A Large Central Bank Balance Sheet? Floor vs Corridor Systems in a New Keynesian Environment

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1 These slides represent only the authors’ views and do not necessarily represent those of the Banco de España or the Eurosystem.
Motivation

- Balance-sheet policies → unprecedented increase in excess reserves & de facto transition from corridor to floor regime
What we do

▶ Research questions:

▶ How do B/S policies and the resulting reserves expansion affect market interest rates, and ultimately the macroeconomy?
▶ Preserve current floor system with large excess reserves, or return to pre-crisis corridor system with (basically) no excess reserves?
What we do

- Research questions:
  - How do B/S policies and the resulting reserves expansion affect market interest rates, and ultimately the macroeconomy?
  - Preserve current floor system with large excess reserves, or return to pre-crisis corridor system with (basically) no excess reserves?
- Propose a New Keynesian framework with a banking sector:
  - Banks intermediate savings from households to firms
  - Have heterogeneous investment opportunities → interbank trade
  - Decentralized OTC interbank market, with CB lending and borrowing facilities as outside options
  - Position of market rates inside corridor endogenous to market liquidity
Main findings

- Reserves expansion stimulates the economy by $\uparrow$ IB market liquidity and $\downarrow$ the \textit{interbank-reserves return spread}
Main findings

- Reserves expansion stimulates the economy by ↑ IB market liquidity and ↓ the interbank-reserves return spread

Floor vs corridor system:

- A permanently large B/S buys additional (interest-rate) policy space wrt the ELB
- However, a small B/S with temporary QE, if appropriately implemented, achieves similar stabilization outcomes
Related literature

- **Macro effects of QE through CB liabilities / reserves**
  - Cúrdia Woodford (2011), Bianchi Bigio (2014), Reis (2016), Christensen Krogstrup (2016)

- **General macro effects of QE**
  - Gertler Karadi (2011, 2013), Gertler Kiyotaki (2010), Cúrdia Woodford (2011)...

- **Interbank market as OTC market w/ search frictions**
  - Afonso Lagos (2015), Armenter Lester (2017), Atkeson Eisfeldt Weill (2015), Bech Monnet (2016), Bianchi Bigio (2014)...)
Outline of the talk

1. Introduction
2. Model
3. Transmission of MP
4. Lean or large balance sheet?
Model overview
Islands: firms and banks

- Continuum of islands $j \in [0, 1]$.
- On each island: repr. bank + repr. intermediate-good-producer ("firm").
Islands: firms and banks

- Continuum of islands $j \in [0, 1]$
- On each island: repr. bank + repr. intermediate-good-producer ("firm")
- End of $t - 1$: bank finances firm’s purchase of capital $K^j_t$ (with unit real price $Q^K_t$) with equity in the amount $Q^K_t A^j_t = Q^K_t K^j_t$ (Gertler Karadi 2011)
  - Only local bank can finance local firm
Islands: firms and banks

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  - Only local bank can finance local firm
- Beginning of $t$: effective capital changes to $\omega_{t-1}^j K_t^j$
  - $\omega_{t-1}^j$ island-specific shock, iid $\sim F(\omega)$, known in $t-1$
Islands: firms and banks

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  - Only local bank can finance local firm
- Beginning of $t$: effective capital changes to $\omega^j_{t-1} K^j_t$
  - $\omega^j_{t-1}$ island-specific shock, iid $\sim F(\omega)$, known in $t - 1$
- After production, bank receives return on $A^j_t$ equal to $R^A_t \times \omega^j_{t-1}$

Banks

- Bank $j$ starts $t$ with pre-dividend equity $E^j_t$
  - Pays fraction $1 - \zeta$ to HH as dividends, retains the rest as equity $N^j_t = \zeta E^j_t$. 
Banks

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- Before drawing $\omega^j_t$: take deposits in the real amount $D^j_t$
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- Before drawing $\omega^j_t$: take deposits in the real amount $D^j_t$
- Deposits market closes, after which $\omega^j_t$ is drawn and bank chooses
  - Investment in local firm $A^j_t$
  - Investment in long-term gov’t bonds, real market value $b^{G,j}_t$
  - Gross lending ($B^{-,j}_t$) and borrowing ($B^{+,j}_t$) in interbank market
Banks

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- Balance sheet constraint,

$$Q^K_t A^j_t + B^{-j}_t + b^{G,j}_t = N^j_t + D^j_t + B^{+j}_t,$$
Banks

- Bank \( j \) starts \( t \) with pre-dividend equity \( E_t^j \)
  - Pays fraction \( 1 - \zeta \) to HH as dividends, retains the rest as equity \( N_t^j = \zeta E_t^j \).

- *Before* drawing \( \omega_t^j \): take deposits in the real amount \( D_t^j \)
- Deposits market closes, *after which* \( \omega_t^j \) is drawn and bank chooses
  - Investment in local firm \( A_t^j \)
  - Investment in *long-term* gov’t bonds, real market value \( b_t^{G,j} \)
  - Gross lending \( (B_t^{-,j}) \) and borrowing \( (B_t^{+,j}) \) in interbank market

- Balance sheet constraint,
  \[
  Q_t^K A_t^j + B_t^{-,j} + b_t^{G,j} = N_t^j + D_t^j + B_t^{+,j},
  \]

- Leverage constraint,
  \[
  Q_t^K A_t^j \leq \phi N_t^j,
  \]
Bank’s problem

- Pre-dividend equity at beginning of $t + 1$,

$$E^j_{t+1} = R_{t+1}^A \omega_t^j Q_t^K A_t^j + \frac{R_t^L}{\pi_{t+1}} B_t^{-j} + \frac{R_{t+1}^G}{\pi_{t+1}} b_t^j, G - \frac{R_t^D}{\pi_{t+1}} D_t^j - \frac{R_t^B}{\pi_{t+1}} B_t^{+j}$$

(1)

$R_t^L, R_t^B$: nominal effective return on IB lending & borrowing

$R_{t+1}^G, R_t^D$: nominal return on gov’t bonds & deposits
Bank’s problem

- Pre-dividend equity at beginning of $t+1$,

\[ E_{t+1}^j = R_{t+1}^A \omega_t^j Q_t^K A_t^j + \frac{R_t^L}{\pi_{t+1}} B_{t-.}^j + \frac{R_{t+1}^G}{\pi_{t+1}} b_{t}^{j,G} - \frac{R_t^D}{\pi_{t+1}} D_{t}^j - \frac{R_t^B}{\pi_{t+1}} B_{t+.}^j \]

(1)

$R_L^t, R_B^t$: nominal effective return on IB lending & borrowing

$R_G^t, R_D^t$: nominal return on gov’t bonds & deposits

- Bank solves

\[
V_t(N_t^j) = \max_{D_t^j \geq 0} \int \bar{V}_t(N_t^j, D_t^j, \omega) dF(\omega),
\]

\[
\bar{V}_t(N_t^j, D_t^j, \omega_t^j) = \max_{A_t^j \geq 0, b_t^{G,j} \geq 0, \quad B_t^{+,j} \geq 0, B_t^{-,j} \geq 0} \mathbb{E}_t \Lambda_{t+1} \left[ (1 - \zeta) E_{t+1}^j + V_{t+1}(\zeta E_{t+1}^j) \right],
\]

s.t. balance-sheet constraint, leverage constraint and (1).
Solution to bank’s problem

- Optimal portfolio depends on $\omega^j_t$
  - for $\omega^j_t > \omega^B_t$,
    \[ Q^K_t A_t^j = \phi N^j_t, \quad B^{+,j}_t = (\phi - 1) N^j_t - D^j_t \]
  - for $\omega^j_t \in [\omega^L_t, \omega^B_t]$,
    \[ Q^K_t A_t^j = N^j_t + D^j_t \]
  - for $\omega^j_t < \omega^L_t$,
    \[ b^j,G_t + B^{-,j}_t = N^j_t + D^j_t, \quad (b^j,G_t, B^{-,j}_t) \geq 0. \]

- IB borrowing & lending threshold,
  \[ \omega^B_t \equiv \frac{\mathbb{E}_t \left[ \tilde{\Lambda}_{t,t+1} R^B_t / (1 + \pi_{t+1}) \right]}{\mathbb{E}_t \left[ \tilde{\Lambda}_{t,t+1} R^A_{t+1} \right]} = \frac{R^B_t}{R^L_t} \omega^L_t \geq \omega^L_t. \]

(In equilibrium $R^B_t \geq R^L_t$)
Solution to bank’s problem

Invest in **bonds** and **interbank market**

Invest in **firms**

Borrow in IB market up to leverage constraint

Invest in **firms**
Solution to bank’s problem (2)

- Nominal deposit rate,

\[
R_t^D = \left[ 1 - F\left( \omega_t^B \right) \right] R_t^B + F\left( \omega_t^L \right) R_t^L \\
+ \left[ F\left( \omega_t^B \right) - F\left( \omega_t^L \right) \right] \frac{\mathbb{E}\left( \omega \mid \omega_t^L \leq \omega \leq \omega_t^B \right) \mathbb{E}_t \tilde{\Lambda}_{t,t+1} R_{t+1}^A}{\mathbb{E}_t \tilde{\Lambda}_{t,t+1} / (1 + \pi_{t+1})}
\in \left[ R_t^L, R_t^B \right].
\]

- Banks break even \textit{ex ante} when taking deposits
Interbank market

- OTC market with search frictions (e.g. Afonso & Lagos 2012, Bianchi & Bigio, 2017)
Interbank market

- OTC market with search frictions (e.g. Afonso & Lagos 2012, Bianchi & Bigio, 2017)
- Banks place per unit lending or borrowing orders. Aggregate # of borrowing & lending orders

\[
\Phi_{t}^{B} \equiv \int_{0}^{1} B_{t}^{+j} dj = \left[ 1 - F \left( \omega_{t}^{B} \right) \right] \left[ (\phi - 1) N_{t} - D_{t} \right],
\]

\[
\Phi_{t}^{L} \equiv \int_{0}^{1} B_{t}^{-j} dj = F \left( \omega_{t}^{L} \right) (N_{t} + D_{t}) - b_{t}^{G}.
\]
Interbank market

- Assume *competitive* search (Armenter & Lester, 2017)
- Interbank market divided in many *submarkets*, each offering a different interest rate ($R^IB_t$)

\[
\begin{align*}
\Phi^B_t \Phi^L_t &= \frac{\Gamma^L_t + \Phi^B_t \Phi^L_t}{\Phi^B_t / \Phi^L_t}, \\
\Phi^L_t \Phi^B_t &= \frac{\Phi^B_t}{\Phi^L_t}, \\
\end{align*}
\]

where $\Phi^B_t / \Phi^L_t$ is IB market tightness
Interbank market

- Assume *competitive* search (Armenter & Lester, 2017)
- Interbank market divided in many *submarkets*, each offering a different interest rate ($R_{t}^{IB}$)
- In each submarket, B and L orders are matched according to a CRS technology $\Upsilon(\Phi^{B}_{t}, \Phi^{L}_{t})$
Interbank market

- Assume competitive search (Armenter & Lester, 2017)
- Interbank market divided in many submarkets, each offering a different interest rate ($R_{IB}^t$)
- In each submarket, B and L orders are matched according to a CRS technology $\Upsilon(\Phi_B^t, \Phi_L^t)$
- Each L and B order is matched with probability

$$\frac{\Upsilon(\Phi_L^t, \Phi_B^t)}{\Phi_L^t} = \Upsilon\left(1, \frac{\Phi_B^t}{\Phi_L^t}\right) \equiv \Gamma^L\left(\frac{\Phi_B^t}{\Phi_L^t}\right),$$

$$\frac{\Upsilon(\Phi_L^t, \Phi_B^t)}{\Phi_B^t} = \Upsilon\left(\frac{1}{\Phi_B^t/\Phi_L^t}, 1\right) \equiv \Gamma^B\left(\frac{\Phi_B^t}{\Phi_L^t}\right),$$

where $\Phi_B^t / \Phi_L^t \equiv \theta_t$ is IB market tightness.
Interbank market

- Assume *competitive* search (Armenter & Lester, 2017)
- Interbank market divided in many *submarkets*, each offering a different interest rate ($R_{t}^{IB}$)
- In each submarket, B and L orders are matched according to a CRS technology $\Upsilon(\Phi_{t}^{B}, \Phi_{t}^{L})$
- Each L and B order is matched with probability

$$
\frac{\Upsilon(\Phi_{t}^{L}, \Phi_{t}^{B})}{\Phi_{t}^{L}} = \Upsilon\left(1, \frac{\Phi_{t}^{B}}{\Phi_{t}^{L}}\right) \equiv \Gamma^{L}\left(\frac{\Phi_{t}^{B}}{\Phi_{t}^{L}}\right),
$$

$$
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$$

where $\Phi_{t}^{B}/\Phi_{t}^{L} \equiv \theta_{t}$ is *IB market tightness*

- Otherwise lend to (borrow from) CB’s deposit (lending) facility at rate $R_{t}^{DF}$ ($R_{t}^{LF}$).
L and B banks choose the submarket (i.e. \( R_{IB}^t, \theta_t \) combination) that maximizes their payoff

B banks minimize their average borrowing cost,

\[
\min_{R_{IB}^t, \theta_t} \Gamma^B(\theta_t) R_{IB}^t + \left( 1 - \Gamma^B(\theta_t) \right) R_{LF}^t. \\
\equiv R_t^B
\]

subject to L banks receiving their highest average return (\( R_t^{L*} \)),

\[
\Gamma^L(\theta_t) R_{IB}^t + \left( 1 - \Gamma^L(\theta_t) \right) R_{DF}^t \equiv R_t^{L*}. \\
\equiv R_t^L
\]
Competitive search equilibrium

- Equilibrium interbank rate

\[ R_t^{IB} = \varphi(\theta_t) R_t^{DF} + (1 - \varphi(\theta_t)) R_t^{LF} \]

where

\[ \varphi(\theta_t) \equiv \frac{\partial Y(\Phi_t^L, \Phi_t^B)}{\partial \Phi_t^B} \frac{\Phi_t^B}{Y(\Phi_t^L, \Phi_t^B)} \]
Competitive search equilibrium

- **Equilibrium interbank rate**

\[ R_t^{IB} = \varphi(\theta_t) R_t^{DF} + (1 - \varphi(\theta_t)) R_t^{LF} \]

where

\[ \varphi(\theta_t) \equiv \frac{\partial Y(\Phi_t^L, \Phi_t^B)}{\partial \Phi_t^B} \frac{\Phi_t^B}{Y(\Phi_t^L, \Phi_t^B)} \]

- **Position of IB rate inside interest rate corridor** \((R_t^{DF}, R_t^{LF})\) depends on IB market tightness
  - through elasticity of matching fct wrt B orders \(\varphi (= \text{borrowers’ surplus share})\)
Competitive search equilibrium

- Equilibrium interbank rate

\[
R_t^{IB} = \phi (\theta_t) R_t^{DF} + (1 - \phi (\theta_t)) R_t^{LF}
\]

where

\[
\phi (\theta_t) \equiv \frac{\partial Y (\Phi_t^L, \Phi_t^B)}{\partial \Phi_t^B} \frac{\Phi_t^B}{Y (\Phi_t^L, \Phi_t^B)}
\]

- Position of IB rate inside interest rate corridor \((R_t^{DF}, R_t^{LF})\) depends on IB market tightness
  
  - through elasticity of matching fct wrt B orders \(\phi \) (= borrowers’ surplus share)

- Focus on technologies that satisfy \(\phi' (\theta_t) < 0\)...  
  
  - In a slack IB market (low \(\theta_t\)), it is easier for borrowers to find lenders  
    → pay lower IB rate
Central bank: interest rate policy & the ZLB

- The central bank sets the two policy rates \((R_{t}^{DF}, R_{t}^{LF})\)
- Assume *constant* corridor width \(\chi\),

\[
R_{t}^{LF} = R_{t}^{DF} + \chi \Rightarrow R_{t}^{IB} = R_{t}^{DF} + [1 - \varphi(\theta_{t})] \chi
\]
Central bank: interest rate policy & the ZLB

The central bank sets the two policy rates \((R_t^{DF}, R_t^{LF})\)

Assume constant corridor width \(\chi\),

\[ R_t^{LF} = R_t^{DF} + \chi \Rightarrow R_t^{IB} = R_t^{DF} + [1 - \varphi(\theta_t)] \chi \]

Set \(R_t^{DF}\) such that IB market rate (the 'operational target') follows

\[ R_t^{IB,*} = \rho R_{t-1}^{IB,*} + (1 - \rho) [\bar{R} + \nu (\pi_t - 1)] , \]

\(\nu > 1\), unless ZLB is hit: \(R_t^{DF} \geq 1\)
The central bank sets the two policy rates \( (R_{DF}^t, R_{LF}^t) \)

Assume constant corridor width \( \chi \),

\[
R_{LF}^t = R_{DF}^t + \chi \\
R_{IB}^t = R_{DF}^t + [1 - \phi(\theta_t)] \chi
\]

Set \( R_{DF}^t \) such that IB market rate (the 'operational target') follows

\[
R_{IB,*}^t = \rho R_{IB,*}^{t-1} + (1 - \rho) [\bar{R} + v(\pi_t - 1)] ,
\]

\( v > 1 \), unless ZLB is hit: \( R_{DF}^t \geq 1 \)

Therefore,

\[
R_{DF}^t = \max \left\{ R_{IB,*}^t - [1 - \phi(\theta_t)] \chi, \ 1 \right\}
\]
The central bank chooses size of its gov’t bond holdings, real market value: $b_{t}^{G,CB}$

subject to its balance sheet constraint,

$$b_{t}^{G,CB} + \Phi_{t}^{B} \left(1 - \Gamma_{t}^{B}\right) = \Phi_{t}^{L} \left(1 - \Gamma_{t}^{L}\right)$$

Net profits are rebated to the Treasury

The Treasury is passive, keeps debt stock constant ($\bar{b}_{t}^{G}$) using lump sum taxes
Outline of the talk

1. Introduction
2. Model
3. Transmission of MP
4. Lean or large balance sheet?
Transmission to market rates: interest-rate policy

Recap of market rates:

- **Interbank** rate

\[ R_{t}^{IB} = \varphi(\theta_{t}) R_{t}^{DF} + [1 - \varphi(\theta_{t})] R_{t}^{LF} \]
Transmission to market rates: interest-rate policy

Recap of market rates:

- **Interbank rate**

\[
R_t^{IB} = \varphi(\theta_t) R_t^{DF} + [1 - \varphi(\theta_t)] R_t^{LF}
\]

- **Effective IB lending & borrowing rates,**

\[
\begin{align*}
R_t^L &= \Gamma^L(\theta_t) R_t^{IB} + [1 - \Gamma^L(\theta_t)] R_t^{DF}, \\
R_t^B &= \Gamma^B(\theta_t) R_t^{IB} + [1 - \Gamma^B(\theta_t)] R_t^{LF}.
\end{align*}
\]
Transmission to market rates: interest-rate policy

Recap of market rates:

- **Interbank** rate

  \[ R_{t}^{IB} = \varphi(\theta_t)R_{t}^{DF} + [1 - \varphi(\theta_t)]R_{t}^{LF} \]

- **Effective IB lending & borrowing** rates,

  \[ R_{t}^{L} = \Gamma^{L}(\theta_t)R_{t}^{IB} + [1 - \Gamma^{L}(\theta_t)]R_{t}^{DF} , \]
  \[ R_{t}^{B} = \Gamma^{B}(\theta_t)R_{t}^{IB} + [1 - \Gamma^{B}(\theta_t)]R_{t}^{LF} . \]

- **Deposit** rate (HH Euler eq.!),

  \[ R_{t}^{D} \in [R_{t}^{L} , R_{t}^{B}] . \]
Transmission to market rates: interest-rate policy

Recap of market rates:

- **Interbank** rate

  \[ R_{t}^{IB} = \varphi(\theta_{t}) R_{t}^{DF} + [1 - \varphi(\theta_{t})] R_{t}^{LF} \]

- **Effective IB lending & borrowing** rates,

  \[ R_{t}^{L} = \Gamma^{L}(\theta_{t}) R_{t}^{IB} + [1 - \Gamma^{L}(\theta_{t})] R_{t}^{DF}, \]
  \[ R_{t}^{B} = \Gamma^{B}(\theta_{t}) R_{t}^{IB} + [1 - \Gamma^{B}(\theta_{t})] R_{t}^{LF}. \]

- **Deposit** rate (HH Euler eq.),

  \[ R_{t}^{D} \in [R_{t}^{L}, R_{t}^{B}]. \]

- **Ceteris paribus**, change in \((R_{t}^{DF}, R_{t}^{LF})\) produces parallel shift in all market rates
Useful benchmark: match-efficiency & lean balance sheet

- The interbank market is **match-efficient** if and only if

  \[ \Upsilon(x, x) = x. \]
Useful benchmark: match-efficiency & lean balance sheet

- The interbank market is **match-efficient** if and only if

  $$\Upsilon(x, x) = x.$$  

- 'Lean' CB balance sheet: $$b_{t, CB}^G = 0.$$ Then

  \[
  \begin{align*}
  \Phi^B_t (1 - \Gamma^B_t) &= \Phi^L_t (1 - \Gamma^L_t) \quad \text{(CB B/S)} \\
  \Phi^B_t \Gamma^B_t &= \Phi^L_t \Gamma^L_t \quad \text{(IB mkt clearing)}
  \end{align*}
  \]

  $$\Rightarrow \Phi^B_t = \Phi^L_t \Leftrightarrow \theta_t = 1$$
Useful benchmark: match-efficiency & lean balance sheet

- The interbank market is **match-efficient** if and only if
  \[ Y(x, x) = x. \]

- 'Lean' CB balance sheet: \( b_t^{G,CB} = 0. \) Then
  \[
  \begin{align*}
  \Phi_t^B (1 - \Gamma_t^B) &= \Phi_t^L (1 - \Gamma_t^L) \quad \text{(CB B/S)} \\
  \Phi_t^B \Gamma_t^B &= \Phi_t^L \Gamma_t^L \quad \text{(IB mkt clearing)}
  \end{align*}
  \]
  \[ \Rightarrow \Phi_t^B = \Phi_t^L \iff \theta_t = 1 \]

- If \( Y \) match-efficient, then \( \Gamma^L(1) = \Gamma^B(1) = 1 \) and
  \[ R_t^L = R_t^B = R_t^D = R_t^{LB} = \varphi(1) R_t^{DF} + [1 - \varphi(1)] R_t^{LF}. \]
  If \( \varphi(1) = 1/2, \) all market rates in the middle of the **corridor**
Transmission of interest-rate policy (under match-efficiency & lean B/S)

\[ R_t^{LF} = R_t^{IB} = R_t^{L} = R_t^{D} \]
Transmission to market rates: QE

- **Interbank & effective IB borrowing** rates,

\[
R_{t}^{IB} = R_{t}^{DF} + \left[1 - \varphi(\theta_t)\right] \chi,
\]

\[
R_{t}^{B} = \Gamma^{B}(\theta_t) R_{t}^{IB} + \left[1 - \Gamma^{B}(\theta_t)\right] R_{t}^{LF},
\]

- **IB market tightness**,

\[
\theta_t = \frac{\Phi_t^{B}}{\Phi_t^{L}} = \frac{[1 - F(\omega_t^{B})] \left[(\phi - 1)N_t - D_t\right]}{F(\omega_t^{L})(N_t + D_t) - b_t^G}
\]
Transmission to market rates: QE

- **Interbank & effective IB borrowing** rates,
  
  \[ R_{t}^{IB} = R_{t}^{DF} + [1 - \varphi(\theta_{t})] \chi, \]
  
  \[ R_{t}^{B} = \Gamma^{B}(\theta_{t}) R_{t}^{IB} + [1 - \Gamma^{B}(\theta_{t})] R_{t}^{LF}, \]

- **IB market tightness**,
  
  \[ \theta_{t} = \frac{\Phi_{t}^{B}}{\Phi_{t}^{L}} = \frac{1 - F(\omega_{t}^{B})} {F(\omega_{t}^{L}) (N_{t} + D_{t}) - b_{t}^{G}} \]

- **QE**: bond absorption (↓ $b_{t}^{G}$) increases IB lending (↑ $\Phi_{t}^{L}$), makes IB market more *slack* (↓ $\theta_{t}$)
  
  - Borrowers get higher surplus share, find lenders more easily (↑ $\varphi, \Gamma^{B}$)
Transmission to market rates: QE

- **Interbank & effective IB borrowing** rates,

  \[ R_t^{IB} = R_t^{DF} + [1 - \varphi(\theta_t)]\chi, \]

  \[ R_t^B = \Gamma^B(\theta_t)R_t^{IB} + [1 - \Gamma^B(\theta_t)]R_t^{LF}, \]

- **IB market tightness**, 

  \[ \theta_t = \frac{\Phi_t^B}{\Phi_t^L} = \frac{[1 - F(\omega_t^B)] [(\phi - 1)N_t - D_t]}{F(\omega_t^L)(N_t + D_t) - b_t^G} \]

- **QE**: bond absorption (\(\downarrow b_t^G\)) increases IB lending (\(\uparrow \Phi_t^L\)), makes IB market more slack (\(\downarrow \theta_t\))

  - Borrowers get higher surplus share, find lenders more easily (\(\uparrow \varphi, \Gamma^B\))

  - As \(\theta \to 0\), and provided \(\lim_{\theta \to 0} \varphi(\theta) = 1\), all market rates converge towards \(R_t^{DF}\) (floor system)

  \[ R_t^L = R_t^B = R_t^D = R_t^{IB} = R_t^{DF}. \]
Transmission of QE

\[ R_t^{LF} \]

\[ R_t^{IB} = R_t^L = R_t^D \]

\[ R_t^{DF} \]
Numerical analysis: calibration

- Use matching function of Den Haan, Ramey & Watson (2000),

\[ Y(x, y) = \frac{xy}{(x^\lambda + y^\lambda)^{1/\lambda}}, \quad \lambda > 0. \]
Numerical analysis: calibration

- Use matching function of Den Haan, Ramey & Watson (2000),
  \[ Y(x, y) = \frac{xy}{(x^\lambda + y^\lambda)^{1/\lambda}}, \quad \lambda > 0. \]

- Borrowers’ surplus share
  \[ \varphi(\theta) = \frac{\partial Y}{\partial y} \frac{y}{Y} = \frac{1}{1 + \theta^\lambda} \Rightarrow \varphi' < 0, \quad \lim_{\theta \to 0} \varphi(\theta) = 1 \]
Numerical analysis: calibration

- Use matching function of Den Haan, Ramey & Watson (2000),
  \[ \Upsilon(x, y) = \frac{xy}{(x^\lambda + y^\lambda)^{1/\lambda}}, \quad \lambda > 0. \]

- Borrowers' surplus share
  \[ \varphi(\theta) = \frac{\partial \Upsilon}{\partial y} \frac{y}{\Upsilon} = \frac{1}{1 + \theta^\lambda} \Rightarrow \varphi' < 0, \quad \lim_{\theta \to 0} \varphi(\theta) = 1 \]

- Choose \( \lambda \) to approximate empirical relationship between (excess) reserves (as % of GDP),
  \[ \Phi^L_{ss} \left[ 1 - \Gamma^L (\theta_{ss}) \right] \frac{1}{Y_{ss}}, \]
  and their opportunity cost,
  \[ R^{IB}_{ss} - R^{DF}_{ss} = [1 - \varphi(\theta_{ss})] \chi, \]
  as we vary central bank’s bond holdings, \( b_{ss}^{G,CB} \)
The EUREPO - DFR spread and excess reserves

- Use EUREPO as proxy for $R_{ss}^B$
- $\lambda = 225 \Rightarrow Y(x, x) = \frac{x}{2^{1/\lambda}} \lesssim x$ : approximately match-efficient
Outline of the talk

1. Introduction
2. Model
3. Transmission of MP
4. Lean or large balance sheet?
Policy space: Lean balance sheet

Since \( R_{ss}^{IB} = R_{ss}^{DF} + [1 - \varphi(1)]\chi = R_{ss}^{D} \stackrel{\text{Euler eq}}{=} \beta^{-1} \), then

\[
R_{ss}^{DF} - 1 = \beta^{-1} - 1 - [1 - \varphi(1)]\chi.
\]

Distance to ZLB falls with corridor width \( \chi \)
Policy space: Large balance sheet

- As B/S grows, *steady-state DFR rises* towards $\beta^{-1}$,

$$R_{ss}^{DF} - 1 = \beta^{-1} - 1 > (R_{ss}^{DF} - 1)_{corridor}.$$  

**More policy space** *vis-à-vis* ZLB!
Policy space: Lean balance sheet with temporary QE

Once DFR hits ZLB, temporary QE allows reducing market rates all the way to floor,

\[ R^D_t = R^{IB}_t = R^{DF}_t \geq 1 \]
Numerical analysis: crisis scenario

![Graphs showing output, inflation, and CB balance sheet trends over time.]

*Corridor and IB rates, lean BS*
Numerical example: crisis scenario

- Output
- Inflation
- CB balance sheet

- Corridor and IB rates, lean BS
- Corridor and IB rates, large BS
Numerical example: crisis scenario

- Output
- Inflation
- CB balance sheet

- Corridor and IB rates, lean BS
- Corridor and IB rates, large BS
- Corridor and IB rates, lean BS with temp. QE
Numerical example: crisis scenario

**Output**

- Dev. from ss (%)
- 0 5 10 15
- 0.5 0 -0.5 -1

**Inflation**

- % (annualized)
- 0 5 10 15
- -8 -6 -4 -2

**CB balance sheet**

- % of SS GDP
- 0 5 10 15
- 5 4 3 2

Legend:
- blue: lean balance sheet
- red: large balance sheet
- yellow: lean balance sheet with temporary asset purchases
- purple: lean balance sheet with delayed temporary asset purchases

**Corridor and IB rates, lean BS**

- % (annualized)
- 0 5 10 15
- 4 3 2 1 0

**Corridor and IB rates, large BS**

- % (annualized)
- 0 5 10 15
- 4 3 2 1 0

**Corridor and IB rates, lean BS with delayed temp. QE**

- % (annualized)
- 0 5 10 15
- 4 3 2 1 0
Conclusions

- B/S policy and ensuing reserves expansion has real effects due to frictions in the interbank market

- A lean balance sheet with a corridor system looks like a good alternative
  - if the CB is willing to *immediately* engage in a QE program when the ELB is binding

- However, a large balance sheet is a better alternative
  - if the ELB is often binding and swift and flexible temporary QE programs are not implementable