A Large Central Bank Balance Sheet? Floor vs Corridor Systems in a New Keynesian Environment[1]

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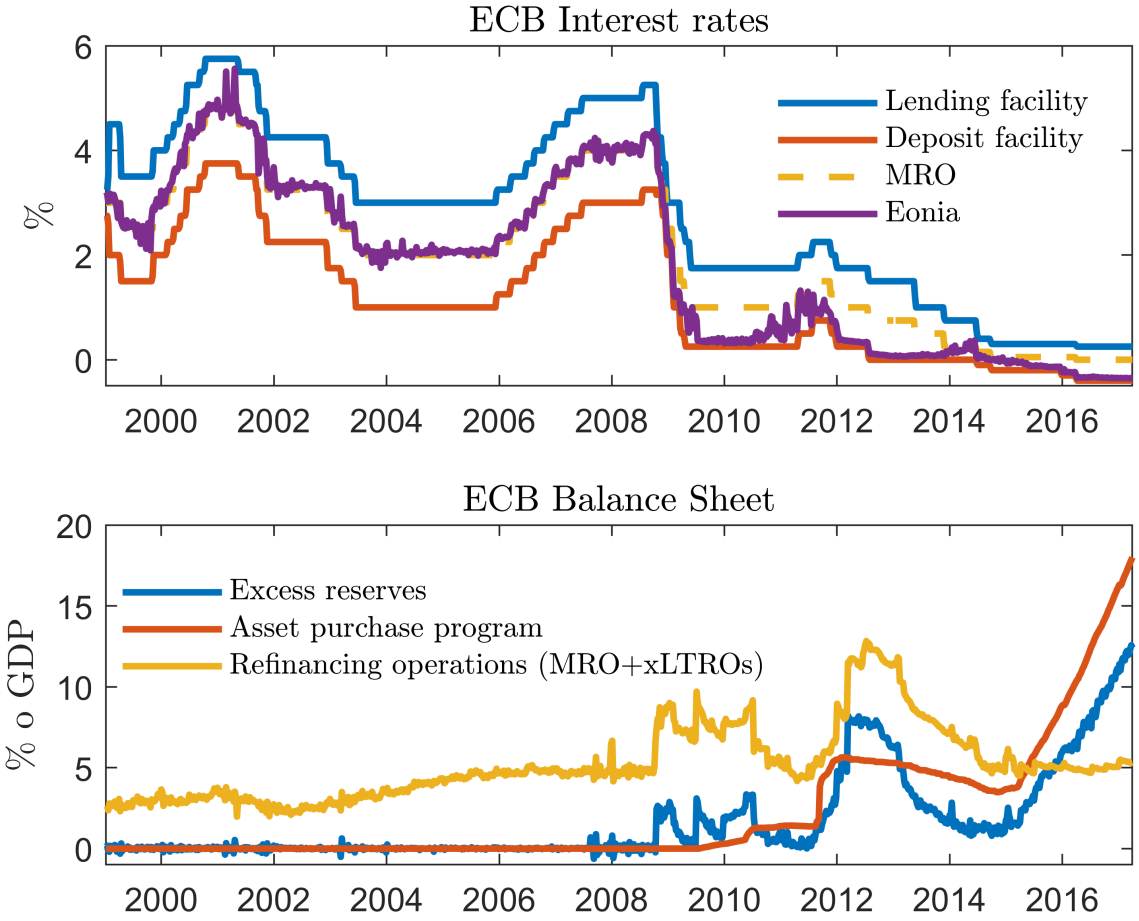
Banco de España

Oxford, 12 Feb 2019

[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?

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  - 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 heterogenous investment opportunities
  - Decentralized OTC interbank market, with CB lending and borrowing facilities as outside options

Main findings

- Reserves expansion stimulates the economy by making the interbank market more 'slack' ($\downarrow$ borrowing/lending orders)
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  - which pushes interbank and all other market rates towards the corridor floor (interest on reserves)
- 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

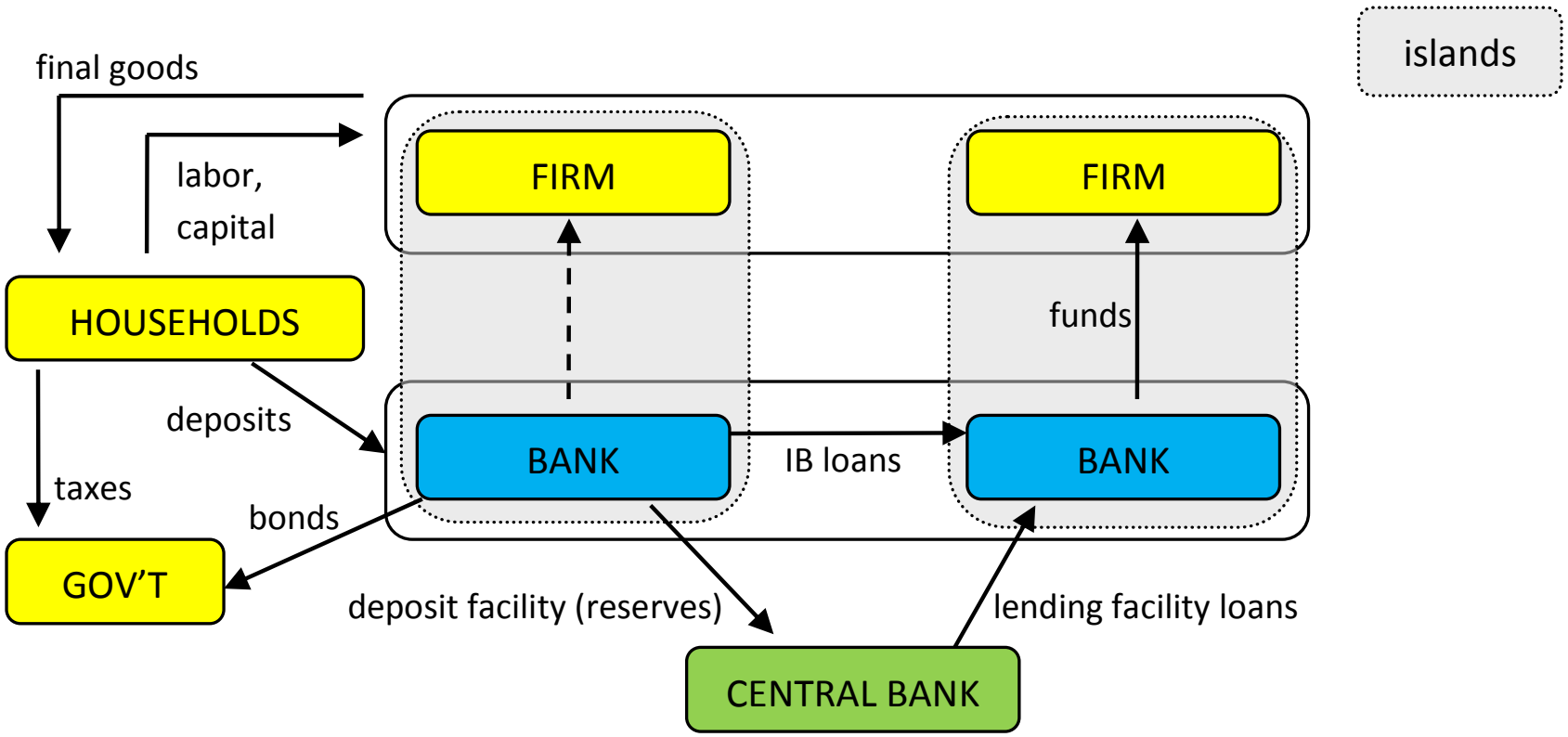
Related literature

- 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")
- Firms produce using capital and labor $Y_t^j = \left(\omega_{t-1}^j K_{t-1}^j\right)^\alpha \left(L_t^j\right)^{1-\alpha}$
- Labor is mobile
- Only local banks can finance capital of local firm

Banks

- Bank j starts t with pre-dividend equity E_t^j
  - Pays fraction $1 - \varsigma$ to HH as dividends, retains the rest as equity $N_t^j = \varsigma E_t^j$.
- Balance sheet constraint,

$$Q_t^K A_t^j + B_t^{-,j} + b_t^{j,G} = N_t^j + D_t^j + B_t^{+,j},$$

- Exogenous leverage constraint (Buera & Moll, 2015),

$$Q_t^K A_t^j \leq \phi N_t^j,$$

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  - banks make portfolio choice
    - finance local firm's capital K_t^j
    - purchase government bond $b_t^{G,j}$
    - Gross lending ($B_t^{L,j}$) and borrowing ($B_t^{B,j}$) in interbank (IB) market

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- Morning of $t+1$:
  - firms hires labor and produces
  - all assets pay off

Bank's problem

- Solves a 2 stage dynamic programming problem
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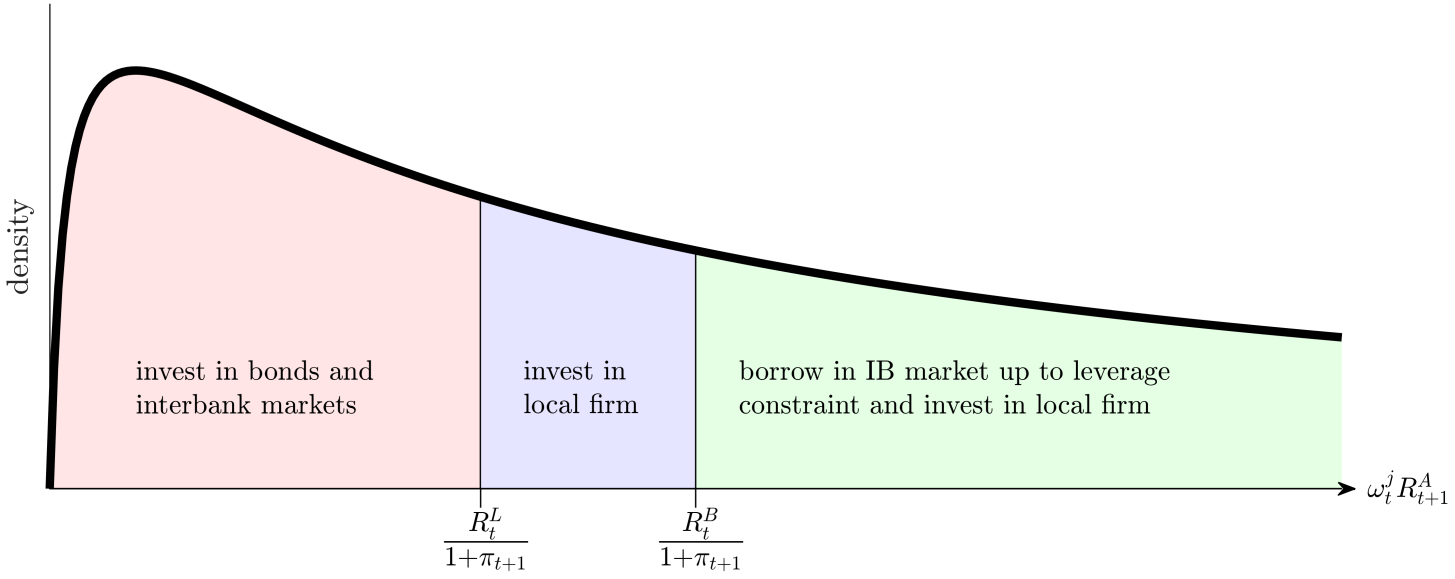
- The bank optimizes shareholder value subject to budget constraint and leverage constraint
- The bank takes asset returns as given
  - $\omega_t^j R_t^K$: return on investing into local firm
  - R_t^L, R_t^B : *effective* return on IB lending & borrowing
  - R_{t+1}^G, R_t^D : return on gov't bonds & deposits

Solution to bank's problem: Afternoon



Solution to bank's problem: Morning

- Banks break even *ex ante* when taking deposits
- Nominal deposit rate, $R_t^D \in [R_t^L, R_t^B]$

Interbank market

- In a frictionless market we would have $R_t^B = R_t^L$
- Instead we model the IB market as an OTC market with matching frictions similar to Bianchi and Bigio (2017) or Afonso and Lagos (2012).
- Assume competitive search (Armenter & Lester, 2017)

Aggregate number of borrowing and lending orders

- Banks place per-unit lending or borrowing orders.

$$\Phi_t^B \equiv \int_0^1 B_t^{+,j} dj = \left[1 - F\left(\omega_t^B\right)\right] \left[(\phi - 1) N_t - D_t\right],$$

$$\Phi_t^L \equiv \int_0^1 B_t^{-,j} dj = F\left(\omega_t^L\right) \left(N_t + D_t\right) - b_t^G.$$

Competitive search

- 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

$$\Gamma^L(\theta_t) \equiv \frac{\Upsilon\left(\Phi_t^L, \Phi_t^B\right)}{\Phi_t^L},$$

$$\Gamma^B(\theta) \equiv \frac{\Upsilon\left(\Phi_t^L, \Phi_t^B\right)}{\Phi_t^B},$$

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}).

Competitive search equilibrium

- Equilibrium interbank rate

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

where $0 \leq \varphi(\theta_t) \leq 1$, $\varphi\prime(\theta_t) < 0$ is the borrower's effective bargaining power

- In a *slack* IB market ($B_t^L > B_t^B$, low θ_t), it is easier for borrowers to find lenders (high Γ^B) $\rightarrow$ pay *lower* IB rate

Effective borrowing and lending rates

- R_t^B $\left(R_t^L\right)$ is the average interest rate a borrower (lender) expects when going to the interbank market

$$R_t^B = \Gamma^B R_t^{IB} + \left(1 - \Gamma^B\right) R_t^{LF}$$

$$R_t^L = \Gamma^L R_t^{IB} + \left(1 - \Gamma^L\right) R_t^{DF}$$

Central bank: interest rate policy & the ZLB

- The central bank sets the two policy rates (R_t^{DF}, R_t^{LF})
  - *constant* corridor width χ,

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

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

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

  $\upsilon > 1$, unless **ZLB** is hit: $R_t^{DF} \geq 1$

- Therefore,

$$R_t^{DF} = \max\left\{R_t^{IB,*} - [1 - \varphi(\theta_t)]\chi, \quad 1\right\}$$

Central bank: balance-sheet policy

- The central bank chooses size of its gov't bond holdings, real market value: $b_t^{G,CB}$
  - subject to its balance sheet constraint,

$$b_t^{G,CB} + \underbrace{\Phi_t^B \left(1 - \Gamma_t^B\right)}_{\text{Lending facility loans}} = \underbrace{\Phi_t^L \left(1 - \Gamma_t^L\right)}_{\text{Deposit facility (Reserves)}}$$

- Net profits are rebated to the Treasury
  - The Treasury is passive, keeps debt stock constant ($\bar{b}^G$) using lump sum taxes

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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 and borrowing rates,

$$\begin{aligned} R_t^L &= \Gamma^L(\theta_t) R_t^{IB} + [1 - \Gamma^L(\theta_t)] R_t^{DF}, \\ R_t^B &= \Gamma^B(\theta_t) R_t^{IB} + [1 - \Gamma^B(\theta_t)] R_t^{LF}. \end{aligned}$$

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

$$R_t^D \in [R_t^L, R_t^B].$$

Useful benchmark: match-efficiency & lean balance sheet

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- 'Lean' CB balance sheet: $b_t^{G,CB} = 0$. Then

$$\left.\begin{array}{ll} \Phi_t^B\left(1-\Gamma_t^B\right) = \Phi_t^L\left(1-\Gamma_t^L\right) & \text{(CB B/S)} \\ \Phi_t^B\Gamma_t^B = \Phi_t^L\Gamma_t^L & \text{(IB mkt clearing)} \end{array}\right\} \Rightarrow \Phi_t^B = \Phi_t^L \Leftrightarrow \theta_t = 1$$

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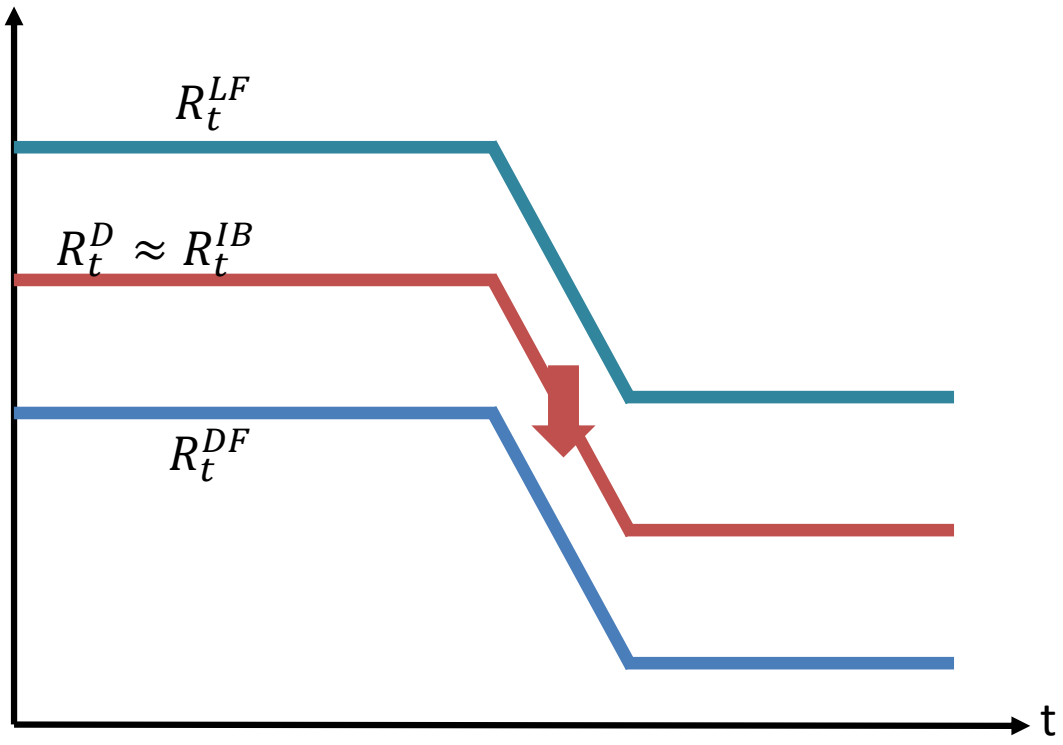
- If Υ match-efficient, then $\Gamma^L(1) = \Gamma^B(1) = 1$ and

$$R_t^L = R_t^B = R_t^D = R_t^{IB} = \varphi(1)R_t^{DF} + [1-\varphi(1)]R_t^{LF}.$$

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)



Transmission to market rates: QE

- Analytical result: all market rates decrease with the size of the balance sheet
- Mechanism:
  - CB bond purchases ($b_t^{G,CB} \uparrow$)
  - private bond absorption ($b_t^G \downarrow$) increases IB lending ($B_t^L \uparrow$) $\Rightarrow$ IB market more *slack* ($\theta_t \downarrow$)
  - Borrowers find lenders more easily ($\Gamma^B \uparrow$), lenders have a harder time ($\Gamma^L \downarrow$)
  - Borrowers get a better deal ($\varphi \uparrow$) $\Rightarrow R_t^{IB} \downarrow$
  - Lenders increasingly use deposit facility $\Rightarrow$ excess reserves $\uparrow$

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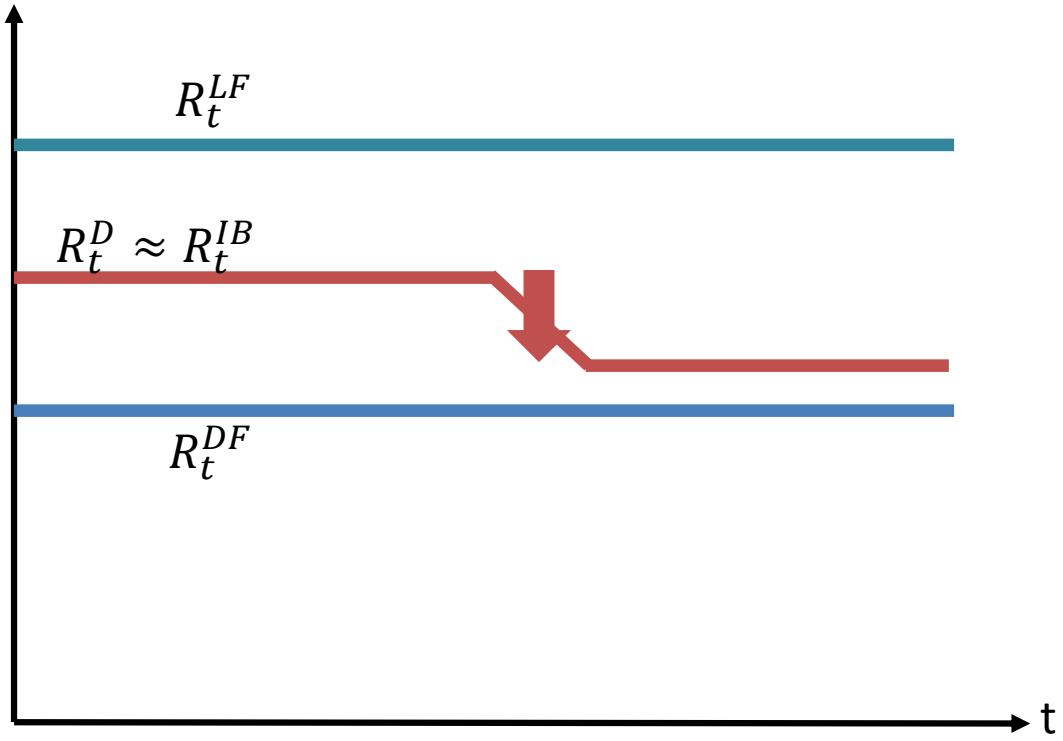

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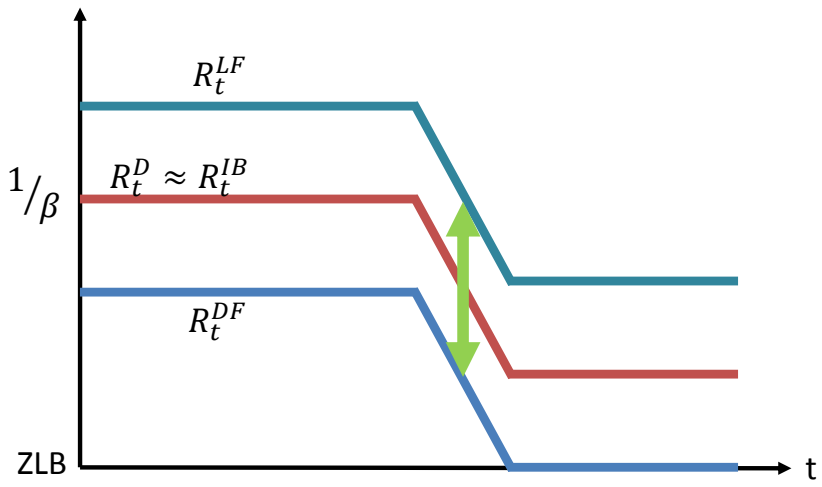
  - The effect of QE on interest rates is **decreasing in scale** (Reis 2016)
  - CB gvt. bond purchases (**APP**) and CB lending to banks at favorable rates (**LTROs**) are substitutes

Outline of the talk

Policy space: Lean vs large balance sheet

Small Balance Sheet



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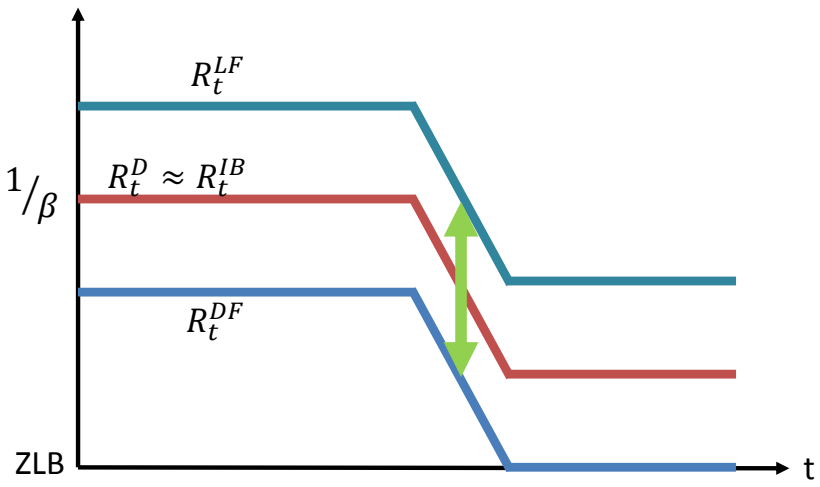

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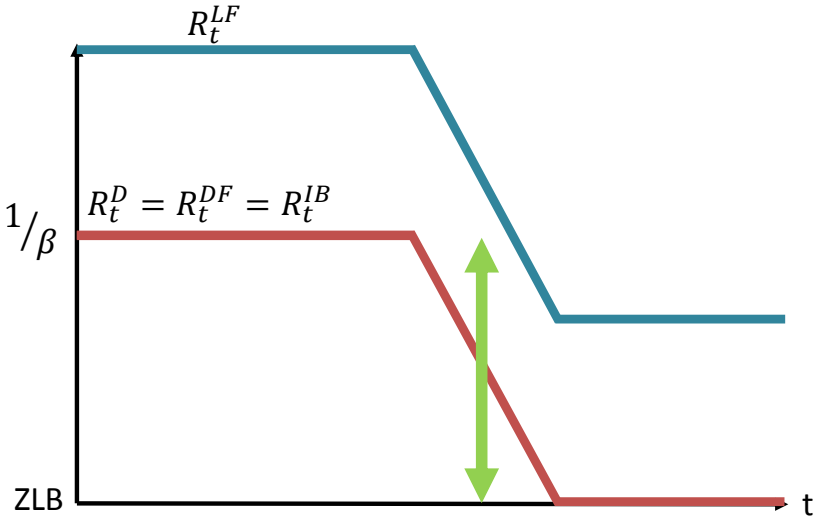

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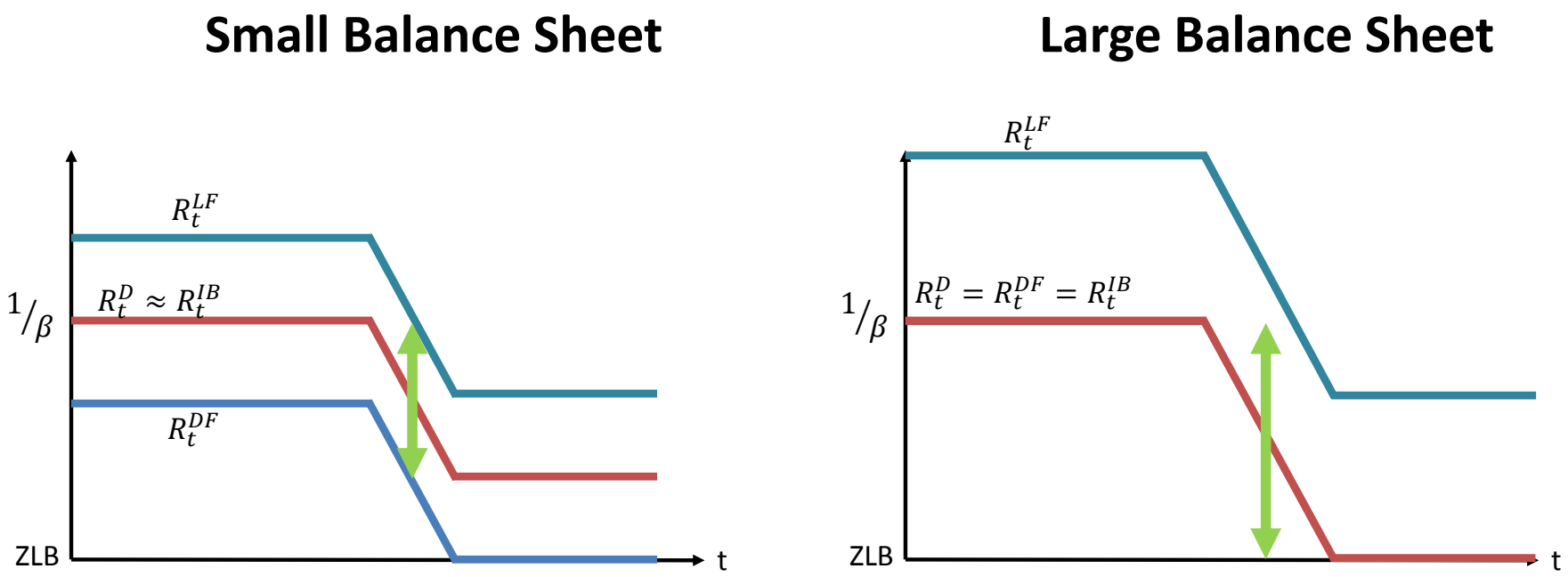

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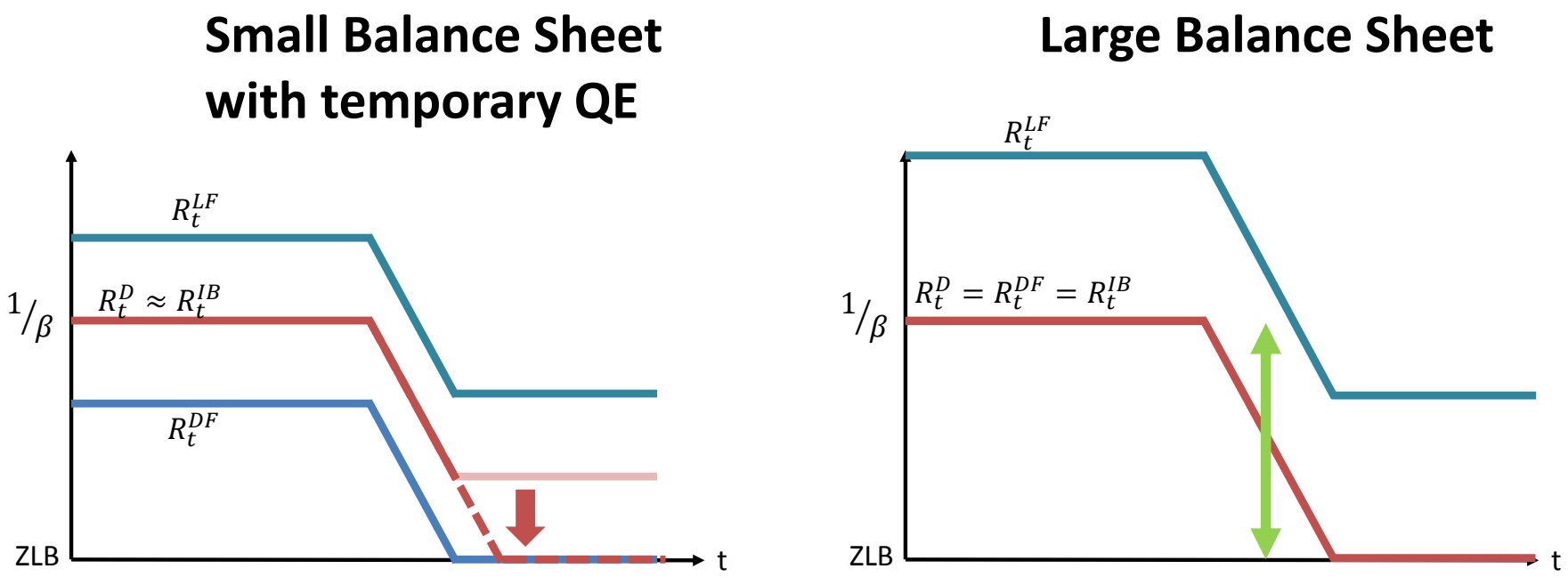

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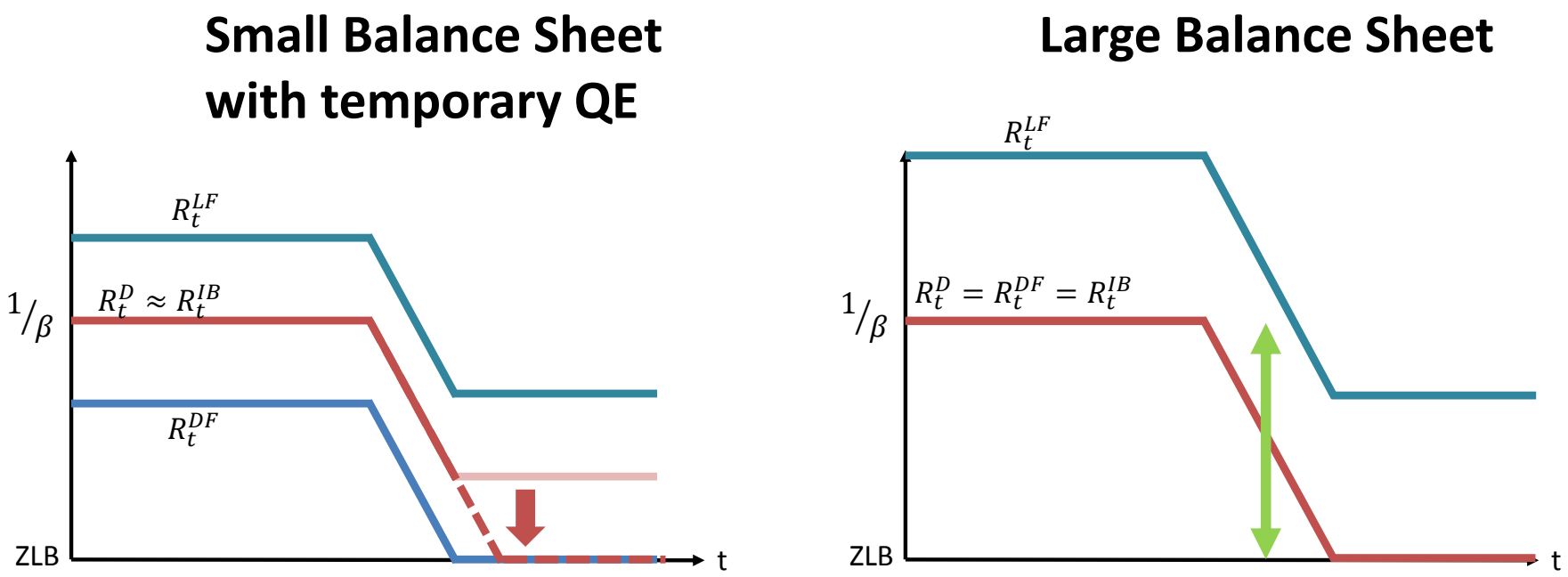


- Large BS provides more policy space wrt the ZLB than small BS
- Small BS with temporary QE provides the same policy space as large BS

Numerical analysis: calibration

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

$$\Upsilon(x, y) = \frac{xy}{(x^{\lambda} + y^{\lambda})^{1/\lambda}}, \qquad \lambda > 0.$$

- Choose λ to approximate empirical relationship between (excess) **reserves** (as % of GDP),

$$\Phi_{ss}^{L}\left[1 - \Gamma^{L}(\theta_{ss})\right]\frac{1}{Y_{ss}},$$

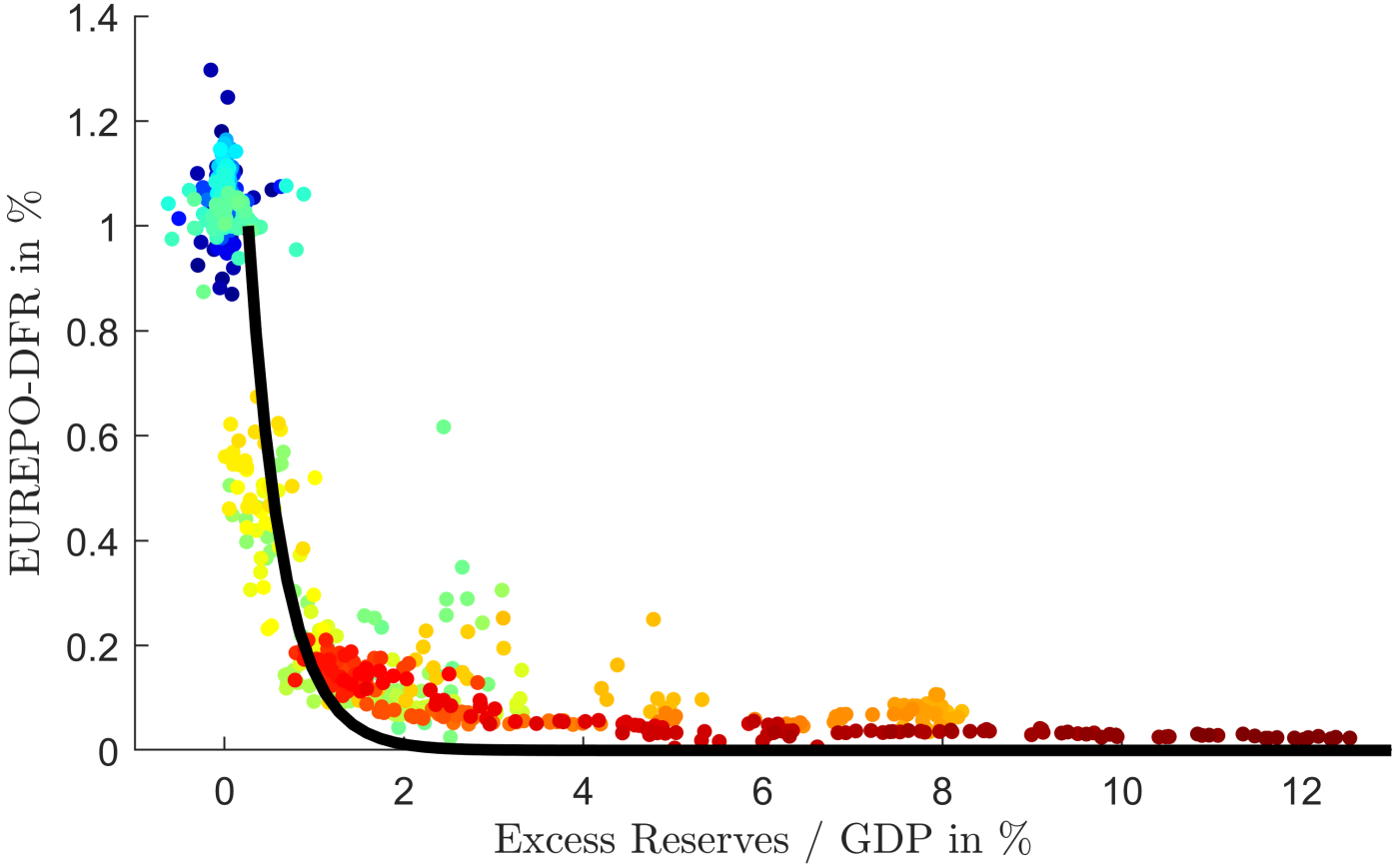
and their **opportunity cost**,

$$R_{ss}^{IB} - R_{ss}^{DF} = [1 - \varphi(\theta_{ss})]\,\chi,$$

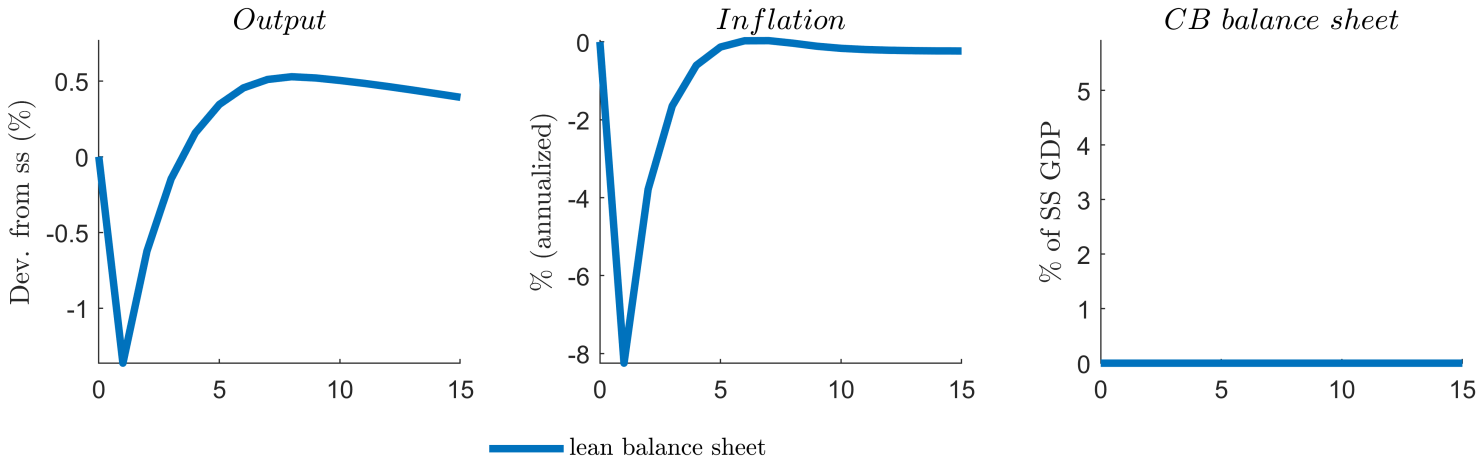
as we vary central bank's bond holdings, $b_{ss}^{G,CB}$

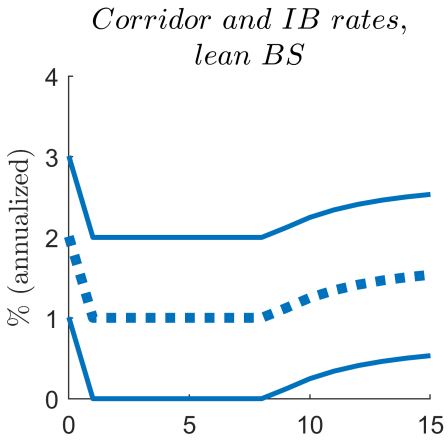
The EUREPO - DFR spread and excess reserves

- Use EUREPO as proxy for R_{ss}^{IB}
- $\lambda = 225 \Rightarrow \Upsilon(x, x) = \frac{x}{2^{1/\lambda}} \lesssim x$: approximately *match-efficient*

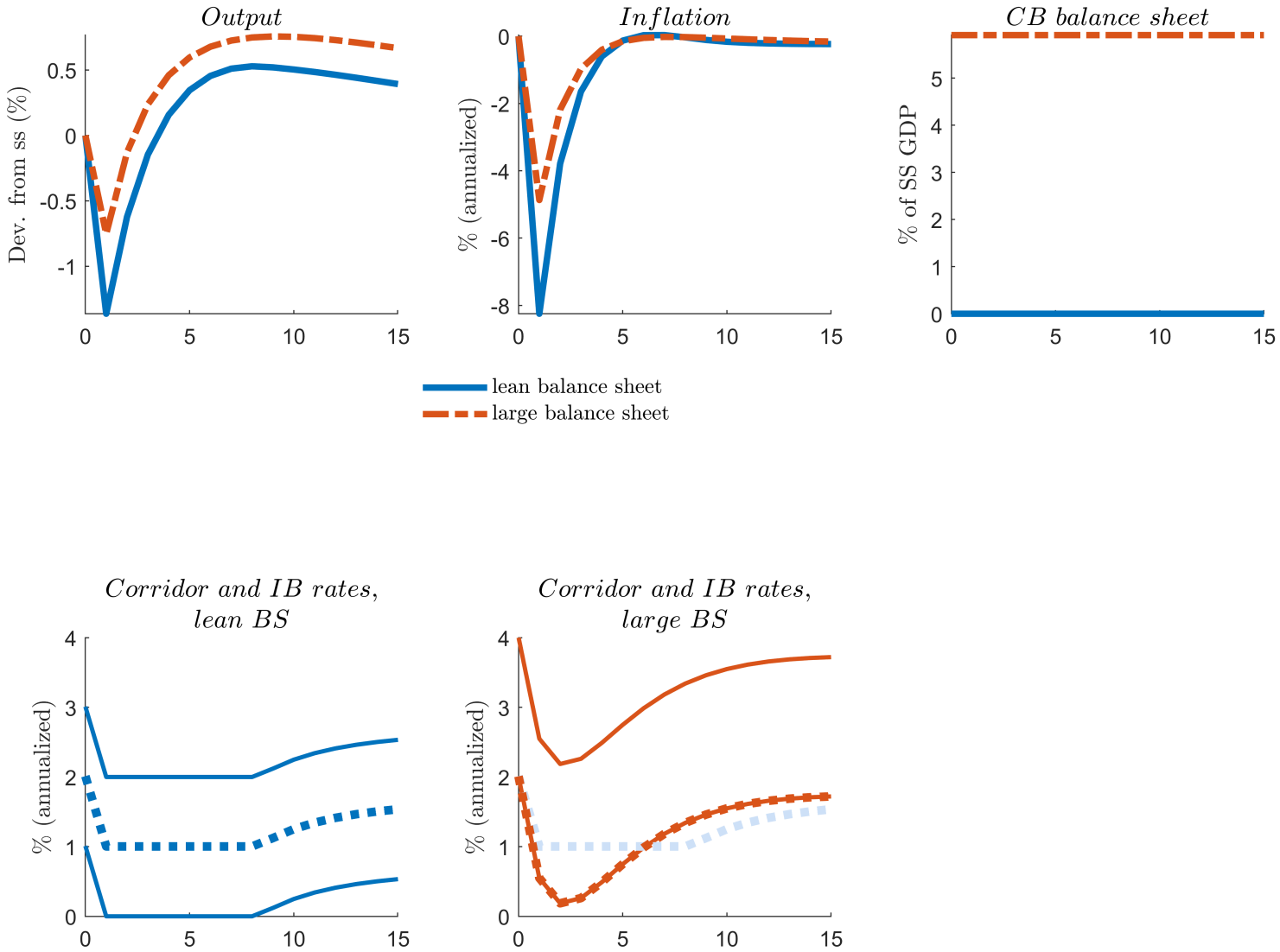


Numerical analysis: crisis scenario





Numerical example: crisis scenario



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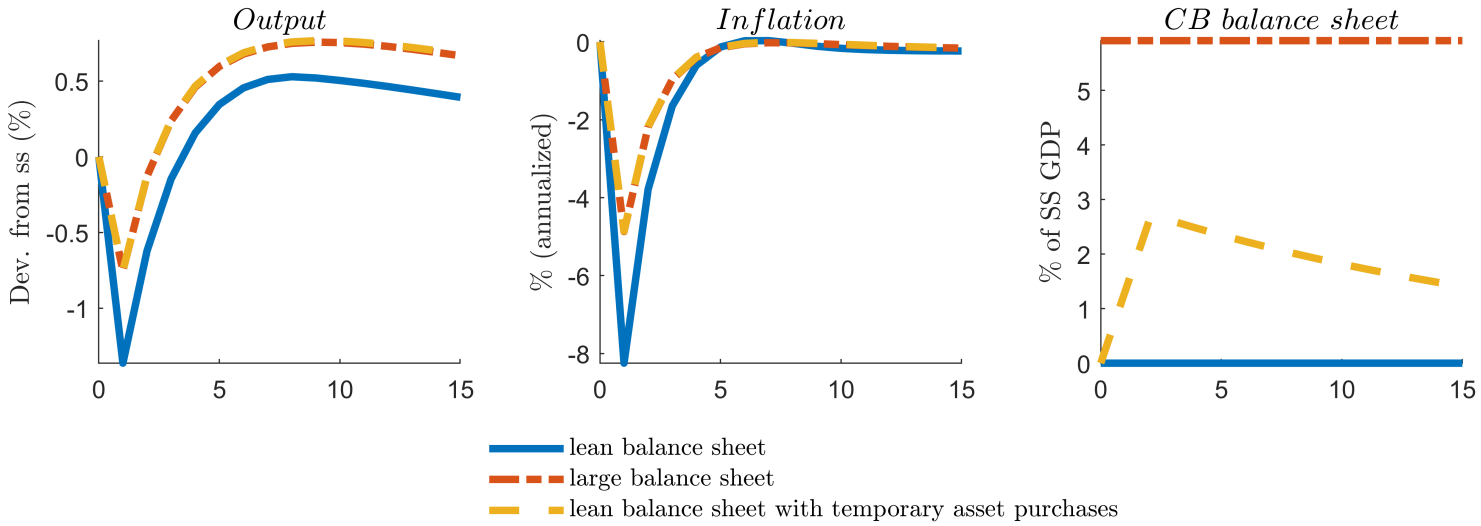

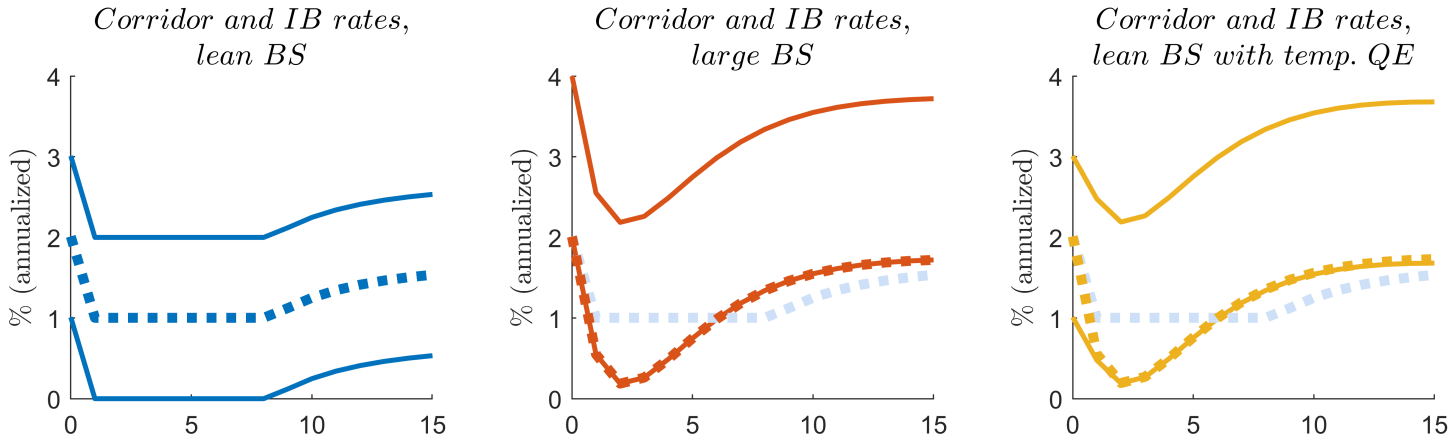

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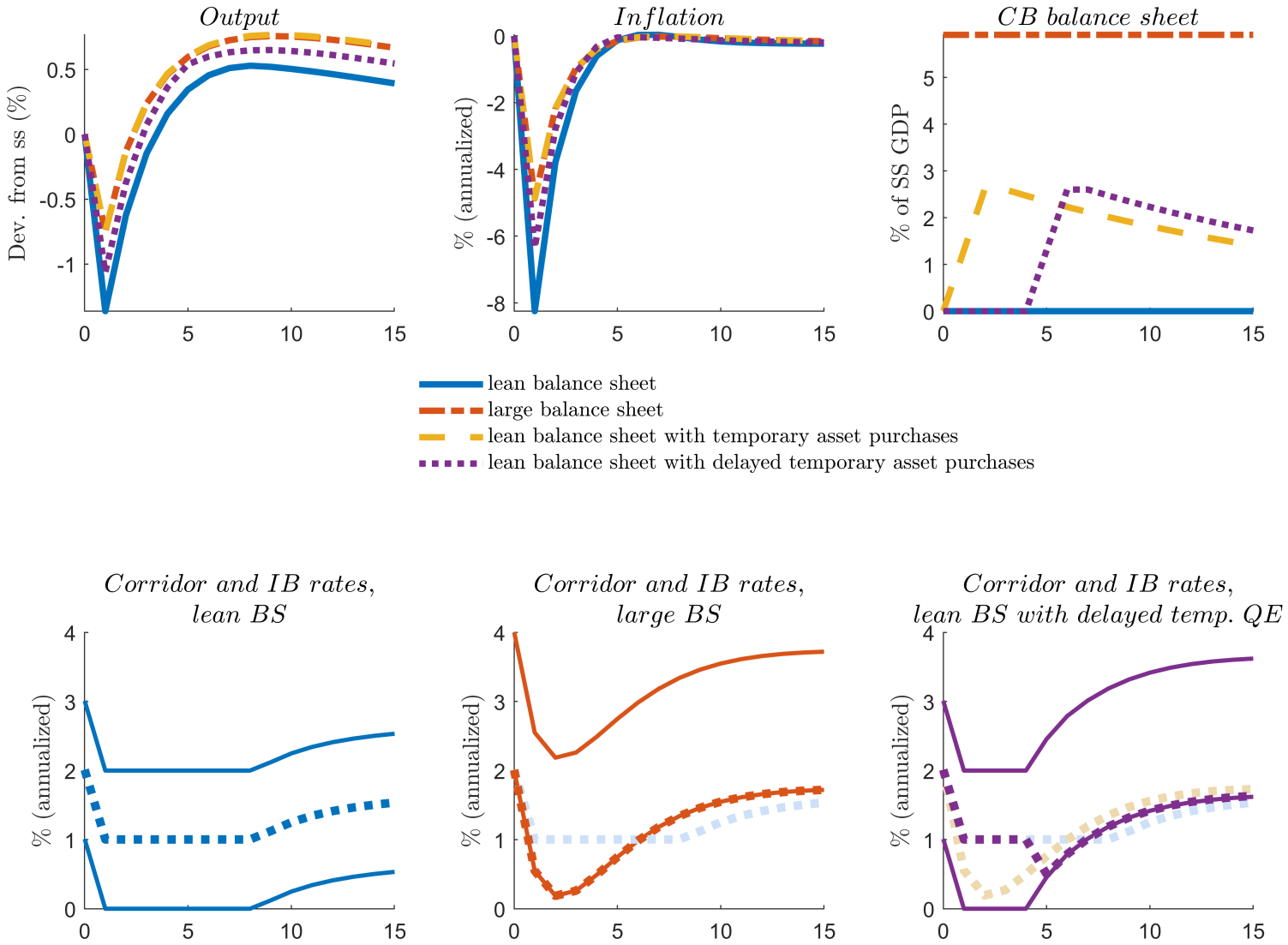

Conclusions

- 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

Calibration

Parameter		Value	Target
α	Capital share	0.33	Literature
δ	Depreciation	0.025	Literature
γ	Risk aversion	2	Literature
ψ	Inverse Frisch elasticity	1.45	Literature
θ	Calvo parameter	0.7	Literature
ϵ	Markup	5	Literature
ι	Investment adjustment	2.4	Literature
υ	Taylor rule inflation	1.5	Literature
ρ	Taylor rule persistence	0.8	Literature
ϕ	Leverage constraint	18.3	Literature
β	Discount factor HH	0.995	Sovereign yield
ζ	Bond maturity	0.05	Literature
$\overline{B}/\overline{Y}$	Government debt	1.577	Debt to quarterly GDP
$\overline{B}^{G,CB}/\overline{B}$	Government debt held by CB	0	no QE
χ	Corridor width	0.5%	Pre-crisis corridor width in the EMU
$\widehat{\beta}$	Discount factor bank	0.975	RoE EMU banks
μ	Mean of idiosyncratic shocks	-0.022	Normalize $\overline{\Omega} = 1$
σ	Std of idiosyncratic shocks	0.0028	Ratio of redistr. to productive assets
λ	Matching function	225	Ratio of interbank to CB lending

Lean or large balance sheet: Comparative statics

- Assuming that the IB market is *not match efficient* (i.e. $\Upsilon(x, x) < x$),
  - Without bond holdings, the CB balance sheet is small but positive in SS
  - Hence CB profits (seniorage) are positive, which is distortionary

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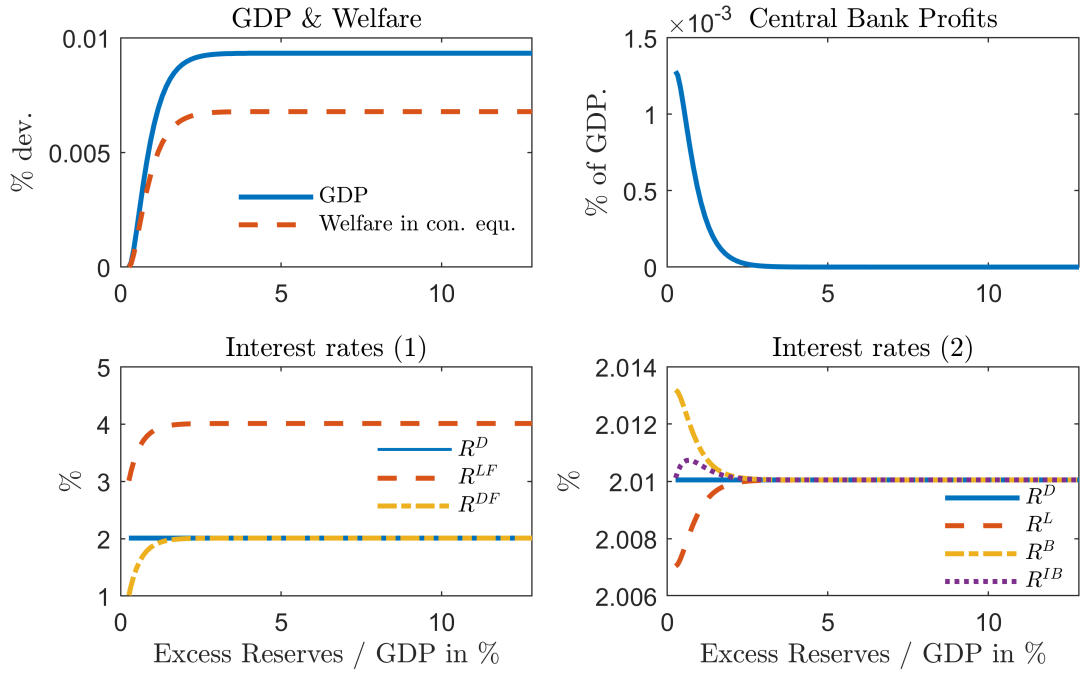
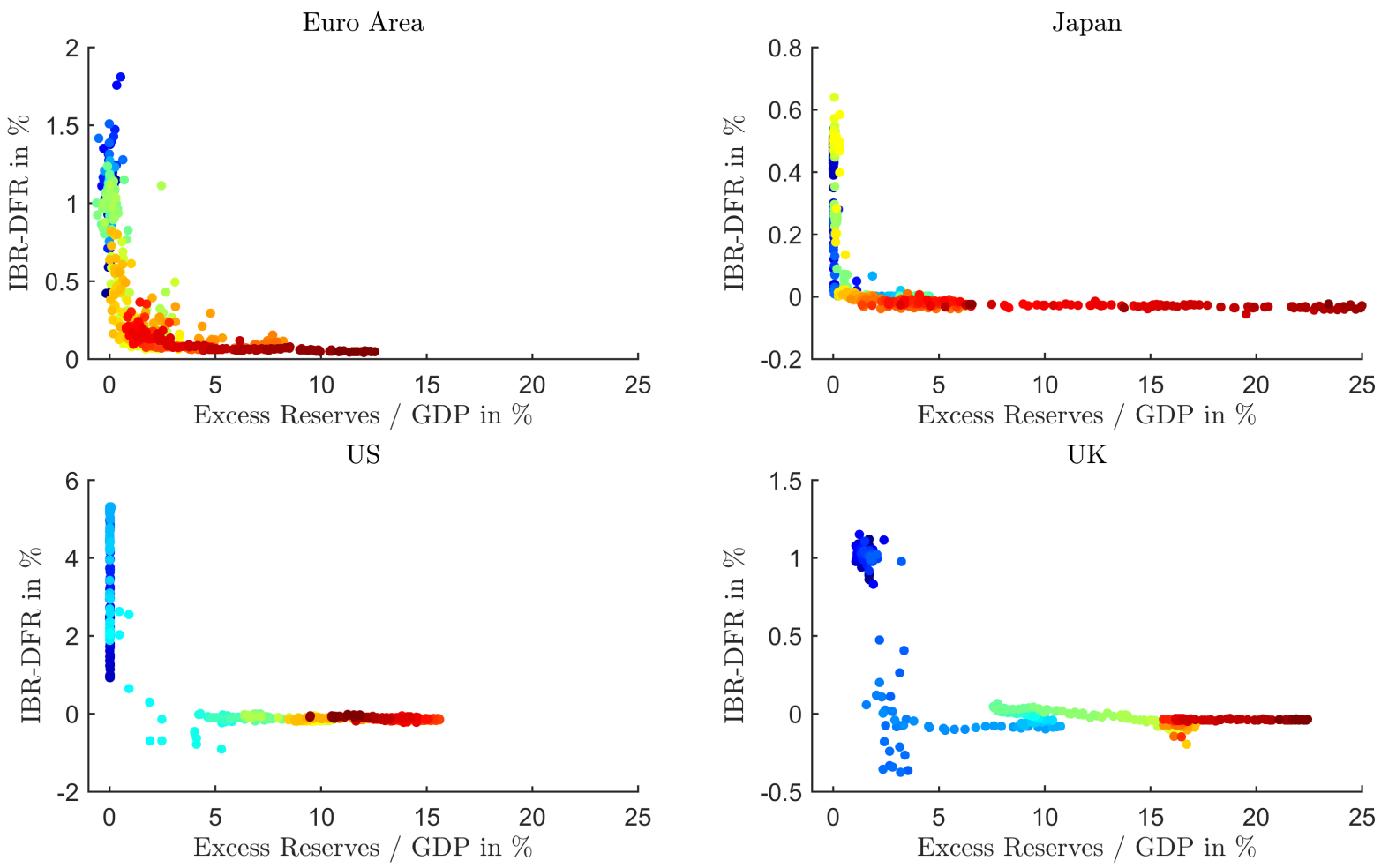
  - Without bond holdings, the CB balance sheet is small but positive in SS
  - Hence CB profits (seniorage) are positive, which is distortionary
  - Higher CB bond holdings imply higher excess reserves and lower lending facility lending
  - Since the spread between bond return and DFR is smaller than the corridor width and converges to 0, seniorage decreases in bond holdings
- The magnitude of this effect is negligible for a reasonable calibration



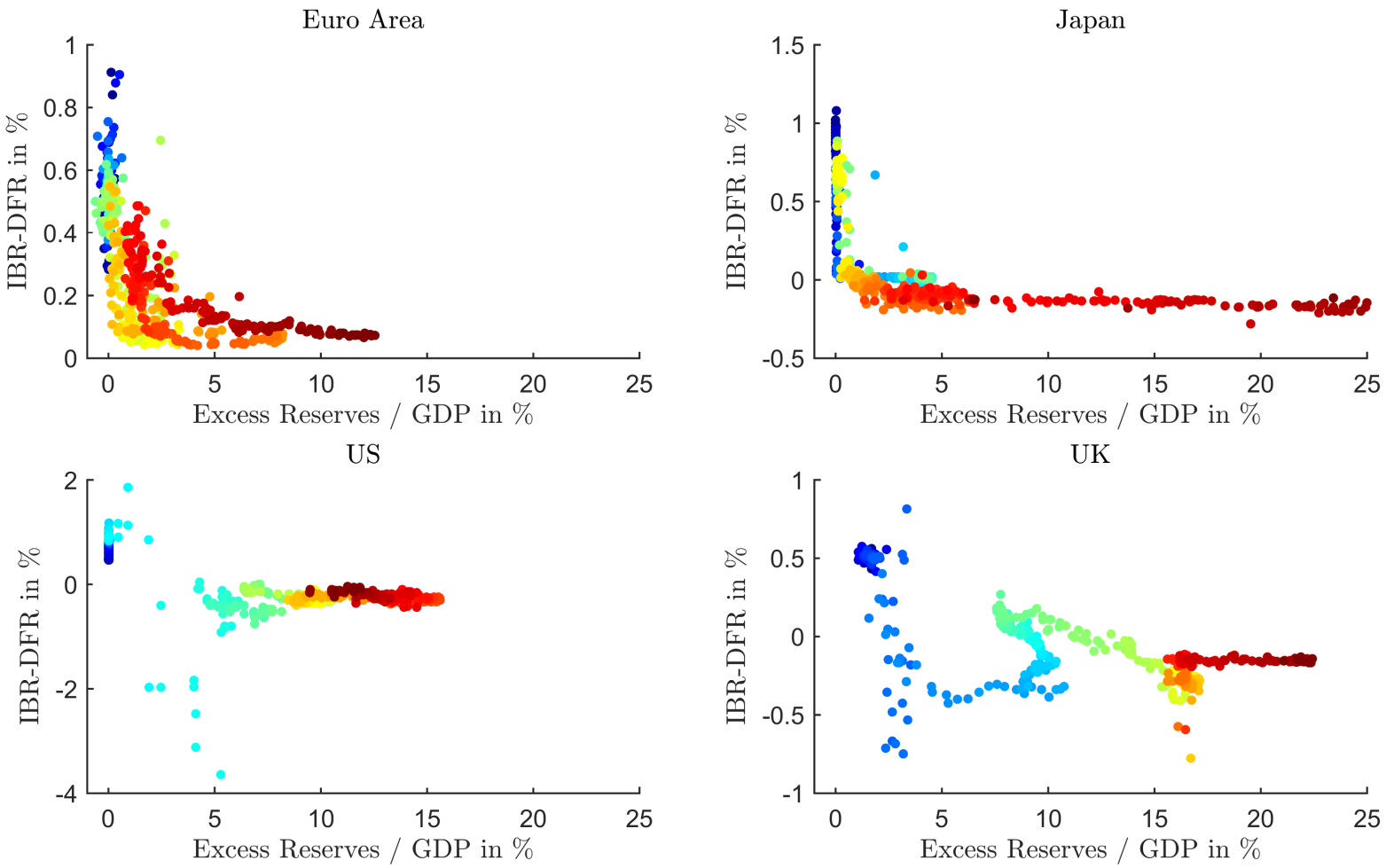
Excess reserves and the Interbank-DFR spread



Euro Area: EONIA - DFR; 1999-2017 US: Fed Funds Rate - IOER (since 2008); 2005-2017

UK: Sonia - IOR (since 2009 bank rate); 2006-2017 Japan: Uncollateralized Overnight rate - IOER (since 2008); 1997-2016

Excess reserves and the Interbank-DFR spread (normalized)



Euro Area: EONIA - DFR; 1999-2017 US: Fed Funds Rate - IOER (since 2008); 2005-2017

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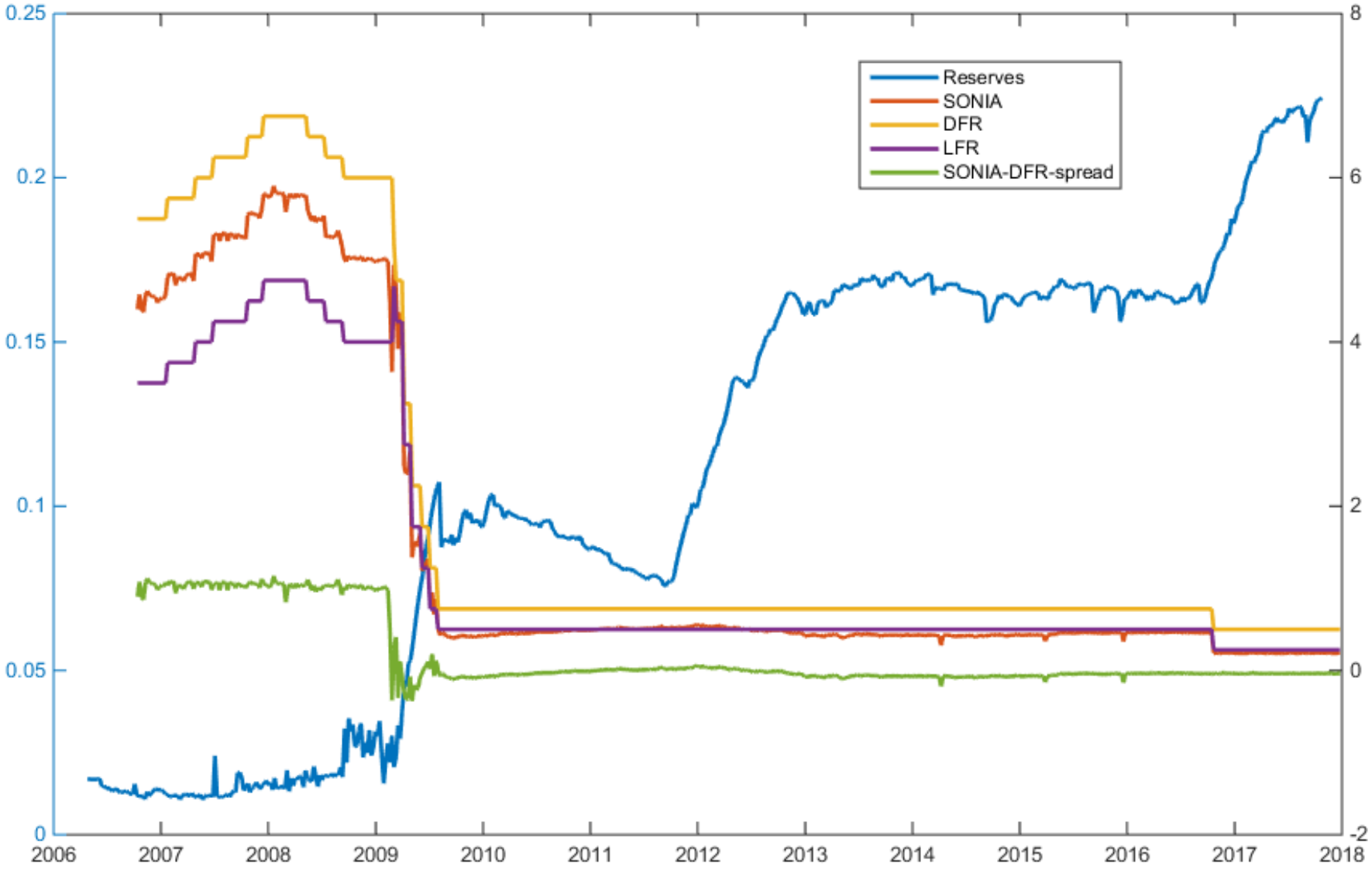
Data UK


Reserves
SONIA
DFR
LFR
SONIA-DFR-spread
0.25
0.2
0.15
0.1
0.05
0
8
6
4
2
0
-2
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018