5] In particular, I do not rely on the widely used Amihud measure due to lack of trading volume data for FX.

[6] In unreported robustness tests, I consider the illiquidity of common stocks trading on the NYSE and confirm the main findings.

[7] For a similar period, Chung and Zhang (2014) show that NASDAQ spreads calculated with CRSP daily data are highly correlated, at over 90%, with high-frequency TAQ spreads.

hand, large caps are largely held by institutional investors that rely on their liquidity for deleveraging during market downturns (Kamara, Lou and Sadka 2008).

The FX market dataset includes ask and bid prices of the USD against the Australian dollar (AUD), Euro (EUR), British pound (GBP), Japanese yen (JPY), and Swiss franc (CHF). Data are from actual trades in a one-minute window around 21:50 GMT (16:50 EST) collected by Thomson Reuters and available through Datastream. For the AUD and the GBP, data are sourced from the Reuters Matching platform. For the other currencies, data are collected primarily from EBS. These currency pairs are the most traded in the global FX market and are widely used in carry trades (BIS 2013). In a carry trade, investors borrow in currencies with low interest rates (funding currencies), such as the JPY, CHF and EUR, to invest in currencies with high interest rate (investment currencies), such as the AUD and the GBP (Galati, Heath and Mcguire 2007). Investment currencies in speculators' portfolios are exposed to the risk of the sudden unwinding of carry trades in times of distress, the so-called crash risk (Brunnermeier, Nagel and Pedersen 2008). This risk is especially relevant in times of distress when traders may be forced to unwind their positions due to greater funding constraints. Along these lines, Mancini, Ranaldo and Wrampelmeyer (2013) and Karnaukh, Ranaldo and Söderlind (2015) document the importance of carry trades for the exposure of currencies to volatility and liquidity risk. In particular, they show that investment currencies are more exposed to volatility and liquidity risk than funding currencies. Building on these findings, I study the exposure and contribution of currencies to illiquidity spirals.

The Determinants of Illiquidity

Following the literature, I identify the potential sources of illiquidity in both markets, focusing on the supply and demand side factors.

Dealers are liquidity suppliers in both the stock and the FX markets. Under certain conditions, when dealers suffer a decline in funding availability, such as increases in capital requirements or margin calls, they may reduce the provision of liquidity to the markets in which they operate (Brunnermeier and Pedersen 2009; Gromb and Vayanos 2010; Acharya and Viswanathan 2011).[8] As opposed to stock dealers, currency dealers tend to carry no inventory overnight. During the day, they pass undesired inventory positions among each other (and, most recently, also among other non-dealer financial institutions), the so-called hot potato phenomenon (Lyons 1997). However, they are affected by inventory considerations when taking up positions during the day. Indeed, they are subject to the risk of not being able to offload them quickly and at low cost, especially during crisis episodes (Melvin and Taylor 2009; Banti and Phylaktis 2015). Dealers are also prime brokers to their hedge fund clients, providing them with funding and access to interdealer trading platforms (Galati, Heath and Mcguire 2007; King, Osler and Rime 2013).

Among the factors that affect funding constraints, I consider credit riskiness in the interbank market. The interbank market is a source of unsecured financing and is thus affected by credit risk. To account for other factors that may affect funding constraints, I consider secured financing in a robustness exercise in Section VII. Given the presence of collateral, secured financing captures the changes in financing availability triggered by adverse moves in asset prices and liquidity.

I focus on two financial centers, London and New York, and employ the UK pound and US dollar TED spreads to proxy for funding constraints (Mancini, Ranaldo and Wrampelmeyer 2013; Karnaukh, Ranaldo and Söderlind 2015). New York is especially relevant for funding availability to dealers on the NASDAQ, whereas London is the main platform for trading in

[8] Empirically, Chordia, Roll and Subrahmanyam (2001) and Hameed, Kang and Viswanathan (2010) find that funding constraints affect illiquidity in stocks, whereas Mancini, Ranaldo and Wrampelmeyer (2013) and Banti and Phylaktis (2015) document this effect in currencies.

FX. Thus, I consider funding conditions in these two financial centers to be representative of the financing constraints faced by dealers in the stock and FX markets. The TED spread is constructed as the 3-month LIBOR over the yield on a generic 3-month government bond. Data are collected from Datastream.

Turning to the demand side, correlated trading by institutional investors (i.e., common buying or selling pressure by these large investors) causes liquidity commonality across stocks (Kamara, Lou, and Sadka 2008; Karolyi, Lee, and van Dijk 2012; Koch, Ruenzi, and Starks 2015). In FX, transactions by financial institutions have price informativeness, as shown by the exchange rate predictive power of their order flow (Carpenter and Wang 2007; Menkhoff et al. 2016). Under particular conditions, severe losses on the balance sheets of institutional investors may lead to sudden and severe deleveraging (so-called fire sales) that, in turn, may cause asset price collapses and market disruptions (Adrian and Shin 2010; Shleifer and Vishny 2011).

Consistent with previous work on the illiquidity linkages between the stock and bond markets by Chordia, Sarkar and Subrahmanyam (2005), I employ flow-induced trading activity by mutual funds as a proxy for the demand for liquidity (Bouwman, Sojli and Tham 2013; Chiu and Kini 2013).[9] Flow-induced trading is the trading activity by mutual funds that is triggered by investors' requests to purchase new shares and redeem existing shares. Studying flow-induced trading, Lou (2012) finds that mutual funds meet redemption requests exclusively by liquidating existing positions and that they increase their positions by approximately 62% after an inflow. In both cases, funds respond by trading more. Thus, I aggregate inflows and outflows towards mutual funds in a measure of institutional correlated trading activity (Coval and

[9] Albeit a partial proxy for institutional trading, the data availability on fund flows makes it possible to focus on flow-driven trading (Lou 2012). Additionally, the defined fund types make it possible to build separate proxies for trading in US equity and FX (as a by-product of investments in foreign equity). Fund flows are also used to proxy for institutional price pressure in Coval and Stafford (2007).

Stafford 2007; Lou 2012). I focus on US mutual funds with investment objectives in domestic and foreign equity markets. In particular, I consider the aggregated flows to mutual funds invested in domestic (US) equity as a proxy for institutional trading in the US stock market. Regarding the foreign equity type, inflows and outflows trigger trading in both the foreign equity market and the related foreign currency (Hau and Rey 2005). Hence, I consider the aggregated flows to mutual funds invested abroad as a proxy for institutional trading in FX. If investors demand liquidity from the market, then an increase in their trading activity should be accompanied by a higher demand for liquidity and greater illiquidity. Because I do not differentiate between buying and selling pressure and use the overall aggregated flows as a proxy for trading, I exclude any information channel and shifts in investor sentiment from the picture to fully capture the illiquidity channel. Data for both fund types are from the Investment Company Institute (ICI) and comprise the monthly dollar inflows and outflows for each type of fund.[10] According to the website, ICI data cover 98% of the mutual fund industry assets in the US. The foreign equity fund flow is on average 4% of the overall aggregated gross US stock portfolio flows (the absolute sum of the purchases and sales of stocks by foreigners), up to over 10% at the end of 2014.

Finally, I follow Goyenko and Ukhov (2009) and investigate the role of unexpected changes to US monetary policy in the cross-market illiquidity dynamics. Monetary policy operations that either increase or reduce the monetary supply trigger portfolio rebalancing and induce liquidity demand. Moreover, the resulting changes in the interest rates affect the cost of holding inventories and may result in shifts in the liquidity supply. In line with Goyenko and Ukhov (2009), I employ the orthogonalized non-borrowed reserves of depository institutions with the FED as the monetary policy proxy (Strongin 1995; Patelis 1997). The orthogonalized

[10] I take the raw flows as opposed to the standardized series (divided by TNA) because the interest is not on the mutual fund industry per se but instead on the effects of fund trading on illiquidity.

non-borrowed reserves are constructed by first normalizing the non-borrowed reserves adjusted for the extended credit by the moving average of the total reserve for 36 months and then storing the residuals from the regression of the normalized non-borrowed reserves on the normalized total reserves.

Descriptive Statistics

Table 1 presents some descriptive statistics for the illiquidity measures. As expected, the stock illiquidity level and variability monotonically decrease as market capitalization rises on average.[11] The average returns are positive for the smallest caps and negative for the largest caps, which is consistent with the presence of a liquidity premium in stock returns (Amihud and Mendelson 1986). Regarding FX, the GBP and the EUR are the most liquid currencies in the sample, whereas the AUD is the least liquid. Overall, the FX market is considerably more liquid than the stock market, with average percentage spreads ranging from 0.03% for the GBP to 0.06% for the AUD, as opposed to a 2.48% for small caps and 0.25% for large caps. All series exhibit a strong autocorrelation. Indeed, illiquidity is persistent, and an illiquid day is likely to be followed by another illiquid day.

[INSERT TABLE 1 HERE]

To investigate their time-series properties, in Figure I, I plot the illiquidity measures for small and large caps and the AUD and the JPY, which are representative of investment currency and funding currency, respectively. All measures exhibit a decline over time, which is consistent with a steady decrease in transaction costs. However, the illiquidity level sharply increases in both markets during crisis episodes, as marked by the shaded areas in the plots. In Panel A, stock illiquidity presents large spikes during the dotcom bubble crisis (2000-01) and

[11] A *t*-test confirms that the difference between the first and last quintiles is statistically different from zero.

the recent financial crisis (2007-09). The illiquidity of small caps increases during the European sovereign debt crisis (2010 onwards) as well. Regarding FX in Panel B, the illiquidity of investment currencies rises during the recent financial and European debt crises, whereas the illiquidity of the funding currencies is volatile in all periods.

[INSERT FIGURE I HERE]

Table 2 shows that the illiquidity series are positively correlated. Illiquidity exhibits stronger commonality during the recent financial crisis, especially between the investment currencies and small caps at over 50%. The documented commonality between the series and its variation across crisis episodes are an interesting starting point for a dynamic analysis of illiquidity across the markets.

[INSERT TABLE 2 HERE]

IV. The Empirical Model

From the contemporaneous correlation, stock and FX markets share common patterns in terms of illiquidity. To investigate the dynamics of these linkages, I estimate the following VAR model of stock and FX illiquidity:

$$X_t = \beta X_{t-1} + \gamma \; seas_t + \epsilon_t \,. \tag{1}$$

The VAR includes dummies ($seas_t$) to control for the presence of regular patterns in both stock and FX illiquidity, as documented in Chordia, Roll and Subrahmanyam (2001), Hameed, Kang and Viswanathan (2010), and Banti and Phylaktis (2015), and it is estimated with 1 lag according to the Schwarz criterion.[12] I estimate two specifications of the VAR model due to

[12] ADF tests show that the null hypothesis of a unit root can be rejected for all series at the conventional significance level. Thus, I include the series in level and address the trend and weekly and monthly seasonality directly in the VAR (Hamilton 1994). The dummy variables are the following: the day of the week, the month of the year and a time trend. Testing the VAR residuals for serial correlation, I can reject the null hypothesis of no serial correlation for 1 lag. Instead of feeding in lags and making estimates less precise, I employ a HAC correction of the standard errors. Matlab codes are from Kevin Sheppard's Toolbox.

the different frequencies of the data for the determinants. All specifications include the volatility of the stock and FX markets, computed as the squared market returns, to disentangle the liquidity channel from the well-documented volatility channel.[13]

The first VAR specification comprises daily equity and FX illiquidity together with funding constraints in the US and UK; thus, $Xt=[Illiq_t^{equity}; Illiq_t^{FX}; Ted_t^{US}; Ted_t^{UK}; Vol_t^{equity}; Vol_t^{FX}]$, where $Illiq_t^{equity}$ is the illiquidity of small and large caps; $Illiq_t^{FX}$ is the illiquidity of the AUD, CHF, EUR, GBP, and JPY; Ted_t^{US} and Ted_t^{UK} are the US and UK TED spreads as proxies for funding constraints; Vol_t^{equity} and Vol_t^{FX} are the volatility in the stock market and the FX market, respectively; and the subscript *t* indicates days. Following the VAR setting in Goyenko and Ukhov (2009), I include all illiquidity measures together in the VAR. In unreported tests, I find that the results are unchanged when I include the measures separately.[14] To establish whether illiquidity spirals are a feature of the recent financial crisis or whether they are typical when markets are in distress, I study the recent financial crisis together with other crisis episodes in the sample, such as the dotcom bubble crisis and the European sovereign debt crisis.[15]

The second VAR specification includes equity and FX illiquidity together with the proxies for institutional trading in stocks and FX and for US monetary policy. In this case, $X_t=[Illiq_t^{equity}; Illiq_t^{FX}; Trading_t^{equity}; Trading_t^{FX}; Reserves_t; Vol_t^{equity}; Vol_t^{FX}]$, where $Trading_t^{equity}$ and $Trading_t^{FX}$ are the aggregated investment flows towards mutual funds invested in the domestic US equity and foreign equity, respectively; and $Reserves_t$ are the non-

[13] In a robustness exercise, I measure volatility as the 28-day moving average of squared returns and I find qualitatively similar results. Results are unreported for brevity, but they are available from the author upon request.
[14] For the sake of brevity, the results are unreported, but they are available from the author upon request.
[15] The recent financial crisis is from August 2007 when BNP Paribas halted redemptions of its subprime funds to the end of the US recession in June 2009; the dotcom bubble crisis is from the market collapse in March 2000 to the end of the US recession at the end of 2001; and the European sovereign debt crisis is from November 2009 when Greece revealed its actual budget size to the end of the sample period in 2014.

borrowed reserves of depository institutions with the FED. The subscript *t* indicates months, given that trading and monetary policy data are available at a monthly frequency. The low number of observations does not allow for a sub-sample analysis; thus, I estimate this specification of the VAR model exclusively for the full sample period.

V. The Cross-Market Dynamics of Illiquidity

Focusing on the first VAR specification at daily frequency, I conduct standard tests on the VAR estimations to identify the illiquidity dynamics across stocks and currencies.

The Full Sample Period

As a preliminary analysis, I estimate the VAR model for the full sample period. For the sake of brevity, the results are unreported, but they are available from the author upon request. If shocks were systemic, then an illiquidity shock in one market would be accompanied by a contemporaneous illiquidity shock in another market. I find that illiquidity shocks are market-specific events, with correlation coefficients of approximately 2% on average. Granger causality tests show that stock illiquidity is generally informative to predict FX illiquidity. Moreover, both investment and funding currencies are informative to predict the illiquidity of small caps. Finally, I investigate the dynamics of these illiquidity linkages, employing the Generalized impulse response functions (IRFs) (Koop, Pesaran and Potter 1996; Pesaran and Shin 1998). I find that illiquidity shocks to both small and large caps result in greater illiquidity in all currencies, whereas only small caps react to FX illiquidity shocks. The Generalized IRFs are invariant to the ordering of the variables in the VAR; thus, there is no need for assumptions on the sequence of shocks. Interdependencies between funding and liquidity identified in the literature do not offer clear indications on the ordering of the variables (Mancini, Ranaldo and Wrampelmeyer 2013; Banti and Phylaktis 2015). Hence, I rely on the Generalized IRFs here and in the subsequent analysis. In Section VII, I compute the responses by using Cholesky decomposition to obtain orthogonal innovations with different orderings of the variables and I confirm the main findings.

Focus on Crisis Episodes

It is during the latest financial crisis that Melvin and Taylor (2009) identify sharp rises in FX illiquidity. Additionally, theoretical models predict stronger illiquidity linkages across asset markets during periods of distress. It is especially in crises that asset price drops coupled with low funding lead to fire sales and market illiquidity (Adrian and Shin 2010; Shleifer and Vishny 2011). In addition, given that funding constraints are tighter during market downturns, traders are more likely to reduce their activity and supply less liquidity in a crisis (Brunnermeier and Pedersen 2009; Gromb and Vayanos 2010; Acharya and Viswanathan 2011). Furthermore, due to cross-market information learning, when investors' risk aversion is high, an illiquidity shock in one market may lead to higher bid-ask spreads in other markets (Cespa and Foucault 2014). Hence, I study the illiquidity dynamics and their determinants during crisis periods.

Table 3 reports the correlation coefficients of the VAR innovations and the results of the Granger causality tests. There is some evidence of commonality in shocks across stocks and currencies. In detail, during the recent financial crisis, illiquidity shocks present a certain degree of commonality between small caps and investment currencies, with coefficients above 10% (Panel A). During the dotcom crisis (Panel B), there is some commonality between the CHF and stock illiquidity. Indeed, CHF illiquidity shocks are associated with positive illiquidity shocks to large caps (9%) and negative shocks to small caps (-8%). Finally, during the European sovereign debt crisis (Panel C), there is some evidence of commonality between the GBP and stock illiquidity at approximately 6%.

[INSERT TABLE 3 HERE]

The Granger causality tests provide some insights into the cross-market linkages. During the recent financial crisis (Panel A), the illiquidity of small caps is informative in predicting the illiquidity of investment currencies, and vice-versa. During the dotcom crisis (Panel B), the illiquidity of both small and large caps is informative to predict the illiquidity of CHF. Additionally, the illiquidity of funding currencies is informative for the illiquidity of large caps. Finally, the illiquidity of small and large caps significantly predicts the illiquidity of the CHF, the GBP and the JPY in the European sovereign debt crisis (Panel C).

Figure II reports the responses of illiquidity in one market to illiquidity shocks in the other market. During the recent financial crisis (Panel A), the impact of illiquidity shocks to small caps is significant for all currencies and is especially strong for the AUD. The impact of large cap illiquidity shocks is weaker, with positive reactions in investment currencies and the JPY. Additionally, illiquidity shocks to investment currencies trigger higher illiquidity in small caps. Thus, there is evidence of illiquidity dynamics across the two markets, especially between small caps and investment currencies. This finding may be related to their exposure to funding constraints. On one hand, trading in small caps is more capital-intensive and sensitive to changes in financing conditions. On the other hand, investment currencies are affected by funding constraints due to their exposure to crash risk. The literature on funding and market liquidity generally focuses on the recent financial crisis. Nevertheless, deteriorating funding conditions and increasing market uncertainty are common to other crisis episodes. Regarding the other crises in the sample period, I find that illiquidity shocks to small and large caps result in greater illiquidity in the FX market during the dotcom bubble crisis (Panel B). As opposed to the recent financial crisis, the most exposed currencies are funding currencies. Moreover, illiquidity shocks to this set of currencies affect stock illiquidity. During the European debt crisis (Panel C), illiquidity shocks to small caps result in greater illiquidity across all currencies. Conversely, illiquidity shocks to large caps affect investment currencies and the JPY.

Additionally, when the illiquidity of large caps unexpectedly increases, the illiquidity of the CHF declines. Among currencies, the illiquidity of small caps reacts to illiquidity shocks to the JPY and to a lower extent to the EUR and the GBP.

[INSERT FIGURE II HERE]

In conclusion, there is evidence of illiquidity linkages across the two markets.[16] The illiquidity in the stock market affects the illiquidity of all currencies. The exposure of stock illiquidity to FX is restricted to the small caps in the two recent crisis episodes. Moreover, currencies in carry trades have different impact on stocks during the dotcom and the recent financial crises. Investment currencies are relevant in the latter, whereas funding currencies are stronger in the former. To shed light on these findings, I now turn to the potential determinants of liquidity and investigate their impact on the illiquidity dynamics.

VI. Potential Sources of the Documented Illiquidity Dynamics

The Role of Funding Constraints

Focusing on the first VAR specification at daily frequency, Figure III reports the interaction of illiquidity and funding constraints (*Ted*). During the recent financial crisis (Panel A), shocks to funding constraints lead to greater illiquidity in both the stock and FX markets. Moreover, funding constraints increase following an illiquidity shock in the stock market. Regarding FX illiquidity shocks, only investment currencies affect funding constraints, especially in the UK.

[INSERT FIGURE III HERE]

During the dotcom bubble crisis (Panel B), funding shocks in the US affect stock illiquidity, especially of small caps, and vice-versa. Funding shocks result in greater illiquidity

[16] In a robustness exercise, I find qualitatively similar results employing the illiquidity of common stocks from the NYSE. Results are unreported for brevity, but they are available from the author upon request.

in all currencies, whereas only illiquidity shocks to funding currencies affect funding constraints, especially in the UK.

Finally, during the European sovereign debt crisis (Panel C), stock illiquidity (especially of small caps) increases after a funding shock, and funding constraints increase following an illiquidity shock to stocks. The relationship between FX illiquidity and funding is more complex. The illiquidity of the AUD, the CHF and the JPY declines after a US funding shock, whereas it increases following a shock to UK funding constraints. UK funding shocks trigger declines in the illiquidity of the other currencies, the EUR and the GBP. Finally, GBP and JPY illiquidity shocks reduce UK funding constraints.

Overall, funding constraints are important determinants of future liquidity in both markets. The recent financial and European debt crises are relatively more global than the dotcom crisis. Indeed, funding shocks from all systems affect stock illiquidity in the former, whereas only funding shocks from the US affect stock illiquidity during the latter. Given the role of London and New York as global currency trading centers, FX illiquidity is generally affected by funding shocks from both financial systems.

Furthermore, I find that illiquidity in both markets affects funding constraints, providing evidence for the presence of illiquidity spirals. This is in line with the theoretical models by Brunnermeier and Pedersen (2009) and Acharya and Viswanathan (2011). There is evidence of stronger linkages with small caps, which is consistent with the proposal that small caps are subject to relatively more stringent funding constraints than large caps are. Consistent with the cross-market illiquidity dynamics identified in the previous section, illiquidity spirals involve investment currencies during the recent financial crisis, whereas they are related to funding currencies during the dotcom bubble crisis. The results are consistent with the different market conditions that characterized these episodes.

At the onset of the dotcom crisis, traders were only starting to lever up and accumulate carry positions after the 1998 crisis (Galati and Melvin 2004; Hattori and Shin 2009). Developments in funding currencies are especially relevant in this crisis because they are important for the functioning of short-term money markets (Mancini, Ranaldo and Wrampelmeyer 2013). So, when market conditions deteriorate and liquidity becomes scarce, illiquidity shocks to this set of currencies may trigger greater funding constraints. Conversely, traders met the recent financial crisis with large carry positions (Hattori and Shin 2009). In fact, there have been severe episodes of carry unwinding during this crisis (Melvin and Taylor 2009). Highly leveraged traders held risky investment currencies that experienced severe price pressure (Plantin and Shin 2014). In this context, illiquidity shocks to these currencies may fuel expectations of further declines in their value and losses on carry trades (Brunnermeier, Nagel and Pedersen 2008). As a result, banks may widen margins and reduce funding availability to traders, resulting in greater funding constraints (Melvin and Taylor 2009).

Finally, there is no evidence of illiquidity spirals across markets during the European debt crisis. Indeed, this period is characterized by very large amounts of "official" liquidity created by the policy responses to the previous financial crisis and the subsequent economic crisis. In turn, the higher reliance of dealers on "official" liquidity may result in a weaker role of "private" funding constraints.

The Role of Institutional Correlated Trading

The IRFs from the second VAR specification of illiquidity and trading activity are reported in Figure IV. An unexpected increase in institutional trading triggers a greater demand for liquidity, resulting in lower liquidity levels. Indeed, stock illiquidity increases after a shock to trading activity in stocks. The illiquidity of large caps also increases due to shocks to FX trading. Furthermore, illiquidity shocks to large caps trigger greater US trading activity, whereas illiquidity shocks to small caps reduce it. Large caps are held by institutional investors that rely on their liquidity in times of distress. As a result, they are more likely to be liquidated in fire sales. Consequently, investors increase their demand for liquidity after an illiquidity shock to large caps, whereas they reduce it following a shock to small caps. Shocks to trading activity in both equity and FX trigger greater FX illiquidity, especially of investment currencies. Additionally, FX trading activity declines following an illiquidity shock to the CHF.

[INSERT FIGURE IV HERE]

In conclusion, I document that the liquidity demand triggered by institutional trading negatively affects the liquidity of stocks and FX. In the stock market, investors are more likely to sell off the most liquid stocks that they hold to limit losses from fire sales. Given the lower frequency of this analysis, I cannot directly test this prediction, but the evidence for the full sample period is consistent with the fact that larger caps are likely to experience stronger demand for liquidity following illiquidity shocks (Adrian and Shin 2010; Shleifer and Vishny 2011).

The Role of Monetary Policy

Figure V reports the responses of illiquidity in both markets to shocks to US monetary policy from the second VAR specification. Monetary policy shocks reduce stock market illiquidity. Thus, following an unexpected increase in FED reserves, stock market liquidity improves. There is only weak evidence with respect to FX illiquidity, whose responses are negative but insignificant.[17]

[17] As a robustness test, I employ the proxy for monetary policy surprises developed by Kuttner (2001). This proxy is the difference in daily one-month Fed Fund future rates around FOMC meeting days, scaled by the proportion of days after the meeting in the month. Results are qualitatively similar and they are not reported for brevity, but they are available from the author upon request.

[INSERT FIGURE V HERE]

VII. Robustness Tests

Alternative Estimation of the IRFs

There is no clear indication from theory on the causal direction of the relationship between illiquidity, volatility and funding constraints. On one hand, microstructure theory suggests that volatility affects illiquidity due to its impact on inventory costs (Stoll 1978; Ho and Stoll 1981) and asymmetric information costs (Copeland and Galai 1983; Glosten and Milgrom 1985). On the other hand, illiquidity may lead to volatility since it exacerbates the price impact of transactions (Pastor and Stambaugh 2003). As discussed above, funding constraints and illiquidity are deeply intertwined, especially in context of high risk aversion and uncertainty, that is high volatility (Brunnermeier and Pedersen 2009). The same uncertainty on the direction of the relationship applies to stock and FX variables. For this reason, I rely on Generalized IRFs in the main analysis. The greater flexibility of Generalized IRFs may also be considered a drawback because the assumption of no ordering is equivalent to considering each variable as the most exogenous in turn. To address this limitation, as a robustness test, I compute the IRFs employing Cholesky decomposition to orthogonalize the shocks. In this case, the ordering of the variables in the VAR is key because variables that are placed before are assumed to have a stronger impact on the other variables.

Thus, I estimate the first VAR specification at daily frequency with the following variable ordering: stock and FX market volatility, stock and FX market illiquidity, and funding constraints in the US and the UK. The responses are consistent with the main results. The results are qualitatively similar when the FX measures are placed before the stock measures and when the funding variables are included prior to the illiquidity variables. For the sake of brevity, I do not report these IRFs, but they are available upon request.

Alternative Funding Liquidity Measure

As a robustness test, I employ an alternative proxy for funding availability based on the amount outstanding of repurchase agreements (repos) in the US and the UK. Repos are a major source of financing for dealers. Thus, their availability captures the amount of financing that is available to them (Baklanova, Copeland and Mccaughrin 2015; Banti and Phylaktis 2015). Monthly data are available from the Federal Reserve Bank of New York and the Bank of England. The responses provide additional support for the presence of illiquidity linkages between funding constraints and illiquidity. For the sake of brevity, I do not report these IRFs, but they are available upon request.

VIII. Conclusions

Illiquidity is an important channel linking the stock and FX markets. Although cross-market linkages were established between stock prices and exchange rates, this study is the first to investigate the dynamics of the illiquidity linkages between stocks and currencies.

Investigating the linkage, I find that specific asset characteristics affect the observed cross-market dynamics. On one hand, stocks of small firms are more exposed to funding constraints and exhibit stronger illiquidity linkages with currencies. On the other hand, illiquidity shocks to stocks of large firms, which are more prevalent in institutional investors' portfolios, trigger greater portfolio rebalancing and liquidity demand. Regarding FX, I show that currencies that are targets of carry trade strategies are more exposed to funding constraints and stock illiquidity shocks.

I provide support for the models by Brunnermeier and Pedersen (2009) and Acharya and Viswanathan (2011) and empirically document illiquidity spirals. Institutional investors' trading activity and dealers' funding constraints may turn an illiquidity shock into an illiquidity spiral with systemic effects. In times of distress, an illiquidity shock may lead institutional investors to increase their liquidity demand, whereas dealers provide less liquidity. In turn, a higher demand for liquidity coupled with a decline in liquidity supply may exacerbate the illiquidity conditions, resulting in the insurgence of illiquidity spirals.

Studies on the interaction between funding and illiquidity, and those on fire sales, have mainly focused on the recent financial crisis. However, I find that the conditions for illiquidity spirals were present at the time of the dotcom bubble crisis as well. This finding suggests that the potential for destabilizing illiquidity linkages are a common feature of markets in distress. However, there is an important exception. Indeed, I do not find evidence of illiquidity spiral conditions across markets during the European sovereign debt crisis. The provision of "official" liquidity by monetary authorities in response to the previous financial crisis may have reduced the exposure of cross-market illiquidity dynamics to "private" funding shocks.

Furthermore, there are important differences with respect to the scope of these potentially destabilizing illiquidity linkages. Possibly due to its decentralized nature, the FX market is exposed to shifts in global conditions. The analysis at a higher frequency of stock illiquidity and funding constraints suggests that the level of financial integration has increased over time, leading to more global spillovers. The dotcom crisis is a largely US-based episode with US stocks responding to shocks to US funding conditions. Conversely, in the more recent episodes, US stocks are exposed to shocks to funding constraints originating not only in the US but also in the UK. Overall, these insights on the importance of global linkages, the implications for illiquidity spirals, and the interaction with monetary policy provide a contribution to the broader discussion on global liquidity and its relevance for financial stability (IMF 2015).

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TABLE 1: Descriptive Statistics of the Illiquidity Measures

Panel A. Stock Illiquidity					
	Small	2	3	4	Large
Mean	0.0248	0.0156	0.0089	0.0051	0.0025
Median	0.0222	0.0130	0.0058	0.0026	0.0014
St. dev.	0.0097	0.0087	0.0071	0.0048	0.0024
Minimum	0.0083	0.0029	0.0016	0.0009	0.0005
Maximum	0.0661	0.0540	0.0442	0.0428	0.0363
AC	0.9719	0.9812	0.9825	0.9655	0.9254
Ave. ret.	0.0004	-0.0001	-0.0002	-0.0004	-0.0006
Ave. vol.	0.0283	0.0255	0.0252	0.0244	0.0228
Panel B. FX Illiquidity					
	AUD	CHF	EUR	GBP	JPY
Mean	0.00063	0.00046	0.00034	0.00031	0.00043
Median	0.00064	0.00042	0.00031	0.00028	0.00042
St. dev.	0.00029	0.00022	0.00020	0.00015	0.00020
Minimum	0.00009	0.00007	0.00000	0.00005	0.00008
Maximum	0.00280	0.00170	0.00140	0.00087	0.00100
AC	0.4510	0.2846	0.5607	0.5115	0.3728
Ave. ret.	0.00007	0.00008	0.00008	-0.00001	-0.00001
Ave. vol.	0.00600	0.00520	0.00490	0.00420	0.00490

Note: The table reports the mean, median, standard deviation (St. dev.), minimum, maximum, and autocorrelation (AC) of the stock (Panel A) and FX (Panel B) percentage bid-ask spreads for the sample period 1999-2014. The last two rows of each panel report the average returns (Ave. ret.) and volatility (Ave. vol.) of the measures. Stocks are sorted by market capitalization at the beginning of each year and divided in five groups. The smallest cap stocks are included in the first column (Small) and the largest cap stocks are in the last column (Large). The illiquidity of each quintile is obtained as the average across the spreads in the group. FX spreads are reported for the Australian dollar (AUD), Swiss franc (CHF), Euro (EUR), British pound (GBP), and Japanese yen (JPY).

TABLE 2: Correlation of the Illiquidity Measures

Panel A. Financial Crisis						
	Large caps	AUD	CHF	EUR	GBP	JPY
Small caps	0.54	0.52	0.28	0.37	0.54	0.28
Large caps		0.16	0.10	0.13	0.20	0.13
AUD			0.20	0.34	0.40	0.25
CHF				0.18	0.35	0.22
EUR					0.43	0.19
GBP						0.29
Panel B. Dotcom Bubble Crisis						
	Large caps	AUD	CHF	EUR	GBP	JPY
Small caps	0.64	-0.09	0.18	0.03	0.06	0.27
Large caps		-0.05	0.11	0.10	0.08	0.17
AUD			0.03	-0.01	0.05	0.02
CHF				0.18	0.15	0.30
EUR					0.07	0.17
GBP						0.13
Panel C. European Sovereign Debt Crisis						
	Large caps	AUD	CHF	EUR	GBP	JPY
Small caps	0.17	0.04	0.01	-0.02	0.01	0.19
Large caps		-0.10	0.24	0.21	0.13	0.14
AUD			-0.01	0.00	0.09	0.09
CHF				0.12	0.17	0.13
EUR					0.12	0.08
GBP						0.14

Note: The table reports the correlation coefficients of the illiquidity measures for the financial crisis episode (2007-09) in Panel A, the dotcom bubble crisis (2000-01) in Panel B, and the European sovereign debt crisis (2010-14) in Panel C. Stocks are sorted by market capitalization at the beginning of each year and divided in five groups. The illiquidity of small and large caps is obtained as the average across the spreads in the group. FX illiquidity is reported for the Australian dollar (AUD), Swiss franc (CHF), Euro (EUR), British pound (GBP), and Japanese yen (JPY).

TABLE 3: Cross-Market Illiquidity Linkages – Tests of VAR Estimations

Panel A. Financial Crisis

Correlation of VAR Innovations

	Large caps	AUD	CHF	EUR	GBP	JPY
Small caps	0.34***	0.13***	0.03	0.06	0.02	0.10**
Large caps		0.04	0.04	0.03	0.06	0.00

Granger Causality Tests (column variable non Granger causing row variable)

	Small caps	Large caps	AUD	CHF	EUR	GBP	JPY
Small caps		0.13	5.12**	0.08	2.34	4.26**	1.78
Large caps	6.17**		0.89	0.21	0.05	2.25	2.13
AUD	11.58***	0.12		0.08	0.15	0.18	0.05
CHF	1.53	0.05	0.41		0.09	0.66	1.99
EUR	2.44	1.62	0.10	1.33		3.13*	4.18**
GBP	3.53*	2.66*	0.04	0.35	0.25		0.01
JPY	1.40	0.83	1.28	0.16	0.95	0.80	

Panel B. Dotcom Bubble Crisis

Correlation of VAR Innovations

	Large caps	AUD	CHF	EUR	GBP	JPY
Small caps	0.27***	-0.05	-0.08*	-0.06	0.03	0.04
Large caps		0.02	0.09**	-0.07	-0.06	-0.03

Granger Causality Tests (column variable non Granger causing row variable)

	Small caps	Large caps	AUD	CHF	EUR	GBP	JPY
Small caps		6.59***	1.38	0.16	1.23	1.54	0.01
Large caps	16.39***		1.86	2.75*	0.57	0.50	4.20**
AUD	0.02	0.42		0.01	0.38	0.04	0.63
CHF	4.66**	14.94***	1.93		0.66	1.71	2.80*
EUR	0.05	0.00	2.84*	8.02***		0.00	1.13
GBP	1.59	0.15	0.49	0.55	1.46		0.11
JPY	1.26	3.60	0.94	2.47	0.65	0.01	

Panel C. European Sovereign Debt Crisis

Correlation of VAR Innovations

	Large caps	AUD	CHF	EUR	GBP	JPY
Small caps	0.36***	-0.04	0.04	0.02	0.06**	0.05*
Large caps		0.01	-0.02	0.04	0.06**	0.03

Granger Causality Tests (column variable non Granger causing row variable)

	Small caps	Large caps	AUD	CHF	EUR	GBP	JPY
Small caps		5.12**	0.05	0.09	1.81	0.11	11.55***
Large caps	9.13***		2.42	2.21	2.05	11.63***	4.54**
AUD	2.47	0.18		0.02	0.43	0.03	0.41
CHF	5.85**	4.75**	4.88**		0.07	0.48	2.55
EUR	2.28	0.22	0.96	1.83		2.02	0.84
GBP	0.11	3.86**	0.00	0.69	1.94		1.77
JPY	10.58***	0.03	3.89**	0.20	0.95	2.54	

Note: The table reports the correlation coefficients of VAR innovations and the $\chi 2$ statistics for the null of the column variables non Granger causing the row variables. VARs include stock and FX illiquidity, funding constraints in the US and UK, and stock and FX market volatility. Stock illiquidity is measured as the average across the 1st and 5th market cap quintiles. FX illiquidity is the bid-ask spread series for AUD, CHF, EUR, GBP, and JPY. VARs are estimated for different time periods: the financial crisis (2007-09) in Panel A, the dotcom bubble crisis (2000-01) in Panel B, and the European sovereign debt crisis (2010-14) in Panel C. VAR(1) are estimated according to the Schwarz criterion and include dummies, such as day of the week, month in a year and a time trend.

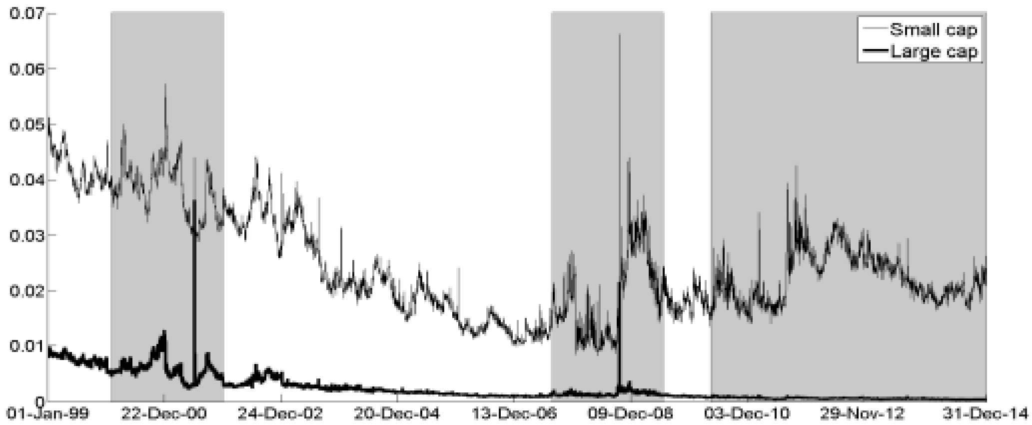
***Significant at the 1% level.

**Significant at the 5% level.

*Significant at the 10% level.

Figure I. Illiquidity Through Time. Plot A depicts the daily series of stock illiquidity for small and large caps for the sample period 1999-2014. Stocks are sorted by market capitalization at the beginning of each year and divided into five groups. Stock illiquidity for small and large caps is the average of percentage bid-ask spreads in the first and last group, respectively. Plot B shows the 2-month moving average of the percentage spreads for the AUD and JPY. Shaded areas are crisis episodes: 2000-01 for dotcom bubble crisis, 2007-09 for the recent financial crisis, and 2010-14 for the European sovereign debt crisis.

A. Stocks



B. FX

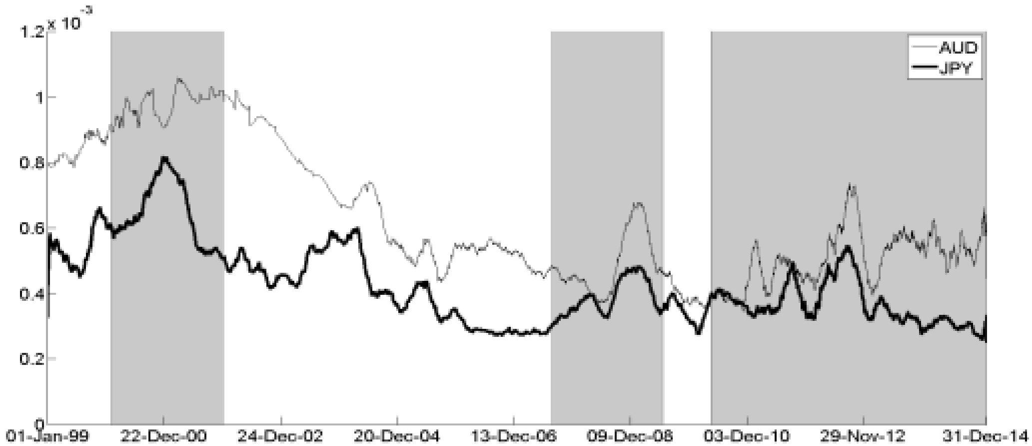
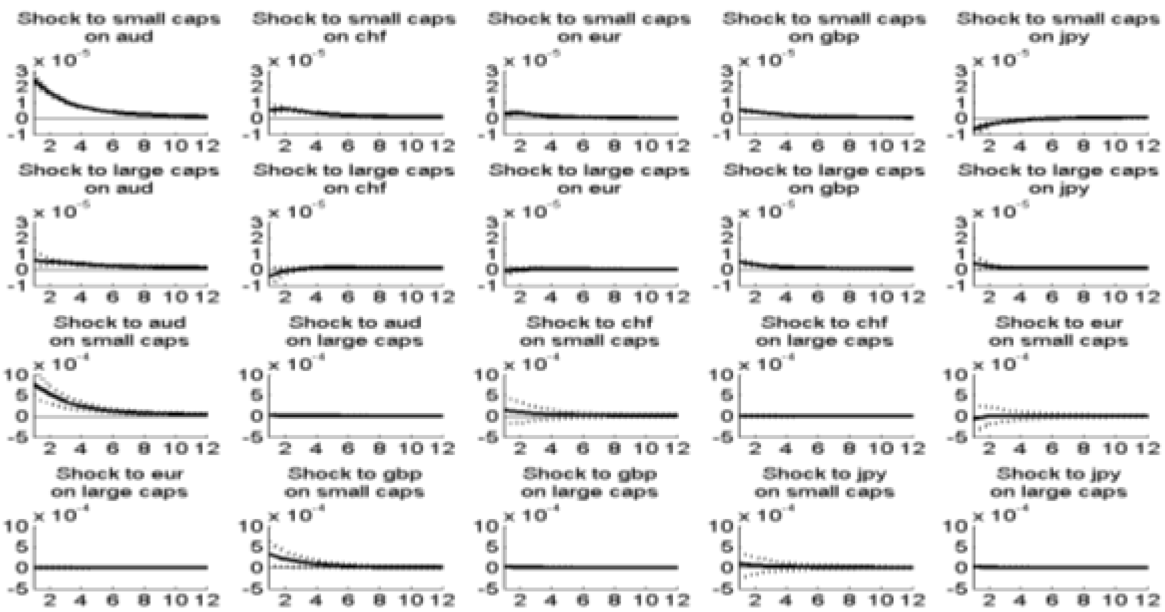
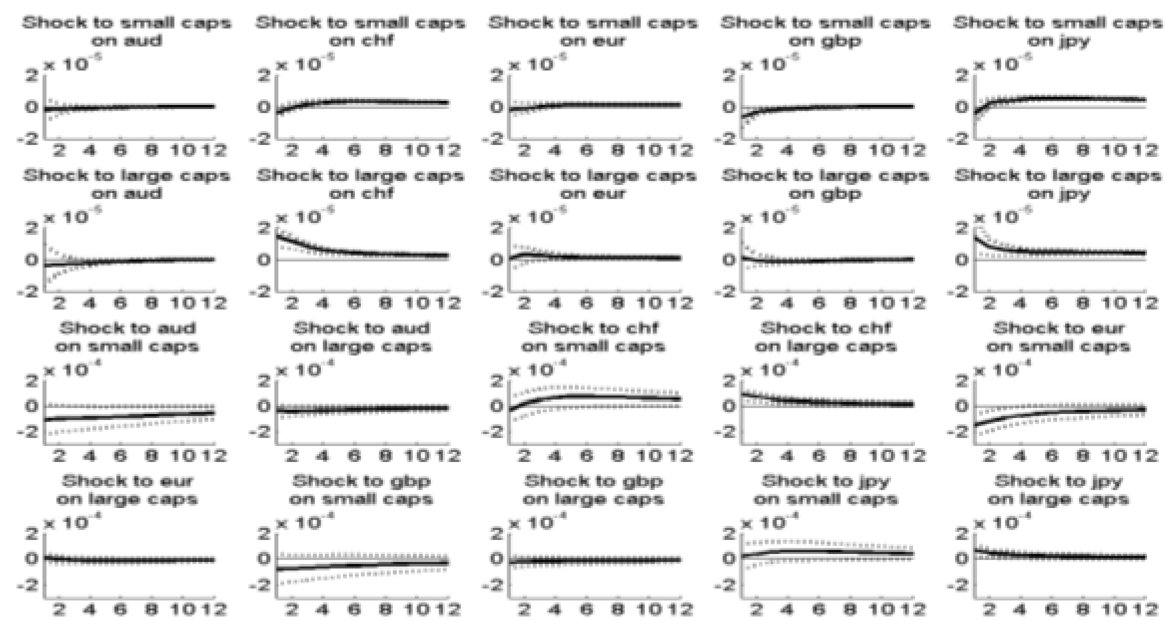


Figure II: Responses of Stock and FX Illiquidity. The solid lines are the Generalized IRFs of an endogenous variable to a one-time shock of one standard deviation to another variable. The dotted lines are bootstrap 95% confidence bands obtained with 1,000 bootstrap replications. VARs include stock and FX illiquidity together with funding constraints in the UK and US and volatility in the stock and FX markets. Panel A reports the IRFs for the recent financial crisis period (2007- 09), Panel B the dotcom bubble crisis (2000-01), and Panel C the European sovereign debt crisis (2010-14). Stocks are sorted by market capitalization at the beginning of each year and divided in five groups. Stock illiquidity for small and large caps is the average of percentage bid-ask spreads in the first and last group, respectively. FX illiquidity measures are the daily bid-ask spreads of the AUD, CHF, EUR, GBP, and JPY. VAR(1) are estimated according to the Schwarz criterion and include dummies, such as day of the week, month of the year, and a time trend.

A. Financial Crisis (2007-09)



B. Dotcom Bubble Crisis (2000-01)



C. European Sovereign Debt Crisis (2010-14)

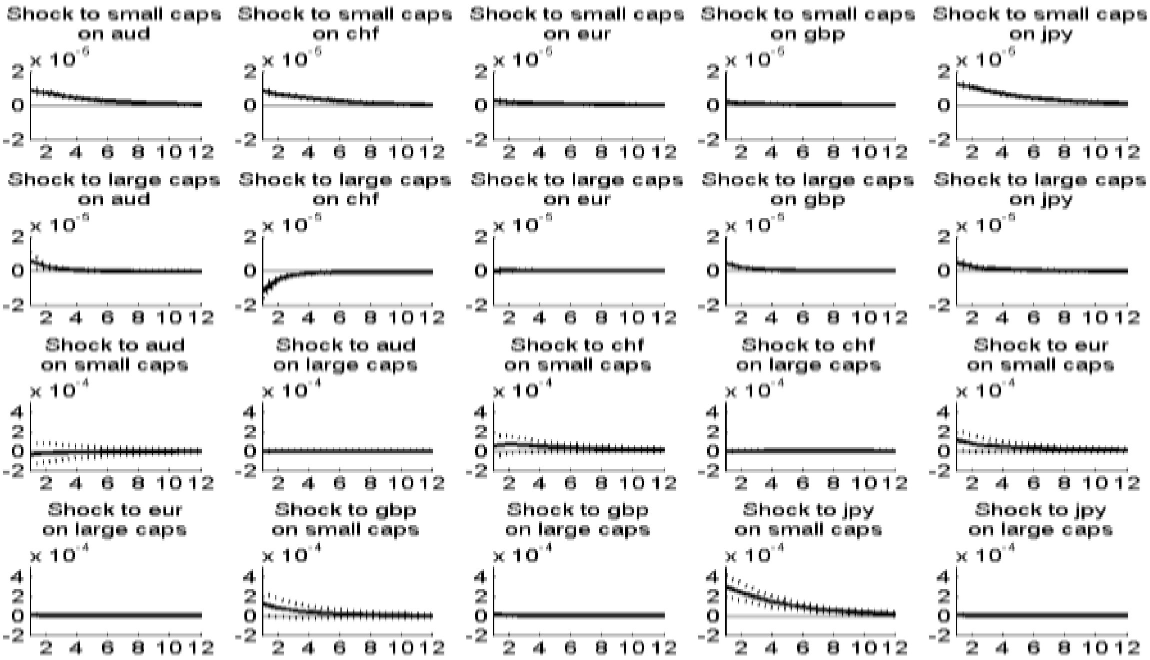
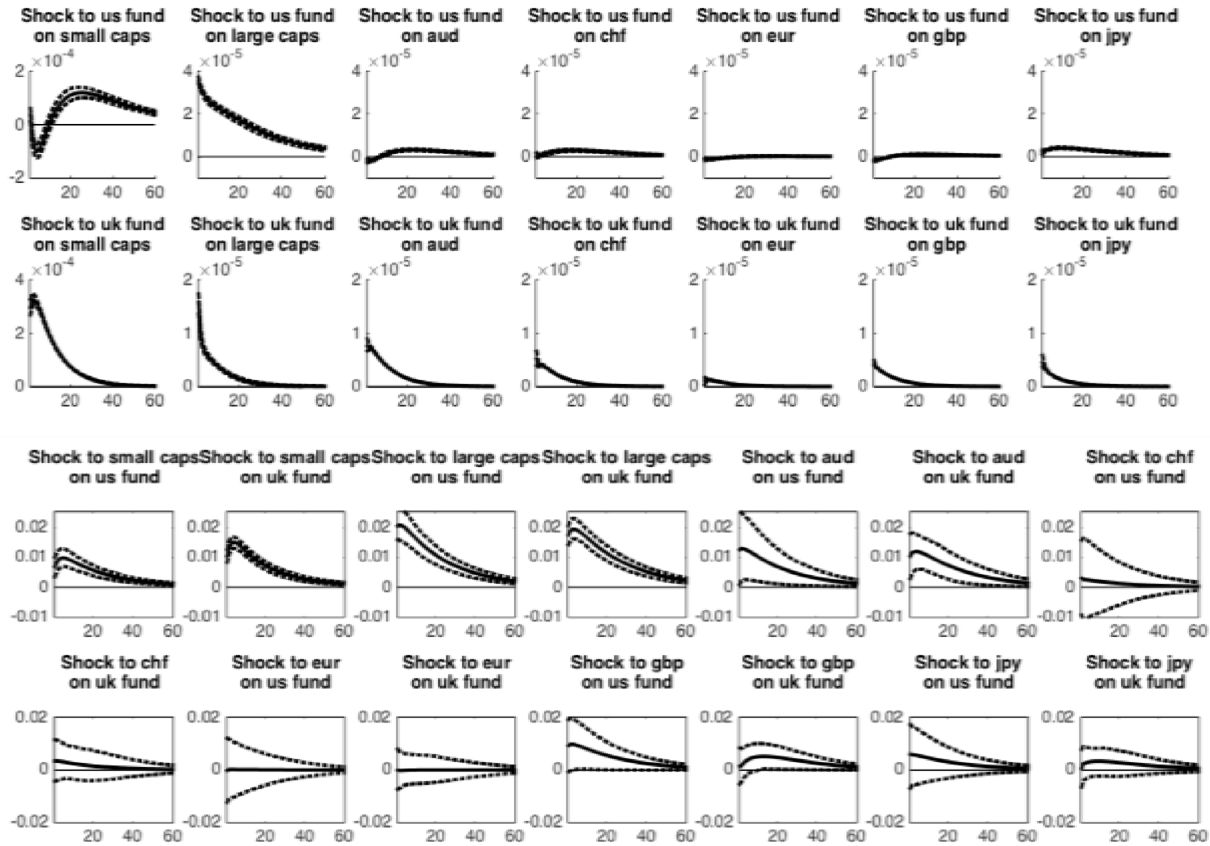
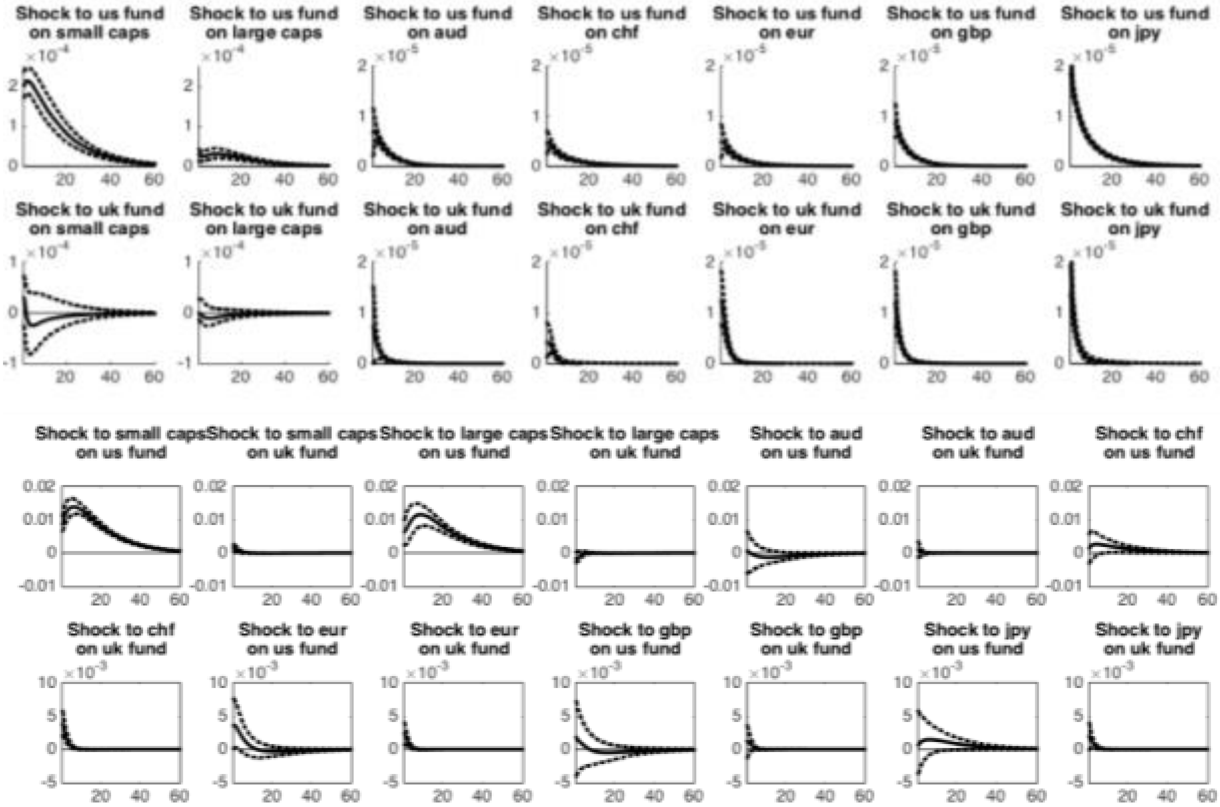


Figure III: Responses of Illiquidity and Funding Constraints. The solid lines are the Generalized IRFs of endogenous variables to a one-time shock of one standard deviation to another variable. The dotted lines are bootstrap 95% confidence bands obtained with 1,000 bootstrap replications. The VAR model includes stock and FX illiquidity, together with funding constraints in the UK and US and volatility in the stock and FX markets. Panel A reports the IRFs for the recent financial crisis period (2007-09), Panel B the dotcom bubble crisis (2000-01), and Panel C the European sovereign debt crisis (2010-14). Stocks are sorted by market capitalization at the beginning of each year and divided in five groups. Stock illiquidity for small and large caps is the average of percentage bid-ask spreads in the first and last group, respectively. FX illiquidity measures are the daily bid-ask spreads of the AUD, CHF, EUR, GBP, and JPY. Funding constraints are measured by the daily UK and US TED spreads. VAR(1) are estimated according to the Schwarz criterion and include dummies, such as day of the week, month of the year, and a time trend.

A. Financial Crisis (2007-09)



B. Dotcom Bubble Crisis (2000-01)



C. European Sovereign Debt Crisis (2010-14)

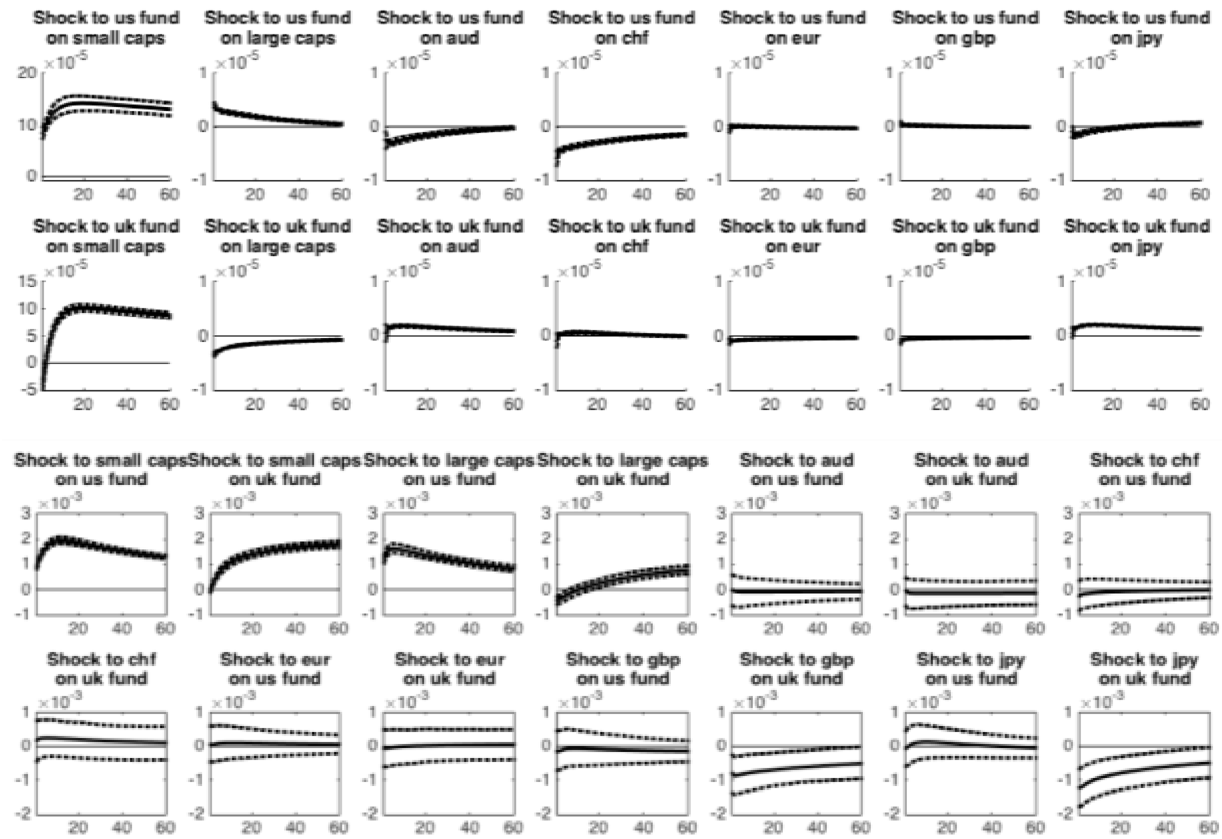


Figure IV: Responses of Illiquidity and Trading Activity. The solid line represents the Generalized IRFs of an endogenous variable of the VAR to a one-time shock of one standard deviation in another variable. The dotted lines are bootstrap 95% confidence bands obtained with 1,000 bootstrap replications. The VAR includes stock and FX illiquidity, together with institutional trading in equity and FX, US monetary policy, and stock and FX market volatility. Institutional trading is calculated as the sum of absolute inflows and outflows of mutual funds invested in US domestic equity and foreign equity, respectively. Monthly measures of illiquidity are calculated as the average daily bid-ask spreads in a month. VAR(1) are estimated according to the Schwarz criterion and include dummies, such as month of the year and a time trend.

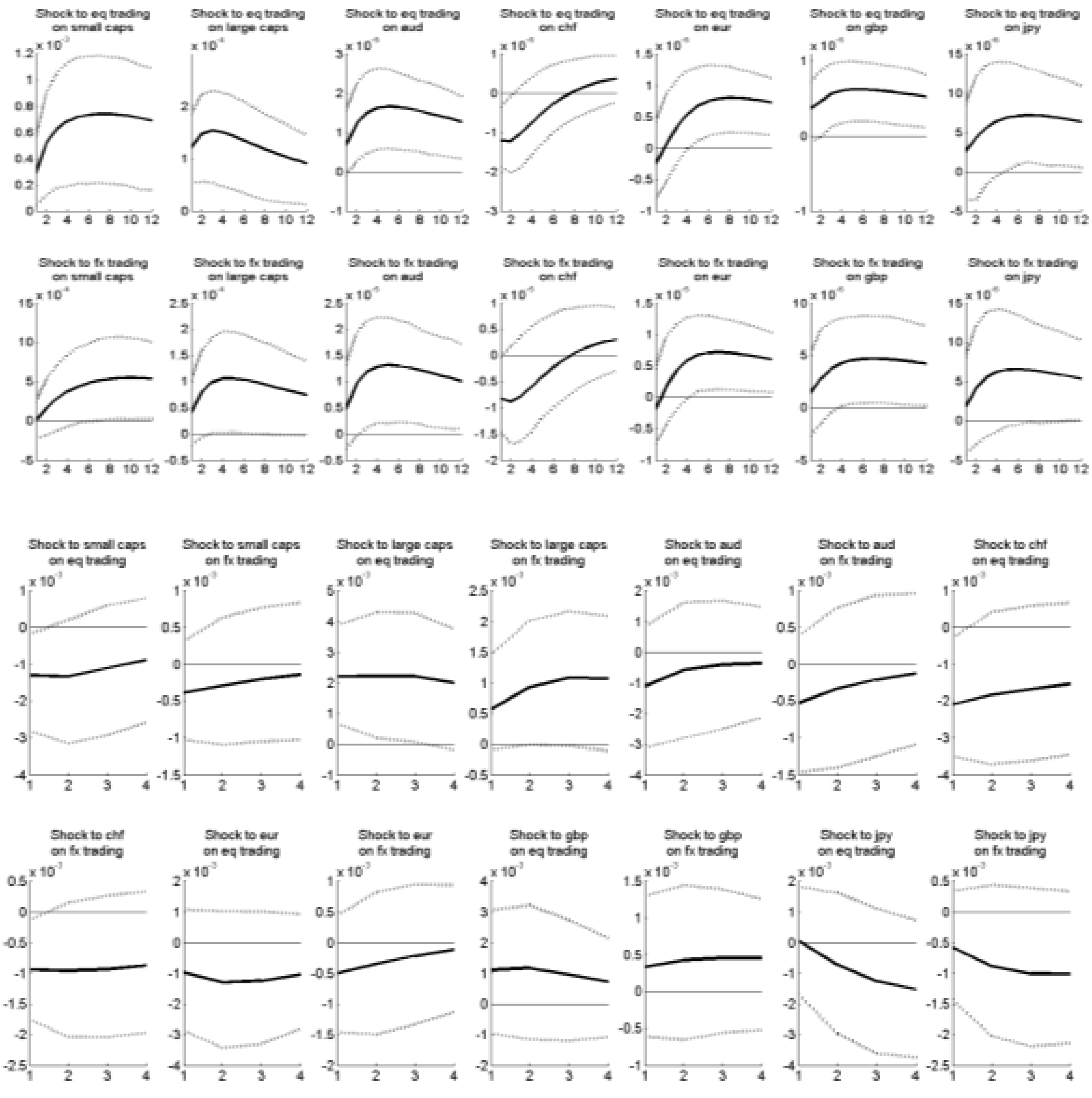


Figure V: Responses of Illiquidity to Unexpected Changes in Monetary Policy. The solid line represents the Generalized IRFs of an endogenous variable of the VAR to a one-time shock of one standard deviation in another variable. The dotted lines are bootstrap 95% confidence bands obtained with 1,000 bootstrap replications. The VAR includes stock and FX illiquidity, together with institutional trading in equity and FX, US monetary policy, and stock and FX market volatility. I measure US monetary policy via the orthogonalized non-borrowed reserves of depository institutions with the FED. Monthly measures of illiquidity are calculated as the average daily bid-ask spreads in a month. VAR(1) are estimated according to the Schwarz criterion and include dummies, such as month of the year and a time trend.