Negative Rates and the Effective Lower Bound: Theory and Evidence

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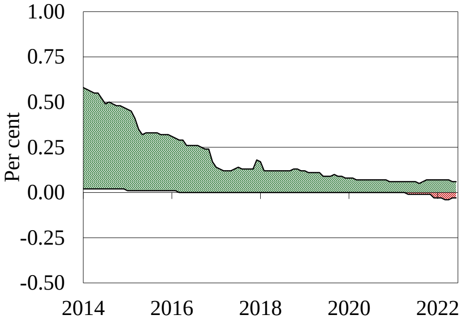
The Plan

1. Some facts about negative interest rates

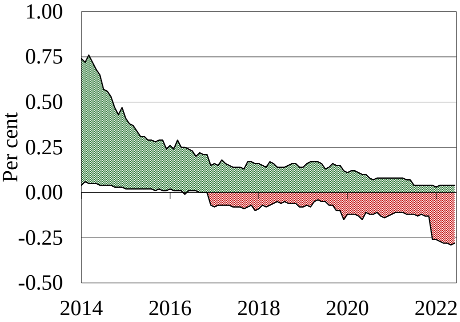
2. A realistic banking model with negative interest rates

3. A macro model to account for different transmission channels

Fact 1: Household sight deposit rates are bounded



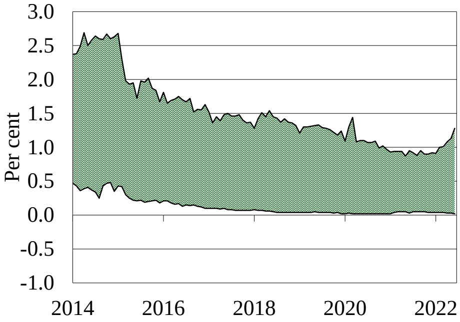
(a) Household sight deposit rates



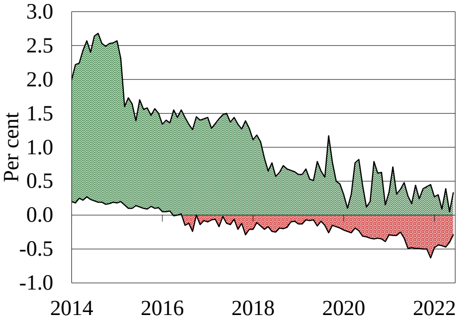
(b) Corporate sight deposit rates

Source: ECB Data Portal. The figures show the ranges of effective aggregate deposit rates (per cent) on new business across all euro-area countries with consistently available data between January 2014 and June 2022.

Fact 1: ... as are household time deposit rates



(a) Household time deposit rates



(b) Corporate time deposit rates

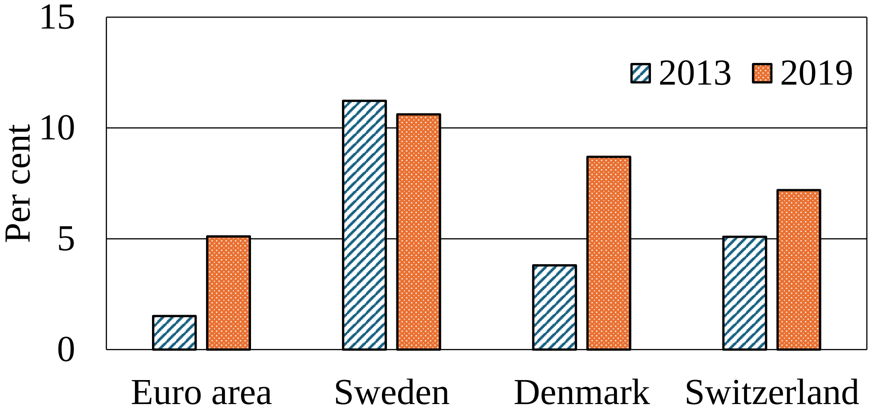
Source: ECB Data Portal. The figures show the ranges of effective aggregate deposit rates (per cent) on new business across all euro-area countries with consistently available data between January 2014 and June 2022.

Fact 2: Pass-through to lending rates has been partial

Table: Estimated pass-through from negative policy rates to lending rates

Region	Pass-through	Source
Euro area	50-80%	Altavilla et al. (2019)
Sweden	0-50%	Erikson and Vestin (2019), Eggertsson et al. (2024)
Denmark	30-40%	Adolfsen and Spange (2020)
Switzerland	0-30%	Baeriswyl et al. (2021), Schelling and Towbin (2020)

Fact 3: Bank profitability was little changed



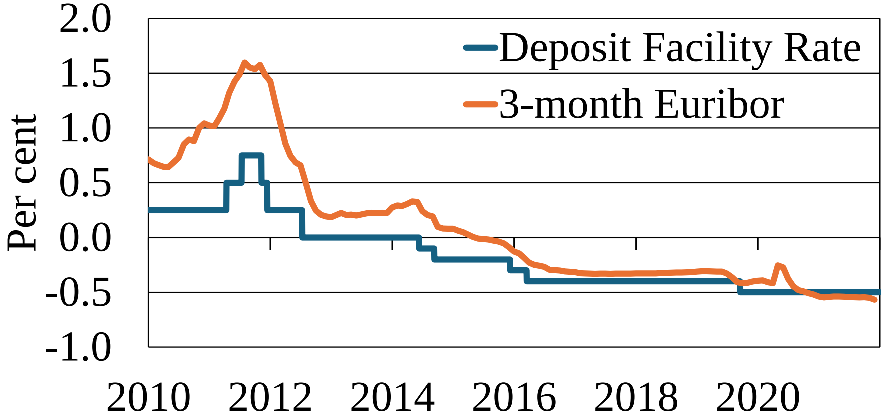
Aggregate bank return on equity

Fact 4: High-deposit banks may be negatively hit

There is consistent evidence that high-deposit banks can come under relative profitability pressure in negative rate environments. A number of papers aslo find evidence that low-deposit banks expand lending relative to high-deposit banks, though this result is not universal.

- Heider et al. (2018), Amzallag et al. (2019), Eggertsson et al. (2024) and Basten and Mariathasan (2018) all find that high-deposit banks expand lending by less than low-deposit banks when the policy rate falls below zero.
- Altavilla et al. (2018), Demiralp et al. (2019), Bottero et al. (2019) Schelling and Towbin (2020) and Hong and Kandrac (2018) find that high-deposit banks actually lend relatively more than low-deposit banks when rates are cut below zero.
- Adolfsen and Spange (2020), Bittner et al. (2021), Klein (2020) and Arce et al. (2018) find no significant relationship between the degree of deposit funding and subsequent lending behaviour.

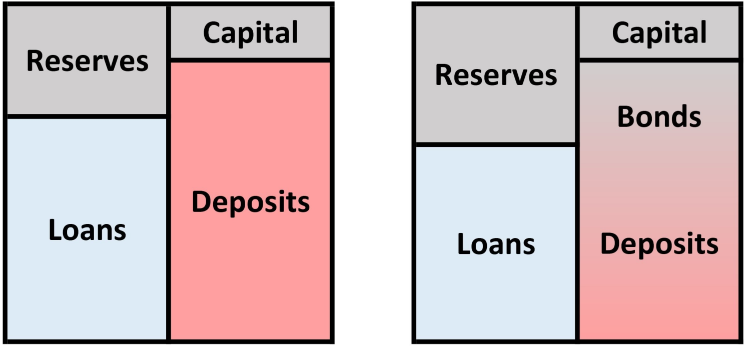
Fact 5: Broader financial market channels of transmission worked normally



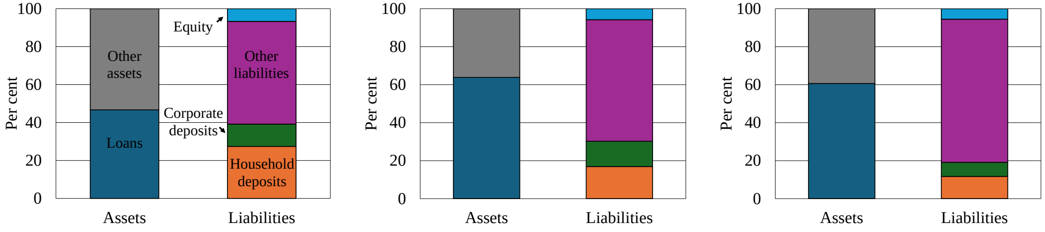
Key stylised facts

1. Transmission to household deposit rates is impaired but corporate deposit rates can fall below zero
2. Aggregate transmission to bank lending rates and volumes is reduced and potentially delayed but remains positive
3. Aggregate banking sector profitability is not adversely affected and may even improve
4. High-deposit banks can come under profitability pressure but do not necessarily experience lending reversal
5. Broader financial market channels of transmission tend to work normally and do not appear to be constrained by a lower bound

Model bank balance sheets



Actual bank balance sheets



(a) Euro area (b) Sweden (c) Denmark

Source: Consolidated banking data from the ECB Data Portal. The figure is based on annual end-of-year data, averaged over 2014 to 2019. Loans refers to loans to households and non-financial corporations only.

Monti-Klein banking model

Local monopoly bank facing loan demand and deposit supply curves, s.t. capital constraint $K \geq \psi L$, capital supplied at premium ρ, wholesale funding at i.

The bank generates profits from lending and deposit taking

$$\max_{L,D} \quad \pi = (i_L - i - \psi\rho)L + (i - i_D)D$$

The lending rate is set as a mark-up on the policy rate

$$i_L^* = i + \psi\rho + \frac{1}{\varepsilon_L}$$

Constant semi-elasticity

Pass-through from the policy rate to the lending rate is complete

$$\frac{di_L^*}{di} = 1$$

Funding constraint: assumption and micro-foundations

- Introduce a funding constraint that requires a (bank-specific) minimum degree of deposit funding: $\phi L \leq D$
- May or may not bind in normal times. Will always bind at the ZLB

1. Regulation
   * Net stable funding ratios
   * Liquidity regulations
2. Synergies
   * Deposit taking reduces information asymmetries
   * Deposit taking builds relationships with loan clients
3. Complexity
   * Insufficient information for marginal cost pricing
   * Banks resort to average cost pricing or NIM targeting

Funding-constrained lending at the ZLB

The funding constraint will always bind at the lower bound

$$\phi L = D, \phi \in (0, 1)$$

Separability is broken. Bank maximises π by setting L s.t. the funding constraint

$$\max_L \quad \pi = (i_L - (1-\phi)i - \phi i_D - \psi\rho)L$$

The policy rate is no longer the sole marginal funding cost for loan pricing

the deposit rate is zero

$$i_L^* = (1-\phi)i + \rho\psi + \varepsilon_L^{-1}$$

Monetary policy transmission to lending is reduced but remains positive

$$di_L^*/di = 1 - \phi \geq 0$$

Competition between homogeneous banks

Profits

$$\max_{L_n} \; \pi_n = \left[i_L \left(L_n + \sum_{m \neq n} L_m^* \right) - (1-\phi)i - \psi\rho \right] L_n$$

Lending rate

$$i_L(L^*) = (1-\phi)i + \psi\rho + \frac{1}{N \cdot \varepsilon_L}$$

Monetary policy transmission to lending at the ZLB

$$di_L^*/di = 1 - \phi \geq 0$$

Competition between heterogeneous banks

Two types of banks with $\phi_1 \neq \phi_2$, abstract from capital for simplicity

Type 1 profit function

$$\max_{L_{1,j}} \left(i_L \left(L_{1,j} + \sum_{m \neq j} L^*_{1,m} + \sum_k L^*_{2,k} \right) - (1-\phi_1) i \right) L_{1,j}$$

Optimal lending

$$L_{1,1} = \ldots = L_{1,n_1} = -\frac{i_L - (1-\phi_1) i}{i_L'}, \qquad L_{2,1} = \ldots = L_{2,n_2} = -\frac{i_L - (1-\phi_2) i}{i_L'}$$

Competition between heterogeneous banks

Differentiating optimal lending for a bank of type 2 (high-deposit) with respect to the policy rate yields

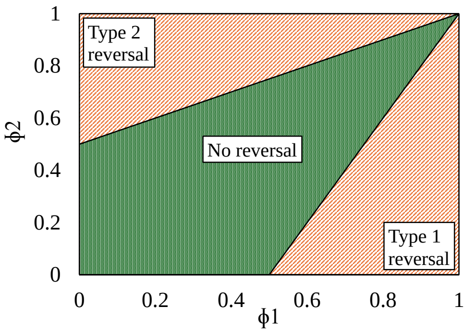
$$\frac{dL_{2,k}}{di} = \frac{(1-\phi_2)\left[(n_1+1)i_L^{'} + n_1 i_L^{''} L_{1,j}\right] - (1-\phi_1)n_1(i_L^{'} + i_L^{''} L_{2,k})}{i_L^{'}\left[(n_1+n_2+1)i_L^{'} + n_1 i_L^{''} L_{1,j} + n_2 i_L^{''} L_{2,k}\right]} \quad \forall k,$$

A bank of type 2 (high-deposit) will expand lending in response to a policy rate cut below zero iff

$$\phi_2 < \frac{i_L^{'} + n_1 i_L^{''}(L_{1,j} - L_{2,k})}{(n_1+1)i_L^{'} + n_1 i_L^{''} L_{1,j}} + \frac{n_1(i_L^{'} + i_L^{''} L_{2,k})}{(n_1+1)i_L^{'} + n_1 i_L^{''} L_{1,j}}\phi_1$$

Competition between heterogeneous banks

- In a duopoly with a linear loan demand function, this condition simplifies to $\phi_2 < \frac{1}{2} + \frac{1}{2}\phi_1$.
- Lending reversal by higher-deposit bank iff difference in funding structures sufficiently large.



Competition between heterogeneous banks

Lending rate

$$i_L = \underbrace{\left(\frac{n_1}{n_1 + n_2}(1 - \phi_1) + \frac{n_2}{n_1 + n_2}(1 - \phi_2) \right) i}_{\text{Average loan funding cost}} + \underbrace{\frac{1}{(n_1 + n_2)\varepsilon}}_{\text{Constant mark-up}}$$

Aggregate pass-through to lending remains positive regardless of the degree of competition

$$\frac{di_L}{di} = \frac{n_1(1 - \phi_1) + n_2(1 - \phi_2)}{n_1 + n_2} > 0$$

Competition between heterogeneous banks

Aggregate profits

$$\begin{aligned}\pi &= n_1 \pi_{1,i} + n_2 \pi_{2,j} \\ &= \left[i_L - \left(\frac{n_1}{n_1 + n_2}(1 - \phi_1) + \frac{n_2}{n_1 + n_2}(1 - \phi_2) \right) i \right] L \\ &= \frac{1}{(n_1 + n_2)\varepsilon} L\end{aligned}$$

Aggregate profits increase when the policy rate is cut below zero

$$\frac{d\pi}{di} = \underbrace{0}_{\text{Delta Mark-up}} \cdot \underbrace{L}_{\text{Loans}} + \underbrace{\frac{1}{(n_1 + n_2)\varepsilon}}_{\text{Mark-up } (>0)} \cdot \underbrace{\frac{dL}{di}}_{\text{Delta Loans } (<0)} < 0$$

Profitability of low-deposit and high-deposit banks

Low-deposit banks will always see an increase in profits following a policy rate cut at the ZLB, while the effect on high-deposit banks' profits is theoretically ambiguous as long as $\phi_2 < 1$.

Low-deposit banks' profits increase when the policy rate is cut below zero

$$\frac{d\pi_{1,j}}{di} = \underbrace{\frac{2n_2\varepsilon L}{n_1+n_2}}_{>0}\left[\underbrace{\frac{n_2}{n_1+n_2}(\phi_1-\phi_2)^2\varepsilon i}_{<0}+\underbrace{\frac{\phi_1-\phi_2}{n_1+n_2}}_{<0}\right]+\underbrace{\left[\frac{n_2}{n_1+n_2}(\phi_1-\phi_2)\varepsilon i+\frac{1}{n_1+n_2}\right]^2}_{>0}\underbrace{\frac{dL}{di}}_{<0} < 0$$

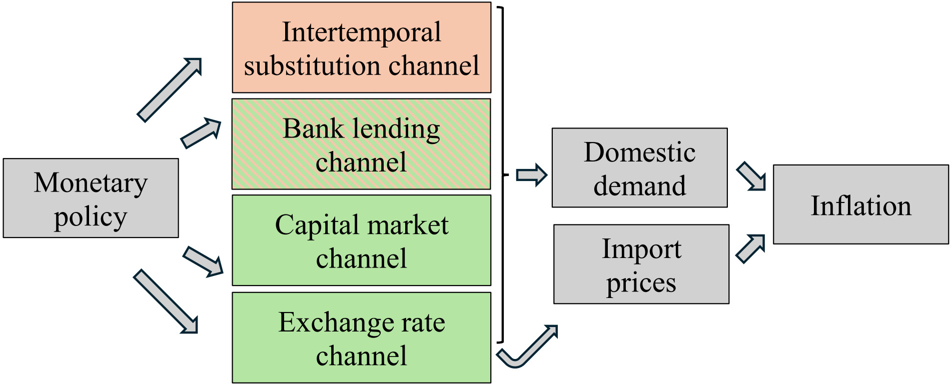
High-deposit banks' profits could increase or decrease

$$\frac{d\pi_{2,k}}{di} = \underbrace{\frac{2n_1\varepsilon L}{n_1+n_2}}_{>0}\left[\underbrace{\frac{n_1}{n_1+n_2}(\phi_2-\phi_1)^2\varepsilon i}_{<0}+\underbrace{\frac{\phi_2-\phi_1}{n_1+n_2}}_{>0}\right]+\underbrace{\left[\frac{n_1}{n_1+n_2}(\phi_2-\phi_1)\varepsilon i+\frac{1}{n_1+n_2}\right]^2}_{>0}\underbrace{\frac{dL}{di}}_{<0}$$

Competition between heterogeneous banks

- A cut in the policy rate into negative territory leads to:
  - A fall in the lending rate
  - An increase in lending - no reversal in aggregate lending
  - A (slight) increase in banking sector profitability
  - Potential changes in market shares: High-deposit banks can experience loss of market share and falling profitability

Stylised Monetary Policy Transmission Mechanism



General Equilibrium

- Small open economy model
  - Cournot banking sector with two types (high-deposit and low-deposit), with ZLB on deposits and funding-constrained banks
  - Some firms are bank-dependent, while others can borrow directly from capital markets at the policy rate as in Abadi et al. (2023)
  - Capital flows and exchange rate determined by financiers rather than households, similar to Gabaix and Maggiori (2015)

We study a large adverse demand shock that creates a deep recession, and solve the model using the Guerrieri and Iacoviello (2015) toolkit for occasionally binding constraints.

Households

Households consume, save and supply labour. They can hold bonds, cash, and bank deposits, and derive liquidity value from the latter two. A household's lifetime utility is defined by

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[u(C_t, C_{t-1}, N_t) + \Phi(\mathcal{L}_t) \right], \text{ where } u(C_t, C_{t-1}, N_t) = \frac{(C_t - hC_{t-1})^{1-\sigma} - 1}{1-\sigma} - \chi \frac{N_t^{1+\frac{1}{\eta}}}{1+\frac{1}{\eta}} \text{ and } \Phi(\mathcal{L}_t) = 1 - e^{-\upsilon \mathcal{L}_t}.$$

The household budget constraint is

$$C_t + \frac{D_t}{P_t} + \frac{M_t}{P_t} + \frac{B_t}{P_t} = \frac{W_t}{P_t} N_t + \Pi_t - T_t + \frac{1 + i_{t-1}^D}{1+\pi_t} \frac{D_{t-1}}{P_{t-1}} + \frac{1}{1+\pi_t} \frac{M_{t-1}}{P_{t-1}} + \frac{1+i_{t-1}}{1+\pi_t} \frac{B_{t-1}}{P_{t-1}}.$$

When the policy rate is above zero, households will hold a mix of deposits and bonds. The Euler equation and households' inverse deposit supply function are

$$1 = \beta \mathbb{E}_t \left[\frac{\rho_{t+1}}{\rho_t} \frac{1+i_t}{1+\pi_{t+1}} \right] \text{ and } i_t^D = i_t - \mathbb{E}_t \left[\frac{(1+\pi_{t+1})\upsilon}{\beta \rho_{t+1}} \right] e^{-\upsilon \frac{D_t}{P_t}}.$$

The Euler equation governing households' intertemporal decisions for all possible levels of the policy rate is

$$1 = \beta \mathbb{E}_t \left[\frac{\rho_{t+1}}{\rho_t} \frac{1 + max\{i_t, 0\}}{1+\pi_{t+1}} \right]. \tag{1}$$

Financiers

There is a perfectly competitive group of global financiers, similar to Gabaix and Maggiori (2015). We think of these as global banks that intermediate across borders, and as such, they have access to reserve accounts at both home and foreign central banks. They elastically supply wholesale finance to banks at the policy rate. In equilibrium, their balance sheet constraint is

$$WF_t + HF_t + e_t HF_t^* + L_t^C = E_t^C + B_t + e_t B_t^* .$$

The rate as which firms with direct capital market access can borrow from financiers is

$$i_t^C = i_t + \mu_F + \kappa \left(\frac{L_t^C}{E_t^C} - \psi \right).$$

Financiers' optimisation problem also yields the uncovered interest parity condition

$$1 + i_t = \mathbb{E}_t \left[(1 + i_t^*)(1 + \pi_{t+1}) \frac{s_{t+1}}{s_t} \right] + \kappa_B (B_t^* - \overline{B^*}).$$

Intermediate Goods Firms

There are two types of intermediate goods producers which differ solely in how they raise finance to purchase capital. A fraction $1-\lambda$ of firms borrow from financiers (type $z=c$), while the larger proportion λ borrow from banks (type $z=b$). There is a separate capital market for each type of intermediate goods firm, but they hire labour from a single labour market as in Abadi et al. (2023).

In period $t-1$, bank-reliant firms need to take out L^B_{t-1} units of loans to finance the purchase of new capital at price q^b_{t-1} from capital producers,

$$L^B_{t-1} = q^b_{t-1} K^b_{t-1}.$$

Banks as well as financiers offer one-period loan contracts, so the gross real loan interest payment that firms have to make at the beginning of period t is $(1+i^z_{t-1}) \times L^z_{t-1}/(1+\pi_t)$. Hence, an intermediate firm's period t real profit is accounted for by product sales revenue, the revenue from selling undepreciated capital back to capital producers, wage costs, and the gross real loan interest payment,

$$\Pi^z_t = \frac{P^m_t}{P_t} Y^z_t + q^z_t \Xi_t (1-\delta) K^z_{t-1} - w_t N^z_t - \frac{(1+i^z_{t-1}) L^z_{t-1}}{(1+\pi_t)}.$$

Capital Producers, Retailers and Final Goods Firm

These are standard New Keynesian ingredients in our model.

1. Perfectly competitive capital producers are subject to investment adjustment costs.
2. Monopolistic retailers are subject to Rotemberg (1982) adjustment costs, such that their problem gives rise to a New Keynesian Phillips curve.
3. A representative final goods firm aggregates differentiated varieties supplied by monopolistic retailers to produce output, which it sells at the competitive price P_t^H.

Banks

Banks have access to wholesale finance at the policy rate i_t and offer one-period deposit and loan contracts. Each bank's balance sheet consists of reserves (H_t) and loans (L_t) on the asset side, and equity (E_t), deposits (D_t) and wholesale finance (WF_t) on the liability side,

$$H_t + L_t = E_t + D_t + WF_t.$$

Imperfect Cournot competition between two different types of banks which differ solely in their funding constraints. Low-deposit banks and high-deposit banks whose funding constraint parameters are

$$0 < \phi^{low} < \phi^{high} < 1.$$

Banks internalise effects of their individual lending decisions on the aggregate lending rate, as well as direct effects of the aggregate lending rate on firms' capital and loan demand. Banks do not internalise wider indirect effects through the labour market or aggregate prices. The resulting equilibrium bank lending rate is a mark-up over the marginal funding cost, which is a weighted average of the policy rate and the deposit rate reflecting the funding constraint, and adjusted for leverage costs.

$$i_t^L = \left[\frac{\mathcal{N}^z \varepsilon_t^L}{\mathcal{N}^z \varepsilon_t^L - \frac{L_t^z}{L_t}} \right] \left((1 - \phi^z)(1 + i_t) + \phi^z (1 + i_t^D) + \kappa \left(\frac{L_t^z}{E_t^z} - \psi \right) \right) - 1.$$

Market Clearing

Total domestic output Y_t is divided between household consumption of the domestic good C_t^H, investment using the domestic good I_t^H, government consumption G_t and exports X_t

$$Y_t = C_t^H + I_t^H + G_t + X_t.$$

The economy's trade balance is the difference between exports and imports. It equals the current account in our model, which must equal the financial account balance,

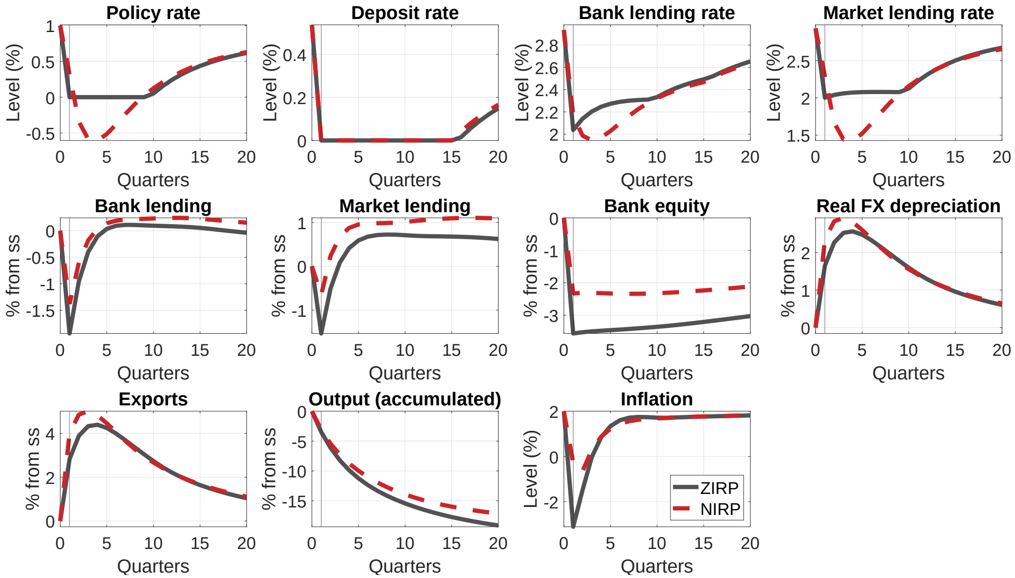
$$TB_t = -s_t B_t^* + s_t(1 + i_{t-1}^*)B_{t-1}^* + s_t \frac{\kappa_B}{2}\left(B_t^* - \overline{B^*}\right)^2 + M_t - M_{t-1},$$

where M_t are cash flows. Monetary policy is set by a Taylor rule with interest-rate smoothing,

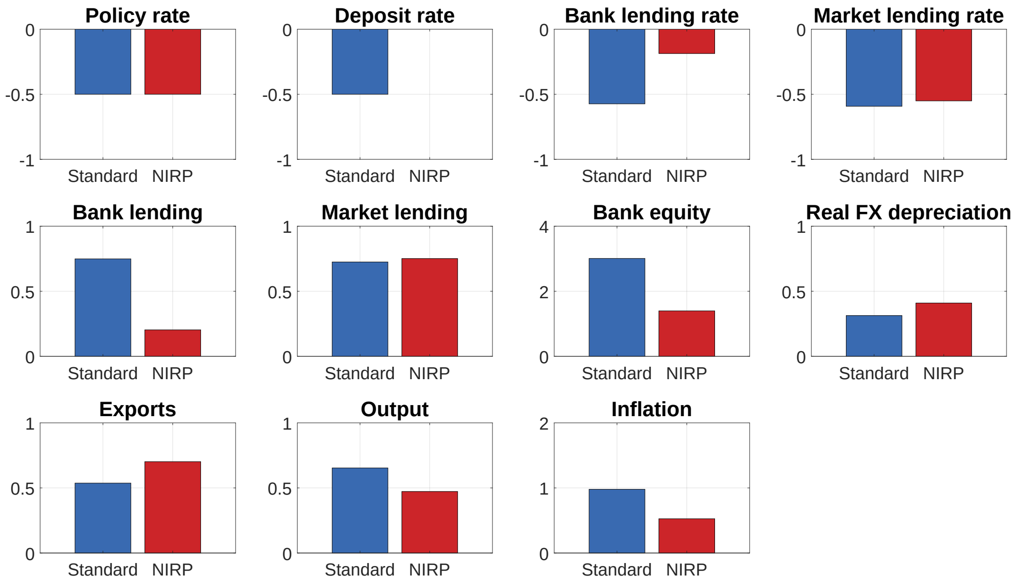
$$i_t = (1 - \rho_i)(\bar{i} + \phi_\pi(\pi_t - \overline{\pi})) + \rho_i i_{t-1} + \varepsilon_t^i, \tag{2}$$

The central bank will follow this rule except in the regime where there is a lower bound on the policy rate, in which case it simply sets a zero policy rate whenever the Taylor rule would call for a negative policy rate. The presence of interest-rate smoothing in the rule will lead to a signalling channel of negative rates, as in de Groot and Haas (2023).

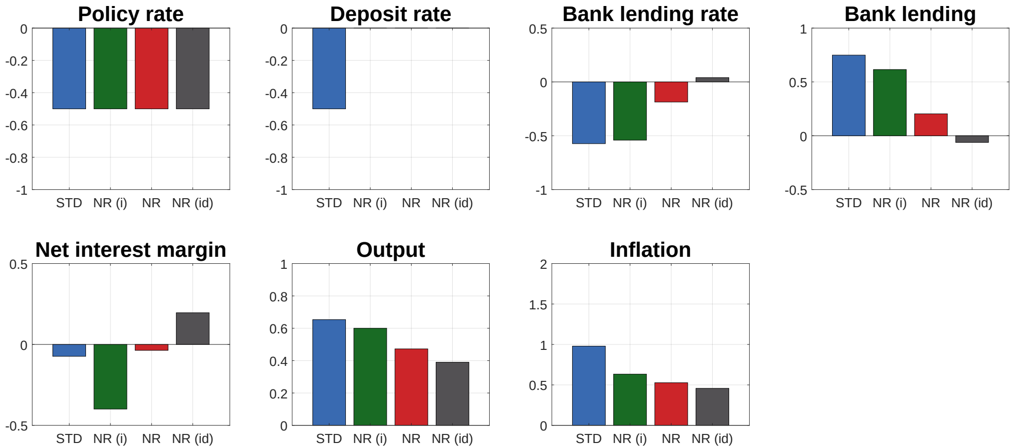
Impulse responses to an adverse demand shock



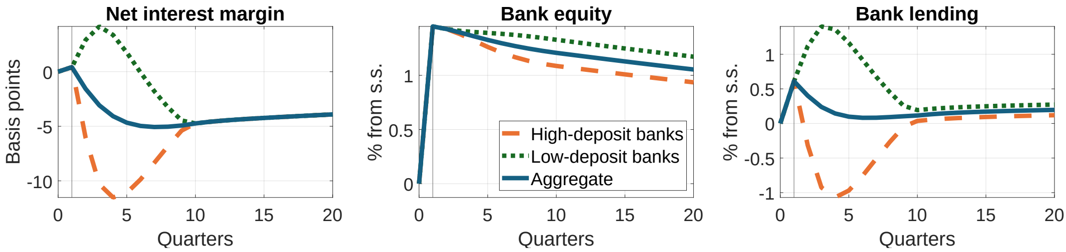
The effectiveness of NIRP compared to a standard rate cut



The effectiveness of NIRP compared to a standard rate cut, based on different marginal funding cost assumptions



The effects of NIRP on high-deposit and low-deposit banks



Conclusions

- ✓ NIRP ease financial conditions and support growth and inflation. Effects on aggregate bank profitability are limited.
- ✓ Hard to generate lending reversal in a realistic banking sector model. As long as banks are partly wholesale-funded, reversal in the aggregate is highly unlikely.
- ✓ Other general-equilibrium channels continue to work and reduce risk of lending reversal, in particular in open economies.
- ✓ Concerns about competition and financial stability when there are large differences in bank business models.