Exchange Rate Policies at the Zero Lower Bound

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The views expressed herein are those of the authors and not necessarily those of the Federal Reserve Bank of Minneapolis or the Federal Reserve System
Interest Parity Condition

\[
(1 + i_t) = \left(1 + i^*_t\right) \frac{s_{t+1}}{s_t}
\]

\(i_t\) nominal interest rate, \(s_t\) today’s exchange rate
\(i^*_t\) foreign interest rate, \(s_{t+1}\) tomorrow’s exchange rate
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- $i_t$ nominal interest rate,
- $s_t$ today’s exchange rate
- $i_t^*$ foreign interest rate,
- $s_{t+1}$ tomorrow’s exchange rate

- Central bank goal: depreciate exchange rate today (higher $s_t$)

$\Rightarrow \downarrow i$
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\[\Rightarrow \downarrow i\]

But what if \(i < 0\)?
A Theory

- Simple monetary model of exchange rate policy
  - Limited international arbitrage
  - Central bank intervention in FX markets

Main Result:

- At ZLB, central bank can achieve exchange rate objectives by accumulating foreign reserves
- But it is costly. Costs can be measured by IP deviations and foreign reserves
Why do we care?

Nominal interest rates, 3M (%)

CHF/EUR exchange rate

Foreign reserves / GDP (%)

Covered interest parity deviation (bp)
Environment

- Two periods, one good, deterministic, open monetary economy
  - See paper for infinite horizon
  - Uncertainty case dealt in ABBP 2017

- Three agents:
  1. Households:
     - Standard consumption/saving problem, hold money
  2. Foreign investors:
     - Buy domestic/foreign assets, and have limited wealth $\bar{w}$
  3. Central Bank
     - Issues money ($M$), buys domestic/foreign assets ($A, F$)
     - Implements exchange rate policy ($s_1, s_2$).
Prices

- Exchange rate:
  - $s_t =$ \# of domestic currency per foreign currency

- Price of good abroad constant (in units of foreign currency) and normalized at 1

- Law of one price holds: $P_t = s_t$

- Nominal interest rate on domestic currency assets: $1 + i$
  - Real interest rate on domestic assets: $1 + r \equiv (1 + i) \frac{s_1}{s_2}$

- Nominal (and real) interest rate on foreign currency assets, $1 + i^*$
  - Perfectly elastic supply of foreign assets
Households

\[
\max_{c_1, c_2, f, a, m} u(c_1) + h \left( \frac{m}{s_1} \right) + \beta u(c_2)
\]

\[
y_1 + T_1 = c_1 + \frac{m + a}{s_1} + f
\]

\[
y_2 + T_2 = c_2 - \frac{(1 + i)a + m}{s_2} - (1 + i^*)f
\]

\[f \geq 0\]

- MIU with satiation level
- \(y_t\): households endowment, \(c_t\): consumption
- \(m\): money holdings, \(a\): domestic bond holdings, \(f\): foreign assets
- \(T_t\): transfers from central bank (CB)
Foreign Investors

- Invest at home in either assets or money, $a^*, m^*$ or internationally in foreign assets $f^*$
- Linear utility over second period consumption
- Have limited initial wealth $\bar{w}$ and cannot borrow

  - limits to international arbitrage

\[
\max_{f^*, a^*, m^*} c^*
\]

s.t. \[\bar{w} = f^* + \frac{a^* + m^*}{s_1}\]

\[c^* = (1 + i^*) f^* + (1 + i) \frac{a^*}{s_2} + \frac{m^*}{s_2}\]

\[f^* \geq 0, a^* \geq 0, m^* \geq 0\]
Central Bank

- Pursues an exogenously given exchange rate policy, \((s_1, s_2)\)

- Manages balance sheet to achieve this objective
  
  \(\text{Issues money, } M \geq 0 \text{ redeemed at } s_2. \text{ Buys foreign reserves } F \geq 0 \text{ and domestic assets } A.\)

- Makes transfers to HH, \((T_1, T_2)\)

\[
\frac{M}{s_1} = F + \frac{A}{s_1} + T_1
\]

\[
(1 + i^*)F + (1 + i)\frac{A}{s_2} = \frac{M}{s_2} + T_2
\]
Monetary Equilibrium given \((s_1, s_2)\)

A monetary equilibrium given the exchange rate policy \((s_1, s_2)\) is:

(i) a domestic nominal interest rate;
(ii) consumption and asset positions for HH & foreign investors;
(iii) money supply, asset purchases, and transfers;

- HH and foreigners maximize,
- CB budget constraints holds,
- Market clearing for domestic assets:

\[
\begin{align*}
a + a^* + A &= 0 \\
m + m^* &= M
\end{align*}
\]
Eqm. Conditions

- Euler equation for domestic assets:
  \[ u'(c_1) = \beta (1 + i) \frac{s_1}{s_2} u'(c_2) \]

- And for foreign bonds:
  \[ u'(c_1) \geq \beta (1 + i^*) u'(c_2) \]

- Interest Parity condition
  \[ (1 + i) \geq (1 + i^*) \frac{s_2}{s_1} \quad \text{(IP)} \]
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- **Interest Parity condition**
  \[ (1 + i) \geq (1 + i^*) \frac{s_2}{s_1} \] (IP)

- If IP holds with **strict inequality**, all private agents invest only in domestic assets \((f = 0, f^* = 0)\)
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- Money demand equation
  \[ h' \left( \frac{m}{s_1} \right) = \frac{i}{1 + i} u'(c_1) \implies i \geq 0 \]
CB interventions in non-monetary economy
Interventions in non-monetary economy

- Forget about exchange rates and money
- Let \( r \) and \( r^* \) the real returns on domestic and foreign bonds
- HH’s BC + Government + Market clearing

\[
c_1 + \frac{c_2}{1 + r} = y_1 + \frac{y_2}{1 + r} - \left[ \frac{r - r^*}{1 + r} \right] (F + f)
\]

Interest Rate diff. \( \geq 0 \)

- HH optimality \( (\frac{r - r^*}{1 + r})f = 0 \)
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Interest Rate diff. $\geq 0$

- HH optimality $\left( \frac{r - r^*}{1 + r} \right) f = 0$
The Effects of CB Interventions

\[ (y_1, y_2) \sim (y, w) \leq 1 + r^* \]
The Effects of CB Interventions

CB intervention:

\[(\tilde{y}_1, \tilde{y}_2)\]

\[c_1\]

\[c_2\]

\[1 + r^*\]

\[\bar{w}\]
The Effects of CB Interventions

\[ \frac{u'(c_1)}{u'(c_2)} = \beta(1 + r) \]
\[ c_1 = y_1 - F + \bar{w} \]
\[ c_2 = y_2 + (1 + r^*)F - (1 + r)\bar{w} \]
The Effects of CB Interventions

\[ F \left( \frac{r - r^*}{1 + r} \right) \]
Taking Stock

- If $\bar{w}$ large enough, intervention is neutral
  - HH’s undo the effect by borrowing

- If $\bar{w}$ not large enough, interventions allow CB to sustain $r > i^*$
  - HH’s attempt to undo the effect by borrowing, but foreign wealth constraint is hit $\Rightarrow$ competition drives up $r$
  - Consumption is distorted and CB incurs losses
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- Why would CB set $F > 0$? Let’s go back to monetary eqm.
Monetary Economy

Exchange Rate Objective \((s_1, s_2)\)

Two cases depending on whether nominal rate consistent with IP is consistent with ZLB:
Monetary Economy

Exchange Rate Objective \((s_1, s_2)\)

Two cases depending on whether nominal rate consistent with IP is consistent with ZLB:

(1) Away from ZLB:

- If \((1 + i^*) \frac{s_2}{s_1} > 1\)
  - CB can implement \((s_1, s_2)\) by setting \(F = 0\) and nominal rate
    \[
    1 + i = (1 + i^*) \frac{s_2}{s_1} > 1
    \]
  - This achieves the best non-monetary eqm
Monetary Economy

(2) At ZLB:

- If \((1 + i^*) \frac{s_2}{s_1} < 1\)
Monetary Economy

(2) At ZLB:

- If \((1 + i^*) \frac{s_2}{s_1} < 1 < 1 + i\)

\[ \Rightarrow 1 + i > (1 + i^*) \frac{s_2}{s_1} \]
Monetary Economy

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- Exchange rate policy and ZLB open gap in IP
Monetary Economy

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- Exchange rate policy and ZLB open gap in IP
- Domestic assets attractive ⇒ Foreign investors go all in
Monetary Economy

(2) At ZLB:

- If \((1 + \star_i) \frac{s_2}{s_1} < 1 < 1 + i\)

\[\Rightarrow 1 + i > (1 + \star_i) \frac{s_2}{s_1}\]

- Exchange rate policy and ZLB open gap in IP
- Domestic assets attractive \(\Rightarrow\) Foreign investors go all in
- One implementation: CB issues more liabilities and buys foreign assets to support exchange rate policy
Monetary Economy

(2) At ZLB:

- If \((1 + \dot{i}^* ) \frac{s_2}{s_1} < 1 < 1 + i\)

\[ \Rightarrow 1 + i > (1 + \dot{i}^*) \frac{s_2}{s_1} \]

- Exchange rate policy and ZLB open gap in IP
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Undesirable interventions are now **needed** to implement exchange rate policy
Monetary Economy: At the ZLB

\[ 1 + r = \frac{s_1}{s_2} \]

\[ A \]

\[ B \]

\[ F \]

\[ 1 + r^* \]

\[ \bar{w} \]
Costs of FX Interventions

- Recap: Central Bank can sustain a depreciated exchange rate at the ZLB by accumulating foreign assets, but there are costs associated.
Costs of FX Interventions

- Recap: Central Bank can sustain a depreciated exchange rate at the ZLB by accumulating foreign assets, but there are costs associated.

Questions:

- What are the determinants of these losses?
- Is financial openness good or bad?
What determines the costs from intervention?

Factors that increase the potential for capital inflows raise the necessity and costs of FX interventions at the ZLB, despite being desirable away from ZLB:

- More foreign wealth, $\bar{w}$
- Lower international rates, $i^*$
- Irrational expectations of appreciation of domestic currency

Role for capital controls
More $\bar{w}$ at the ZLB

\[ \bar{w} > \bar{w}' \]

\[ 1 + r = \frac{s_1}{s_2} \]

\[ 1 + r^* \]
More $\bar{w}$ at the ZLB

\[ \bar{w}' > \bar{w} \]

\[ 1 + r = \frac{s_1}{s_2} \]

\[ 1+ r^* \]
More $\bar{w}$ at the ZLB

$\Delta F \left( \frac{r - r^*}{1 + r} \right)$

$\bar{w}' > \bar{w}$
More $\bar{w}$ at the ZLB

Larger inflows, but larger outflows!

\[ 1 + r = \frac{s_1}{s_2} \]

\[ 1 + r^* = \frac{1}{\Delta F \left( \frac{r - r^*}{1 + r} \right)} \]

\[ \bar{w}' > \bar{w} \]
Alternative policy instruments

- **Capital controls**
  - **Quantity:** lower $\bar{w}$ improves welfare
    - Optimal $\bar{w}$ implies $F = 0$
  - **Prices:** taxes on foreign purchases of domestic assets
    - Optimal tax implies IP holds with equality
    - **Note:** At the ZLB need to tax foreign holdings of money

- **Negative nominal interest rates**
  - Allow the CB to restore interest parity and eliminate losses
    - Contrasts with usual reason to allow for negative rates
Why would CB follow such policies?

- So far, exchange rate policy \((s_1, s_2)\) exogenous
- Endogeneize \((s_1, s_2)\) in model with nominal rigidities
- A shock to \(\beta\) makes devaluation optimal
- If recession is severe enough, CB is at ZLB and intervene by buying foreign assets
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- If recession is severe enough, CB is at ZLB and intervene by buying foreign assets
- Likewise, “abandonment” triggered by improvement in economic activity, reduction in \(i^*\) or increase in \(\bar{w}\)
A simple sticky-wage model

- Two sectors, producing T-NT goods
- Output in sector $j$ produced with Cobb-Douglas,
  \[ y_t^j = (l_t^j)^\alpha \]
- Nominal wages are fixed in domestic currency, and constant over time $\bar{p}^w$
- Firms in both sectors maximize profits
  \[ \Pi_t^j = \max_{l_t^j} p_t^j y_t - \frac{\bar{p}^w}{s_t} l_t^j \]
- Firms’ FOC:
  \[ l_t^N = \left( \frac{\alpha p_t^N s_t}{\bar{p}^w} \right)^{\frac{1}{1-\alpha}} \]
  \[ l_t^T = \left( \frac{\alpha s_t}{\bar{p}^w} \right)^{\frac{1}{1-\alpha}} \]
The problem of the Central Bank

- The Central Bank chooses \((i, s_1, s_2, F)\) to maximize HH’s welfare taking as given optimality of HH’s, firms, and foreign investors.

- Let \(\bar{p}_t^{w,fb}\) be the real wage that achieves the first best level of production,

\[
\begin{align*}
    v'(n_t) &= u_T(c_T)f'(l^T_t) \quad v'(n_t) = u_N(c_N)f'(l^N_t)
\end{align*}
\]

- Absent ZLB, CB chooses \((s_1, s_2)\) to achieve first best
  - Depreciate when output inefficiently low
  - Appreciate when output inefficiently high
Central Bank’s Solution

- If \((1 + i^*) \frac{s_{fb}^2}{s_{fb}^1} \geq 1\), then
  - ZLB does not bind
  - Setting \(i\) consistent with IP, \(s_{fb}^1, s_{fb}^2\) achieves first-best

- If \((1 + i^*) \frac{s_{fb}^2}{s_{fb}^1} < 1\), then
  - CB trade-offs losses of production efficiency with losses from FX interventions
  - **Solution**: intervene only when losses of production efficiencies are sufficiently large
Numerical example: discount factor shock

- An increase in $\beta$ lowers $c$ today relative to tomorrow
- First best requires CB depreciating today relative to tomorrow
- $\downarrow i$ until ZLB. After that, $F >$ if large recession
Empirical Analysis
Understanding FX Interventions

- Model has two main implications
  1. FX interventions and IP deviations go hand in hand
  2. Interventions are necessary at ZLB

- Are these predictions consistent with basic facts about foreign reserves, IP deviations and nominal interest rates?
  - Cross-section of advanced economies (2000-2016)
  - Look at a different ZLB period: Switzerland in the late 1970s

Cross-section of advanced economies (2000-2016)

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- Measure IP deviation using covered interest parity (CIP):
  Right measure in model with uncertainty (ABBP, 2017)
Positive relation between reserves and CIP gaps
CIP deviations and Nominal Interest Rates

- Deviations from CIP for countries with rates close to zero
A Different ZLB Period

A similar pattern observed for Switzerland in the 1970s
Quantifying the costs of FX Interventions

**Losses:**

\[
\left[1 - \frac{1 + i^* s_2}{1 + i s_1}\right] \times F
\]

- **IP deviation**
- **foreign reserves**
Quantifying the costs of FX Interventions

CIP deviations and Reserves

Annualized CIP gap (basis points)

Reserves/GDP (%)

CIP deviation

reserves/GDP

2005 2010 2015

0

100

200

300

0

50

100

32/35
- Losses can be sizable (1% of monthly GDP)
Agenda: Which assets should CB buy?

- **ABBP 2017**: Exchange Rate Policy + Uncertainty
- Two goals: minimize losses and intertemporal distortions
- **New principles for optimal reserve management**
- Relatively closed economies:
  - Invest in foreign assets that pay when the currency appreciates.
  - ⇒ Lower marginal utility when money pays a higher return
  - Idea: Make money less attractive to hold, reducing intertemporal distortions
- Relatively open economies:
  - Make sure that foreign investors demand domestic currency
  - ⇒ Reduce losses
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Conclusions

- Simple monetary model of exchange rate policy
  - Limited international arbitrage
  - Central bank intervention in FX markets

- At ZLB, accumulation of foreign assets is necessary and costly

- Framework can rationalize recent evidence on reserves, CIP, and interest rates

Agenda:
- A theory of timing of peg abandonment
  - (Reverse Speculative Attacks, ABBP, 2016)
- Optimal Reserve Management