International Monetary Equilibrium with Default

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Outline

- Motivation
- Model
- Propositions
- Numerical Example
- Comparative Statics
- Extensions
The Crisis of 1929

- Speculation in housing and stock market so
- Fed tightened money supply

Figure: Why Money Matters, Friedman, WSJ, 17-Nov-06
The Crisis of 2007

In our view

- Procyclicality of Monetary Policy created conditions for crisis
- Leverage Cycle (Geanakoplos 2003) amplified severity
The Crisis of 2007: Tightening Liquidity
The Crisis of 2007: Supported by Capital Inflow
Transmission of crisis from a single sector of the UK to global economy demands relationship be understood in an international context.

- Orthodoxy in international finance literature primarily rested on studying transmission of domestic shocks via PPP (nominal or real frictions - Mundell-Fleming, Obstfeld Rogoff) and Current Account.
- No room to study liquidity or default as no nominal price effects (the classical dichotomy).
- Macroeconomic effects of asset accumulation, default and regulation are ad-hoc at best.
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The predictions of IMED consistent with recent financial events without any ad-hoc assumptions to supplement the model.

- Lower short term rates transmit to lower long term yields domestically, higher leverage globally, and when short term rates rise, higher default.

- Predictions of terms of trade moving against home country, higher asset prices and subsequently higher default globally are consistent with stylized facts.
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**IMED**

Has non-trivial 1) QTM, 2) Term Structure, 3) Fisher Effect, 4) PPP, 5) UIP and 6) Default propositions.

- **IMED** provides coherent framework to analyse international effects of monetary policy and hence liquidity, prices and hence trade, default and hence regulation.
- Captures foundations of full-bodied monetary general equilibrium model of agent optimisation, rational expectations, market clearing and positive nominal interest rates and value for money (and hence nominal determinacy).
- In IMED monetary policy affects interest rates, that in turn affects the cost of repayment and hence default rates, that then affect the relative attractiveness of assets.

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Extends Geanakoplos and Tsomocos (2002) to uncertainty, incomplete markets and endogeneous default (Shubik and Wilson, 1977 and Dubey et al., 2005) and as a result combines international trade with asset pricing and finance.


- Easily computable and readily adapted to allow for institutional realism by allowing for an explicit banking system (Tsomocos, 2003, and Goodhart et al., 2006), fiscal policy, government budget constraints or regional trade blocs.
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International Monetary Economy

- $t \in T = \{0, 1\}$ time horizon.
- $s \in S = \{1, \ldots, S\}$ states of nature.
- State 0 occurs in period 0, while in period 1 nature chooses $s \in S$ states of nature. $s \in S^* = 0 \cup S$
- Countries $c \in C = \{1, 2, \ldots, C\}$. Where $\alpha \in C$ we denote another country as $\beta \in C \neq \alpha$.
- $\gamma \in C$ set of governments.
- $h \in H$ set of agents in the international monetary economy.
- Each agent $h \in H = \bigcup_{\alpha \in C} H^\alpha$ belongs to a country.
- $l \in L = \{1, 2, \ldots, L\}$ perishable commodities exist in the international economy and cannot be inventoried between periods.
- We also associate each commodity with a single country, and we write for example $l \in L^\alpha$.
- The commodity space can be viewed as $\mathbb{R}^{S^* \times L}$ whose axes are indexed by $S^* \times L$. 
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International Monetary Economy

- \( e^h_s = e^h_{sl} \in \mathbb{R}^{S^* L} \) endowment vector for agent \( h \in H^\alpha \) in state \( s \).
- Each asset \( A^j \) for \( j \in J = \{1, \ldots, J\} \) is an \((A, \lambda, Q)\) triple and is an \((L + C) \times S\) dimensional vector whose sth components \((A^j_1, \ldots, A^j_L, \ldots, A^j_\alpha, \ldots, A^j_C)\) represents the amount \( A^j_{sl} \) of commodity \( l \in L \) and the money of country \( \alpha \in C \), \( A^j_{s\alpha} \), due in state \( s \in S \).
- The private monetary endowment from Country \( \alpha \) in state \( s \in S^* \) belonging to agent \( h \) is \( m^h_{s\alpha} \).
- \( u^h : \mathbb{R}^{S^* L} \to \mathbb{R} \) utility function of agent \( h \in H \).
- \( U^h(w^h) = u^h(x) - \sum_{j \in J} \sum_{s \in S^*} \lambda^h_s \frac{[\phi^h_j A^j_{s\alpha} - D^h_j]_+}{p_s v_s} \). This is the final payoff to each agent of his optimising decisions.
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- The private monetary endowment from Country $\alpha$ in state $s \in S^*$ belonging to agent $h$ is $m^h_{s\alpha}$.
- $u^h : R^{S \times L}_+ \rightarrow R$ utility function of agent $h \in H$.
- $U^h(w^h) = u^h(x) - \sum_{j \in J} \sum_{s \in S^*} \lambda^h_s [\phi^h_j A^j_{s\alpha} - D^h_j]^{+}_{p_s v_s}$. This is the final payoff to each agent of his optimising decisions.
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Time Line

First Period
1. First Period Money Market Opens
2. Foreign Exchange Market
3. Asset Market
4. Goods Market
5. First Period Money Market Closes

Second Period, State $s$
6. Second Period Money Market Opens
7. Asset Market Deliveries
8. Foreign Exchange Market
9. Goods Market
10. Second Period Money Market Closes

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Definition of Equilibrium

\((\eta, (\sigma^h)_{h \in H})\) is an **International Monetary Equilibrium with Default (IMED)** for the world economy \(E = ((u^h, e^h, m^h)_{h \in H}, M^\gamma, \mu^\gamma)_{h \in H}, \gamma \in C \) iff:

1. \((\sigma^h) \in \text{Argmax}_{\sigma^h \in B(\eta)} U(x^h).

**Agents optimise**

2. \(p_{sl} \sum_{h \in H^\alpha} q_{sl}^h = \sum_{h \in H} b_{sl}^h + \sum_{\gamma \in C} M_{sl}^\gamma.\)

**Goods market clears**

3. \(\pi_{s\alpha\beta} \left( \sum_{h \in H} b_{s\alpha\beta}^h + \sum_{\gamma \in C} M_{s\alpha\beta}^\gamma \right) = \sum_{h \in H} b_{s\beta\alpha}^h + \sum_{\gamma \in C} M_{s\beta\alpha}^\gamma.\)

**Currency market clears**

4. \(\sum_{h \in H} \mu_{s\alpha}^h + \sum_{\gamma \in C} \mu_{s\alpha}^\gamma = \sum_{h \in H} d_{\alpha}^h + \sum_{\gamma \in C} M_{s\alpha}^\gamma.\)

**Money market clears**

5. \(\sum_{h \in H} \bar{\mu}_{s\alpha}^h + \sum_{\gamma \in C} \bar{\mu}_{s\alpha}^\gamma = \sum_{h \in H} d_{\alpha}^h + \sum_{\gamma \in C} \bar{M}_{s\alpha}^\gamma.\)

**Bond market clears**

6. \(K_j^i = \left\{ \begin{array}{ll} \frac{\sum_{h \in H} D_{j}^h + \sum_{\gamma \in C} D_{j}^{\gamma h}}{\sum_{h \in H} A_{s}^j} & \text{if } \sum_{h \in H} A_{s}^j \phi_{j}^h > 0 \\ \text{arbitrary} & \text{if } \sum_{h \in H} A_{s}^j \phi_{j}^h = 0 \end{array} \right\}.\)

**Asset market clears**

for agents \(\forall s \in S^* \) and \(\forall \gamma \in C, \forall \alpha, \beta \in C, \forall j \in J \) and \(h \in H.\)
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   **Agents optimise**

2. \(\rho_{sl} \sum_{h \in H^\alpha} q^h_{sl} = \sum_{h \in H} b^h_{sl} + \sum_{\gamma \in C} M^\gamma_{sl}\).  
   **Goods market clears**

3. \(\pi_{s\alpha\beta}(\sum_{h \in H} b^h_{s\alpha\beta} + \sum_{\gamma \in C} M^\gamma_{s\alpha\beta}) = \sum_{h \in H} b^h_{s\beta\alpha} + \sum_{\gamma \in C} M^\gamma_{s\beta\alpha}\).  
   **Currency market clears**

4. \(\frac{\sum_{h \in H} \mu^h_{s\alpha} + \sum_{\gamma \in C} \mu^\gamma_{s\alpha}}{(1 + r^\alpha_{s\alpha})} = \sum_{h \in H} d^h_{s\alpha} + \sum_{\gamma \in C} M^\gamma_{s\alpha}\).  
   **Money market clears**

5. \(\frac{\sum_{h \in H} \bar{\mu}^h_{s\alpha} + \sum_{\gamma \in C} \bar{\mu}^\gamma_{s\alpha}}{(1 + \bar{r}^\alpha_{s\alpha})} = \sum_{h \in H} \bar{d}^h_{s\alpha} + \sum_{\gamma \in C} \bar{M}^\gamma_{s\alpha}\).  
   **Bond market clears**

6. \(K^j_s = \begin{cases} 
   \frac{\sum_{h \in H} D^{jh}_{s\phi^h} + \sum_{\gamma \in C} D^{\gamma j}_{s\phi^\gamma}}{\sum_{h \in H} A^j_s \phi^h} & \text{if } \sum_{h \in H} A^j_s \phi^h > 0 \\
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\end{cases}\).  
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for agents \(\forall s \in S^*\) and \(\forall \gamma \in C, \forall \alpha, \beta \in C, \forall j \in J\) and \(h \in H\).
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\[\begin{align*}
1. & \quad (\sigma^h) \in \text{Argmax}_{\sigma^h \in B(\eta)} U(x^h). \\
& \quad \text{Agents optimise} \\
2. & \quad \rho_{sl} \sum_{h \in H^\alpha} q_{sl}^h = \sum_{h \in H} b_{s\alpha}^h + \sum_{\gamma \in C} M_{s\gamma}^\gamma. \\
& \quad \text{Goods market clears} \\
3. & \quad \pi_{s\alpha\beta}(\sum_{h \in H} b_{s\alpha\beta}^h + \sum_{\gamma \in C} M_{s\alpha\beta}^\gamma) = \sum_{h \in H} b_{s\beta\alpha}^h + \sum_{\gamma \in C} M_{s\beta\alpha}^\gamma. \\
& \quad \text{Currency market clears} \\
4. & \quad \frac{\sum_{h \in H} \mu_{s\alpha}^h + \sum_{\gamma \in C} \mu_{s\alpha}^\gamma}{(1 + r_{s\alpha})} = \sum_{h \in H} d_{s\alpha}^h + \sum_{\gamma \in C} M_{s\alpha}^\gamma. \\
& \quad \text{Money market clears} \\
5. & \quad \frac{\sum_{h \in H} \bar{\mu}_{s\alpha}^h + \sum_{\gamma \in C} \bar{\mu}_{s\alpha}^\gamma}{(1 + \bar{r}_{s\alpha})} = \sum_{h \in H} \bar{d}_{s\alpha}^h + \sum_{\gamma \in C} \bar{M}_{s\alpha}^\gamma. \\
& \quad \text{Bond market clears} \\
6. & \quad K_{s\gamma}^j = \begin{cases} 
\frac{\sum_{h \in H} D_{s\gamma}^h + \sum_{\gamma \in C} D_{s\gamma}^\gamma}{\sum_{h \in H} A_{s\gamma}^h \phi_{s\gamma}^h} & \text{if } \sum_{h \in H} A_{s\gamma}^j \phi_{s\gamma}^h > 0 \\
\text{arbitrary} & \text{if } \sum_{h \in H} A_{s\gamma}^j \phi_{s\gamma}^h = 0
\end{cases}.
& \quad \text{Asset market clears}
\end{align*}\]

for agents \(\forall s \in S^*\) and \(\forall \gamma \in C, \forall \alpha, \beta \in C, \forall j \in J\) and \(h \in H\).
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1. $(\sigma^h) \in \text{Argmax}_{\sigma^h \in B(\eta)} U(x^h)$. 
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2. $\rho_{sl} \sum_{h \in H^\alpha} q^h_{sl} = \sum_{h \in H} b^h_{sl} + \sum_{\gamma \in C} M^\gamma_{sl}$. 
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3. $\pi_{s\alpha\beta}(\sum_{h \in H} b^h_{s\alpha\beta} + \sum_{\gamma \in C} M^\gamma_{s\alpha\beta}) = \sum_{h \in H} b^h_{s\beta\alpha} + \sum_{\gamma \in C} M^\gamma_{s\beta\alpha}$. 
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4. $\frac{\sum_{h \in H} \mu^h_{s\alpha} + \sum_{\gamma \in C} \mu^\gamma_{s\alpha}}{(1 + r_{s\alpha})} = \sum_{h \in H} d^h_{\alpha} + \sum_{\gamma \in C} M^\gamma_{s\alpha}$. 
   **Money market clears**

5. $\frac{\sum_{h \in H} \bar{\mu}^h_{\alpha} + \sum_{\gamma \in C} \bar{\mu}^\gamma_{\alpha}}{(1 + r_{\alpha})} = \sum_{h \in H} \bar{d}^h_{\alpha} + \sum_{\gamma \in C} \bar{M}^\gamma_{\alpha}$. 
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6. $K^j_s = \begin{cases} \frac{\sum_{h \in H} D^h_{s} + \sum_{\gamma \in C} D^\gamma_{s}}{\sum_{h \in H} A^j_s \phi^h_{ij}} & \text{if } \sum_{h \in H} A^j_s \phi^h_{ij} > 0 \\ \text{arbitrary} & \text{if } \sum_{h \in H} A^j_s \phi^h_{ij} = 0 \end{cases}$. 
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3. $\pi_{s_{\alpha,\beta}} (\sum_{h \in H} b_{s_{\alpha,\beta}}^h + \sum_{\gamma \in C} M_{s_{\alpha,\beta}}^\gamma) = \sum_{h \in H} b_{s_{\beta,\alpha}}^h + \sum_{\gamma \in C} M_{s_{\beta,\alpha}}^\gamma$. 
   **Currency market clears**

4. $\frac{\sum_{h \in H} \mu_{s_{\alpha}}^h + \sum_{\gamma \in C} \mu_{s_{\alpha}}^\gamma}{(1 + r_{s_{\alpha}})} = \sum_{h \in H} d_{\alpha}^h + \sum_{\gamma \in C} M_{s_{\alpha}}^\gamma$. 
   **Money market clears**

5. $\frac{\sum_{h \in H} \bar{\mu}_{\alpha}^h + \sum_{\gamma \in C} \bar{\mu}_{\alpha}^\gamma}{(1 + \bar{r}_{\alpha})} = \sum_{h \in H} \bar{d}_{\alpha}^h + \sum_{\gamma \in C} \bar{M}_{\alpha}^\gamma$. 
   **Bond market clears**

6. $K^j_s = \begin{cases} \frac{\sum_{h \in H} D_{s}^{h_j} + \sum_{\gamma \in C} D_{s}^{\gamma_j}}{\sum_{h \in H} A_s^h \phi_{s_j}^h} & \text{if } \sum_{h \in H} A_s^h \phi_{s_j}^h > 0 \\ \text{arbitrary} & \text{if } \sum_{h \in H} A_s^h \phi_{s_j}^h = 0 \end{cases}$. 
   **Asset market clears**

for agents $\forall s \in S^*$ and $\forall \gamma \in C$, $\forall \alpha, \beta \in C$, $\forall j \in J$ and $h \in H$. 

Peiris and Tsomocos Oxford
Definition of Equilibrium

\((\eta, (\sigma^h)_{h \in H})\) is an **International Monetary Equilibrium with Default (IMED)** for the world economy \(E = ((u^h, e^h, m^h)_{h \in H}, M^\gamma, \mu^\gamma)_{h \in H}, \gamma \in C\) iff:

1. \((\sigma^h) \in \text{Argmax}_{\sigma^h \in B(\eta)} U(x^h)\).

   **Agents optimise**

2. \(\rho_{sl} \sum_{h \in H^\alpha} q_{sl}^h = \sum_{h \in H} b_{sl}^h + \sum_{\gamma \in C} M_{sl}^\gamma\).

   **Goods market clears**

3. \(\pi_{s\alpha\beta}(\sum_{h \in H} b_{s\alpha\beta}^h + \sum_{\gamma \in C} M_{s\alpha\beta}^\gamma) = \sum_{h \in H} b_{s\beta\alpha}^h + \sum_{\gamma \in C} M_{s\beta\alpha}^\gamma\).

   **Currency market clears**

4. \(\frac{\sum_{h \in H} \mu_{s\alpha}^h + \sum_{\gamma \in C} \mu_{s\alpha}^\gamma}{(1 + r_{s\alpha})} = \sum_{h \in H} d_{s\alpha}^h + \sum_{\gamma \in C} M_{s\alpha}^\gamma\).

   **Money market clears**

5. \(\frac{\sum_{h \in H} \bar{\mu}_{s\alpha}^h + \sum_{\gamma \in C} \bar{\mu}_{s\alpha}^\gamma}{(1 + \bar{r}_{s\alpha})} = \sum_{h \in H} \bar{d}_{s\alpha}^h + \sum_{\gamma \in C} \bar{M}_{s\alpha}^\gamma\).

   **Bond market clears**

6. \(K_{s}^j = \begin{cases} \frac{\sum_{h \in H} D_{s}^h + \sum_{\gamma \in C} D_{s}^\gamma}{\sum_{h \in H} A_{s}^h \phi_{s}^h} & \text{if } \sum_{h \in H} A_{s}^h \phi_{s}^h > 0 \\ \text{arbitrary} & \text{if } \sum_{h \in H} A_{s}^h \phi_{s}^h = 0 \end{cases}\).

   **Asset market clears**

for agents \(\forall s \in S^*\) and \(\forall \gamma \in C, \forall \alpha, \beta \in C, \forall j \in J\) and \(h \in H\).
Existence of Equilibrium

**Theorem**

There always exists an IMED of $E(M, \lambda, \gamma)$ provided

1. Gains-to-trade and Inactive Market Hypothesis holds
2. $M, \lambda > 0$. 

Peiris and Tsomocos Oxford
Quantity Theory of Money

Period 0

$$\sum_{h \in H} \sum_{l \in L^\alpha} p_{0l} q_{0l}^h \leq M_{0\alpha} + m_{0\alpha}$$

Period 1

$$\sum_{h \in H} \sum_{l \in L^\alpha} p_{sl} q_{sl}^h \leq M_{s\alpha} + m_{s\alpha} + \hat{m}_{s\alpha}$$
At any IMED, for all $s \in S^*$ and for all $\alpha \in C$,

**Period 0**

\[
d_0\alpha (1 + r_{0\alpha}) + \frac{\mu_{0\alpha}}{1 + r_{0\alpha}} + b_{0\alpha} + \frac{\bar{\mu}_\alpha}{1 + \bar{r}_\alpha} + \sum_{j \in J^\alpha} \psi_j \phi_j + \hat{m}_{s\alpha} \\
= d_{0\alpha} + \mu_{0\alpha} + b_{0\alpha} + \bar{d}_\alpha + \sum_{j \in J^\alpha} \psi_j \theta_j + b_{0\cdot} + m_{0\alpha}
\]

**Period 1**

\[
d_{s\alpha} (1 + r_{s\alpha}) + \frac{\mu_{s\alpha}}{1 + r_{s\alpha}} + b_{s\cdot\alpha} + \bar{d}_\alpha (1 + \bar{r}_\alpha) + \sum_{j \in J^\alpha} \theta_j K_s^j A_s^j \\
= d_{s\alpha} + \mu_{s\alpha} + b_{s\alpha} + \bar{\mu}_{s\alpha} + \sum_{j \in J^\alpha} D_s^j + b_{s\cdot} + m_{s\alpha} + \hat{m}_{s\alpha}
\]

The RHS represents the money flowing into the system, and the LHS represents the money flowing out of the system. If all government expenditures and transfers are zero and there is no private money in the economy then interest rates are not determined endogenously and are zero.
Term Structure of Interest Rates

At any IMED, for all \( s \in S^* \) and for all \( \alpha \in C \),

**Period 0**

\[
d_{0\alpha}(1 + r_{0\alpha}) + \frac{\mu_{0\alpha}}{1 + r_{0\alpha}} + b_{0\alpha} + \frac{\bar{\mu}_\alpha}{1 + \bar{r}_\alpha} + \sum_{j \in J^\alpha} \psi^j \phi^j + \hat{m}_{s\alpha} \\
= d_{0\alpha} + \mu_{0\alpha} + b_{0\alpha} + \bar{d}_\alpha + \sum_{j \in J^\alpha} \psi^j \theta^j + b_{0\cdot} + m_{0\alpha}
\]

**Period 1**

\[
d_{s\alpha}(1 + r_{s\alpha}) + \frac{\mu_{s\alpha}}{1 + r_{s\alpha}} + b_{s\cdot\alpha} + \bar{d}_\alpha(1 + \bar{r}_\alpha) + \sum_{j \in J^\alpha} \theta^j K_s^j A_s^j \\
= d_{s\alpha} + \mu_{s\alpha} + b_{s\cdot\alpha} + \bar{\mu}_{s\alpha} + \sum_{j \in J^\alpha} D_s^j + b_{s\cdot} + m_{s\alpha} + \hat{m}_{s\alpha}
\]

The RHS represents the money flowing into the system, and the LHS represents the money flowing out of the system. If all government expenditures and transfers are zero and there is no private money in the economy then interest rates are not determined endogenously and are zero.
Corollary: *At any IMED for all \( s \in S \) and \( \gamma \in C \),

\[
1 + r_{0\gamma} \leq \frac{M_{0\gamma} + m_{0\gamma}}{M_{0\gamma}}
\]

\[
1 + r_{s\gamma} \leq \frac{M_{s\gamma} + m_{s\gamma} + \hat{m}_{s\gamma}}{M_{s\gamma}}
\]

- Clearly if the government spends too much money without expanding the money supply, then interest rates will rise and trade will come to a complete halt.
- Through this we can see how fiscal policy, monetary policy and (when it is allowed in the money market) default are connected in a financial economy.
Corollary: At any IMED for all $s \in S$ and $\gamma \in C$,

$$1 + r_{0\gamma} \leq \frac{M_{0\gamma} + m_{0\gamma}}{M_{0\gamma}}$$

$$1 + r_{s\gamma} \leq \frac{M_{s\gamma} + m_{s\gamma} + \hat{m}_{s\gamma}}{M_{s\gamma}}$$

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Corollary: At any IMED for all \( s \in S \) and \( \gamma \in C \),

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- Clearly if the government spends too much money without expanding the money supply, then interest rates will rise and trade will come to a complete halt.
- Through this we can see how fiscal policy, monetary policy and (when it is allowed in the money market) default are connected in a financial economy.
For agent \( h \in H \) who buys good \( \alpha \) from Country \( \alpha \) and purchases good \( \beta \) from country \( \beta \neq \alpha \) who faces exchange rate \( \pi_{s\alpha \beta} \) which is foreign currency per unit of home currency we have:

\[
\frac{u'(c_{s\alpha}^h)}{u'(c_{s\beta}^h)} = \frac{\pi_{s\alpha \beta} p_{s\alpha}}{p_{s\beta}}
\]

\[
\frac{u'(c_{s\alpha}^h)}{u'(c_{s\beta}^h)} = \frac{\pi_{s\alpha \beta} p_{s\alpha}}{(1 + r_{s\alpha}) p_{s\beta}}
\]
Suppose that some agent $h$ in Country $\alpha$ who sells a bond domestically and in Country $\alpha$ and chooses $b_{0\alpha}^h > 0$ and $b_{s\alpha}^h > 0$ for state both state 1 and state 2 and has some Country $\alpha$ money left over when long loans come due in period 1, then at IME we must have:

$$\frac{u'(c_{0\alpha}^h)}{p_{0\alpha}} = 1 + \bar{r}_\alpha$$

$$\sum_{s \in S} \theta_s^h \frac{u'(c_{s\alpha}^h)}{p_{s\alpha}} = 1 + \bar{r}_\alpha$$

$$\frac{u'(c_{0\alpha}^h)}{p_{0\alpha}} (1 + r_{s\alpha}) \theta_s^h \frac{u'(c_{s\alpha}^h)}{p_{s\alpha}} = 1 + \bar{r}_\alpha$$

where $\alpha \in C$ and $\theta^h$ is the subjective belief of agents.
Rearranging the above and taking logarithms allows us to interpret the above as the nominal rate of interest being equal to the real rate of interest plus (expected) inflation plus risk premium term.

\[
\log\left(\frac{u'(c^h_{0\alpha})}{u'(c^h_{1\alpha})}\right) + \log\left(\frac{p_{1\alpha}}{p_{0\alpha}}\right) + \left[ \log\left(\frac{\theta_1^h u'(c^h_{1\alpha})}{p_{1\alpha}}\right) - \log(\theta_1^h) \right] \approx \bar{r}_{\alpha}
\]

From here we can see that the nominal interest rate is approximately the real interest rate plus the rate of inflation plus a risk premium term.
Suppose in period 0 agent $h$ has one unit of country $\alpha$ money. He can either deposit the money domestically and convert it to country $\beta$ money in the future or he can convert it to country $\beta$ money immediately and invest the money there. These two strategies will have the same value in expectation. That is, we must have:

$$\frac{\pi_{0\alpha\beta} (1 + \bar{r}_\beta)}{1 + \bar{r}_\alpha} = \sum_{s \in S} \pi_{1\alpha\beta} \times \tilde{\theta}_\beta s$$

$$= \mathbb{E}_{\tilde{\theta}_\beta} [\pi_{1\alpha\beta}^1]$$

That is, the UIP proposition gives the future exchange rate (the exchange rate in period 1 is given by $\pi_{1\alpha\beta}^1$) under the risk neutral measure ($\tilde{\theta}_\beta$). 

Uncovered Interest Rate Parity
Motivation

Propositions

Numerical Example

Comparative Statics

Extensions

Untraded Assets

On-the-verge Condition

\[(1 + r_s \alpha) u'(c^h_{s \alpha}) = \lambda\]

Paper has two examples that highlight the importance on the decision to trade assets of

1. different monetary policy regimes
2. different regulatory regimes in determining which assets are traded and by which agents.
2 countries, home is US, foreign is UK. Representative agent in each country endowed with a single good each.

- 2 periods, 2 states of the world in second period. Single risky bond in each country. Agents borrow in bond market at home and purchase bonds abroad.
- Agents can only participate in domestic money market. Symmetric data in each country.
- Central Bank in each country willing to offer money for loan in money market.
World Economy

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Data of World Economy

<table>
<thead>
<tr>
<th></th>
<th>Agent $h^a$</th>
<th>Agent $h^b$</th>
<th>Agent $h^a$</th>
<th>Agent $h^b$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outside Money in State 0,1,2</td>
<td>$m^a_{0a}, m^b_{0b}$</td>
<td>10.000</td>
<td>10.000</td>
<td>$e_{01}, e_{02}$</td>
</tr>
<tr>
<td></td>
<td>$m^a_{1a}, m^b_{1b}$</td>
<td>10.000</td>
<td>10.000</td>
<td>$e_{11}, e_{12}$</td>
</tr>
<tr>
<td></td>
<td>$m^a_{2a}, m^b_{2b}$</td>
<td>10.000</td>
<td>10.000</td>
<td>$e_{21}, e_{22}$</td>
</tr>
<tr>
<td>Endowments of Goods 1,2 in State 0,1,2</td>
<td>$e_{01}, e_{02}$</td>
<td>100.000</td>
<td>100.000</td>
<td></td>
</tr>
<tr>
<td>Preferences for home good</td>
<td>$h^a, h^b$</td>
<td>0.500</td>
<td>0.500</td>
<td>$\theta^a, \theta^b$</td>
</tr>
<tr>
<td>Subjective Probabilities for State 1</td>
<td>CRRA Risk Aversion</td>
<td>$\rho^a, \rho^b$</td>
<td>.500</td>
<td>.500</td>
</tr>
<tr>
<td>Money Supply in States 0,1,2</td>
<td>US</td>
<td>UK</td>
<td>Default Penalty</td>
<td>US</td>
</tr>
<tr>
<td></td>
<td>$M^a_{01}, M^b_{02}$</td>
<td>120.000</td>
<td>120.000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$M^a_{11}, M^b_{12}$</td>
<td>75.000</td>
<td>75.000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$M^a_{21}, M^b_{22}$</td>
<td>100.000</td>
<td>100.000</td>
<td></td>
</tr>
</tbody>
</table>

|                  | $\lambda^a, \lambda^b$ | 0.077 | 0.077 |

**Table:** Parameters of Initial Equilibrium
### Equilibrium Micro Variables

<table>
<thead>
<tr>
<th></th>
<th>Agent $h^\alpha$</th>
<th>Agent $h^\beta$</th>
<th>Agent $h^\alpha$</th>
<th>Agent $h^\beta$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Consumption of Good 1 in State 0,1,2</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$c_{01}^\alpha$, $c_{01}^\beta$</td>
<td>53.977</td>
<td>46.023</td>
<td>$c_{02}^\alpha$, $c_{02}^\beta$</td>
<td>46.023</td>
</tr>
<tr>
<td>$c_{11}^\alpha$, $c_{11}^\beta$</td>
<td>56.455</td>
<td>43.545</td>
<td>$c_{12}^\alpha$, $c_{12}^\beta$</td>
<td>43.545</td>
</tr>
<tr>
<td>$c_{21}^\alpha$, $c_{21}^\beta$</td>
<td>54.758</td>
<td>45.242</td>
<td>$c_{22}^\alpha$, $c_{22}^\beta$</td>
<td>45.242</td>
</tr>
<tr>
<td><strong>Consumption of Good 2 in State 0,1,2</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Money Offered for Goods 1, 2 in State 0,1,2</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$b_{02}^\alpha$, $b_{01}^\beta$</td>
<td>101.767</td>
<td>101.767</td>
<td>$b_{012}^\alpha$, $b_{021}^\beta$</td>
<td>130.000</td>
</tr>
<tr>
<td>$b_{12}^\alpha$, $b_{11}^\beta$</td>
<td>85.000</td>
<td>85.000</td>
<td>$b_{112}^\alpha$, $b_{121}^\beta$</td>
<td>61.597</td>
</tr>
<tr>
<td>$b_{22}^\alpha$, $b_{21}^\beta$</td>
<td>110.00</td>
<td>110.000</td>
<td>$b_{212}^\alpha$, $b_{221}^\beta$</td>
<td>78.346</td>
</tr>
<tr>
<td><strong>Money Offered to Foreign Exchange Market in State 0,1,2</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Amount Repaid to Short-Term Money Market in State 0,1,2</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\mu_{0\alpha}^\alpha$, $\mu_{0\beta}^\beta$</td>
<td>130.000</td>
<td>130.000</td>
<td>$\bar{\mu}<em>{1\alpha}^\alpha$, $\bar{\mu}</em>{1\beta}^\beta$</td>
<td>31.654</td>
</tr>
<tr>
<td>$\mu_{1\alpha}^\alpha$, $\mu_{1\beta}^\beta$</td>
<td>85.000</td>
<td>85.000</td>
<td>$\bar{\mu}<em>{1\alpha}^\alpha$, $\bar{\mu}</em>{1\beta}^\beta$</td>
<td>31.654</td>
</tr>
<tr>
<td>$\mu_{2\alpha}^\alpha$, $\mu_{2\beta}^\beta$</td>
<td>110.00</td>
<td>110.000</td>
<td>$\bar{\mu}<em>{2\alpha}^\alpha$, $\bar{\mu}</em>{2\beta}^\beta$</td>
<td>31.654</td>
</tr>
<tr>
<td><strong>Utility of Agents</strong></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>$U_{0\alpha}^\alpha$, $U_{0\beta}^\beta$</td>
<td>28.088</td>
<td>28.088</td>
<td>$U_{1\alpha}^\alpha$, $U_{1\beta}^\beta$</td>
<td>28.088</td>
</tr>
</tbody>
</table>

**Table:** Endogenous Variables of Economy
Equilibrium Macro Variables

<table>
<thead>
<tr>
<th></th>
<th>US</th>
<th>UK</th>
<th></th>
<th>US</th>
<th>UK</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Price of Goods 1,2 in States 0,1,2</strong></td>
<td></td>
<td></td>
<td><strong>Short Term interest Rates in States 0,1,2</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$p_{01}$, $p_{02}$</td>
<td>2.211</td>
<td>2.211</td>
<td>$r_{0\alpha}$, $r_{0\beta}$</td>
<td>8.3%</td>
<td>8.3%</td>
</tr>
<tr>
<td>$p_{11}$, $p_{12}$</td>
<td>1.952</td>
<td>1.952</td>
<td>$r_{1\alpha}$, $r_{1\beta}$</td>
<td>13.3%</td>
<td>13.3%</td>
</tr>
<tr>
<td>$p_{21}$, $p_{22}$</td>
<td>2.431</td>
<td>2.431</td>
<td>$r_{2\alpha}$, $r_{2\beta}$</td>
<td>10.0%</td>
<td>10.0%</td>
</tr>
<tr>
<td><strong>Sales of Goods 1,2 in States 0,1,2</strong></td>
<td></td>
<td></td>
<td><strong>Long Term interest Rate</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$q_{01}$, $q_{02}$</td>
<td>46.023</td>
<td>46.023</td>
<td>$R_{\alpha}$, $R_{\beta}$</td>
<td>12.1%</td>
<td>12.1%</td>
</tr>
<tr>
<td>$q_{11}$, $q_{12}$</td>
<td>43.545</td>
<td>43.545</td>
<td><strong>Delivery Rate</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$q_{21}$, $q_{22}$</td>
<td>45.242</td>
<td>45.242</td>
<td>$K_{11}$, $K_{12}$</td>
<td>73.9%</td>
<td>73.9%</td>
</tr>
</tbody>
</table>

| **US Nominal Trade Balance in States 0,1,2** | **Exchange Rates in States 0,1,2** |
| $TB_{0\alpha}$ | $TB_{1\alpha}$ | $TB_{2\alpha}$ | $\pi_{0\alpha\beta}$ | $\pi_{1\alpha\beta}$ | $\pi_{2\alpha\beta}$ |
| 0         | 0          | 0         | 1            | 1            | 1            |

**Table:** Macroeconomic Variables of Economy
Initial Equilibrium

- Money enters the economy through the money markets in IMED and, in equilibrium, the demand for money will meet the money supply at a price of the short term interest rates.
- Lower the interest rate $\equiv$ efficient trade (Dubey and Geanakoplos, 1992 and Espinoza et al., 2009). Micro table shows a bias toward home consumption due to the financing cost creating an inefficiency in purchasing foreign goods.
- Macro table shows price level depends on the quantity of money offered to the goods market $\Rightarrow$ depends on money supply.
- In period 0 only fraction of the money used in goods market while in period 1 all money available used.
- Liquidity in the currency markets also dependent on the quantity of money available $\Rightarrow$ money offered to FX but
- currency demand depends on relative demand for assets and goods $\Rightarrow$ FX rate not simply ratio of money supplies.
Initial Equilibrium

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- Macro table shows price level depends on the quantity of money offered to the goods market $\Rightarrow$ depends on money supply.

- In period 0 only fraction of the money used in goods market while in period 1 all money available used.

- Liquidity in the currency markets also dependent on the quantity of money available $\Rightarrow$ money offered to FX but currency demand depends on relative demand for assets and goods $\Rightarrow$ FX rate not simply ratio of money supplies.
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Table: Comparative Statics For (Non-Cooperative) Monetary Expansion in US

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## Money Supply

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Peiris and Tsomocos Oxford
Unanticipated Increase in Money Supply

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PPP effects

- From term structure of interest rates (TS) - expansion in domestic (US) money supply lowers the money market interest rate there.
  - ↓ interest rate ⇒ cost of purchasing imports ↓.
  - From purchasing power parity (PPP) US then ↑ imports and ↑ demand for Pounds to purchase UK goods ⇒ depreciates Dollar.
  - Stronger UK Pound ⇒ British ↑ imports and financed by an ↑ exports and debt ⇒ increase in the volume of global trade and a (slight) deterioration in the US nominal trade balance.
  - From UIP, expect (slight) improvement in US nominal trade balance in future.

Compatible with predictions of Mundell-Fleming but extend analysis to intertemporal optimisation.
PPP effects

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- Higher debt levels in the future need to be repaid in the presence of liquidity constraints. If the government does not commit to expanding money supply in the future, then from the on-the-verge (OTV) condition we know that in the state of the world where we expect default, the marginal cost of repayment > default penalty.
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• Agents ↑ default as marginal cost of repayment > marginal cost of default ⇒ delivery rates in both countries fall.

• In good state, agents have a higher MRS domestically than abroad where they have asset returns. From PPP ⇒ agents send less money abroad and ↓ liquidity in the currency market.
Default

- Agents $\uparrow$ default as marginal cost of repayment $> \text{marginal cost of default} \Rightarrow \text{delivery rates in both countries fall.}$

- In good state, agents have a higher MRS domestically than abroad where they have asset returns. From PPP $\Rightarrow$ agents send less money abroad and $\downarrow$ liquidity in the currency market.
Summary

- **↓ welfare for the US while for the UK ↑.**
  - In a setting with default we need to analyse both the allocation and the deadweight loss associated with the penalty imposed on default. Allocationally US ↑ imports in period 0 while in every other state ↑ in UK consumption.
  - First order effect in the model is change in the short term interest rate in the US. Prompts a large expenditure from home good towards imports in the US and from the future to the present.
  - As the UK responds to price effects, they do not accomodate American consumption demands and trade in a mutually beneficial way as would be possible in a closed economy setting but rather the UK benefits from the inefficient intertemporal re-allocation for American.

Prices and quantities have limited response due to default penalty. Main welfare results through intertemporal transmission. ↑ welfare for British, ↓ for American.
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Extensions

- Banking Sector (Goodhart et al., 2006)
- Production
- Infinite Horizon (eg. Bewley, 1980)