Payments, Liquidity, and Exchange Rates

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Conference: Frictions and Exchange Rates
I recently heard a high official be asked: “What is the source of Euro-dollar deposits?” His answer: U.S. current-account deficits. This answer is complete nonsense. The correct answer for both Euro-dollars deposits and US deposits) is a bookkeeper’s pen.
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M. Friedman, The Euro-Dollar Market, 1969
Motivation - International Payment System

- Daily creation of $ deposits abroad
  - Dollar liability in non-US bank (Euro-Dollar deposit) (US deposits)
**Motivation - International Payment System**

- Daily creation of $ deposits abroad
  - Dollar liability in non-US bank *(Euro-Dollar deposit)* *(US deposits)*

- Circulation of Euro-Dollar (joint liability)
  - Indispensable for int trade, goods and assets
  - Payment system *(SWIFT)* *(CHIPS)*
Motivation - International Payment System

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  - Dollar liability in non-US bank (Euro-Dollar deposit) (US deposits)

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- International Settlements:
  - need settlement assets
  - clearing (“Nostro” account @ correspondent) (Fed account)
Motivation - International Payment System

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- International Settlements:
  - need settlement assets
  - clearing ("Nostro" account @ correspondent) (Fed account)

- Potential $ settlement deficit
  - Interbank market (LIBOR) (Fed Funds)
  - Tap deficit w/ (credit line @ correspondent) (Fed discount window)
This Paper

- Implications of settlements frictions in $ and €
  - principle: interbank market unsecured
  - frictions: deviations (potentially persistent) from UIP/CIP
  - consequence: FX determination

- Study effects:
  - US and Euro monetary policies
  - Payment (volatility) and Matching (confidence) shocks
  - role of $ transaction size
Equilibrium Bank Currency Balances

ISO-basis:

\[ L \left( \mu, \mu^*, \Theta^{tech}, \Theta^{pol} \right) = R^m - R_{*,m} \]

Dollar Liquidity Premium

Euro Safe Real Return

Dollar Real Return

subject to (normalized) liquid asset budget:

\[ \mu (1 - \nu^*) + \mu^* \nu^* = 1 - \Lambda \]

\[ \mu = \frac{\text{€ reserve}}{\text{€ deposit ratio}} \]

\[ \mu^* = \frac{\text{$ reserve}}{\text{$ deposit ratio}} \]

\[ \Lambda = \frac{\text{illiquid assets}}{\text{total deposit}} \]

\[ \nu^* = \frac{\text{$ deposit}}{\text{total deposit}} \]

▶ At and away from steady state
Main Results II - FX Determination

Classic FX Determination

\[ e = \frac{p^\varepsilon}{p^\$} = \frac{M}{\mu(1 - \nu^*)} = \frac{M^*}{\mu^* \nu^*} = \frac{\text{(nominal / real } \varepsilon \text{ balances)}}{\text{(nominal / real } \$ \text{ balances)}} \]

- lop
- quantity equations
Main Results II - FX Determination

Classic FX Determination

\[
e = \frac{p^\epsilon}{p^\$} = \frac{\frac{M}{\mu(1-\nu^*)}}{\frac{M^*}{\mu^*\nu^*}} = \frac{(\text{nominal / real } \epsilon \text{ balances})}{(\text{nominal / real } \$ \text{ balances})}
\]

▶ Quantity-Theory-Like Equations (Lucas, ’82)
Main Results II - FX Determination

Classic FX Determination

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- Quantity-Theory-Like Equations (Lucas, ’82)

- Novelty
  - money demand depends on \( \mathcal{L} \)
  - determination if currencies imperfect substitutes
    - e.g. unless (permanent) satiation in both
  - individual bank: portfolio indifferent always
US Basis and Spot FX

- (recent) correlation between $L$ and $e$

Figure 1: U.S. dollar broad index and the cross-currency basis

Courtesy of: Stefan Avdjiev, Wenxin Du, Catherine Koch and Hyun Song Shin
Why is this Important?

- Empirical Evidence of Persistent $UIP/CIP deviation
  - Jiang-Krishnamurthy-Lustig, Engel-Wu

- Importance to connect to International Puzzles
  - Gabaix-Maggiori, Itshoki-Muhkin

- Empirical Research - calls for liquidity consideration
  - Alvarez-Atkeson-Kehoe, Backus-Gavazzoni-Telmer-Zin

- Connects with payments/exorbitant privilege/micro-structure literature
  - Evans-Lions, Gopinath-Gourinchas, Gourinchas-Rey, Gopinath-Stein, Lane-Shambaugh

- Alternative to limit-to-arbitrage theories
  - Gabaix-Maggiori, Amador-Bianchi-Boccola-Perri, Stein
AGENDA

- steady-state analysis
  - different regimes (satiation in 0,1,2 currencies)

- comparative statics:
  - trading technology, policy rates, size effect
Payments - Single Currency
Single Currency Bank - BB Model

- Competitive, Free-entry, No Equity

<table>
<thead>
<tr>
<th>Assets</th>
<th>Liabilities</th>
</tr>
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<tbody>
<tr>
<td>$m$</td>
<td>$d$</td>
</tr>
<tr>
<td>$b$</td>
<td></td>
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</tbody>
</table>

- Budget constraint:

$$m + b = d$$

- Real returns:

$$R^x_{t+1} = \frac{1 + i^x_{t+1}}{1 + \pi_{t+1}} \text{ for } x \in \{b, d, m\}$$
PORTFOLIO w/ SETTLEMENT FRICTIONS

- Bank Objective

\[ \Pi = \max_{\{m,b,d\}} \left( R^b \cdot b + R^m m - R^d d \right) + \mathbb{E} [\chi(s) | \theta] \]

subject to \( m, b, d \geq 0 \) and \( m + b = d \).

- Settlement balance

\[ s = \begin{cases} 
  m + \delta d \text{ pr. } 1/2 \\
  m - \delta d \text{ pr. } 1/2 
\end{cases} \]

- \( \chi \) given by:

\[ \chi(s) = \begin{cases} 
  \chi^- s & \text{if } s \leq 0 \\
  \chi^+ s & \text{if } s > 0 
\end{cases} \]

- \( b \) is illiquid, \( d \) circulates, \( m \) settles,

  - \( \chi \) “settlement cost”
Timeline - Settlements

- Portfolio Choices ($m, b, d$)
- Withdrawal Shock
- OTC Interbank Market ($\bar{R}, \psi^+, \psi^-$)
- End of Settlements
- Average Market Payouts ($\chi^+, \chi^-$)
Microfoundation - Intermediation Cost

- Dynamic OTC model of Bianchi and Bigio (2017)

- Sequential search for reserves:
  \[ \theta_t \equiv \frac{\delta D - M}{\delta D + M} = -\frac{S^-}{S^+} \]
  Interbank market tightness

- Clearing:
  \[ \psi_t^- (\theta_t) \cdot S^- = \psi_t^+ (\theta_t) \cdot S^+ \]
Dynamic OTC model of Bianchi and Bigio (2017)

Sequential search for reserves:

\[ \theta_t \equiv \frac{\delta - \frac{M}{D}}{\delta + \frac{M}{D}} = -\frac{S^-}{S^+} \]

Interbank market tightness

Clearing:

\[ \psi_t^- (\theta_t) \cdot S^- = \psi_t^+ (\theta_t) \cdot S^+ \]
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Interbank market tightness

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Microfoundations - Intermediation Cost

B^−  |  B^+  
---|---
Balances
MICROFOUNDA TION - INTERMEDIATION COST

Balances

B^-

B^+

Balances
MICROFOUNDATION - INTERMEDIATION COST

\[ \text{Balances} \]

\[ B^- \quad B^+ \]

Diagram illustrating the concept of Microfoundation - Intermediation Cost with a horizontal axis labeled 'Balances' and two vertical bars representing 'B-' and 'B+'.
MICROFOUNDATION - INTERMEDIATION COST

Balances

B^-

B^+

Balances
MICROFOUNDATION - INTERMEDIATION COST

B<sup>-</sup>  B<sup>+</sup>  Balances
# Microfoundation - Intermediation Cost

## Liquidity Yields

**Policy Spread:**

\[ \Delta R \equiv R^{dw} - R^m \]

**Penalty Rate**

\[ \psi^+ (\bar{R} - R^m) \text{ and } \psi^- (\bar{R} - R^m) + \Delta R (1 - \psi^-) \]

Average liquidity yields:
Microfoundation - Intermediation Cost

Liquidity Yields

Explicit Solution

\( \chi^{-}(\theta) = \Delta R \cdot \frac{(\theta + (1 - \theta) \exp(\lambda))^{1/2} - \theta}{(1 - \theta) \exp(\lambda)} \)

\( \chi^{+}(\theta) = \Delta R \cdot \frac{\theta (\theta + (1 - \theta) \exp(\lambda))^{1/2} - \theta}{(1 - \theta) \exp(\lambda)}. \)
### Yields Equilibrium Rates

#### Liquidity Premia

**Illiquid Asset:**

\[ R^b = R^m + \frac{1}{2} \left[ \chi^+ + \chi^- \right] \]

**Illiquid Liability:**

\[ R^d = R^m + \frac{1}{2} \left[ \chi^+ + \chi^- \right] - \frac{\delta}{2} \left[ \chi^- - \chi^+ \right] \]

**Average Interbank Rate:**

\[ \bar{R} = R^m + \frac{\chi^+}{\psi} \]
YIELDS EQUILIBRIUM RATES

Liquidity Premia

Illiquid Asset:

\[ R^b = R^m + \frac{1}{2} \left( \chi^+ + \chi^- \right) \]

Illiquid Liability:

\[ R^d = R^m + \frac{1}{2} \left( \chi^+ + \chi^- \right) - \frac{\delta}{2} \left( \chi^- - \chi^+ \right) \]

Average Interbank Rate:

\[ \bar{R} = R^m + \frac{\chi^+}{\psi^+} \]

- Liquidity premia like “risk” premia, \( \{ \chi^+, \chi^- \} \)
- **NOT:** risk aversion, Lagrange multiplier (limit to arb)
- **YES:** currency payment size, settlement technology, policy variables
ADD SEMI-LIQUID ASSET

Portfolios Choices \((m, b, d)\)
Withdrawal Shock
OTC Interbank Market \((\bar{R}, \psi^+, \psi^-)\)
End of Settlements
Average Market Payouts \((\chi^+, \chi^-)\)

Trade
Semi-Liquid Asset
YIELDS EQUILIBRIUM RATES

Liquidity Premia

Illiquid Asset:

\[ R^b = R^m + \frac{1}{2} [\chi^+ + \chi^-] \]

Illiquid Liability:

\[ R^d = R^m + \frac{1}{2} [\chi^+ + \chi^-] - \frac{\delta}{2} [\chi^- - \chi^+] \]

Average Interbank Rate:

\[ \bar{R} = R^m + \frac{\chi^+}{\psi^+} \]

Semi-Liquid Asset:

\[ R^l = R^m + \chi^+ \]
Equilibrium System \{P, D, R^d, B, R^b, \theta\}

Reserve Tightness:

\[ \theta \equiv \frac{\delta - \mu}{\delta + \mu} \]
Equilibrium Determination

Equilibrium System \( \{ P, D, R^d, B, R^b, \theta \} \)

Reserve Tightness:

\[
\theta \equiv \frac{\delta - \mu}{\delta + \mu}
\]

Demand Supply System

\[
d = \Theta^d \left( R^d \right)^{\varepsilon_d}
\]

\[
b = \Theta^b \left( R^b \right)^{\varepsilon_b}
\]
Equilibrium Determination

Equilibrium System \( \{ P, D, R^d, B, R^b, \theta \} \)

Reserve Tightness:

\[ \theta \equiv \frac{\delta - \mu}{\delta + \mu} \]

Demand Supply System

\[ d = \Theta^d \left( R^d \right)^{\varepsilon_d} \]

\[ b = \Theta^b \left( R^b \right)^{\varepsilon_b} \]

\[ R^d = R^m + \frac{1}{2} \left[ (1 + \delta) \chi^+(\theta) + (1 - \delta) \chi^-(\theta) \right] \]

\[ R^b = R^m + \frac{1}{2} \left[ \chi^+(\theta^*) + \chi^-(\theta^*) \right] \]
EQUILIBRIUM DETERMINATION

Equilibrium System \(\{P, D, R^d, B, R^b, \theta\}\)

Reserve Tightness:

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\[
R^b = R^m + \frac{1}{2} \left[ \chi^+ (\theta^*) + \chi^- (\theta^*) \right]
\]

Budget Constraint:

\[
b + m = d
\]
**Equilibrium Determination**

**Equilibrium System \( \{ P, D, R^d, B, R^b, \theta \} \)**

**Reserve Tightness:**

\[
\theta \equiv \frac{\delta - \mu}{\delta + \mu}
\]

**Demand Supply System**

\[
d = \Theta^d \left( R^d \right)^{e_d}
\]

\[
b = \Theta^b \left( R^b \right)^{e_b}
\]

\[
R^d = R^m + \frac{1}{2} \left[ (1 + \delta) \chi^+(\theta) + (1 - \delta) \chi^-(\theta) \right]
\]

\[
R^b = R^m + \frac{1}{2} \left[ \chi^+(\theta^*) + \chi^-(\theta^*) \right]
\]

**Budget Constraint:**

\[
\Lambda + \mu = 1
\]
Equilibrium System \( \{ P, D, R^d, B, R^b, \theta \} \)

Reserve Tightness:

\[
\theta \equiv \frac{\delta - \mu}{\delta + \mu}
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Demand Supply System

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d = \Theta^d \left( R^d \right)^{\epsilon_d}
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\]

\[
R^b = R^m + \frac{1}{2} \left[ \chi^+ (\theta^*) + \chi^- (\theta^*) \right]
\]

Price Determination:

\[
\frac{M}{P} = \mu
\]
Payments - Two Currency World

(Steady States)
ENVIRONMENT

- Time: $t$, discrete, infinite horizon
  - portfolio stage
  - settlement stage

- Deterministic Environment

- One good:
  \[ P_t = P^*_t e_t \]

- $P_t$ denominated in €, $P^*_t$ denominated in $\$
  - * dollar denominated objects
Agents

- Representative Household
  - quasi-linear $U$
  - saves deposit in $\$\,$ and €
  - CIA in corresponding currency

- Multinational Firms
  - borrows in $\$\,$ and €

- Global Banks
  - issue loans and deposits (both currencies)
  - hold dollar and Euro reserve assets
  - zero profits
Global Asset Demand System

Asset Demand System

\[
\frac{D}{P} = \Theta_t^D \left( R^D_{t+1} \right)^{\epsilon^D} \\
\frac{D^*}{P^*} = \Theta_t^{D,*} \left( R^D_{t+1} \right)^{\epsilon^{D,*}} \\
\frac{B}{P} = \Theta_t^B \left( R^B_{t+1} \right)^{\epsilon^B} \\
\frac{B^*}{P^*} = \Theta_t^{B,*} \left( R^B_{t+1} \right)^{\epsilon^{B,*}}
\]

- **important**
  - deposits not perfectly elastic
  - add “non-separable” goods, inter-currency elasticity
RATES OF RETURN

- Dollar Loans, Deposit, and Reserves:

\[ R_{t+1}^{x,*} = \frac{1 + i_{t+1}^{x,*}}{1 + \pi_{t+1}^{*}} , \quad \text{for } x \in \{b, d, m\} \]

- Euro Loans, Deposit, and Reserves:

\[ R_{t+1}^{x} = \frac{1 + i_{t+1}^{x}}{1 + \pi_{t+1}} , \quad \text{for } x \in \{b, d, m\} \]
Instantaneous profits:

\[ \Pi = \sum_{x \in \{b,-d,m\}} R_{t+1}^x \cdot x_t + \mathbb{E}[\chi_t | \theta_t] + \sum_{x \in \{b,-d,m\}} R_{t+1}^{x,*} \cdot x_t^* + \mathbb{E}[\chi_t^* (s_t^*)] \]

where

\[ s_t = \begin{cases} m_t + \delta d_t \text{ pr. } 1/2 \\ m_t - \delta d_t \text{ pr. } 1/2 \end{cases} \quad \text{and} \quad s_t^* = \begin{cases} m_t^* + \delta^* d_t^* \text{ pr. } 1/2 \\ m_t^* - \delta^* d_t^* \text{ pr. } 1/2 \end{cases} \]
Settlement Stage

- OTC in own currency

- Trade in FX market, but...
  - borrowing a Euro for $ settlement not useful
  - timing matters
**Central Bank Policy**

- **Instrument #1: corridor rates**
  \[
  \left\{ i^m, i^{dw} \right\} \text{ and } \left\{ i^{m*}, i^{dw} \right\}
  \]

- **Instrument #2: money supply**
  \[
  \{ M, M^* \}
  \]

- **Budget constraint in each CB:**
  \[
  M_{t+1} + T_t + \Psi_t = M_t (1 + i^m_t)
  \]

- **$T$ lump sum taxes/transfers to households**
  - $\Psi_t$ CBs operating profits
  - CB can choose $\{ M_t, i^m, i^{dw} \}$, then choose $T_t$ to balance
  - absent OMOs
Trading Frictions and Policy Regimes
Timeline - FX during Portfolio Stage

- No FX
- FX
- No FX

Portfolio Choices ($m^*, b^*, d^*, m, b, d$)
Withdrawal Shock
OTC Interbank Market ($\bar{R}, \Psi^+, \Psi^-$)
End of Settlements
Average Market Payouts ($\chi^+, \chi^-$)
Timeline - FX after $\delta$

- No FX
- FX
- No FX

Portfolio Choices: $(m^*, b^*, d^*, m, b, d)$
Withdrawal Shock
OTC Interbank Market: $(\bar{R}, \Psi^+, \Psi^-)$
End of Settlements
Average Market Payouts: $(\chi^+, \chi^-)$
Timeline - FX during Settlement

No FX  FX  No FX

Portfolio Choices  Withdrawal Shock  OTC Interbank Market  End of Settlements  Average Market Payouts

$(m^*, b^*, d^*, m, b, d)$  $\overline{R}, \Psi^+, \Psi^-$  $(\chi^+, \chi^-)$
Satiation

\[ R^{dw} = R^m \text{ or } \mu > \delta \]

Effect:

\[ \chi^+ = \chi^- = 0. \]

Three Regimes

- satiation in both currencies, one currency, neither currency
**Definition**

[Kareken Wallace Interdeterminacy] KW equilibrium:

- Classic Monetary Economics:
  \[
  \frac{e_t}{e_{t+1}} R^m = R_{m,*}^* = \frac{e_t}{e_{t+1}} R^d = R_{d,*}^* = \frac{e_t}{e_{t+1}} R^b = R_{b,*}^*
  \]

- Interest Rate Differential
  \[
  i^m - i_{m,*}^* = \frac{e_t}{e_{t+1}}.
  \]

- Kareken-Wallace (Level) indeterminacy:
  \[
  \frac{M}{P} + \frac{M^*}{P^*} = \text{Real Savings} - \text{Real Credit}.
  \]
## Cases

- **FX Determinacy and Basis?**

<table>
<thead>
<tr>
<th></th>
<th>Satiation</th>
<th>Portfolio Stage</th>
<th>+Post $\delta$</th>
<th>+Settlement Stage</th>
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<td><strong>Neither</strong></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>KW</td>
</tr>
<tr>
<td>€</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>No Equilibrium</td>
</tr>
<tr>
<td>$&amp;$ €</td>
<td>KW</td>
<td>KW</td>
<td>KW</td>
<td>KW</td>
</tr>
</tbody>
</table>


Assume (for now) Euros are Satiated

- No FX after withdrawals

Operates as two independent versions of single currency model:

\[ R^m + \frac{1}{2} \left[ \chi^+ (\theta) + \chi^- (\theta) \right] = R^{m,*} + \frac{1}{2} \left[ \chi^+ (\theta^*) + \chi^- (\theta^*) \right] \]

tightness:

\[ \theta^* = -\frac{\mu^* - \delta^*}{\mu^* + \delta^*} \quad \text{and} \quad \theta = -\frac{\mu - \delta}{\mu + \delta} \]

- \( R^b = R^{b,*} \)

- deposits as before
  - exchange rate? YES!
Euros are Satiated
  ▶ No FX after withdrawals

Then Euro is illiquid assets:

\[ R^{b,*} = R^b = R^d = R^m = R^{m,*} + \frac{1}{2} \left[ \chi^+ (\theta^*) + \chi^- (\theta^*) \right] \]

where $\theta^*$ tightness is:

\[ \theta^* = -\frac{\mu^* - \delta^*}{\mu^* + \delta^*} \]

$\mu$ deposit rate, same as before
  ▶ Exchange Rate Determination? YES!
Inelastic Asset Supply | FX Determination
Trade pattern

sell the currency you are long in
Interrelated Model:

\[ R^m + \frac{1}{2} \chi^+ (\theta) = R^{m,*} + \frac{1}{2} \chi^+ (\theta^*) \]

but extra equation:

\[ \chi^+ (\theta) - \chi^+ (\theta^*) = \chi^- (\theta) - \chi^- (\theta^*) \]

where $\$ tighness is:

\[ \theta^* = -\frac{\mu^* + \tau + \frac{1}{2} \mu - \delta^*}{\mu^* - \frac{1}{2} \mu + \delta^*} \]
\[ \theta = -\frac{\mu - \tau + \frac{1}{2} \mu^* - \delta}{\mu - \frac{1}{2} \mu^* + \delta} \]

where $\tau$ is ex-post trade that guarantees both conditions.
Assume Euros are Satiated
   - Euro traded after withdrawal

Equilibrium works like semi-liquid asset

\[ R^{b,*} = R^b = R^d = R^{m,*} + \frac{1}{2} \left[ \chi^+ (\theta^*) + \chi^- (\theta^*) \right] > R^m = R^{m,*} + \chi^+ (\theta^*) \]

but now tightness is:

\[ \theta^* = -\frac{\mu^* + \frac{1}{2} \mu - \delta}{\mu^* - \frac{1}{2} \mu + \delta}. \]

Intuition: deficit side sells Euros, in exchange for dollars
**Inelastic Asset Supply | FX after δ**

![Graph showing Iso-Dollar Premium (R^m - R^{m*}) (BPS)](image-url)

The graph illustrates the relationship between 

\[
\mu^* \nu^* + \mu (1 - \nu^*) = \text{Liquid Funds}
\]
Comparative Statics
Comparative Statics

- simplest case:
  - inelastic assets (not important)
  - timing: trade after $\delta$
  - satiation in Euros (simples case)
**EURO SATIATION - TECHNOLOGY SHOCKS**

![Graphs](image-url)
EURO SATIATION - POLICY SHOCKS
Euro Satiation - Dollar Size Effect
Conclusion

- Presented a theory liking UIP deviation to FX
CONCLUSION

- Presented a theory liking UIP deviation to FX

- Comparative Statics

- Working on ways to discriminate shocks
  - we are linking UIP deviations to FX
  - function of bank balances