Liquidity in the Foreign Exchange Market: Measurement, Commonality, and Risk Premiums

Loriano Mancini
Swiss Finance Institute and EPFL

Angelo Ranaldo
University of St. Gallen

Jan Wrampelmeyer
University of St. Gallen

Motivation

- **Liquidity**
  - key concept (LTCM, Subprime crisis, etc.)
  - relevant for investors, central bankers, regulators, etc.
- Liquidity in equity and bond markets studied extensively
- Only very few studies on FX liquidity (paucity of data)
- Liquidity in FX market important
  - Currency traders averse to liquidity shocks
  - Liquidity spirals aggravate currency crashes
  - International diversification through FX positions typically unhedged (only about 30% of FX risk is hedged)
  - etc.
Outline

FX market

Measures of liquidity

Liquidity of individual FX rates

Commonality in liquidity

Liquidity risk premium
Foreign Exchange market

- Large market:
  - average daily turnover 4 trillion USD (BIS 2010)
  - > 10-time daily turnover global equity markets (WFE 2009)
- Large variety ofFX traders world-wide:
central bankers, institutional traders, fund managers, daily traders, etc., algorithmic
- Open 24 hours a day
- FX spot market fragmented structure with several trading venues: dealer, broker, mixed dealer-broker, over-the-counter, internet, etc.
- Two leading trading platforms:
  Electronic Broking Services (EBS) and Reuters
Electronic Broking Services (EBS)

- Electronic limit order book
- Market share $\geq 60\%$  
  ⇒ global market place for spot FX interdealer trading
- Primary trading venue for EUR/USD, USD/JPY, EUR/JPY, USD/CHF, EUR/CHF
- Dealers pre-screened for credit  
  ⇒ counterparty risk not a concern
- All EBS quotes are transactable  
  ⇒ reliably represent prevalent FX rates
- First platform to facilitate algorithmic trading in spot FX
Our EBS database

▶ Access via Swiss National Bank
▶ Tick-by-tick trades, quotes, volume indicators, signs
  ⇒ exact calculation of price impact and liquidity measures
▶ ≈ 90’000 observations each, per currency per day
▶ Sample period: from 1/2007 to 12/2009
▶ 9 FX rates: AUD/USD, EUR/CHF, EUR/GBP, EUR/JPY, EUR/USD, GBP/USD, USD/CAD, USD/CHF, USD/JPY
How EBS screen looks like

EBS

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Measures of liquidity

Liquidity has many aspects ⇒ various measures

Estimated *daily*, using *intraday* data:

1. Price impact
2. Return reversal
3. Bid-ask spread
4. Effective cost
5. Price dispersion (volatility)
6. Latent liquidity (Principal Component Analysis)
Price impact and return reversal

- **Intuition:** if currency is illiquid, net buying pressure leads
  - Excessive appreciation of the currency
  - Followed by a reversal to the fundamental value

- **Model:**
  - Regression of one-minute returns on contemporaneous and lagged imbalance order flows:

    \[
    p_t - p_{t-1} = \theta + \varphi(v_{b,t} - v_{s,t}) + \gamma(v_{b,t-1} - v_{s,t-1}) + \varepsilon_t
    \]

  - \(\varphi\) **price impact**
    - ↑ asymmetric information \(\Rightarrow\) ↑ illiquidity
  - \(\gamma\) **return reversal**
    - market maker’s inventory risk and transaction costs

- Compute benchmark liquidity measures: no need of proxies
  e.g. Amihud (2002), Pastor and Stambaugh (2003)
Trading costs and price dispersion

- **Proportional bid-ask spread** $= \frac{(P^A - P^B)}{P^M}$
  cost aspect of illiquidity

- **Effective cost** $= \begin{cases} \frac{(P - P^M)}{P^M}, & \text{for buyer-initiated trades} \\ \frac{(P^M - P)}{P^M}, & \text{for seller-initiated trades} \end{cases}$
  account for inter-quote trading

- **Price dispersion** $= \text{volatility (TSRV)}$
  $\uparrow$ volatility $\Rightarrow$ MM requires more compensation for risk

$^A$ Ask, $^B$ Bid, $^M$ Mid quote, $P$ transaction price
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Summary statistics show that

- EUR/USD, USD/JPY traded most frequently
- AUD/USD, USD/CAD traded least frequently
- Average price impact $\varphi$ positive
- Average return reversal $\gamma$ negative
- EUR/USD most liquid
- GBP/USD rather illiquid (mostly traded on Reuters)
- EUR/CHF, USD/CHF highly liquid (flight-to-quality, CHF safe haven; Ranaldo and Söderlind 2010)
- AUD, GBP depreciated, EUR, CHF, JPY appreciated vs. USD
Effective cost

Most liquid (up) and least liquid (bottom) FX rates.

Effective cost = \[
\begin{cases} 
(P - P^M)/P^M, & \text{for buyer-initiated trades} \\
(P^M - P)/P^M, & \text{for seller-initiated trades} 
\end{cases}
\]

Sign adjusted to measure liquidity. Daily base.
Cost of illiquidity: carry trade example

- U.S. investor engages in AUD-JPY carry trade:
  - borrow at low interest rate (1%) in Japan
  - invest at high interest rate (8%) in Australia
- Carry trade initiated:
  - selling JPY vs. USD
  - buying AUD vs. USD
- Unwind carry trade under two liquidity scenarios:
  - High liquidity, i.e. small bid-ask spreads:
    - 2.64bps AUD/USD, 0.90bps USD/JPY
    - cost due to illiquidity = 0.5% of profit
  - Low liquidity, i.e. large bid-ask spreads:
    - 54.03bps AUD/USD (as in 10/2008)
    - cost due to illiquidity = 10.7% of profit!
- Additional costs when FX liquidity low: usually
  - Funding currency (JPY) appreciates,
  - Investment currency (AUD) depreciates
  - Low liquidity in fixed income market too
Carry trade AUD-JPY

Cumulative AUD/USD carry trade return

Cumulative JPY/USD carry trade return

Liquidity of individual FX rates
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Commonality in liquidity

Commonality means FX liquidity is driven by shocks that affect the entire FX market rather than individual FX rates

- Is there any commonality in liquidity across FX rates?
- Consistent with liquidity spirals (Brunnermeier and Pedersen 2009)
- Unexpected shocks to market-wide liquidity affect investors, regulators, etc.
- Commonality necessary for liquidity risk premium
Market-wide liquidity

Two approaches:

1. Cross-sectional average of FX rate liquidities, $L_{j,t}$:

   $$L^M_t = \frac{1}{N} \sum_{j=1}^{N} L_{j,t}$$

   (e.g. Chordia, Roll and Subrahmanyam 2000)

2. Principal Component Analysis (PCA)
   (e.g. Korajczyk and Sadka 2008)
Latent liquidity within measure

Commonality within a liquidity measure:

- Consider one liquidity measure (e.g. effective cost), $L_{j,t}$
- **Cross-sectional** PCA, i.e. across FX rate liquidities 
  \{L_{j,t}, j = 1, \ldots, N\}
  \Rightarrow \text{Latent common factors } L_t^{(1)}, L_t^{(2)}, \ldots
- **Time series** regression for each FX rate liquidity $L_{j,t}$:
  - Regression 1: $L_{j,t} = \theta_0 + \theta_1 L_t^{(1)} + \varepsilon_{j,t}$
  - Regression 2: $L_{j,t} = \theta_0 + \theta_1 L_t^{(1)} + \theta_2 L_t^{(2)} + \varepsilon_{j,t}$
  - etc.
- Repeat above procedure for each liquidity measure
## Evidence for commonality in liquidity

<table>
<thead>
<tr>
<th>Measure</th>
<th>Factors</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>1,2</td>
<td>1,2,3</td>
<td></td>
</tr>
<tr>
<td>Return reversal ($K = 1$)</td>
<td>0.28</td>
<td>0.41</td>
<td>0.53</td>
<td></td>
</tr>
<tr>
<td>Return reversal ($K = 3$)</td>
<td>0.32</td>
<td>0.44</td>
<td>0.56</td>
<td></td>
</tr>
<tr>
<td>Return reversal ($K = 5$)</td>
<td>0.32</td>
<td>0.44</td>
<td>0.55</td>
<td></td>
</tr>
<tr>
<td>Price impact</td>
<td>0.63</td>
<td>0.74</td>
<td>0.82</td>
<td></td>
</tr>
<tr>
<td>Bid-ask spread</td>
<td>0.72</td>
<td>0.80</td>
<td>0.88</td>
<td></td>
</tr>
<tr>
<td>Effective cost</td>
<td>0.89</td>
<td>0.93</td>
<td>0.95</td>
<td></td>
</tr>
<tr>
<td>volume-weighted</td>
<td>0.90</td>
<td>0.94</td>
<td>0.96</td>
<td></td>
</tr>
<tr>
<td>Price dispersion (TSRV, 1 min.)</td>
<td>0.80</td>
<td>0.86</td>
<td>0.91</td>
<td></td>
</tr>
<tr>
<td>Price dispersion (TSRV, 5 min.)</td>
<td>0.81</td>
<td>0.86</td>
<td>0.90</td>
<td></td>
</tr>
</tbody>
</table>

**Table**: Average (across FX rates) adjusted-$R^2$. Daily base.

Similar results when only including FX rates vs. USD

$\Rightarrow$ commonality not induced by triangular relationships.
Liquidity sensitivity

- **Individual** FX rate liquidity, $L_{j,t}^{(ec)}$:
  Effective cost for FX rate $j$

- **Market-wide** liquidity measure, $L_{M,t}^{(ec)}$:
  Average across FX rates of effective costs, excluding FX rate $j$

- **Idiosyncratic** liquidity, $L_{j,t}^{(i)}$:

  $$L_{j,t}^{(ec)} = a_j + b_j L_{M,t}^{(ec)} + L_{j,t}^{(i)}$$

  i.e. residual
Liquidity sensitivity: Estimates

<table>
<thead>
<tr>
<th></th>
<th>AUD/USD</th>
<th>EUR/CHF</th>
<th>EUR/GBP</th>
<th>EUR/JPY</th>
<th>EUR/USD</th>
</tr>
</thead>
<tbody>
<tr>
<td>( b_j )</td>
<td>3.15</td>
<td>0.35</td>
<td>1.09</td>
<td>0.56</td>
<td>0.17</td>
</tr>
<tr>
<td></td>
<td>(0.066)</td>
<td>(0.005)</td>
<td>(0.023)</td>
<td>(0.007)</td>
<td>(0.003)</td>
</tr>
</tbody>
</table>

\[ R^2 = 0.76 \quad 0.85 \quad 0.76 \quad 0.90 \quad 0.81 \]

**Table**: Sensitivity to market-wide liquidity, \( b_j \), from regression:
\[ L_{j,t}^{(ec)} = a_j + b_j L_{M,t}^{(ec)} + L_{j,t}^{(i)} \]
Robust standard errors in parentheses.
Market-wide liquidity across measures

- All liquidity measures proxy **liquidity**
- Correlations up to 0.8 for weekly liquidity measures
- To extract all common information
  ⇒ PCA across liquidity measures *and* across FX rates
  (Korajczyk and Sadka 2008)
## Interpretation of market-wide liquidity

<table>
<thead>
<tr>
<th></th>
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<th>EUR/GBP</th>
<th>EUR/JPY</th>
<th>EUR/USD</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>First Principal Component loadings</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Return reversal</td>
<td>0.31</td>
<td>0.32</td>
<td>0.23</td>
<td>0.36</td>
<td>0.31</td>
</tr>
<tr>
<td>Price impact</td>
<td>0.42</td>
<td>0.46</td>
<td>0.42</td>
<td>0.46</td>
<td>0.47</td>
</tr>
<tr>
<td>Bid-ask spread</td>
<td>0.47</td>
<td>0.48</td>
<td>0.46</td>
<td>0.46</td>
<td>0.48</td>
</tr>
<tr>
<td>Effective cost</td>
<td>0.50</td>
<td>0.48</td>
<td>0.54</td>
<td>0.48</td>
<td>0.47</td>
</tr>
<tr>
<td>Price dispersion</td>
<td>0.49</td>
<td>0.45</td>
<td>0.51</td>
<td>0.45</td>
<td>0.46</td>
</tr>
<tr>
<td>cum. explained</td>
<td>72%</td>
<td>77%</td>
<td>59%</td>
<td>80%</td>
<td>80%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
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<th>EUR/GBP</th>
<th>EUR/JPY</th>
<th>EUR/USD</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Second Principal Component loadings</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Return reversal</td>
<td>0.92</td>
<td>0.93</td>
<td>0.94</td>
<td>0.92</td>
<td>0.94</td>
</tr>
<tr>
<td>Price impact</td>
<td>−0.34</td>
<td>−0.02</td>
<td>0.09</td>
<td>−0.18</td>
<td>−0.13</td>
</tr>
<tr>
<td>Bid-ask spread</td>
<td>−0.09</td>
<td>−0.15</td>
<td>−0.23</td>
<td>−0.09</td>
<td>−0.16</td>
</tr>
<tr>
<td>Effective cost</td>
<td>−0.13</td>
<td>−0.18</td>
<td>−0.15</td>
<td>−0.15</td>
<td>−0.20</td>
</tr>
<tr>
<td>Price dispersion</td>
<td>−0.06</td>
<td>−0.26</td>
<td>−0.13</td>
<td>−0.29</td>
<td>−0.13</td>
</tr>
<tr>
<td>cum. explained</td>
<td>87%</td>
<td>91%</td>
<td>77%</td>
<td>91%</td>
<td>94%</td>
</tr>
</tbody>
</table>
Liquidity: global phenomenon?

VIX = SPX implied volatility index, “fear index”
TED-spread = Interbank loans − T-bill
proxy for credit-risk and funding liquidity

Sign adjusted to measure liquidity. Daily base.
Correlation: FX liquidity-VIX −0.8; FX liquidity-TED −0.5
Evidence for liquidity spirals

Link between traders’ funding liquidity and market-wide FX liquidity.

\[ L_{FX,t}^{pca} = \text{const} + \beta_{VIX} VIX_{t-1} + \beta_{TED} TED_{t-1} + \text{error}_t \]

<table>
<thead>
<tr>
<th></th>
<th>const</th>
<th>VIX_{t-1}</th>
<th>TED_{t-1}</th>
<th>Adj. R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coeff.</td>
<td>18.94</td>
<td>-0.69</td>
<td>-1.26</td>
<td>0.76</td>
</tr>
<tr>
<td>Std. err.</td>
<td>(0.98)</td>
<td>(0.04)</td>
<td>(0.44)</td>
<td></td>
</tr>
</tbody>
</table>


When \( VIX_{t-1} \uparrow 1\sigma_{VIX} \Rightarrow L_{FX,t}^{pca} \downarrow 0.8\sigma_{FX} \)
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Liquidity of individual FX rates

Commonality in liquidity

Liquidity risk premium
Documented commonality in liquidity:

- Is liquidity risk priced in FX market?
- Investors are averse to shocks in market-wide liquidity
  E.g. Currency crashes
  (Brunnermeier, Nagel and Pedersen 2009)
  ⇒ FX liquidity risk priced
- Have shocks to market-wide liquidity a persistent impact?
Autocorrelation systematic liquidity

Price impact

Return reversal

Bid-ask spread

Effective cost

Price dispersion

Latent liquidity (PCA)
Carry trade returns

- Daily carry trade returns
  \[ r_{j,t+1}^e = i_t^f - i_t^d - \Delta p_{j,t+1} \]

- Base currency: USD

- USD appreciated > 15% vs. major currencies in 2 and 1/2 months after Lehman bankruptcy!
Risk factors for FX returns

- Liquidity risk factor, *IML*: return of portfolio long two FX rates most illiquid and short two FX rates most liquid
- Market risk factor, *AER*: Average Excess Return for U.S. investor
Carry trade and liquidity risk

Asset pricing model:

\[ r_{j,t}^e = \alpha_j + \beta_{IML,j} IML_t + \beta_{AER,j} AER_t + error_{j,t} \]

<table>
<thead>
<tr>
<th></th>
<th>JPY</th>
<th>CHF</th>
<th>EUR</th>
<th>CAD</th>
<th>AUD</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \alpha )</td>
<td>0.018</td>
<td>0.018</td>
<td>0.001</td>
<td>0.006</td>
<td>0.014</td>
</tr>
<tr>
<td></td>
<td>(0.016)</td>
<td>(0.013)</td>
<td>(0.008)</td>
<td>(0.017)</td>
<td>(0.016)</td>
</tr>
<tr>
<td>( \beta_{AER} )</td>
<td>0.608</td>
<td>1.137</td>
<td>1.093</td>
<td>0.651</td>
<td>1.050</td>
</tr>
<tr>
<td></td>
<td>(0.026)</td>
<td>(0.021)</td>
<td>(0.014)</td>
<td>(0.029)</td>
<td>(0.026)</td>
</tr>
<tr>
<td>( \beta_{IML} )</td>
<td>−0.382</td>
<td>−0.200</td>
<td>−0.091</td>
<td>0.197</td>
<td>0.330</td>
</tr>
<tr>
<td></td>
<td>(0.009)</td>
<td>(0.007)</td>
<td>(0.005)</td>
<td>(0.010)</td>
<td>(0.009)</td>
</tr>
<tr>
<td>( R^2 )</td>
<td>0.730</td>
<td>0.803</td>
<td>0.903</td>
<td>0.714</td>
<td>0.892</td>
</tr>
</tbody>
</table>

Liquidity betas and interest rate differentials

![Graph showing liquidity betas and interest rate differentials.](image)

- AUD
- CAD
- DKK
- EUR
- SEK
- NZD
- JPY
- CHF
- GBP

Liquidity risk premium
Main message

- High interest rate currencies (e.g., AUD, NZD):
  - low liquidity
  - high liquidity sensitivity
  - large positive liquidity beta, $\beta_{IML} > 0 \Rightarrow$
    - exposure to liquidity risk
    - compensation for poor liquidity

- Low interest rate currencies (e.g., JPY, CHF):
  - high liquidity
  - low liquidity sensitivity
  - large negative liquidity beta, $\beta_{IML} < 0 \Rightarrow$
    - insurance against liquidity risk
    - “insurance premium” to pay for high liquidity
Carry trade return and liquidity

Cumulative AUD/USD carry trade return

Cumulative JPY/USD carry trade return

Market-wide FX liquidity (PCA)
Conclusion

- Liquidities of individual FX rates:
  - large temporal and cross sectional variation
  - respond differently to shocks in market-wide liquidity
  - drop quickly after Lehman bankruptcy
  - recover slowly during 2009

- Strong commonality in liquidity across FX rates:
  When central bank injects liquidity in its own currency
  - Spill over effects to other currencies
  - High interest rate currencies react more
    (may boost speculation)

- Liquidity risk “priced” in FX market:
  - High interest rate currencies expose to liquidity risk
  - Low interest rate currencies insure against liquidity risk
  - Liquidity spirals trigger the mechanism