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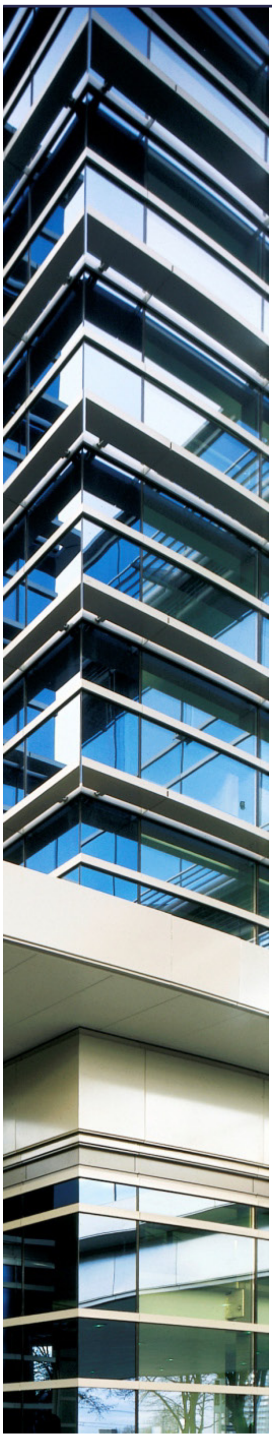

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The Economic Impact of the Deposit Interest Rate Adjustment Speed

Patrick Grüning*

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Abstract

During the recent monetary policy tightening cycle, the pass-through of monetary policy to interest rates offered by commercial banks and the size of bank profits have attracted substantial attention. In this study, I explore the economic effects of reducing the adjustment speed of monetary policy changes to deposit interest rates, using a suitable New-Keynesian dynamic stochastic general equilibrium model. A lower deposit interest rate adjustment speed increases macroeconomic volatility but decreases the volatility of the credit spread (except in the case of a very low adjustment speed). Bank net interest income and aggregate consumption typically increase relative to a model where the deposit interest rate perfectly tracks the monetary policy rate, while aggregate output and investment dynamics deteriorate. Introducing a tax on the interest income earned by setting deposit interest rates below the monetary policy rate leads to amplified short- and medium-run macroeconomic costs. However, the tax improves long-run economic dynamics.

Keywords: Monetary policy, Financial intermediaries, Deposit interest rates, New-Keynesian DSGE model, Excess bank interest income tax

JEL codes: E31, E32, E44, E52, H25

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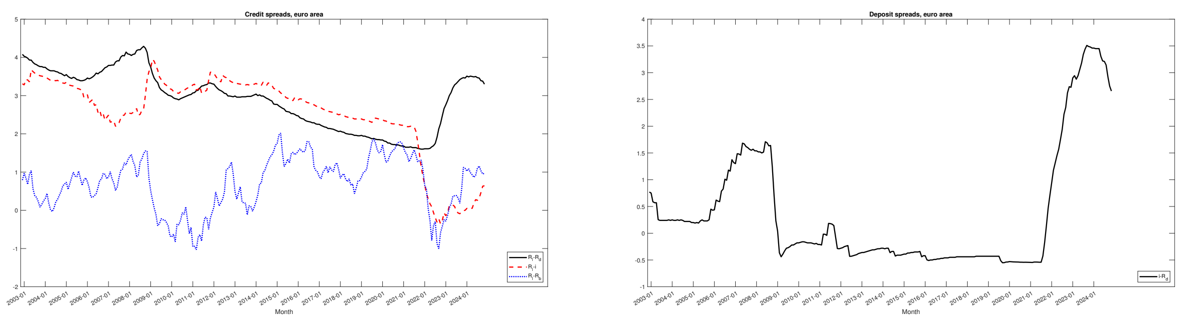
1 Introduction

Monetary policy implemented by the central bank is supposed to control the general level of loan and deposit interest rates in the economy, thereby keeping inflation stable. Possibly, a central bank's mandate also includes keeping employment or economic growth stable. The main instrument to achieve these goals is setting an interest rate (the monetary policy rate) at which commercial banks can deposit funds with or borrow from the central bank. For monetary policy to be effective, commercial banks need to pass on the change in the monetary policy rate to their customers via adjusting the deposit and loan interest rates applied to households and non-financial corporations accordingly. The monetary policy pass-through might thus be impaired if commercial banks do not change deposit or loan interest rates sufficiently or by a long delay in response to a monetary policy rate change. There is ample empirical evidence that the pass-through of monetary policy rate changes to both loan and deposit interest rates is imperfect and asymmetric (Hannan and Berger, 1991; Hofmann and Mizen, 2004; De Graeve et al., 2007; Hristov et al., 2014; Drechsler et al., 2016; Altavilla et al., 2020; Boeckx et al., 2020; Canova and Pérez Forero, 2024; Kho, 2024; Vilerts et al., 2025). However, the theoretical literature rationalizing these empirical facts in general equilibrium models, and studying the resulting economic consequences, is rather limited (Binning et al., 2019; Levieuge and Sahuc, 2021). This study contributes to this rather scant theoretical literature as the recent episode of monetary policy tightening in response to the spiking inflation figures in the aftermath of the COVID-19 pandemic and the start of the Russian war of aggression against Ukraine seems to be plagued by an imperfect pass-through of monetary policy as well. Indeed, inspecting Figure 1 that depicts credit and deposit spreads for the euro area yields evidence of a spike in the deposit spread from the beginning of 2022 onward and a similar, slightly delayed increase in credit spreads from the second half of 2022 onward.

Figure 1: Credit and deposit spread measures in the euro area



Notes: This figure depicts three credit spread measures and the deposit spread in the euro area for the period from January 2003 to December 2024. The left panel depicts the credit spread measures where the first measure – black solid lines – is the loan interest rate minus the deposit interest rate, the second measure – red dashed lines – is the loan interest rate minus the monetary policy rate, and the third measure – blue dotted lines – is the loan interest rate minus the 10-year euro government bond interest rate. The right panel shows the deposit spread: the monetary policy rate minus the deposit interest rate.

Specifically, I will develop a New-Keynesian dynamic stochastic general equilibrium (DSGE) model with Rotemberg (1982)-style price and wage rigidities and financial intermediaries lending to firms for capital investment. These loans are financed by household deposits and equity, following the structure of the financial sector in Gertler and Karadi (2011, 2013). This allows the exploration of economic effects of different deposit interest rate adjustment speeds to monetary policy rate changes. In the benchmark calibration, I will assume that nominal wholesale deposit interest rates are always equal to the nominal monetary policy rate. Then, I will compare the results from this benchmark model to the ones from alternative calibrations, in which it will take some time until a monetary policy change is fully reflected in the deposit interest rate.

The motivation for this project originates from two sources. First, the theoretical literature seems to concentrate its efforts so far on an imperfect pass-through of monetary policy rate changes to loan interest rates. The model by Levieuge and Sahuc (2021) features asymmetric adjustment costs for bank branches deciding on loan interest rates charged on housing loans (mortgages) to impatient households and corporate loans. Specifically, adjustment costs are higher for decreasing loan interest rates than for increasing them. This is in line with novel empirical evidence for the euro area that bank lending rates are downward rigid. In Binning et al. (2019), a regime-switching New-Keynesian DSGE model is employed with four regimes along two dimensions: whether the economy is in the zero lower bound or not and whether banks charge a high or low interest rate mark-up (mark-down) on investment loans to firms (deposits to households). Thus, the credit spread between loan and deposit interest rates is regime-dependent. The novel model in this study in contrast concentrates on the deposit interest rate channel.

Second, novel empirical evidence uncovered by Kho (2024) points to significant asymmetry in the deposit interest rate adjustment speed in response to positive monetary policy changes in countries with concentrated banking sectors that feature low competition among banks. Moreover, several governments from EU countries, among them countries with highly concentrated banking sectors and a prevalence for flexible-rate loans (for example, the Baltic countries), have recently introduced additional taxes on banks due to highly increased profits, which could have been fueled in part by banks adjusting deposit interest rates slowly, after the start of the monetary policy tightening cycle in the euro area in July 2022. An overview of these new taxes is provided by Maneely and Ratnovski (2024). This empirical evidence and governmental reactions point to the importance of the deposit rate adjustment speed channel in determining bank profits and the likelihood of changes to bank legislation.

Besides standard frictions of New-Keynesian DSGE models such as price rigidity, wage rigidity, and investment adjustment costs and customary stochastic shocks such as classic and investment productivity shocks, price and wage mark-up shocks, monetary policy shocks, and government spending shocks, the most important model feature is the financial sector. The financial intermediaries collect deposits from households and use their own net worth to finance loans to the intermediate goods firms with which they finance their investment expenditures by means of a loan-in-advance constraint. In order to match the empirically observed credit and deposit spreads in the euro area, the financial intermediaries retain some market power in pricing loans and deposits via separately modeling the wholesale and retail branches of financial intermediaries. In addition, this allows for a loan interest rate mark-up shock to be added to the set of shocks analyzed in the impulse response function analysis. To keep matters simple and to proxy for loan pricing dynamics similar to the situation in Latvia (among others), I assume that the wholesale branches set their loan rates (which act as the cost of financing for the retail branches) equal to the monetary policy short rate plus a constant risk premium term.

First, in the simulated model moment analysis, I find that decreasing the adjustment speed of deposit interest rates to monetary policy rate changes leads to higher macroeconomic volatility (i.e. higher output, consumption, and investment growth volatility) and lower financial volatility (i.e. lower credit spread volatility). The financial volatility, however, also increases when assuming a very low deposit rate adjustment speed.

Second, in the impulse response function analysis, I find that banks can increase their net interest income over all horizons in response to most (5 out of 7) shocks. The two exceptions are positive investment productivity shocks and negative loan interest rate mark-up shocks. In these five shock scenario cases, aggregate cumulative output contracts over all horizons. For four out of these five cases, aggregate investment also contracts. The additional exception is a positive monetary policy shock. Aggregate consumption in contrast increases when investment contracts. This is due to the higher net interest income of banks which fuels the transfers to households from the banking sector (dividends and net worth of non-surviving banks) and the substitution of resources from investment to consumption. Therefore, a lower deposit rate adjustment speed is bad news for economic dynamics (output/investment) but good news for households' consumption. Unsurprisingly, bank net interest income typically increases when deposit rates are more slowly adjusted.

Introducing a tax on the interest income earned by banks on the spread between retail deposit interest rates and the monetary policy rate, amplifies economic costs (for output and investment) in the short to medium run. However, the long-run implications are beneficial in terms of output and investment dynamics. The introduction of the tax reduces households' consumption and bank profits significantly across all horizons.

Therefore, for a policy-maker focusing on long-run economic dynamics the introduction of such a tax seems like a good idea. However, a policy that motivates banks to pay the monetary policy rate as the deposit interest rate might be the even better policy response as it avoids any economic costs of the low deposit interest rate adjustment speed in terms of output/GDP.

A rich empirical literature finds that the pass-through of policy rates to retail bank rates is often incomplete due to market power within the banking sector (Hannan and Berger, 1991) and that the pass-through can vary significantly across different types of banks, meaning institutional factors can limit the effectiveness of monetary policy (Hofmann and Mizen, 2004). De Graeve et al. (2007) uncover, for example, the role of competition intensity for the transmission of monetary policy to loan and deposit rates in the case of Belgium. They find that a larger competition intensity leads to an increase in monetary policy effectiveness. Similarly, Kho (2024) provides an up-to-date exploration of the role of concentration (competition) using euro area data concentrating on the pass-through of monetary policy to deposit interest rates. He finds that in countries with highly concentrated banking sectors, the delay in the transmission speed can be up to half a year. Other factors influencing the monetary policy pass-through by banks are the severity of funding constraints (Boeckx et al., 2020) or other bank characteristics such as the capital ratio, the exposure to domestic sovereign debt, and the percentage of non-performing loans (Altavilla et al., 2020). Levieuge and Sahuc (2021) provide novel empirical evidence that bank lending rates are adjusted more slowly and less completely in response to negative changes in the monetary policy rate than to positive changes in the euro area. Using U.S. data, Drechsler et al. (2016) document an increase in the market power of banks after the monetary policy rate increases, making them increase their deposit spreads. Canova and Pérez Forero (2024) find that the level of inflation influences monetary policy effectiveness due to a lower responsiveness of output growth and inflation to conventional monetary policy shock at times of low inflation.

On the theoretical front, Binning et al. (2019) develop a regime-switching DSGE model with a banking sector to explore the incomplete and asymmetric pass-through of monetary policy rates. Their findings indicate that the pass-through is delayed in the short run and incomplete in the long run, impacting macroeconomic dynamics. This incomplete pass-through results in less effective monetary policy, especially under zero lower bound (ZLB) conditions, where the asymmetry between loan and deposit rate shocks becomes more pronounced. The model developed by Levieuge and Sahuc (2021) features asymmetric Rotemberg (1982)-style loan interest rate adjustment costs making it more costly for banks to reduce loan interest rates than to increase them. This model feature implies that a central bank would have to cut the monetary policy rate more aggressively to achieve the same effect as in a symmetric adjustment costs calibration. As banks become more downward rigid when the ZLB binds, monetary policy pass-through becomes even more impaired.

The remainder of this study is structured as follows. Section 2 develops the model. Section 3 discusses its calibration and data fit. It also provides an analysis of simulated moments. Next, Section 4 is devoted to the analysis of the model's impulse response functions and to derive policy implications. Finally, Section 5 concludes this study.

2 Model

I develop a New-Keynesian DSGE model that will be used to explore the economic relevance of the transition speed of monetary policy rate changes to deposit rate changes.

2.1 Households

The household sector features a continuum of households, indexed by $h \in [0,1]$. Each household obtains utility from the consumption of final goods and dis-utility from supplying labor such that her lifetime utility $U_{h,t}$ is specified as follows:

$$U_{h,t} = \mathbf{E}_t \left[\sum_{s=0}^{\infty} \frac{\beta^s}{1-\gamma} \left(C_{h,t+s} - \frac{a(N_{h,t+s})^{1+1/f}}{1+1/f} \right)^{1-\gamma} \right], \tag{1}$$

where γ is the relative risk aversion parameter, a the labor dis-utility scale parameter, $N_{h,t}$ the labor supply, $C_{h,t}$ the consumption of final goods, and f the Frisch elasticity of labor supply. Household h faces the following nominal budget constraint:

$$\begin{aligned} P_t C_{h,t} + D_{h,t} + P_t T_t + \Phi^n_{b,t} &= R_{D,t-1} D_{h,t-1} + W_{h,t} N_{h,t} \qquad (2) \\ &- \frac{\phi_w W_t N_t}{2} \left(\frac{W_{h,t}}{W_{h,t-1}} - \widetilde{\Pi}_{w,t} \right)^2 + (1-\theta) K^n_{b,t-1} + Z^A_t + Z^B_t + \Phi_t, \end{aligned}$$

where $D_{h,t}$ is deposits held between time t and $t+1$, $R_{D,t-1}$ is the retail deposit interest rate on deposits held between time $t-1$ and t, $\Phi^n_{b,t}$ is a start-up fund given to new banks, $W_{h,t}$ is the wage for labor service by household h, ϕ_w is the Rotemberg wage adjustment cost parameter, θ is the bank survival probability, $K^n_{b,t-1}$ is the equity or net worth of banks at the end of period $t-1$, T_t is a lump-sum tax, Z^A_t is aggregate profits of the non-financial sector, Z^B_t is the aggregate flow of funds from the banking sector, and Φ_t is the sum of all adjustment costs that are rebated in lump-sum form to households (price, wage, retail loan interest rate, and retail deposit interest rate adjustment costs). Finally, P_t is the nominal price index of the final good. The wages are indexed according to the parameter ξ_w and, thus, wage inflation obeys:

$$\Pi_{w,t} = W_t / W_{t-1}, \tag{3}$$

$$\widetilde{\Pi}_{w,t} = (\Pi_{w,t})^{\xi_w} (\bar{\Pi})^{1-\xi_w}. \tag{4}$$

Market power of labor unions within households in the setting of wages implies the following expression for the aggregate labor supply:

$$N_t = \left(\int_0^1 (N_{h,t})^{(\epsilon_w - 1)/\epsilon_w} dh \right)^{\epsilon_w/(\epsilon_w - 1)}, \tag{5}$$

where ϵ_w determines the market power of labor unions. The nominal profits of the labor unions are given by:

$$Z_t^W = W_t N_t - \int_0^1 \mathbb{W}_t W_{h,t} N_{h,t} \, dh, \tag{6}$$

where $\mathbb{W}_t$ is a wage mark-up shock that obeys the following process:

$$\ln(\mathbb{W}_t) = \rho_w \cdot \ln(\mathbb{W}_{t-1}) + \varepsilon_{w,t}. \tag{7}$$

2.2 Final goods producer

The final goods producer uses all differentiated intermediate goods to assemble a final good for consumption according to the following aggregator function:

$$Y_t = \left(\int_0^1 (Y_{i,t})^{(\epsilon_p - 1)/\epsilon_p} \, dh \right)^{\epsilon_p/(\epsilon_p - 1)}, \tag{8}$$

where ϵ_p determines the market power of intermediate goods producers. The nominal profits of the final goods producer are given by:

$$Z_t^Y = P_t Y_t - \int_0^1 \mathbb{P}_t P_{i,t}^y Y_{i,t} \, di, \tag{9}$$

where $\mathbb{P}_t P_{i,t}^y$ is the nominal price of differentiated intermediate good h.

2.3 Intermediate goods firms

A continuum of firms, indexed by $i \in [0, 1]$, produces differentiated intermediate goods by employing labor $N_{i,t}$ from households and capital $K_{i,t}$ via the following production function:

$$Y_{i,t} = A_{Y,t} K_{i,t}^{\alpha} N_{i,t}^{1-\alpha}, \tag{10}$$

where the parameter α denotes the capital share and $A_{Y,t}$ is the total factor productivity (TFP), governed by the following exogenous process:

$$\ln(A_{Y,t}) = \rho_{a,y} \cdot \ln(A_{Y,t-1}) + \varepsilon_{a,y,t}, \tag{11}$$

where $\rho_{a,y}$ is the persistence of productivity shocks and $\varepsilon_{a,y,t} \sim \mathcal{N}(0, \sigma_{a,y})$. The firm-specific capital stock accumulates according to the following law of motion:

$$K_{i,t+1} = (1 - \delta) K_{i,t} + I_{h,t} \left[1 - \frac{\phi_I}{2} \left(\frac{I_{i,t}}{I_{i,t-1}} - 1 \right)^2 \right], \tag{12}$$

where $I_{i,t}$ is the amount of investment purchased from the investment goods producer by firm i and ϕ_I is a parameter determining the amount of investment adjustment costs the intermediate goods firms must bear. To account for price stickiness in the model, I introduce Rotemberg price adjustment costs that are in nominal terms given by:

$$\Phi^n_{p,t} = \frac{\phi_p P_t Y_t}{2} \left(\frac{P^y_{i,t}}{P^y_{i,t-1}} - \widetilde{\Pi}_t \right)^2, \tag{13}$$

$$\widetilde{\Pi}_t = (\Pi_{t-1})^{\xi_p} (\bar{\Pi})^{1-\xi_p}, \tag{14}$$

where $\widetilde{\Pi}_t$ is price indexing-adjusted inflation, taking into account that firms adjust their prices according to the parameter ξ_p to the past inflation rate, and ϕ_p is the price stickiness parameter. Finally, due to the following loan-in-advance constraint, the intermediate goods firm i has to take out a loan of $L_{i,t}$ from the banking sector for a fraction χ of their nominal investment expenditure:

$$L_{i,t} = \chi P^I_t I_{i,t}, \tag{15}$$

where P^I_t is the nominal relative price of the investment good in terms of final consumption good units. The profits of intermediate goods firm i are given by:

$$Z^y_{i,t} = \mathbb{P}_t P^y_{i,t} Y_{i,t} - W_t N_{i,t} - P^I_t I_{i,t} + L_{i,t} - R_{L,t-1} L_{i,t-1} - \frac{\phi_p P_t Y_t}{2} \left(\frac{P^y_{i,t}}{P^y_{i,t-1}} - \widetilde{\Pi}_t \right)^2, \tag{16}$$

where $\mathbb{P}_t$ is a price mark-up shock that obeys the following process:

$$\ln(\mathbb{P}_t) = \rho_p \cdot \ln(\mathbb{P}_{t-1}) + \varepsilon_{p,t}. \tag{17}$$

2.4 Investment goods producers

Each intermediate goods producer buys an identical final investment good from an individual perfectly competitive investment goods producer, of which there is a continuum. Thus, each investment goods producer is identical, i.e. $I_{i,t} \equiv I_t$. The production function of an investment goods producer is simple:

$$I_{i,t} = A_{I,t} X_{i,t}, \tag{18}$$

where $X_{i,t}$ is the final goods input for investment goods producer $i \in [0, 1]$, and $A_{I,t}$ is an investment-specific technology process:

$$\ln(A_{I,t}) = \rho_{a,I} \cdot \ln(A_{I,t-1}) + \varepsilon_{a,I,t}, \tag{19}$$

where $\rho_{a,I}$ is the persistence of investment-specific shocks and $\varepsilon_{a,I,t} \sim \mathcal{N}(0, \sigma_{a,I})$. The profits of an individual investment goods producer are given by:

$$Z_{i,t}^{I} = P_t^I I_{i,t} - P_t X_{i,t}. \tag{20}$$

2.5 Banks

In order to allow for some market power in loan and deposit origination, the banking sector is composed of a continuum of banks, organizationally divided into wholesale and retail branches. The retail branches retain some market power in setting the loan interest rates to intermediate goods firms and the deposit interest rates to households, while the wholesale branches are perfectly competitive.

2.5.1 Wholesale branches

There is a continuum of wholesale bank branches, indexed by j, with mass 1. The wholesale branches allocate loans to and obtain deposits from the retail branches. The balance sheet of an individual wholesale branch obeys:

$$K_{b,j,t}^{n} + D_{j,t} = L_{j,t}, \tag{21}$$

while the nominal net worth of individual wholesale branch j evolves as follows:

$$K_{b,j,t}^{n} = R_{\ell,t-1} L_{j,t-1} - R_{d,t-1} D_{j,t-1}, \tag{22}$$

where $R_{d,t-1}$ ($R_{\ell,t-1}$) is the wholesale deposit (loan) interest rate. The value of an individual wholesale branch $V_{j,t}(K_{b,j,t}^{n})$ is conjectured to satisfy $V_{j,t}(K_{b,j,t}^{n}) = v_t K_{b,j,t}^{n}$. Since I assume that a fixed proportion θ of wholesale branches must to exit every period, the Bellman equation for the value of individual wholesale branch j is given by:

$$V_{j,t}(K_{b,j,t}^{n}) = v_t K_{b,j,t}^{n} = \mathbf{E}_t[(1-\theta)\mathbf{M}_{t,t+1}^{\$} K_{b,j,t+1}^{n} + \theta \mathbf{M}_{t,t+1}^{\$} v_{t+1} K_{b,j,t+1}^{n}], \tag{23}$$

where $\mathbf{M}_{t,t+1}^{\$}$ is the nominal stochastic discount factor of households (to be derived in the appendix). The wholesale branches maximize their value, that is defined via the above Bellman equation, by choosing the nominal bank net worth $K_{b,j,t}^{n}$. The wholesale loan interest rate is for simplicity and to be in line with loan pricing in countries such as Latvia equal to the monetary policy rate plus a constant risk premium term as follows:

$$\ln(R_{\ell,t}) = \ln(i_t) + \overline{\text{RP}}, \tag{24}$$

where i_t is the nominal monetary policy rate and $\overline{\text{RP}}$ is a constant risk premium term.

In order to keep the mass of banks equal to 1 across periods, new banks enter to replace the exited banks with mass θ. These new banks obtain start-up funds from households in the nominal amount of $\Phi^n_{b,t}$. Since all banks take the same decisions, all bank quantities are identical. Thus, I can drop the j subscript from all bank-related equations. Therefore, the aggregate net worth of the banking sector obeys:

$$K^n_{b,t} = \theta \left(\frac{(R_{\ell,t-1} - R_{d,t-1})L_{t-1}}{K^n_{b,t-1}} + R_{d,t-1} \right) K^n_{b,t-1} + \Phi^n_{b,t-1}, \tag{25}$$

where the (nominal) bank start-up fund is assumed to be a fixed percentage φ of aggregate bank net worth as follows:

$$\Phi^n_{b,t} = \varphi K^n_{b,t}. \tag{26}$$

2.5.2 Retail loan branches

The retail loan branches handle the price setting of loans to the intermediate goods firms and retain market power in setting the retail loan interest rates. Therefore, the aggregate loan demand of intermediate goods producer $i \in [0,1]$ is composed of differentiated loans by the continuum of retail branches, indexed by $z \in [0,1]$, as follows:

$$L_{i,t} = \left(\int_0^1 (L_{z,i,t})^{(\epsilon_\ell - 1)/\epsilon_\ell} dz \right)^{\epsilon_\ell/(\epsilon_\ell - 1)}, \tag{27}$$

where ϵ_ℓ determines the retail loan rate mark-up. Nominal profits of retail branch z are:

$$Z^{R,L}_{z,t} = R_{L,z,t}L_{z,i,t} - R_{L,t}L_{i,t} + R_{L,z,t}L_{z,t} - \mathbb{R}_t R_{\ell,t} L_{z,t} - \frac{\phi_\ell R_{L,t} L_t}{2} \left(\frac{R_{L,z,t}}{R_{L,z,t-1}} - 1 \right)^2, \tag{28}$$

where $\mathbb{R}_t$ is a retail loan interest rate mark-up shock process ($\varepsilon_{r,t} \sim \mathcal{N}(0, \sigma_r)$):

$$\ln(\mathbb{R}_t) = \rho_r \cdot \ln(\mathbb{R}_{t-1}) + \varepsilon_{r,t}. \tag{29}$$

2.5.3 Retail deposit branches

The retail deposit branches handle the price setting of deposits to the households and retain market power in setting the retail deposit interest rates. Therefore, the aggregate deposit demand of household $h \in [0,1]$ is composed of differentiated deposits by the continuum of retail branches, indexed by $z \in [0,1]$, by means of the following aggregator:

$$D_{h,t} = \left(\int_0^1 (D_{z,h,t})^{(\epsilon_d - 1)/\epsilon_d} dz \right)^{\epsilon_d/(\epsilon_d - 1)}, \tag{30}$$

where ϵ_d determines the mark-down for retail deposit rates. The nominal profits of retail branch z are given by:

$$Z_{z,t}^{R,D} = R_{D,t}D_{h,t} - R_{D,z,t}D_{z,h,t} + \mathbb{D}_t R_{d,t} D_{z,t} - R_{D,z,t}D_{z,t} \\ - \frac{\phi_d R_{D,t} D_t}{2}\left(\frac{R_{D,z,t}}{R_{D,z,t-1}} - 1\right)^2 - \tau_b(i_t - R_{D,z,t})D_{z,t}, \tag{31}$$

where τ_b is the tax rate on excess income earned by offering retail deposit interest rates below the monetary policy rate. This tax is meant to capture additional taxes on banks, such as the excess bank profit taxes introduced recently in several European countries during the recent inflation and monetary policy rate surge that has allowed banks to increase their net interest income considerably in the last years (Maneely and Ratnovski, 2024). Moreover, $\mathbb{D}_t$ is a retail deposit interest rate mark-down shock ($\varepsilon_{D,t} \sim \mathcal{N}(0, \sigma_D)$):

$$\ln(\mathbb{D}_t) = \rho_D \cdot \ln(\mathbb{D}_{t-1}) + \varepsilon_{D,t}. \tag{32}$$

2.5.4 Aggregate bank variables

With this bank sector structure, I can find the aggregate nominal flow of funds from wholesale and both retail branches that are transferred to households to be given by:

$$Z_t^B = \mathbb{R}_{t-1} R_{\ell,t-1} L_{t-1} - L_t + \int_0^1 Z_{z,t-1}^{R,L}\, dz + D_t - \mathbb{D}_{t-1} R_{d,t-1} D_{t-1} \\ + \int_0^1 Z_{z,t-1}^{R,D}\, dz - \tau_b(i_{t-1} - R_{D,t-1})D_{t-1} + \Phi_{b,t}^n - (1-\theta)K_{b,t-1}^n, \tag{33}$$

where aggregate loan demand and aggregate deposit demand satisfy:

$$L_t = \int_0^1 L_{i,t}\, di, \tag{34}$$

$$D_t = \int_0^1 D_{h,t}\, dh. \tag{35}$$

Finally, I define the aggregate net interest income of banks as a measure of bank profitability as follows:

$$\text{Profit}_t^B = R_{L,t-1}L_{t-1} - R_{D,t-1}D_{t-1}. \tag{36}$$

2.6 Fiscal authority

The fiscal authority operates a level of real (wasteful) government consumption G_t by levying a lump-sum tax on households T_t and using the proceeds from the tax on banks $\tau_b(i_{t-1} - R_{D,t-1})D_{t-1}$. I assume that real government consumption obeys the following exogenous process:

$$\ln(G_t) = (1-\rho_g)\bar{G} + \rho_g \ln(G_{t-1}) + \varepsilon_{g,t}, \tag{37}$$

where $\varepsilon_{g,t} \sim \mathcal{N}(0, \sigma_g)$ and the steady-state level of government consumption is denoted by $\bar{G}$. The government budget clears according to the following constraint:

$$T_t = G_t - \tau_b(i_{t-1} - R_{D,t-1})D_{t-1}. \tag{38}$$

2.7 Central bank

The central bank sets the nominal short-term interest rate i_t according to a Taylor-type interest rule by responding to the inflation gap $\hat{\pi}_t = \ln(\Pi_t) - \ln(\bar{\Pi})$ and the output gap $\hat{y}_t = \ln(Y_t) - \ln(\bar{Y})$ as follows:

$$\ln(i_t) = (1-\rho_i)\bar{i} + \rho_i \cdot \ln(i_{t-1}) + (1-\rho_i)[\kappa_\pi \hat{\pi}_t + \kappa_y \hat{y}_t] + \varepsilon_{i,t}, \tag{39}$$

where $\varepsilon_{i,t} \sim \mathcal{N}(0, \sigma_i)$ is a monetary policy shock, ρ_i determines monetary policy rate smoothing, and the parameters κ_π and κ_y determine the strength of the reaction to the inflation gap and the output gap, respectively. The deposit rate is linked to the monetary policy rate according to the following rule, in which the deposit interest rate adjustment speed ρ_{di} is the key parameter of interest:

$$\ln(R_{d,t}) = \rho_{di} \cdot \ln(R_{d,t-1}) + (1-\rho_{di}) \ln(i_t). \tag{40}$$

2.8 Market clearing conditions and aggregation

Aggregate profits of the non-financial sector, aggregate output, aggregate investment, and aggregate final goods input to investment goods production are given by:

$$Z_t^A = Z_t^Y + Z_t^W + \int_0^1 Z_{i,t}^y \, di + \int_0^1 Z_{i,t}^I \, di, \tag{41}$$

$$Y_t = \int_0^1 Y_{i,t} \, di, \tag{42}$$

$$I_t = \int_0^1 I_{i,t} \, di, \tag{43}$$

$$X_t = \int_0^1 X_{i,t} \, di. \tag{44}$$

Finally, the following aggregate resource constraint emerges:

$$Y_t = C_t + X_t + G_t. \tag{45}$$

The model's first order conditions are derived in Appendix A.

3 Calibration, Data Fit, and Simulated Moments

The model is calibrated to a quarterly frequency using data for the euro area at different frequencies (annual, quarterly, monthly, and daily) for the period between 1999 and 2024:Q2 (or shorter if not available for the whole period). Appendix B provides details on the data employed. Table 1 provides an overview of the calibrated parameters.

First, I discuss the household-specific parameters. The time discount factor is chosen to be 0.9975 to obtain low nominal and real interest rates. The relative risk aversion parameter is chosen to be 2 while the labor supply elasticity is set equal to the conventional value of 0.5. The labor dis-utility scale parameter is set such that households' aggregate labor supply is equal to 1 in the steady state, i.e. $\overline{N} = 1$.

Next, the production sector parameters are discussed. The elasticity of substitution between any two intermediate goods and any two labor services is equal to 6, implying a profit markup for intermediate goods producers and labor unions of 20%. The capital share is set to 0.31, which ensures – together with the choice of the capital depreciation rate of 0.025 – that the investment to GDP ratio in euro area data of roughly 21% is matched well by the model. To ensure sufficiently volatile investment, the investment adjustment costs parameter is quite low at $\phi_I = 1.5$. The price indexation parameter is equal to 0.5 and the wage indexation parameter equal to 0.75. The steady state inflation is equal to 1.005, which implies an average inflation rate of around 2 percentage points, consistent with the medium-run inflation target of the ECB. The Rotemberg price and wage adjustment cost parameters are chosen to be equivalent to Calvo price and wage rigidity parameters of 0.75, i.e. the intermediate goods producer (labor union) is on average allowed to reset the price (wage) every 4 quarters. The persistence and volatility of the price mark-up shocks are equal to 0.85 and 0.002, respectively. For wage mark-up shocks, the chosen values for the persistence and volatility of the shock are 0.85 and 0.005. To ensure matching the loan to annualized GDP ratio in the data of slightly more than 100%, the intermediate goods producers must take loans in the amount of twenty times their investment expenditures. The intermediate and investment goods productivity processes are calibrated as follows: $\rho_{a,y} = \rho_{a,I} = 0.85$, and $\sigma_{a,y} = \sigma_{a,I} = 0.005$. These choices ensure data-consistent output growth and investment growth volatilities.

Third, the exogenous and wasteful public consumption process is governed by the parameters $\bar{G} = -0.6340$, $\rho_g = 0.85$, and $\sigma_g = 0.005$. This allows for fitting the public consumption to GDP ratio of 20.6% and for the volatility of public consumption growth. The bank excess net interest income tax rate is set to $\tau_b = 0$ in the benchmark calibration but equal to $\tau_b = 0.60$ in an alternative calibration utilized below in the impulse response function analysis. The level of this tax rate is aligned with the bank super-profits tax

Table 1: Parameters

Parameter	Description	Value
β	Time discount factor	0.9975
γ	Relative risk aversion	2
f	Labor supply elasticity	0.5
a	Labor dis-utility scale parameter	1.2339
ϵ_w	Labor union market power parameter	6
ξ_w	Wage indexation parameter	0.75
ϕ_w	Rotemberg wage adjustment cost parameter	$\frac{(\epsilon_w-1)0.75}{(1-0.75)(1-0.75\beta)}$
ρ_w	Persistence of wage mark-up shocks	0.85
σ_w	Volatility of wage mark-up shocks	0.005
ϵ_p	Intermediate goods producer market power parameter	6
α	Capital share	0.31
δ	Capital depreciation rate	0.025
ϕ_I	Investment adjustment costs parameter	1.5
χ	Fraction of investment financed by loans	20
ξ_p	Price indexation parameter	0.5
$\bar{\Pi}$	Steady state inflation	1.005
$\rho_{a,y}$	Persistence of intermediate goods productivity shocks	0.85
$\sigma_{a,y}$	Volatility of intermediate goods productivity shocks	0.005
ϕ_p	Rotemberg price adjustment cost parameter	$\frac{(\epsilon_p-1)0.75}{(1-0.75)(1-0.75\beta)}$
ρ_p	Persistence of price mark-up shocks	0.85
σ_p	Volatility of price mark-up shocks	0.002
$\rho_{a,I}$	Persistence of investment technology shocks	0.85
$\sigma_{a,I}$	Volatility of investment technology shocks	0.005
$\bar{G}$	Log steady state public consumption	-0.6340
ρ_g	Persistence of public consumption shocks	0.85
σ_g	Volatility of public consumption shocks	0.005
τ_b	Bank excess net interest income tax	(0, 0.60)
$\overline{\text{RP}}$	Loan risk premium above monetary policy rate	0.00425
θ	Bank survival probability	0.974
φ	Size of bank start-up fund	0.0055
ϵ_ℓ	Retail loan branches mark-up parameter	426
ϵ_d	Retail deposit branches mark-up parameter	-1751
ϕ_ℓ	Rotemberg loan interest rate adjustment cost parameter	$\frac{(\epsilon_\ell-1)0.75}{(1-0.75)(1-0.75\beta)}$
ϕ_d	Rotemberg deposit interest rate adjustment cost parameter	$\frac{(-\epsilon_d-1)0.75}{(1-0.75)(1-0.75\beta)}$
ρ_r	Persistence of loan interest rate mark-up shocks	0.85
σ_r	Volatility of loan interest rate mark-up shocks	0.0015
ρ_D	Persistence of deposit interest rate mark-down shocks	0.85
σ_D	Volatility of deposit interest rate mark-down shocks	0.0015
$\bar{i}$	Steady state monetary policy rate	$\ln(\bar{\Pi}/\beta)$
ρ_i	Persistence of monetary policy shocks	0.85
σ_i	Volatility of monetary policy shocks	0.003
κ_π	Inflation term in monetary policy rule	2.74
κ_y	Output gap term in monetary policy rule	0.10
ρ_{di}	Deposit rate adjustment speed	(0, 0.75, 0.8333, 0.995)

Notes: This table reports the model parameters.

introduced in Latvia in 2025.[1]

Fourth, in the banking sector, I choose the risk premium term $\overline{\text{RP}}$ to be equal to 0.00425 in order to reproduce the empirical average of loan interest rates in euro area data. In this way, the quarterly wholesale loan interest rate is the monetary policy rate plus 42.5 basis points. In other words, the annual risk premium is equal to 1.7 percentage points. The bank survival probability has been chosen to be equal to roughly the same value as in Gertler and Karadi (2013) and a common value in the literature, while the size of the bank start-up fund is chosen to match the bank leverage ratio of around 4.5 in the data. The retail loan branch mark-up parameter is equal to 426, which allows for matching the retail loan interest rate to deposit interest rate spread in the data. Similarly, for the retail deposit branches I choose the mark-up parameter to be -1751 to match the monetary policy rate to retail deposit interest rate spread in the data. The chosen Rotemberg loan interest rate adjustment cost parameter implies the equivalence of the loan interest rate setting friction in the model to a probability of 0.75 that a retail branch cannot reset its retail loan interest rate in a Calvo-type loan interest rate setting friction. For simplicity, the same strategy is applied for the Rotemberg adjustment cost parameter of retail deposit interest rate changes.[2] Retail loan (deposit) interest rate mark-up (mark-down) shocks feature both a persistence of 0.85 and a volatility of 0.0015.

Fifth, the monetary policy interest rule gives rise to a few parameters that I discuss in the following. By means of the Fischer equation, the steady state monetary policy rate $\bar{i}$ has to equal $\ln(\bar{\Pi}/\beta)$. The inflation term is chosen to a high value and the output gap term to a low value as advocated by Coenen et al. (2018) in line with the single mandate of the ECB. The persistence of monetary policy shocks is equal to 0.85 and the volatility of monetary policy shocks is chosen to be 0.003 or 30 basis points.

Finally, I discuss the values for the deposit adjustment speed ρ_{di} that are used in the model simulations. The lowest value chosen is 0, which implies that wholesale deposit interest rates and monetary policy rates coincide at all times. For the two intermediate values, I choose 0.75 and 0.8333. With the first parameter the time half of the monetary policy change is transmitted to deposit rates is about 2.4 quarters, while with the latter parameter, the time period increases to roughly 3.8 quarters. The difference between these two adjustment speeds is in line with the empirical evidence put forward by Kho (2024), who shows that in countries with highly concentrated banking sectors an increase in the monetary policy rate is delayed by up to half a year relative to countries with less concentrated banking sectors. As the final and highest value, I will also use $\rho_{di} = 0.995$ so that by comparing the lowest and higher deposit rate adjustment speed the maximum consequences of the deposit rate adjustment channel in the model can be explored in my

[1] See `LSM article on super-profit tax` (accessed December 4, 2024).

[2] Note that due to the negative value of ϵ_d, the absolute value of ϵ_d is used in the Rotemberg adjustment cost parameter value formula in order to obtain a positive value for ϕ_d.

analysis.

Table 2: Simulated model moments and data counterparts

Moment	Data	$\rho_{di} = 0$	$\rho_{di} = 0.75$	$\rho_{di} = 0.8333$	$\rho_{di} = 0.995$
$\mathbb{E}[I_t/Y_t]$	21.09	20.55	20.54	20.54	20.58
$\mathbb{E}[C_t/Y_t]$	54.75	58.88	58.88	58.88	58.89
$\mathbb{E}[G_t/Y_t]$	20.60	20.61	20.61	20.61	20.62
$\mathbb{E}[L_t/(4Y_t)]$	104.11	102.71	102.71	102.71	102.87
$\mathbb{E}[L_t/K_{b,t}]$	4.55	4.22	4.21	4.21	4.45
$\mathbb{E}[D_t/(4Y_t)]$	43.95	78.33	78.30	78.30	79.16
$\mathbb{E}[\ln(\Pi_t)]$	2.12	1.98	1.98	1.98	1.98
$\mathbb{E}[\ln(R_{L,t}) - \ln(R_{D,t})]$	2.90	2.88	2.87	2.87	2.87
$\mathbb{E}[\ln(i_t) - \ln(R_{D,t})]$	0.23	0.24	0.24	0.24	0.23
$\sigma[\ln(\Pi_t)]$	1.82	1.61	1.32	1.32	1.53
$\sigma[\ln(R_{L,t}) - \ln(R_{D,t})]$	0.76	0.88	0.82	0.80	1.38
$\sigma[\ln(i_t) - \ln(R_{D,t})]$	1.08	1.11	1.01	1.02	1.65
$\sigma[\Delta y_t]$	2.05	2.76	2.89	2.95	3.22
$\sigma[\Delta c_t]$	2.30	3.80	3.88	3.93	4.43
$\sigma[\Delta i_t]$	4.36	4.57	4.58	4.69	5.37
$\sigma[\Delta g_t]$	0.93	0.94	0.94	0.94	0.94
$\text{corr}[\Delta y_t, \Delta c_t]$	0.89	0.96	0.98	0.97	0.96
$\text{corr}[\Delta y_t, \Delta i_t]$	0.78	0.66	0.72	0.74	0.72
$\text{corr}[\Delta y_t, \Delta g_t]$	−0.01	0.07	0.05	0.04	0.06
$\text{corr}[\Delta c_t, \Delta i_t]$	0.63	0.43	0.53	0.55	0.52
$\text{corr}[\Delta c_t, \Delta g_t]$	−0.02	0.03	0.02	0.01	0.04
$\text{corr}[\Delta i_t, \Delta g_t]$	−0.09	−0.09	−0.11	−0.11	−0.10
$\mathbb{E}[U_t]$	—	−362.07	−362.07	−362.07	−362.06

Notes: This table reports the simulated model moments and the corresponding data counterparts for a variety of macroeconomic variables. The model moments have been obtained from a stochastic simulation of the model for 40000 periods (quarters) using a second-order perturbation approximation with pruning in dynare 4.5.4 for four different parameter choices for the deposit rate adjustment speed parameter ρ_{di}, i.e. 0, 0.75, 0.8333, and 0.995 when the bank excess interest income tax τ_b is set to 0. The resulting model data, where appropriate, has been annualized by summing up four consecutive quarters before computing the moments. All moments are reported in percentage points with the exception of correlations and the bank leverage ratio.

Table 2 reports simulated model moments and their empirical counterparts for the four discussed choices of the parameter ρ_{di}. The model variant with $\rho_{di} = 0$ is referred to as the benchmark model which fits the data best while all the other parameters are kept constant across the other model variants for isolating the effect of the choice of ρ_{di} on the simulated moments.

Discussing first the fit of the benchmark model ($\rho_{di} = 0$) to the data, all grand ratios are matched very well by the model as per the calibration choices, with the exception of the deposit to annualized GDP ratio which is about 34 percentage points higher in the model than in the data. Similarly, the average level of the inflation rate, the loan to deposit interest rate spread, and the monetary policy to deposit interest rate spread are accurately reproduced. The volatilities of these quantities are also not far from the empirical counterparts. While investment growth volatility, and public consumption growth volatility are the same in the model and the data, the model produces slightly more GDP growth volatility and substantially more private consumption growth volatility than in the data. In terms of correlations, the model produces moderately underestimated correlations between GDP and investment growth and between consumption and investment growth but reproduces the other reported correlations effectively.

From studying the next three columns in Table 2, which correspond to an features an increasing value for ρ_{di}, i.e. a decreasing deposit rate adjustment speed to monetary policy changes, two effects of this parameter on the simulated moments can be found. First, macroeconomic volatility increases as witnessed by an increase in output, consumption, and investment growth volatility. Second, the credit spread, deposit spread, and inflation volatilities first decrease from the benchmark model moment for moderate decreases in the deposit rate adjustment speed ($\rho_{di} = 0.75$ and $\rho_{di} = 0.8333$), while the interest spread volatilities increase relative to the benchmark model for the very slow deposit rate adjustment speed of $\rho_{di} = 0.995$. In addition, inflation volatility rises relative to the two middle deposit rate adjustment speed cases but remains below the benchmark model moment.

The mechanism behind these observations is that with a lower pass-through, the risk of monetary policy changes is borne less by the financial sector, resulting in households (i.e. the real economy) having to adapt. This translates into higher macroeconomic volatility and lower financial volatility. However, this does not hold for the extremely low deposit rate adjustment speed, since then the very large inflexibility of the banks to adjust deposit rates – approaching constant deposit rates after a monetary policy shock – also makes the interest rate spreads more volatile. This is due to the fact that with moderately lower deposit adjustment speeds, the retail branches' market power can be used to smooth interest rate spreads, while this mechanism does not work anymore with the extreme assumption on ρ_{di} in the last case. The resulting dynamics in the interest rate spreads across these different deposit rate adjustment speed cases shape the observations for inflation volatility to a large extent as well.

Finally, it remains to note that household welfare, as proxied by the average lifetime utility index, is not affected by the choice for ρ_{di}.

4 Impulse Response Function Analysis

In this section, I analyze the impulse response functions of seven shocks in my model. I depict the impulse response functions for three different calibrations. Specifically, in all upcoming figures, the blue solid lines depict the impulse response functions for a shock in the benchmark model ($\rho_{di} = 0$, $\tau_b = 0$). The red solid lines depict the impulse response functions in the very low adjustment speed calibration without the bank excess interest income tax ($\rho_{di} = 0.995$, $\tau_b = 0$). Although such a stark difference between deposit interest rate adjustment speeds seems empirically unrealistic, this analysis can contribute to understanding the effects of this channel. Finally, the red dashed lines feature a low deposit adjustment speed of $\rho_{di} = 0.995$ as well, while also featuring a substantial bank excess interest income tax of $\tau_b = 0.60$.

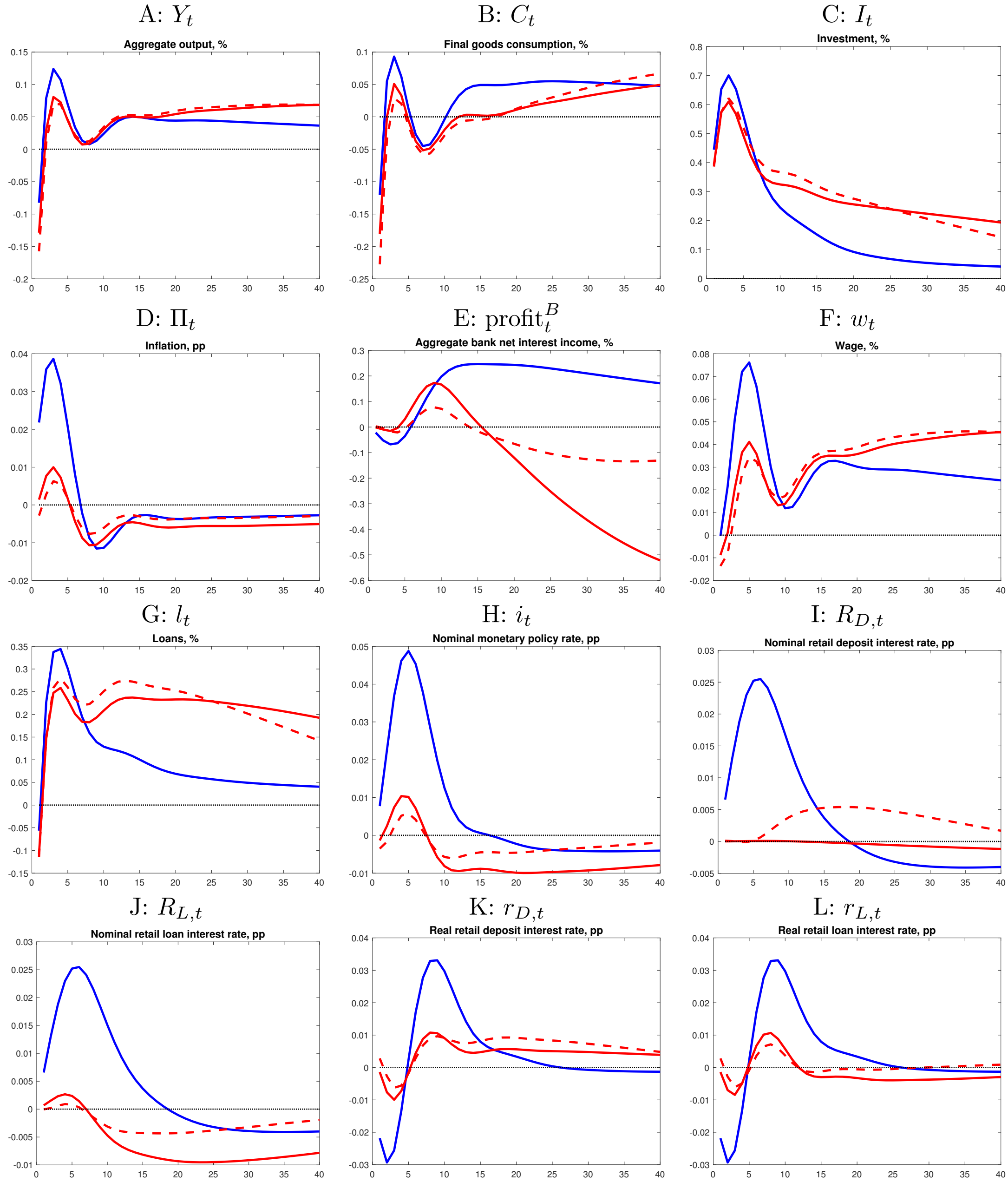
In every figure, twelve variables are depicted: output Y_t (Panel A), consumption C_t (Panel B), investment I_t (Panel C), inflation Π_t (Panel D), aggregate real bank net interest income profit_t^B (Panel E), real wage w_t (Panel F), real loan stock ℓ_t (Panel G), nominal monetary policy interest rate i_t (Panel H), nominal retail deposit interest rate $R_{D,t}$ (Panel I), nominal retail loan interest rate $R_{L,t}$ (Panel J), real retail deposit interest rate $r_{D,t}$ (Panel K), and real retail loan interest rate $r_{L,t}$ (Panel L). The graphs depict the percentage deviation from steady state for all macroeconomic quantities, while the absolute deviation in percentage points is depicted for the log inflation rate and all asset returns. The shocks analyzed are one-standard-deviation shocks in period 1 and comprise the following shocks: positive investment productivity shock (Figure 2), negative intermediate goods productivity shock (Figure 3), positive government consumption shock (Figure 4), positive monetary policy shock (Figures 5 and C.1), positive price mark-up shock (Figure 6), negative loan interest rate mark-up shock (Figure 7), and positive wage mark-up shock (Figure 8). With the exception of the positive monetary policy shock, all these shocks are inflationary or cost-push shocks. The common feature to all shocks is that they prompt a monetary policy tightening response from the monetary authority. In this way, the comparison between these shocks is simplified.

4.1 Productivity shocks

In this section, I analyze the responses of macroeconomic and financial variables to productivity shocks. First, Figure 2 depicts the impulse response functions for a positive shock to investment productivity. Second, Figure 3 depicts the impulse response functions for a negative shock to intermediate goods productivity.

When investment productivity is positively affected, the production of investment goods increases, as witnessed by a strong expansion of investment. This causes output and consumption to fall initially, as higher investment increases production only with a lag, some resources are shifted away from consumption, and labor demand is reduced initially. In the longer run, however, the higher investment leads to higher production volumes and eventually also higher consumption. Furthermore, the real wage increases alongside aggregate output. Due to loan demand being linked to investment expenditures

Figure 2: Impulse response functions after a positive investment productivity shock



Notes: This figure depicts impulse response functions for a positive shock to investment productivity. The shock with size $\varepsilon_{a,I,1} = 0.005$ occurs in period 1, with no further shocks simulated thereafter. The blue solid lines correspond to the benchmark full pass-through regime with $\rho_{di} = 0$ and no bank excess net interest income tax applied (i.e. $\tau_b = 0$), while the red solid and dashed lines correspond to the slow pass-through regime with $\rho_{di} = 0.995$ without and with the tax ($\tau_b = 0$ vs. $\tau_b = 0.60$).

via the loan-in-advance constraint, the loan demand becomes larger.

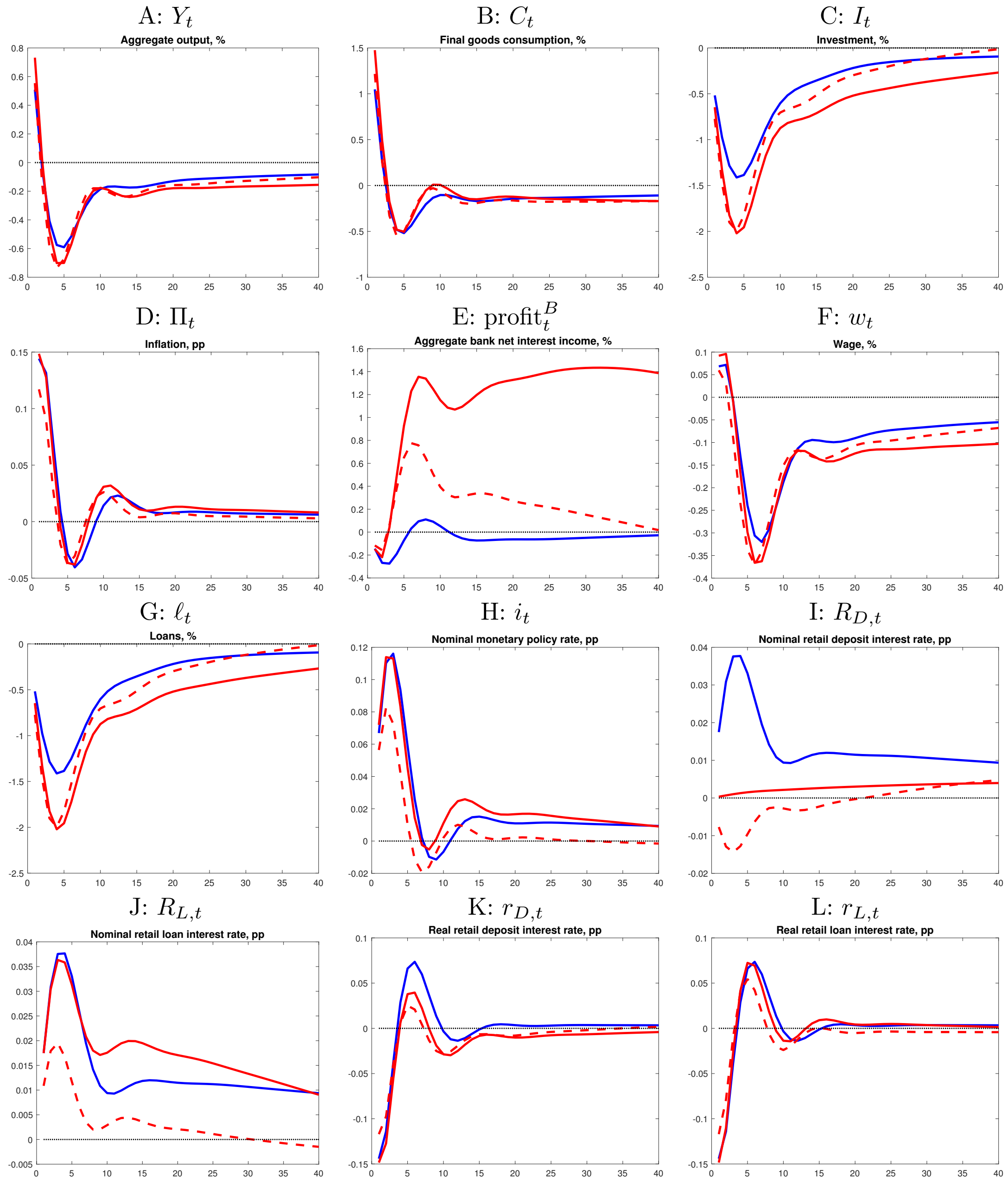
In the benchmark model, the shock is highly inflationary due to the increase in economic activity and larger labor costs. The nominal wholesale deposit interest rate perfectly tracks the nominal monetary policy rate by assumption and the nominal retail deposit interest rate tracks it very closely. The monetary policy rate is increased due to the inflation surge. The nominal and real loan interest rates move in tandem with the deposit interest rates, resulting initially in almost no response of bank net interest income, as loan demand does not initially increase – but with a short lag. Once loan demand becomes substantially higher, bank net interest income increases. Since the inflation increase is stronger initially than the monetary policy rate hike (due to the initially negative reaction of output and thus a short-lived negative output gap), the real deposit and loan interest rates initially decrease. However, they increase in the medium to long run due to the non-persistent inflation increase and the persistent increase in nominal deposit interest rates.

When nominal wholesale deposit interest rates react very sluggishly to the monetary policy rate change, this is translated to a similar behavior of the nominal retail deposit interest rates and affects macroeconomic dynamics. Most noteworthy are the muted inflation response and the resulting lower increase of the monetary policy rate. Since households do not enjoy a similar increase in nominal deposit interest rates, they reduce their consumption more than in the benchmark model. Similarly, labor supply is lower than in the benchmark model, resulting in a lower increase of economic activity. While the banks enjoy slightly higher net interest income for the first 10 quarters after the shock, fueled by the short-lived increase in nominal retail loan interest rates (i.e. an increase in the spread between loan and deposit interest rates), bank net interest income is lower in the longer run than in the benchmark model and also falls below the steady state. Due to the resulting lower net worth of banks and the lower inflation response, lower nominal loan interest rates in the longer run fuel higher loan supply and investment relative to the benchmark model. In the longer run, therefore, output dynamics are more favorable than in the benchmark model, while consumption dynamics stay below the benchmark model's consumption response due to higher investment expenditures that need to be sustained.

The introduction of the bank excess interest income tax reduces the initial increase in banks' net interest income and thus partially undoes the positive reduction of loan interest rates for firms, which lower their aggregate demand for labor, resulting in a more severe reduction of output initially. Since banks raise deposit rates after some time to reduce the tax burden, consumption dynamics are slightly improved upon in the longer run for households. Moreover, inflation increases even less than in the other two cases. Thus, loan demand is stronger until around quarter 25, resulting in similar dynamics for investment relative to the case without the tax. Bank net interest income is thus also larger in the longer run with the tax than without the tax.

Summing up these observations, a more sluggish adjustment of deposit rates to monetary policy rate changes accentuates short-run economic costs but leads to better dynamics in the longer run, except for consumption which, due to the lower deposit interest rate income, displays worse dynamics than in the instantaneous deposit rate adjustment model. This sluggish adjustment also reduces the inflationary response. The introduction of the bank excess interest income tax leads to even higher short-run costs, but the dynamics on the longer run become somewhat better. Additionally, consumption is also improved in the long run relative to the case without the tax due to the banks being prompted to increase deposit rates over time due to the tax.

Figure 3: Impulse response functions after a negative intermediate goods productivity shock



Notes: This figure depicts impulse response functions for a negative shock to intermediate goods productivity. The shock with size $\varepsilon_{a,y,1} = -0.005$ occurs in period 1, with no further shocks simulated thereafter. The blue solid lines correspond to the benchmark full pass-through regime with $\rho_{di} = 0$ and no bank excess net interest income tax applied (i.e. $\tau_b = 0$), while the red solid and dashed lines correspond to the slow pass-through regime with $\rho_{di} = 0.995$ without and with the tax ($\tau_b = 0$ vs. $\tau_b = 0.60$).

There is a second productivity shock in the model which is the classic total factor productivity shock in intermediate goods production. Thus, I now analyze the economic effects of a negative shock to intermediate goods productivity.

First, I look at the responses in the benchmark model with instantaneous adjustment of deposit interest rates to monetary policy rate changes, i.e. the blue solid lines in Figure 3. The negative productivity shock depresses the production of final goods. In turn, investment and loan demand are reduced, and the real wage decreases. This happens in the medium to long run, while more labor is supplied by households initially to sustain consumption and output in the short run. Thus, labor supply more than compensates the decrease in productivity initially. Possibly, this is due to the assumed functional form of the utility function in Equation (1) that eliminates the wealth effect on labor supply and thus makes the labor supply response stronger than with preferences that are separable in consumption and labor. Since a negative intermediate goods productivity shock is a negative supply shock, it is inflationary. The inflationary pressure prompts the central bank to increase the monetary policy rate. Thus, nominal deposit interest rates increase in roughly the same fashion (the banks reduce their endogenous deposit rate mark-down and increase deposit rates more than the monetary policy rate). The aggregate bank net interest income thus falls as the loan interest rates are adjusted in a very similar way.

When the wholesale deposit interest rate barely reacts to the change in the monetary policy rate, the result is summarized by the red solid lines in Figure 3. The almost complete absence of any increase in the nominal retail deposit rate after the increase of the monetary policy rate allows for considerably higher bank net interest income. Due to the higher net worth and thus higher transfers from banks to households, consumption dynamics are improved despite no increase in deposit interest income for households. The incentive to invest is reduced due to the lower productivity in the intermediate goods sector and loan supply falls in a similar fashion. To keep profits high, the retail loan interest rates remain elevated relative to the benchmark model, further reinforcing the investment slump, output fall, and loan demand reduction.

The bank excess interest income tax prompts the retail deposit branch of the bank to even reduce their nominal deposit rates offered, but even more so their loan interest rates relative to the case without the tax (compare the red dashed lines to the red solid lines in Panels I and J of Figure 3). Thus, bank net interest income is reduced relative to the model without the tax and the red dashed lines fall somewhat into the middle between the red and blue solid lines (Panel E). The loan demand reduction due to the lower deposit rate adjustment speed is somewhat undone and, therefore, output and investment dynamics are better with the tax than without it. Consumption dynamics are worse than without the tax due to lower transfers from banks to households, especially in the long run.

As a summary, a more sluggish adjustment of deposit rates amplifies economic costs in the short and long run. Only consumption dynamics are improved due to the much higher net interest income of banks and thus higher transfers from banks to households. In contrast to these observations, introducing a bank excess interest income tax alleviates these negative effects somewhat. However, households will not profit from the introduction of this tax, as will be more deeply analyzed in Section 4.4.

4.2 Fiscal and monetary policy shocks

In this section, attention is given to the effects of the deposit interest rate adjustment channel for fiscal and monetary policy shocks. To this extent, Figure 4 depicts the impulse response functions for a positive shock to government spending and Figure 5 the impulse response functions for a monetary policy tightening shock.

Since increases in public expenditure are typically found to be inflationary in DSGE models and since public expenditure shocks have played a vital role during the COVID-19 pandemic, the effect a positive shock to government consumption has on macroeconomic quantities and asset returns for the two familiar deposit interest rate adjustment speeds is analyzed in the following.

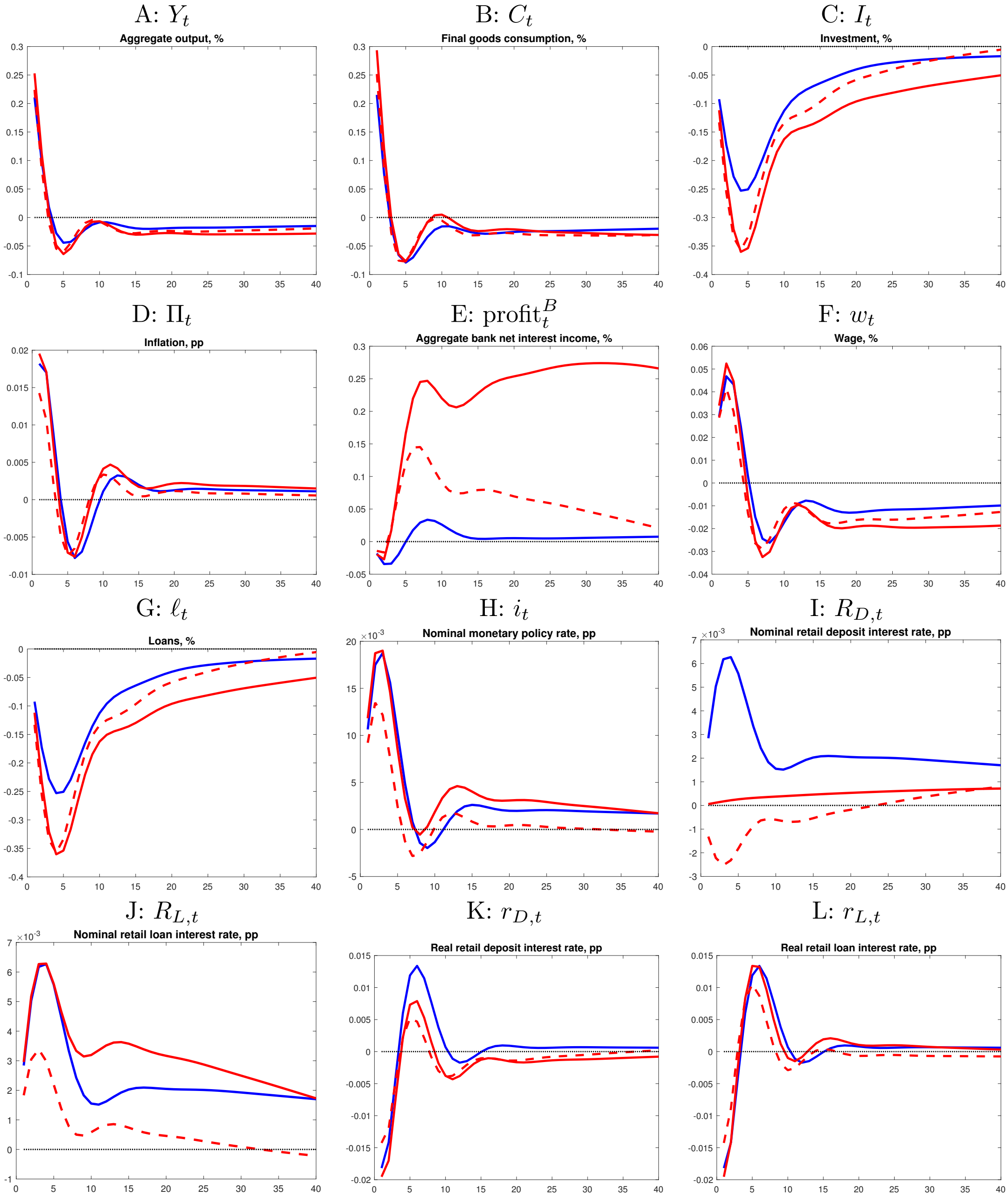
In all model variations, the shock is indeed inflationary. In the benchmark model (blue solid lines), the government consumption shock prompts intermediate goods firms to substitute investment with labor. Taken together, these changes allow for higher final goods output production and consumption in the short run, while in the medium to long run output and consumption levels decline due to the persistent impact of lower investment. Naturally, lower investment implies lower loan demand by firms. For asset returns, there are similar patterns as with the negative intermediate goods productivity shock. The monetary policy rate is raised due to the inflation surge and the nominal deposit and loan interest rates follow a similar pattern in the benchmark model.

When the deposit rate adjustment speed is very low, the lower deposit interest rates relative to the benchmark model imply higher nominal loan interest rates in the medium run. Thus, investment and output are further reduced and consumption stays relatively higher, as compared to the benchmark model, due to the large increase in the bank net interest income.

The introduction of the bank excess interest income tax increases the economic costs of the shock in the short to medium run due to a similar mechanism, as discussed for the negative intermediate goods productivity shock. In the long run, output and investment dynamics fare a bit better with the tax than without it. Investment even improves over the benchmark model's impulse response function at the end of the considered impulse response function horizon of 40 quarters.

Taken together, the effect of a slower adjustment of deposit interest rates to monetary policy changes in response to a positive government consumption shock is similar to a negative intermediate goods productivity shock: the economic costs become larger across

Figure 4: Impulse response functions after a positive government consumption shock

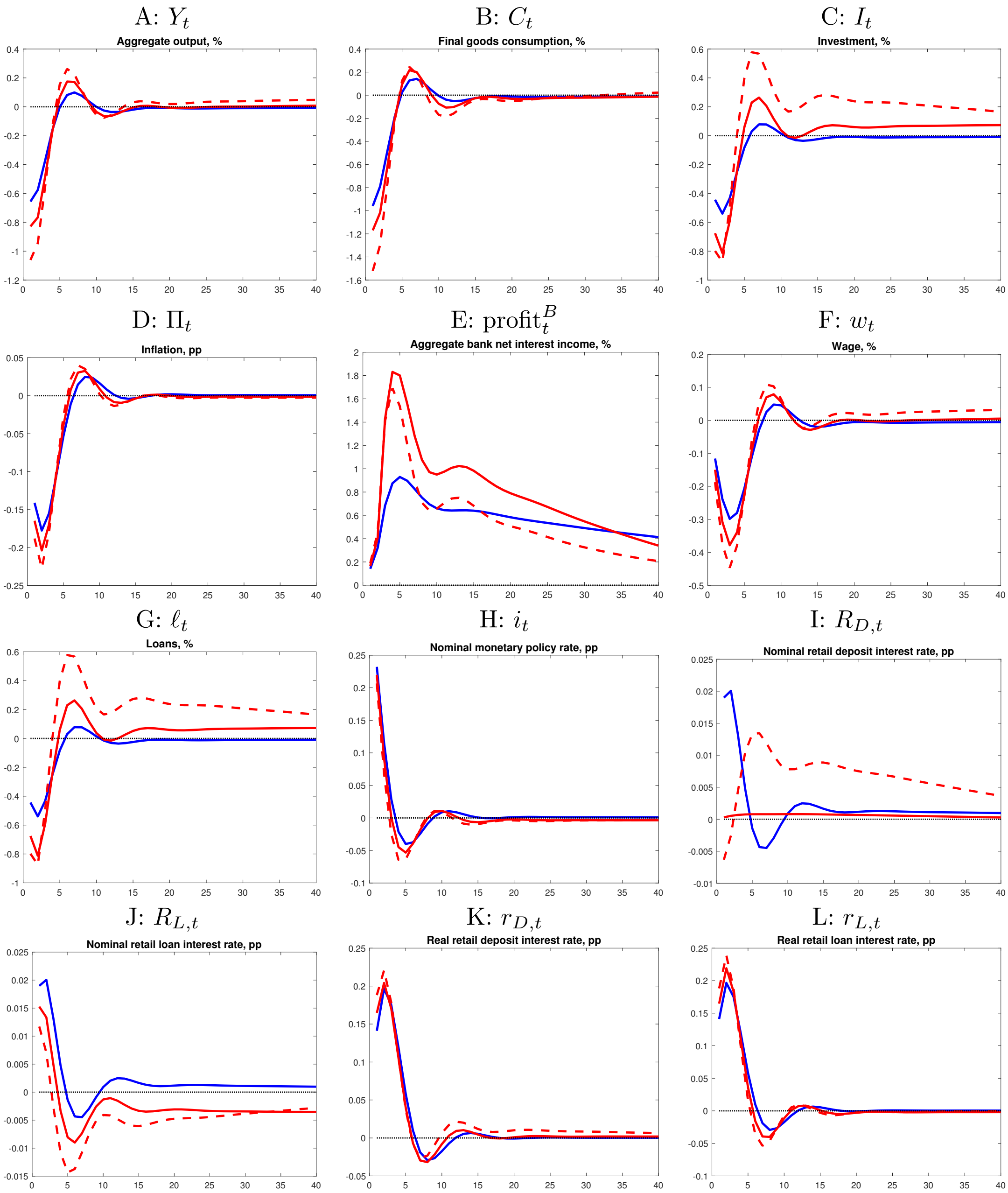


Notes: This figure depicts impulse response functions for a positive shock to government consumption expenditure. The shock with size $\varepsilon_{g,1} = 0.005$ occurs in period 1, with no further shocks simulated thereafter. The blue solid lines correspond to the benchmark full pass-through regime with $\rho_{di} = 0$ and no bank excess net interest income tax applied (i.e. $\tau_b = 0$), while the red solid and dashed lines correspond to the slow pass-through regime with $\rho_{di} = 0.995$ without and with the tax ($\tau_b = 0$ vs. $\tau_b = 0.60$).

all horizons, but the bank excess income tax alleviates some of these additional economic costs in the longer run, especially with respect to investment. However, households would prefer the tax to not be introduced due to their lower consumption in this case.

The shock considered in Figure 5 is a positive shock in the Taylor rule of size equal to one standard deviation or 30 basis points (without taking any contemporaneous inflation

Figure 5: Impulse response functions after a positive monetary policy shock



Notes: This figure depicts impulse response functions for a positive shock to the monetary policy rate. The shock with size $\varepsilon_{i,1} = 0.003$ occurs in period 1, with no further shocks simulated thereafter. The blue solid lines correspond to the benchmark full pass-through regime with $\rho_{di} = 0$ and no bank excess net interest income tax applied (i.e. $\tau_b = 0$), while the red solid and dashed lines correspond to the slow pass-through regime with $\rho_{di} = 0.995$ without and with the tax ($\tau_b = 0$ vs. $\tau_b = 0.60$).

or output gap effects into account).

As customary in a New-Keynesian DSGE model, increasing the monetary policy rate brings down inflation considerably by depressing economic activity via demand-side channels. Indeed, investment decreases substantially and, consequently, output in the short run also decreases. The higher deposit and loan interest rates due to the increase in the monetary policy rate make loans more expensive, as visible in the dynamics of the nominal and real retail loan interest rates, thus leading to higher bank net interest income and lower loan demand.

When banks do not pass on the increase of the monetary policy rate to deposit interest rates, the nominal loan interest rate increases less in the short run and is even reduced in the long run. However, loans and investment are lower in the short run due to lower incentives to invest in this case. In the longer run, the dynamics for these variables as well as output and consumption look better due to the lower costs for banks and firms that allow more economic activity to be sustained. Inflation can be reduced more in the short run but increases slightly more in the medium run due to these effects from the low deposit adjustment speed. Therefore, economic costs are amplified in the short run but reduced in the medium to long run.

The introduction of a bank excess interest income tax in this setting (red dashed lines) leads to higher offered deposit interest rates from quarter 4 onward. Due to the resulting larger costs for the banks, loan supply and investment are reduced relative to the case without the tax, resulting in larger economic costs overall in the very short run up to quarter 4. Once bank net interest income is substantially reduced by the tax, the dynamics become better due to cheaper loans and more deposit interest income for households, both relative to the benchmark model and the model with slow deposit interest rate adjustment and without the tax. The usual exception pertains to consumption which is lower with the tax than without it.

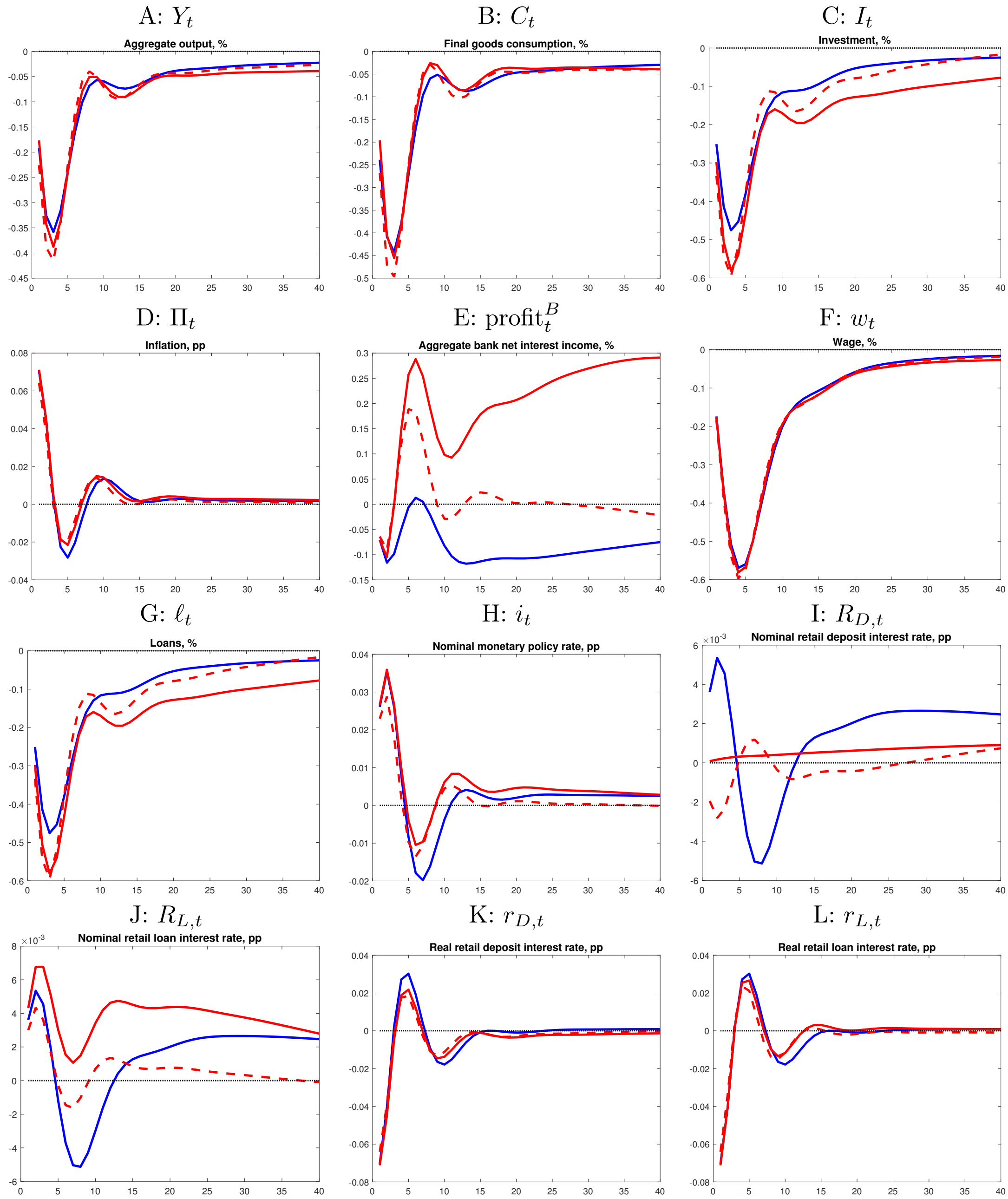
As seen, inflation is reduced more in the two cases with a lower deposit interest rate adjustment speed. Thus, a natural next question to ask is how much lower the monetary policy rate change would have to be in these two cases to lead to the same inflation response as the original shock in the benchmark calibration. I find that one has to reduce the shock size to 86% of the original shock size in the case without the tax and to 74% of the original shock size in the case with the tax in place.

The resulting impulse response functions are displayed in Appendix C, Figure C.1. The blue solid lines for the benchmark model are the same as in Figure 5, but the red solid and dashed lines feature the aforementioned smaller shock sizes of 86% and 74% of the original shock size, respectively. As one can see from the figure, the output losses are slightly larger initially with a low deposit interest rate adjustment speed when the aim of the monetary policy tightening is a fixed inflation reduction. These higher costs originate from more depressed investment dynamics due to the lower returns from investing in deposits and thus the lower financial wealth of households.

4.3 Mark-up shocks

The final category of shocks that are incorporated into the model are mark-up shocks. There can be mark-up shocks to intermediate goods prices, to retail loan interest rates, or to wages. Therefore, Figure 6 depicts the impulse response functions for a positive shock to intermediate goods firms' price mark-up, Figure 7 depicts the impulse response functions for a negative shock to retail banks' loan interest rate mark-up, and Figure 8 depicts the impulse response functions for a positive shock to wage mark-up.

Figure 6: Impulse response functions after a positive price mark-up shock



Notes: This figure depicts impulse response functions for a positive shock to the intermediate goods price mark-up. The shock with size $\varepsilon_{p,1} = 0.002$ occurs in period 1, with no further shocks simulated thereafter. The blue solid lines correspond to the benchmark full pass-through regime with $\rho_{di} = 0$ and no bank excess net interest income tax applied (i.e. $\tau_b = 0$), while the red solid and dashed lines correspond to the slow pass-through regime with $\rho_{di} = 0.995$ without and with the tax ($\tau_b = 0$ vs. $\tau_b = 0.60$).

First, I analyze the impulse response functions for a positive intermediate goods price mark-up shock. The increase in intermediate goods prices leads to higher inflation, lower output, lower consumption, and lower investment. Due to the decline in output and the increase in inflation, the real wage decreases as well. The surge in inflation is fought against by the central bank with a higher monetary policy rate. The nominal retail deposit and loan interest rates increase less than the monetary policy rate in the benchmark model due to rigid rate setting in the retail bank branches. Due to the inflation surge, the real deposit and loan interest rates first decline before they increase after the third quarter. All these effects are to be expected from a price mark-up shock. Aggregate real bank net interest income declines in response to the shock.

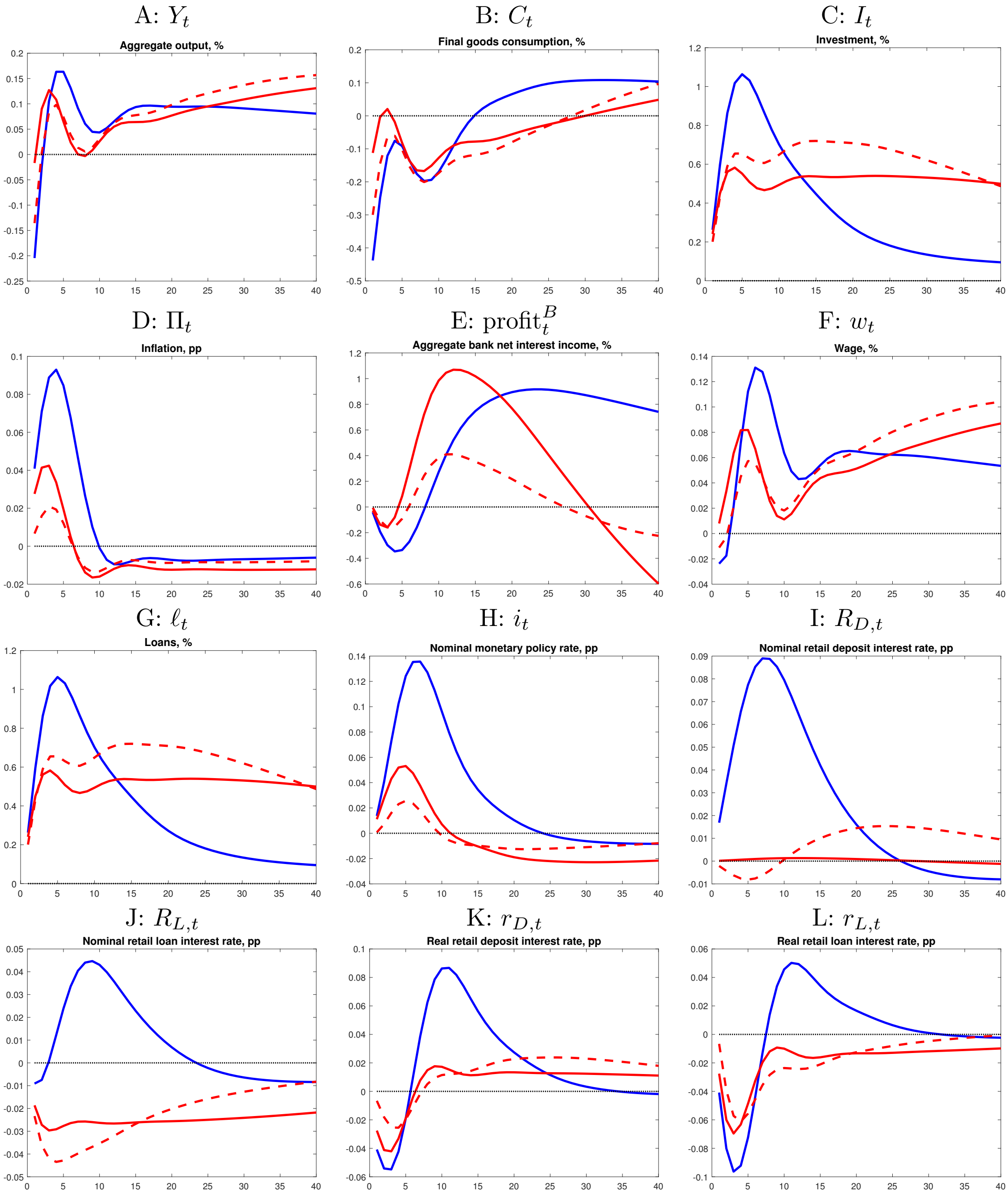
The broad picture does not change when the economy is plagued by a low deposit rate adjustment speed. However, due to the absence of an increase in nominal deposit rates and an even more pronounced and persistent increase in nominal retail loan interest rates, the banks' net interest income increases. This worsens investment demand relative to the benchmark model and in conjunction with the unwillingness of households to hold deposits poses a financing challenge for banks and thus they reduce their loan supply even more. Therefore, output dynamics are slightly worse than in the benchmark model as well, while consumption dynamics are not more negatively affected due to higher transfers from the banking sector due to their higher net worth.

As a result of the extra cost to banks, when a bank excess interest income tax is introduced, the increase in bank net interest income is first reduced and then vanishes in the longer run due to higher loan supply and lower loan interest rates relative to the case without the tax. The investment dynamics become better in the longer run as well and catch up with the benchmark model's dynamics at the end of the impulse response function horizon. The macroeconomic dynamics for output become slightly better and for consumption slightly worse with the tax as a consequence. In the short run, the deposit spread is increased by retail bank branches offering lower nominal deposit interest rates. In the medium run, the deposit spread is lowered. This partially shifts the tax burden from the medium to the short run. However, bank net interest income is always lower with the tax than without the tax.

Summing up these observations, the effect of the deposit rate adjustment speed for intermediate goods price mark-up shocks is similar to other inflationary shocks like a government consumption shock or a negative intermediate goods productivity shock.

Second, the effects of a negative retail loan interest rate mark-up shock are considered. Such a shock encourages additional loan supply and investment. Initially, as visible in Panel J of Figure 7, the retail loan interest rate also declines in accordance with the expected effect of such a shock, while from quarter 3 onward, the inflation surge induces loan interest rates to rise, alongside monetary policy and deposit interest rates. Due to lower labor supply and a substitution of resources, consumption and output levels initially fall, while output increases substantially from quarter 3 onward due to the investment

Figure 7: Impulse response functions after a negative loan interest rate mark-up shock



Notes: This figure depicts impulse response functions for a negative shock to the retail loan interest rate mark-up. The shock with size $\varepsilon_{r,1} = -0.0015$ occurs in period 1, with no further shocks simulated thereafter. The blue solid lines correspond to the benchmark full pass-through regime with $\rho_{di} = 0$ and no bank excess net interest income tax applied (i.e. $\tau_b = 0$), while the red solid and dashed lines correspond to the slow pass-through regime with $\rho_{di} = 0.995$ without and with the tax ($\tau_b = 0$ vs. $\tau_b = 0.60$).

boom. In the short run, deposit interest rates rise more and faster than loan interest rates, leading to lower bank net interest income. In the longer run, this effect is reversed, and loan interest rates remain elevated more persistently due to the loan and investment boom.

With a lower adjustment speed of deposit rates to monetary policy changes, the increase in the monetary policy rate is not passed on to deposit rates and banks can reduce their loan interest rates while still enjoying higher net interest income. While the initial loan and investment boom is somewhat subdued, the long-run effects are more positive in this model variant, furthermore consumption does not decline as much in the short to medium run due to the larger bank profits and net worth transferred to households. The inflation response is more muted due to the smaller effects on investment and loans.

The bank excess interest income tax added to the low deposit rate adjustment speed model variant amplifies these changes relative to the benchmark model with even better long-run macroeconomic dynamics with respect to output, investment, and loans. The costs for this must be borne by the households who face consumption dynamics closer to the benchmark model in the short run, i.e. more negative outcomes. They become worse than in both the benchmark model and the low deposit rate adjustment speed model variant in the medium run from quarter 12 onward. From around quarter 25 onward, the long-run consumption dynamics, despite the reduction in transfers from banks to households due to reduced bank profits, turn better than in the case without the tax. Thus, here the tax is again making things better with respect to aggregate output and investment dynamics by forcing banks to increase deposit rates endogenously in the longer run. This is particularly evident in the dynamics of bank net interest income, which initially exceeds the benchmark model but turns lower from around quarter 12 onward (Panel E).

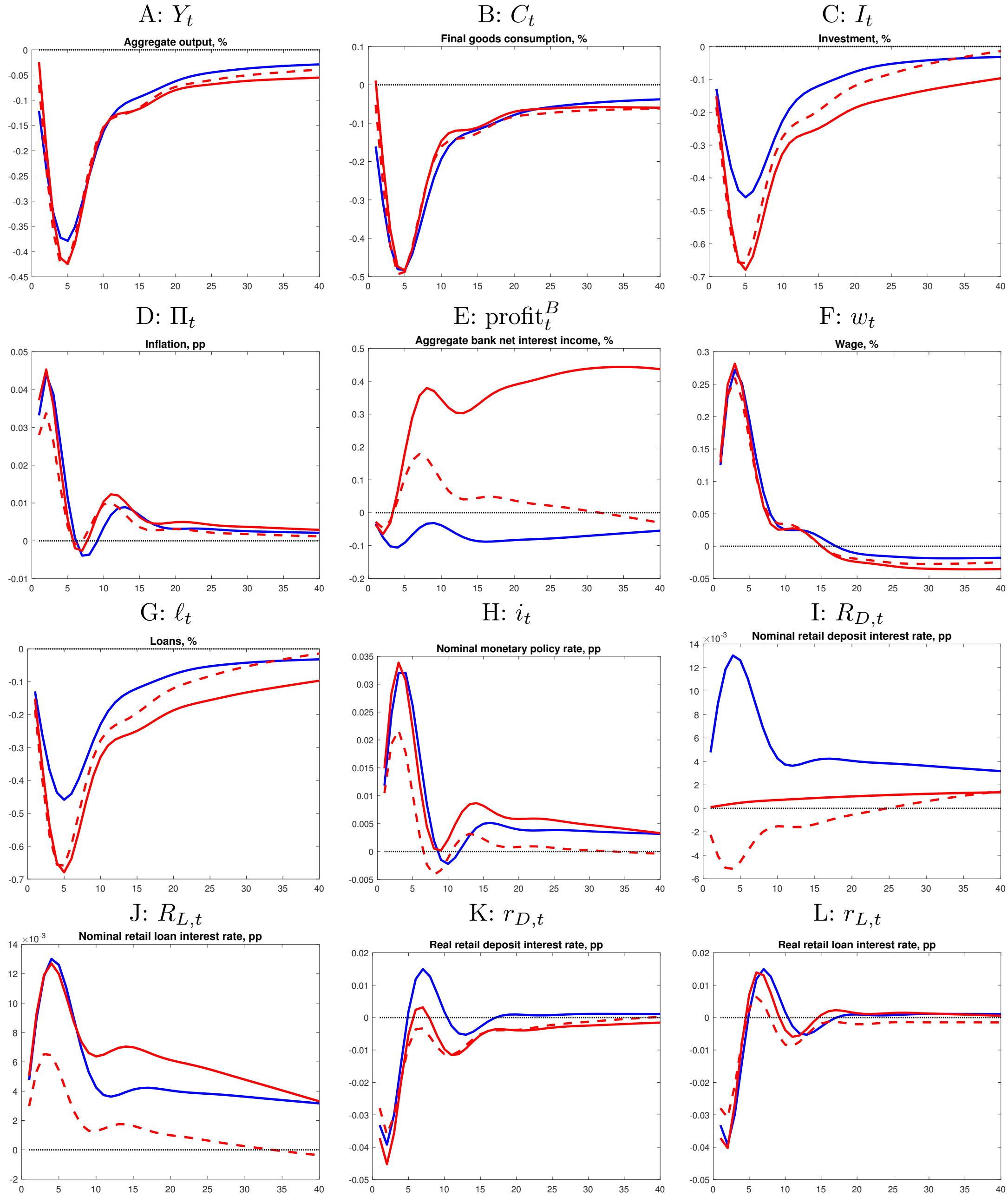
Third, attention to the consequences of a positive wage mark-up shock for macroeconomic quantities and asset returns is paid.

The real wage increases in response to the wage mark-up shock which makes the labor input more expensive. Thus, labor demand shrinks, leading to reductions in investment, output, and consumption. Despite the economic recession, inflation increases due to the inflationary pressure from higher wages. The central bank responds by increasing the policy rate as the weight on the inflation gap is several times higher than the weight on the output gap. This results in higher nominal deposit and loan interest rates. The real deposit and loan interest rates fall initially due to the inflation surge.

When nominal deposit interest rates do not follow the increase in the monetary policy rate in the low deposit rate adjustment speed model variant, the higher bank profits transferred to households induce lower investment incentives and thus investment, output, and loan dynamics worsen considerably. Additionally, the retail loan interest rates are kept higher for longer, resulting in more pronounced negative long-run dynamics. Due to the higher bank profits, consumption is higher than in the benchmark model, albeit only in the short to medium run.

Introducing the bank excess interest income tax partially undoes the additional negative effects with respect to investment, output, and loan dynamics. However, it also

Figure 8: Impulse response functions after a positive wage mark-up shock



Notes: This figure depicts impulse response functions for a positive shock to the wage mark-up. The shock with size $\varepsilon_{w,1} = 0.005$ occurs in period 1, with no further shocks simulated thereafter. The blue solid lines correspond to the benchmark full pass-through regime with $\rho_{di} = 0$ and no bank excess net interest income tax applied (i.e. $\tau_b = 0$), while the red solid and dashed lines correspond to the slow pass-through regime with $\rho_{di} = 0.995$ without and with the tax ($\tau_b = 0$ vs. $\tau_b = 0.60$).

prompts the banks to lower nominal retail deposit interest rates, which worsens consumption outcomes slightly. All in all, the tax is nevertheless a good idea to correct the adverse effects of a low deposit adjustment speed.

Table 3: Cumulative effects relative to the benchmark model

Investment productivity	Deposit interest rate adj. speed only				Deposit interest rate adj. speed + Tax			
Horizon	Y	C	I	Bank	Y	C	I	Bank
8	−0.22	−0.23	−0.40	0.41	−0.27	−0.37	−0.24	0.15
20	−0.17	−0.64	1.04	−1.86	−0.18	−0.85	1.59	−2.52
40	0.25	−1.01	4.11	−12.35	0.30	−1.00	4.32	−8.57
Intermediate productivity	**Deposit interest rate adj. speed only**				**Deposit interest rate adj. speed + Tax**			
Horizon	Y	C	I	Bank	Y	C	I	Bank
8	−0.05	1.07	−3.30	5.64	−0.35	0.42	−2.85	3.66
20	−0.50	1.62	−7.00	19.96	−0.67	0.38	−4.33	7.95
40	−1.74	1.08	−11.51	46.92	−1.20	−0.54	−4.26	11.51
Government consumption	**Deposit interest rate adj. speed only**				**Deposit interest rate adj. speed + Tax**			
Horizon	Y	C	I	Bank	Y	C	I	Bank
8	0.00	0.20	−0.59	0.95	−0.05	0.09	−0.52	0.62
20	−0.08	0.30	−1.27	3.48	−0.11	0.10	−0.83	1.42
40	−0.31	0.21	−2.12	8.35	−0.22	−0.06	−0.88	2.15
Monetary policy	**Deposit interest rate adj. speed only**				**Deposit interest rate adj. speed + Tax**			
Horizon	Y	C	I	Bank	Y	C	I	Bank
8	−0.22	−0.37	0.00	4.07	−0.42	−1.19	1.36	2.65
20	−0.27	−0.68	0.64	7.55	−0.30	−1.99	4.28	2.74
40	−0.06	−0.83	2.08	8.60	0.59	−1.87	8.27	−0.18
Price mark−up	**Deposit interest rate adj. speed only**				**Deposit interest rate adj. speed + Tax**			
Horizon	Y	C	I	Bank	Y	C	I	Bank
8	0.00	0.15	−0.42	1.29	−0.06	−0.02	−0.23	0.85
20	−0.09	0.28	−1.24	4.31	−0.13	−0.02	−0.55	2.07
40	−0.36	0.26	−2.47	10.92	−0.22	−0.12	−0.73	3.67
Loan mark-up	**Deposit interest rate adj. speed only**				**Deposit interest rate adj. speed + Tax**			
Horizon	Y	C	I	Bank	Y	C	I	Bank
8	−0.09	0.81	−2.78	2.83	−0.30	0.27	−2.25	1.51
20	−0.35	0.22	−2.36	6.62	−0.42	−0.77	0.16	−1.92
40	0.00	−1.63	4.69	−8.71	0.43	−2.31	8.75	−18.76
Wage mark-up	**Deposit interest rate adj. speed only**				**Deposit interest rate adj. speed + Tax**			
Horizon	Y	C	I	Bank	Y	C	I	Bank
8	0.00	0.42	−1.19	1.67	−0.09	0.25	−1.13	1.09
20	−0.15	0.63	−2.54	6.48	−0.20	0.30	−1.83	2.58
40	−0.60	0.45	−4.18	15.73	−0.44	−0.04	−2.04	3.93

Notes: This table reports the cumulative effects relative to the benchmark calibration with instantaneous deposit interest rate adjustment for four variables – aggregate output (Y), aggregate consumption (C), aggregate investment (I), and aggregate bank net interest income (Bank) – and all shocks considered in the impulse response function analysis. The reported numbers correspond to percentage differences across the models as a fraction of the initial steady-state value of the variable.

4.4 Cumulative effects and summary

In this section, I compute and compare the cumulative effects of the bank excess interest income tax and the deposit interest rate adjustment speed for all eight shocks relative to the benchmark model (instantaneous deposit interest rate adjustment, no bank excess interest income tax). For the four considered variables – i.e. output, consumption, investment, and bank net interest income – I take the differences of the impulse response functions for the two alternative calibrations relative to the benchmark model's impulse response functions and sum up these differences (appropriately discounted). As the discount rate, I am using the steady-state real monetary policy rate, i.e. the steady state of r_t. The results for horizons of 8, 20, and 40 quarters are reported in Table 3. These horizons allow the total short-, medium-, and long-run effects of the deposit rate adjustment speed and the bank excess profits tax to be easily compared and summarized.

First, I summarize the implications for a positive investment productivity shock. Relative to the effect in the benchmark model, banks adjusting the deposit rates only very sluggishly leads to gains in the net interest income for banks in the short run. This is due to the previously discussed lower loan interest rates after the shock as well as to lower investment and – to a smaller extent – to lower output and consumption in the short run. In the long run, bank net interest income falls substantially, while output and investment increase, and consumption falls significantly. In the medium run, output still exhibits a cumulative decline relative to the benchmark model. If both the tax is levied on banks and the deposit interest rate adjustment speed is low, in the short run, after 8 quarters, the macroeconomic effects are negative, but after 40 quarters cumulative investment and output dynamics look better than without the tax, while bank net interest income does not fall as much as in the model without the tax.

Second, the intermediate goods productivity shock leads to higher bank interest income relative to the benchmark model for both the lower deposit interest rate speed and when both model modifications are implemented jointly. However, the increase in bank net interest income is substantially lower in the long run with the tax. Investment and output suffer substantially in the long run due to the lower deposit interest rate adjustment speed, but consumption increases. If the tax is applied in addition, output and investment losses are reduced, but consumption also falls in the long run.

Third, the positive government consumption shock leads to lower output and investment alongside higher bank net interest income when both the deposit rate adjustment speed is lower and when the tax is introduced. Consumption increases for all horizons in the first case, while the effect becomes negative in the long run when both modifications are implemented. The tax reduces the increase in bank net interest income and limits the decrease in investment and output at the expense of worse consumption dynamics.

Fourth, after a positive monetary policy shock bank net interest income is substantially increased alongside investment with a lower deposit interest rate adjustment speed. This comes at the expense of lower cumulative consumption and to a much smaller extent reduced cumulative production output. Introducing the tax leads to still somewhat higher bank net interest income in the short and medium run, while the effect becomes essentially zero in the long run. This stimulates investment significantly in the long run, in particular output dynamics after a tougher trough become better than in the benchmark model. The costs are borne again by households who cumulatively consume 1.87% less (as a fraction of the initial steady-state value for consumption) after 40 quarters.

Fifth, price mark-up shocks and wage mark-up shocks lead to similar observations. Bank net interest income increases due to the lower deposit rate adjustment speed and much less so when the tax is also applied. Output in the long run and investment fall, while consumption is either minimally affected or increases over time relative to the benchmark model.

Sixth, bank net interest income increases only in the short run and falls in the long run with a lower deposit interest rate adjustment speed after a loan mark-up shock – also when the tax is introduced additionally. This shock is thus the only other shock besides the negative investment productivity shock where this is observed. However, investment is positively impacted in the long run. Furthermore, output expands when both the tax is active and the deposit rate adjustment speed is low relative to the benchmark model. The relative effects on consumption are positive in the short run and negative in the long run, opposite to the observations for investment.

Taken together, bank net interest income typically profits from a lower deposit interest rate speed, while – naturally – the introduction of a bank excess interest income tax lowers the increase in bank net interest income. Especially in the long run, the lower deposit interest rate adjustment speed leads to worse output dynamics, while the introduction of the tax reduces the losses or often even yields better dynamics than in the benchmark model. Typically, the tax nevertheless yields worse consumption dynamics. The effect on consumption dynamics from a lower deposit rate adjustment speed alone are very mixed, but due to the substitution effect always opposite to the effect for investment. The decision regarding the size of capital investment is the main savings decision of the economy. There is another asset available to households to transfer funds across time, i.e. deposits. However, the decision between how much to consume or how much to invest in deposits is for the aggregate economy far less important than the trade-off between consumption and investment.[3] This explains the observed behavior of consumption and investment in Table 3. For about half of the shocks analyzed the long-run effect is positive, for the other half it is negative. Note that the worse dynamics for household consumption

[3]See the aggregate resource constraint (45) where only aggregate consumption C_t and aggregate investment production input X_t appear but not aggregate deposits D_t. Via Equation (18), X_t and aggregate investment I_t are strongly related with each other.

with the tax are due to the fact that the households own the banks, and the resulting reduction in bank profit transfers harms the households relative to the model variant with only a lower deposit rate adjustment speed.

4.5 Policy implications

The purpose of this section is not only to highlight the policy implications of a slow adjustment of nominal deposit interest rates by commercial banks and – most importantly – the potential of the introduction of a bank excess profits tax (see Maneely and Ratnovski, 2024, for an overview of real-life examples) to combat such a low pass-through of monetary policy to households, but also to mention a few limitations of the conducted analysis.

The slow adjustment of nominal deposit interest rates to monetary policy rate changes leads to higher bank profits in response to almost all shocks considered that share as common the feature that they lead to an increase in monetary policy rates. The only exceptions are positive investment productivity shocks and negative loan interest rate mark-up shocks (for the latter shock, only in the long run). Aggregate output is negatively affected in the long run, relative to the case of instantaneous deposit rate adjustment, for the same shocks with the same exceptions. Similar observations can be drawn for aggregate investment; the only diverging implication is that a positive monetary policy shock induces aggregate investment to increase in the long run. Opposite implications hold for aggregate consumption which decreases for the three shocks that see investment increase in the long run, relative to the benchmark model, and increases for the other four shocks.

The introduction of the bank excess profits tax corrects these implications for most shocks and aligns the dynamics of the model closer to the benchmark model implications. This holds at least for the long run, while the short- to medium-run costs are typically amplified by the introduction of the tax. The introduction of the tax might not be a good idea, however, in response to higher investment productivity, since the increase of bank profits due to a low deposit interest rate adjustment speed is rather short-lived.

Therefore, the slow adjustment of nominal deposit interest rates has negative consequences for the aggregate economic performance. However, it might lead to an increase in welfare for households. The bank excess profits tax on the one hand is beneficial for aggregate economic dynamics in the long run but also amplifies economic costs in the short to medium run. Households' consumption, and thus probably welfare, does not profit from the introduction of the tax for any time horizon up to 40 quarters on the other hand.

Thus, taken all together, it might be a good response of the fiscal authority to respond to excess bank profits with such a tax if it cares mostly about long-run economic dynamics in terms of economic output Y_t. However, an even better response might be to explore policies that motivate commercial banks to pay the monetary policy rate or a value very close to it on deposits by households at all times. Such a policy would lead to the dynamics in the benchmark model (or dynamics close to it). As seen, economic output Y_t performs better in the short and medium run in the benchmark model for all shocks, and for four out of the seven analyzed shocks long-run economic output also performs better in the benchmark model.

The utilized model is relatively simple and thus some limitations should be mentioned. Firstly, the households in the model are fully homogeneous and thus the mentioned implications for households face the caveat of not modeling some realistic household heterogeneity. There could be different implications for different household groups, for example. Secondly, the model is a closed-economy model and thus does not feature economic openness of any kind. Therefore, the implications of or for international trade are ignored, and my results might look different in a small open economy. Thirdly, the production sector is also fully homogeneous, lacking a multi-sector structure and input-output linkages, which – if included – might change some results. Finally, financial stability considerations, an analysis of different loan reference rates (other than the short-term monetary policy rate) and risk premium processes in Equation (24), an explicit modeling of a bank capital requirement or macro-prudential policies, and long-term loans are absent from the model. These issues and extensions are left for future research.

5 Conclusion

In this study, I investigate the economic effects of delaying the adjustment of deposit interest rates paid to households on their bank deposits to monetary policy rate changes by utilizing a suitable New-Keynesian DSGE model with a banking sector. Specifically, the comparison between assuming a very low deposit interest rate adjustment speed to assuming that the (wholesale) deposit interest rate is always equal to the monetary policy rate, are analyzed in detail. The following key takeaways emerge.

First, decreasing the deposit interest rate adjustment leads to an increase in macroeconomic volatility (i.e. higher output, consumption, and investment growth volatility), while it also leads to a decrease in the volatility of the credit spread unless a very low deposit rate adjustment speed is assumed.

Second, bank net interest income increases especially in the long run due to a low deposit interest rate adjustment speed for most shocks – the two exceptions are positive investment productivity shocks and negative loan interest rate mark-up shocks. While aggregate consumption typically benefits from a lower deposit rate adjustment speed in response to various shocks, aggregate output and investment decline substantially.

Third, when the government introduces a tax on excess interest income earned by the banks due to offering retail deposit interest rates below the monetary policy rate, it is found that this tax improves long-run aggregate economic dynamics (output and investment) while it leads to lower long-run consumption for households. However, short- to medium-run costs become amplified.

The exploration of other (for example, endogenous) mechanisms to induce different deposit adjustment speeds as well as considering changing other model assumptions as detailed at the end of Section 4.5 are left for future research.

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A Model Solution

In this appendix, I solve for the model's equilibrium, re-express every equation that is in nominal terms in real terms, before formally defining the equilibrium of the model.

A.1 Households

The optimization problem of household h leads to the following Lagrangian:

$$\begin{aligned}\mathcal{L}^H = \mathbf{E}_t\Bigg[\sum_{s=0}^{\infty} \frac{\beta^s}{1-\gamma}\Big(C_{h,t+s} - \frac{a(N_{h,t+s})^{1+1/f}}{1+1/f}\Big)^{1-\gamma}\Bigg] \\ - \lambda^n_{t+s}\Bigg(P_{t+s}C_{h,t+s} + D_{h,t+s} + \Phi^n_{d,t+s} + P_{t+s}T_{t+s} + \Phi^n_{b,t+s} - R_{D,t+s-1}D_{h,t+s-1} - W_{h,t+s}N_{h,t+s} \\ - \frac{\phi_w W_{t+s}N_{t+s}}{2}\Big(\frac{W_{h,t+s}}{W_{h,t+s-1}} - \widetilde{\Pi}_{w,t+s}\Big)^2 - (1-\theta)K^n_{b,t+s-1} - Z^A_{t+s} - Z^B_{t+s} - \Phi_{t+s}\Bigg),\end{aligned}$$

where λ^n_{t+s} is the (nominal) shadow price attached to the budget constraint of the household. The first order conditions with respect to consumption $C_{h,t}$ and bank deposits $D_{h,t}$ are given by:

$$P_t\lambda^n_t = \Big(C_t - \frac{aN_t^{1+1/f}}{1+1/f}\Big)^{-\gamma}, \tag{A.1}$$

$$1 = \mathbf{E}_t\Big[\mathbb{M}^{\$}_{t,t+1}R_{D,t}\Big], \tag{A.2}$$

where I used the following definition of the nominal stochastic discount factor:

$$\mathbb{M}^{\$}_{t,t+1} = \beta\cdot\lambda^n_{t+1}/\lambda^n_t. \tag{A.3}$$

A.2 Labor unions and wage setting mechanism

The optimization problem of the labor union leads to the following Lagrangian:

$$\mathcal{L}^W = W_t\Big(\int_0^1 (N_{h,t})^{(\epsilon_w-1)/\epsilon_w}\,dh\Big)^{\epsilon_w/(\epsilon_w-1)} - \int_0^1 \mathbb{W}_t W_{h,t}N_{h,t}\,dh.$$

The first order condition with respect to household h's differentiated labor supply $N_{h,t}$ leads to the following labor demand condition:

$$N_{h,t} = N_t(\mathbb{W}_t W_{h,t}/W_t)^{-\epsilon_w}. \tag{A.4}$$

This condition is inserted into the household's Lagrangian to yield:

$$\begin{aligned}\mathcal{L}^H = \mathbf{E}_t\Bigg[\sum_{s=0}^{\infty} \frac{\beta^s}{1-\gamma}\Big(C_{h,t+s} - \frac{a\left((\mathbb{W}_t W_{h,t}/W_t)^{-\epsilon_w}N_{t+s}\right)^{1+1/f}}{1+1/f}\Big)^{1-\gamma}\Bigg] \\ - \lambda^n_{t+s}\Bigg(P_{t+s}C_{h,t+s} + D_{h,t+s} + \Phi^n_{d,t+s} + P_{t+s}T_{t+s} + \Phi^n_{b,t+s} - R_{d,t+s-1}D_{h,t+s-1} \\ - \Big(\frac{\mathbb{W}_t}{W_t}\Big)^{-\epsilon_w}(W_{h,t+s})^{1-\epsilon_w}N_{t+s} + \frac{\phi_w W_{t+s}N_{t+s}}{2}\Big(\frac{W_{h,t+s}}{W_{h,t+s-1}} - \widetilde{\Pi}_{w,t+s}\Big)^2 \\ - (1-\theta)K^n_{b,t+s-1} - Z^A_{t+s} - Z^B_{t+s} - \Phi_{t+s}\Bigg).\end{aligned}$$

Taking the derivative with respect to the labor-type differentiated wage $W_{h,t}$ yields:

$$
\begin{aligned}
0 = & \frac{\lambda_t^n P_t a \epsilon_w (N_t)^{1+1/f}}{W_{h,t}} \left(\frac{\mathbb{W}_t W_{h,t}}{W_t} \right)^{-\frac{\epsilon_w f}{1+f}} + \lambda_t^n (1-\epsilon_w) \left(\frac{\mathbb{W}_t W_{h,t}}{W_t} \right)^{-\epsilon_w} N_t \\
& - \frac{\lambda_t^n \phi_w W_t N_t}{W_{h,t-1}} \left(\frac{W_{h,t}}{W_{h,t-1}} - \widetilde{\Pi}_{w,t} \right) + \mathbf{E}_t \left[\beta \lambda_{t+1}^n \phi_w N_{t+1} \left(\frac{W_{t+1} W_{h,t+1}}{(W_{h,t})^2} \right) \left(\frac{W_{h,t+1}}{W_{h,t}} - \widetilde{\Pi}_{w,t+1} \right) \right].
\end{aligned} \tag{A.5}
$$

Noting that every household takes the same decision implies $W_{h,t} \equiv W_t$ which leads to:

$$
\begin{aligned}
0 = & \frac{\lambda_t^n P_t a \epsilon_w (N_t)^{1+1/f}}{W_t} (\mathbb{W}_t)^{-\frac{\epsilon_w f}{1+f}} + \lambda_t^n (1-\epsilon_w)(\mathbb{W}_t)^{-\epsilon_w} N_t \\
& - \lambda_t^n \phi_w N_t \left(\frac{W_t}{W_{t-1}} \right) \left(\frac{W_t}{W_{t-1}} - \widetilde{\Pi}_{w,t} \right) + \mathbf{E}_t \left[\beta \lambda_{t+1}^n \phi_w N_{t+1} \left(\frac{W_{t+1}}{W_t} \right)^2 \left(\frac{W_{t+1}}{W_t} - \widetilde{\Pi}_{w,t+1} \right) \right].
\end{aligned} \tag{A.6}
$$

This equation can be further simplified to:

$$
\begin{aligned}
\mathbf{E}_t \left[\frac{\mathbb{M}^{\$}_{t,t+1} \phi_w}{\epsilon_w - 1} \left(\frac{N_{t+1}}{N_t} \right) \left(\frac{W_{t+1}}{W_t} \right)^2 \left(\frac{W_{t+1}}{W_t} - \widetilde{\Pi}_{w,t+1} \right) \right] = & - \frac{P_t a \epsilon_w (N_t)^{1/f} (\mathbb{W}_t)^{-\frac{\epsilon_w f}{1+f}}}{(\epsilon_w - 1) W_t} \\
& + \frac{\phi_w}{\epsilon_w - 1} \left(\frac{W_t}{W_{t-1}} \right) \left(\frac{W_t}{W_{t-1}} + \widetilde{\Pi}_{w,t} \right) + (\mathbb{W}_t)^{-\epsilon_w}.
\end{aligned} \tag{A.7}
$$

A.3 Final goods producer

The optimization problem of the final goods producer leads to the following Lagrangian:

$$
\mathcal{L}^Y = P_t \left(\int_0^1 (Y_{i,t})^{(\epsilon_p - 1)/\epsilon_p} di \right)^{\epsilon_p/(\epsilon_p - 1)} - \int_0^1 \mathbb{P}_t P^y_{i,t} Y_{i,t} \, di.
$$

The first order condition of firm $i \in [0,1]$ with respect to intermediate goods input $Y_{i,t}$ is given by:

$$
Y_{i,t} = Y_t (\mathbb{P}_t P^y_{i,t} / P_t)^{-\epsilon_p}. \tag{A.8}
$$

A.4 Intermediate goods producers

The intermediate goods producers maximize their (nominal) value function subject to the capital accumulation equation, the loan-in-advance constraint, and their production technology, which implies that the following Lagrangian needs to be solved:

$$
\begin{aligned}
\mathcal{L}_i^y = \mathbf{E}_t \Bigg[\sum_{s=0}^{\infty} \mathbb{M}^{\$}_{t,t+s} \Bigg(& \mathbb{P}_{t+s} P^y_{i,t+s} Y_{i,t+s} - W_{t+s} N_{i,t+s} - P^I_{t+s} I_{i,t+s} + L_{i,t+s} - R_{L,t+s-1} L_{i,t+s-1} \\
& - \frac{\phi_p P_{t+s} Y_{t+s}}{2} \left(P^y_{i,t+s} / P^y_{i,t+s-1} - \widetilde{\Pi}_{t+s} \right)^2 \Bigg) \\
& - Q_{i,t+s} \mathbb{M}^{\$}_{t,t+s} \left((1-\delta) K_{i,t+s} + I_{i,t+s} \left[1 - \frac{\phi_I}{2} \left(I_{i,t+s} / I_{i,t+s-1} - 1 \right)^2 \right] - K_{i,t+s+1} \right) \\
& + \lambda^{\mathtt{LIA}}_{i,t+s} \mathbb{M}^{\$}_{t,t+s} \left(L_{i,t+s} - \chi P^I_{t+s} I_{i,t+s} \right) \\
& - \Phi^n_{i,t+s} \mathbb{M}^{\$}_{t,t+s} \left(Y_{i,t+s} - A_{Y,t+s} K^{\alpha}_{i,t+s} N^{1-\alpha}_{i,t+s} \right) \Bigg],
\end{aligned}
$$

where $Q_{i,t+s} \mathbb{M}^{\$}_{t,t+s}$ is the (nominal) shadow price attached to the capital accumulation equation, $\lambda^{\mathtt{LIA}}_{i,t+s} \mathbb{M}^{\$}_{t,t+s}$ is the (nominal) shadow price attached to individual intermediate goods producer's loan-in-advance constraint, and $\Phi^n_{i,t+s}\mathbb{M}^\$_{t,t+s}$ is the (nominal) shadow price attached to firm i's production technology. Substituting in the final goods producer's first order condition, I get:

$$\begin{aligned}
\mathcal{L}^y_i = \mathbf{E}_t\Bigg[\sum_{s=0}^{\infty}\mathbb{M}^\$_{t,t+s}\Bigg(& Y_{t+s}(\mathbb{P}_{t+s}P^y_{i,t+s})^{1-\epsilon_p}(P_{t+s})^{\epsilon_p} - W_{t+s}N_{i,t+s} - P^I_{t+s}I_{i,t+s} + L_{i,t+s} - R_{L,t+s-1}L_{i,t+s-1} \\
& - \frac{\phi_p P_{t+s}Y_{t+s}}{2}\left(P^y_{i,t+s}/P^y_{i,t+s-1} - \widetilde{\Pi}_{t+s}\right)^2\Bigg) \\
& + Q_{i,t+s}\mathbb{M}^\$_{t,t+s}\Bigg((1-\delta)K_{i,t+s} + I_{i,t+s}\left[1 - \frac{\phi_I}{2}\left(I_{i,t+s}/I_{i,t+s-1} - 1\right)^2\right] - K_{i,t+s+1}\Bigg) \\
& + \lambda^{\mathtt{LIA}}_{i,t+s}\mathbb{M}^\$_{t,t+s}\Bigg(L_{i,t+s} - \chi P^I_{t+s}I_{i,t+s}\Bigg) \\
& - \Phi^n_{i,t+s}\mathbb{M}^\$_{t,t+s}\Bigg(Y_{t+s}\left(\mathbb{P}_{t+s}P^y_{i,t+s}/P_{t+s}\right)^{-\epsilon_p} - A_{Y,t+s}K^{\alpha}_{i,t+s}N^{1-\alpha}_{i,t+s}\Bigg)\Bigg].
\end{aligned}$$

The first order conditions with respect to firm i's loan demand $L_{i,t}$, investment demand $I_{i,t}$, next period's stock of firm-specific capital $K_{i,t+1}$, labor demand $N_{i,t}$, and intermediate goods price $P^y_{i,t}$ are given by:

$$1 + \lambda^{\mathtt{LIA}}_{i,t} = \mathbf{E}_t\Big[\mathbb{M}^\$_{t,t+1}R_{L,t}\Big], \tag{A.9}$$

$$\begin{aligned}
(1+\chi\lambda^{\mathtt{LIA}}_{i,t})P^I_t = {} & Q_{i,t}\left[1 - \frac{\phi_I}{2}\left(\frac{I_{i,t}}{I_{i,t-1}} - 1\right)^2 - \phi_I\left(\frac{I_{i,t}}{I_{i,t-1}} - 1\right)\left(\frac{I_{i,t}}{I_{i,t-1}}\right)\right] \\
& + \mathbf{E}_t\left[Q_{i,t+1}\mathbb{M}^\$_{t,t+1}\phi_I\left(\frac{I_{i,t+1}}{I_{i,t}} - 1\right)\left(\frac{I_{i,t+1}}{I_{i,t}}\right)^2\right],
\end{aligned} \tag{A.10}$$

$$Q_{i,t} = \mathbf{E}_t\left[\mathbb{M}^\$_{t,t+1}\left(\frac{\Phi^n_{i,t+1}\alpha Y_{i,t+1}}{K_{i,t+1}} + (1-\delta)Q_{i,t+1}\right)\right], \tag{A.11}$$

$$W_t = \Phi^n_{i,t}(1-\alpha)Y_{i,t}/N_{i,t}, \tag{A.12}$$

$$\begin{aligned}
\frac{\phi_p P_t}{P^y_{i,t-1}}\left(\frac{P^y_{i,t}}{P^y_{i,t-1}} - \widetilde{\Pi}_t\right) = {} & \mathbf{E}_t\left[\frac{\mathbb{M}^\$_{t,t+1}\phi_p P_{t+1}P^y_{i,t+1}Y_{t+1}}{(P^y_{i,t})^2 Y_t}\left(\frac{P^y_{i,t+1}}{P^y_{i,t}} - 1\right)\right] \\
& + \frac{\epsilon_p\Phi^n_{i,t}(\mathbb{P}_t)^{-\epsilon_p}}{P^y_{i,t}}\left(\frac{P^y_t}{P^y_{i,t}}\right)^{1+\epsilon_p} + (1-\epsilon_p)(\mathbb{P}_t)^{1-\epsilon_p}\left(\frac{P^y_t}{P^y_{i,t}}\right)^{\epsilon_p}.
\end{aligned} \tag{A.13}$$

Assuming that all firms choose the same capital-labor ratio implies that all firms will take identical decisions regarding production inputs, produce the same output, and choose the same price and capital stock. Thus, a symmetric equilibrium occurs which implies: $P^y_{i,t} \equiv P^y_t \equiv P_t$, $N_{i,t} \equiv N_t$, $L_{i,t} \equiv L_t$, $K_{i,t} \equiv K_t$, and $I_{i,t} \equiv I_t$. Therefore, one obtains $Y_{i,t} \equiv Y_t$. Hence, the shadow prices attached to the constraints are the same: $\Phi^n_{i,t} \equiv \Phi^n_t$, $Q_{i,t} \equiv Q_t$, and $\lambda^{\mathtt{LIA}}_{i,t} \equiv \lambda^{\mathtt{LIA}}_t$. This leads to the following equilibrium conditions in the symmetric equilibrium:

$$1 + \lambda^{\mathtt{LIA}}_t = \mathbf{E}_t\Big[\mathbb{M}^\$_{t,t+1}R_{L,t}\Big], \tag{A.14}$$

$$\begin{aligned}
(1+\chi\lambda^{\mathtt{LIA}}_t)P^I_t = {} & Q_t\left[1 - \frac{\phi_I}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2 - \phi_I\left(\frac{I_t}{I_{t-1}} - 1\right)\left(\frac{I_t}{I_{t-1}}\right)\right] \\
& + \mathbf{E}_t\left[Q_{t+1}\mathbb{M}^\$_{t,t+1}\phi_I\left(\frac{I_{t+1}}{I_t} - 1\right)\left(\frac{I_{t+1}}{I_t}\right)^2\right],
\end{aligned} \tag{A.15}$$

$$Q_t = \mathbf{E}_t\left[\mathbb{M}^\$_{t,t+1}\left(\frac{\Phi^n_{t+1}\alpha Y_{t+1}}{K_{t+1}} + (1-\delta)Q_{t+1}\right)\right], \tag{A.16}$$

$$W_t = \Phi^n_t(1-\alpha)Y_t/N_t, \tag{A.17}$$

$$\phi_p\left(\frac{P_t}{P_{t-1}}\right)\left(\frac{P_t}{P_{t-1}}-\widetilde{\Pi}_t\right)=\mathbf{E}_t\left[\mathbb{M}^{\$}_{t,t+1}\phi_p\left(\frac{Y_{t+1}}{Y_t}\right)\left(\frac{P_{t+1}}{P_t}\right)^2\left(\frac{P_{t+1}}{P_t}-\tilde{\Pi}_{t+1}\right)\right]+\frac{\epsilon_p\Phi^n_t(\mathbb{P}_t)^{-\epsilon_p}}{P_t}+(1-\epsilon_p)(\mathbb{P}_t)^{1-\epsilon_p}, \tag{A.18}$$

$$Y_t = A_{Y,t}K_t^\alpha N_t^{1-\alpha}, \tag{A.19}$$

$$K_{t+1} = (1-\delta)K_t + I_t\left[1-\frac{\phi_I}{2}\left(\frac{I_t}{I_{t-1}}-1\right)^2\right]. \tag{A.20}$$

A.5 Investment goods producers

The optimization problem of the investment goods producer that provides intermediate goods producer i with the investment goods demanded leads to the following Lagrangian:

$$\mathcal{L}_i^I = P_t^I A_{I,t}X_{i,t} - P_tX_{i,t}.$$

The first order condition with respect to final goods input $X_{i,t}$ for investment goods producer $i \in [0,1]$ is given by:

$$P_t^I A_{I,t} = P_t. \tag{A.21}$$

Due to firm symmetry in the general production sector and the investment goods sector, one also obtains:

$$I_t = A_{I,t}X_t. \tag{A.22}$$

A.6 Banks

Each bank is divided into a wholesale branch and two retail branches, whose optimization problems are discussed sequentially in the following three sections.

A.6.1 Wholesale branches

The individual wholesale branch j's optimization problem leads to the following Lagrangian:

$$\mathcal{L}_j^B = \mathbf{E}_t\left[(1-\theta)\mathbf{M}^{\$}_{t,t+1}K^n_{b,j,t+1} + \theta\mathbf{M}^{\$}_{t,t+1}v_{t+1}K^n_{b,j,t+1}\right] - v_tK^n_{b,j,t} - \mu_t^{\mathtt{icc}}\left(\Delta L_{j,t} - v_tK^n_{b,j,t}\right),$$

where $\mu_t^{\mathtt{icc}}$ is the (real) shadow price attached to the incentive compatibility constraint of bank j. The first order condition with respect to individual bank j's equity $K_{b,j,t}$ is given by:

$$(1-\mu_t^{\mathtt{icc}})v_t = \mathbf{E}_t\left[\mathbb{M}^{\$}_{t,t+1}\Omega_{t+1}R_{d,t}\right], \tag{A.23}$$

where the following modification term for the stochastic discount factor is applied:

$$\Omega_t = 1-\theta+\theta v_t. \tag{A.24}$$

Due to the absence of any j in the first order condition, all banks take the same decisions and a symmetric equilibrium is obtained. This implies that the bank balance sheet is simplified to the following equation:

$$K^n_{b,t} + D_t = L_t. \tag{A.25}$$

A.6.2 Retail loan branches

Each retail loan branch consists of two departments, a loan aggregating department and a loan pricing department. The perfectly competitive loan aggregating department chooses the loan supply $L_{z,i,t}$ to firm i by maximizing the following profit expression:

$$\mathcal{L}_i^{R,L} = \int_0^1 R_{L,z,t} L_{z,i,t}\, dz - R_{L,t} L_{i,t}.$$

The first order condition with respect to $L_{z,i,t}$ yields the following individual loan demand function:

$$L_{z,i,t} = \left(\frac{R_{L,z,t}}{R_{L,t}}\right)^{-\epsilon_\ell} L_{i,t}. \tag{A.26}$$

Aggregating across all intermediate goods producers, I obtain:

$$L_t = \int_0^1 L_{i,t}\, di = \int_0^1 \left(\int_0^1 (L_{z,i,t})^{(\epsilon_\ell-1)/\epsilon_\ell} dz\right)^{\epsilon_\ell/(\epsilon_\ell-1)} di = \left(\int_0^1 (L_{z,t})^{(\epsilon_\ell-1)/\epsilon_\ell} dz\right)^{\epsilon_\ell/(\epsilon_\ell-1)}, \tag{A.27}$$

which yields the aggregate demand function by maximizing the expression $\int_0^1 \mathcal{L}_i^{R,L}\, di$ with respect to $L_{z,t}$ using the just derived expression and $\int_0^1 L_{z,i,t}\, di = L_{z,t}$:

$$L_{z,t} = \left(\frac{R_{L,z,t}}{R_{L,t}}\right)^{-\epsilon_\ell} L_t. \tag{A.28}$$

The monopolistically competitive loan pricing department chooses the interest rate it charges to each firm $R_{L,z,t}$ by maximizing the following value function:

$$\mathbf{E}_t\left[\mathbb{M}^{\$}_{0,t}\left(R_{L,z,t}L_{z,t} - \mathbb{R}_t R_{\ell,t} L_{z,t} - \frac{\phi_\ell R_{L,t} L_t}{2}\left(\frac{R_{L,z,t}}{R_{L,z,t-1}} - 1\right)^2\right)\right].$$

Substituting in the demand function (A.28) yields:

$$\mathbf{E}_t\left[\mathbb{M}^{\$}_{0,t}\left((R_{L,z,t})^{1-\epsilon_\ell}(R_{L,t})^{\epsilon_\ell} L_t - \mathbb{R}_t R_{\ell,t} (R_{L,z,t})^{-\epsilon_\ell}(R_{L,t})^{\epsilon_\ell} L_t - \frac{\phi_\ell R_{L,t} L_t}{2}\left(\frac{R_{L,z,t}}{R_{L,z,t-1}} - 1\right)^2\right)\right].$$

The first order condition with respect to $R_{L,z,t}$ is given by:

$$\begin{aligned} 0 = (1-\epsilon_\ell)\left(\frac{R_{L,z,t}}{R_{L,t}}\right)^{-\epsilon_\ell} L_t + \epsilon_\ell \mathbb{R}_t \left(\frac{R_{\ell,t}}{R_{L,t}}\right)\left(\frac{R_{L,z,t}}{R_{L,t}}\right)^{-\epsilon_\ell - 1} L_t - \frac{\phi_\ell R_{L,t} L_t}{R_{L,z,t-1}}\left(\frac{R_{L,z,t}}{R_{L,z,t-1}} - 1\right) \\ + \mathbf{E}_t\left[\mathbb{M}^{\$}_{t,t+1}\phi_\ell L_{t+1}\left(\frac{R_{L,t+1}R_{L,z,t+1}}{(R_{L,z,t})^2}\right)\left(\frac{R_{L,z,t+1}}{R_{L,z,t}} - 1\right)\right]. \end{aligned} \tag{A.29}$$

Taking into account that each retail branch takes the same decision so that $R_{L,z,t} \equiv R_{L,t}$, the expression above simplifies to:

$$\begin{aligned} \mathbf{E}_t\left[\mathbb{M}^{\$}_{t,t+1}\left(\frac{\phi_\ell}{\epsilon_\ell - 1}\right)\left(\frac{L_{t+1}}{L_t}\right)\left(\frac{R_{L,t+1}}{R_{L,t}}\right)^2\left(\frac{R_{L,t+1}}{R_{L,t}} - 1\right)\right] = \frac{\phi_\ell}{\epsilon_\ell - 1}\left(\frac{R_{L,t}}{R_{L,t-1}}\right)\left(\frac{R_{L,t}}{R_{L,t-1}} - 1\right) \\ + 1 - \frac{\epsilon_\ell}{\epsilon_\ell - 1}\left(\frac{\mathbb{R}_t R_{\ell,t}}{R_{L,t}}\right). \end{aligned} \tag{A.30}$$

A.6.3 Retail deposit branches

Each retail deposit branch consists of two departments, a deposit aggregating department and a deposit pricing department. The perfectly competitive deposit aggregating department chooses the deposit supply $D_{z,h,t}$ to household h by maximizing the following profit expression:

$$\mathcal{L}_i^{R,D} = R_{D,t} D_{h,t} - \int_0^1 R_{D,z,t} D_{z,h,t} \, dz.$$

The first order condition with respect to $D_{z,h,t}$ yields the following individual loan demand function:

$$D_{z,h,t} = \left(\frac{R_{D,z,t}}{R_{D,t}} \right)^{-\epsilon_d} D_{h,t}. \tag{A.31}$$

Aggregating across all households, I obtain:

$$D_t = \int_0^1 D_{h,t} \, dh = \int_0^1 \left(\int_0^1 (D_{z,h,t})^{(\epsilon_d - 1)/\epsilon_d} dz \right)^{\epsilon_d/(\epsilon_d - 1)} dh = \left(\int_0^1 (D_{z,t})^{(\epsilon_d - 1)/\epsilon_d} dz \right)^{\epsilon_d/(\epsilon_d - 1)}, \tag{A.32}$$

which yields the aggregate demand function by maximizing the expression $\int_0^1 \mathcal{L}_h^{R,D} \, dh$ with respect to $D_{z,t}$ using the just derived expression and $\int_0^1 D_{z,h,t} \, dh = D_{z,t}$:

$$D_{z,t} = \left(\frac{R_{D,z,t}}{R_{D,t}} \right)^{-\epsilon_d} D_t. \tag{A.33}$$

The monopolistically competitive deposit pricing department chooses the interest rate it charges to each household $R_{D,z,t}$ by maximizing the following value function:

$$\mathbf{E}_t \left[\mathbb{M}_{0,t}^{\$} \left(\mathbb{D}_t R_{d,t} D_{z,t} - R_{D,z,t} D_{z,t} - \frac{\phi_d R_{D,t} D_t}{2} \left(\frac{R_{D,z,t}}{R_{D,z,t-1}} - 1 \right)^2 - \tau_b (i_t - R_{D,z,t}) D_{z,t} \right) \right].$$

Substituting in the demand function (A.33) yields:

$$\mathbf{E}_t \Bigg[\mathbb{M}_{0,t}^{\$} \Bigg(\mathbb{D}_t R_{d,t} \left(\frac{R_{D,z,t}}{R_{D,t}} \right)^{-\epsilon_d} D_t - R_{D,z,t} \left(\frac{R_{D,z,t}}{R_{D,t}} \right)^{-\epsilon_d} D_t - \frac{\phi_d R_{D,t} D_t}{2} \left(\frac{R_{D,z,t}}{R_{D,z,t-1}} - 1 \right)^2 - \tau_b (i_t - R_{D,z,t}) \left(\frac{R_{D,z,t}}{R_{D,t}} \right)^{-\epsilon_d} D_t \Bigg) \Bigg].$$

The first order condition with respect to $R_{D,z,t}$ is given by:

$$\begin{aligned} 0 = & -\epsilon_d \mathbb{D}_t \left(\frac{R_{d,t}}{R_{D,t}} \right) \left(\frac{R_{D,z,t}}{R_{D,t}} \right)^{-\epsilon_d - 1} D_t - (1 - \epsilon_d) \left(\frac{R_{D,z,t}}{R_{D,t}} \right)^{-\epsilon_d} D_t - \frac{\phi_d R_{D,t} D_t}{R_{D,z,t-1}} \left(\frac{R_{D,z,t}}{R_{D,z,t-1}} - 1 \right) \\ & - \tau_b \cdot \left[-\epsilon_d \left(\frac{R_{D,z,t}}{R_{D,t}} \right)^{-\epsilon_d - 1} \frac{i_t D_t}{R_{D,t}} - (1 - \epsilon_d) \left(\frac{R_{D,z,t}}{R_{D,t}} \right)^{-\epsilon_d} D_t \right] \\ & + \mathbf{E}_t \left[\mathbb{M}_{t,t+1}^{\$} \phi_d D_{t+1} \left(\frac{R_{D,t+1} R_{D,z,t+1}}{(R_{D,z,t})^2} \right) \left(\frac{R_{D,z,t+1}}{R_{D,z,t}} - 1 \right) \right]. \end{aligned} \tag{A.34}$$

Taking into account that each retail branch takes the same decision so that $R_{D,z,t} \equiv R_{D,t}$, the expression above simplifies to:

$$\mathbf{E}_t \left[\mathbb{M}_{t,t+1}^{\$} \left(\frac{\phi_d}{1 - \epsilon_d} \right) \left(\frac{D_{t+1}}{D_t} \right) \left(\frac{R_{D,t+1}}{R_{D,t}} \right)^2 \left(\frac{R_{D,t+1}}{R_{D,t}} - 1 \right) \right] - 1 \tag{A.35}$$

$$= \frac{\epsilon_d}{1-\epsilon_d}\left(\frac{\mathbb{D}_t R_{d,t}}{R_{D,t}}\right) + \frac{\phi_d}{1-\epsilon_d}\left(\frac{R_{D,t}}{R_{D,t-1}}\right)\left(\frac{R_{D,t}}{R_{D,t-1}} - 1\right) + \tau_b\left[\left(\frac{\epsilon_d}{\epsilon_d - 1}\right)\left(\frac{i_t}{R_{D,t}}\right) - 1\right].$$

A.7 Normalization of variables and equations

In the following sub-sections I provide the real versions of all equations given in nominal terms so far as my formal definition of the equilibrium will make use mostly of real variables and the corresponding equilibrium conditions in real terms.

A.7.1 Households and labor union

The shadow price attached to the budget constraint (i.e. marginal utility of consumption) in real terms is denoted and defined by $\lambda_t = P_t\lambda_t^n$, the real wage by $w_t = W_t/P_t$, the real (gross) deposit return by $r_{d,t+1} = R_{d,t}/\Pi_{t+1}$, and the real stochastic discount factor by $\mathbb{M}_{t,t+1} = \mathbb{M}^{\$}_{t,t+1}\Pi_{t+1}$, which implies the following equations that are used in the equilibrium system:

$$\lambda_t^n = \lambda_t/P_t, \tag{A.36}$$

$$\lambda_t = \left(C_t - \frac{aN_t^{1+1/f}}{1+1/f}\right)^{-\gamma}, \tag{A.37}$$

$$\Pi_{w,t} = w_t/w_{t-1}\cdot\Pi_t, \tag{A.38}$$

$$\mathbf{E}_t\left[\frac{\mathbb{M}_{t,t+1}\phi_w N_{t+1}}{\Pi_{t+1}}(\Pi_{w,t+1})^2\left(\Pi_{w,t+1} - \widetilde{\Pi}_{w,t+1}\right)\right] = -\frac{a\epsilon_w(N_t)^{1+1/f}(\mathbb{W}_t)^{-\frac{\epsilon_w f}{1+f}}}{w_t} + \phi_w\Pi_{w,t}N_t\left(\Pi_{w,t} - \widetilde{\Pi}_{w,t}\right) - (1-\epsilon_w)(\mathbb{W}_t)^{-\epsilon_w}N_t, \tag{A.39}$$

$$r_{D,t+1} = R_{D,t}/\Pi_{t+1}, \tag{A.40}$$

$$1 = \mathbf{E}_t[\mathbb{M}_{t,t+1}r_{D,t+1}], \tag{A.41}$$

$$\mathbb{M}_{t,t+1} = \beta\cdot\lambda_{t+1}/\lambda_t. \tag{A.42}$$

A.7.2 General production sector

The loan stock in real terms is denoted and defined by $\ell_t = L_t/P_t$, the real retail loan return by $r_{L,t} = R_{L,t-1}/\Pi_t$, the real shadow price of investment (real marginal Tobin's Q) by $q_t = Q_t/P_t$, the real relative price of investment by $p_t^I = P_t^I/P_t$, and the real shadow price of production technology by $\Phi_t = \Phi_t^n/P_t$. Moreover, I cannot identify the price index P_t and thus express everything in terms of inflation $\Pi_t = P_t/P_{t-1}$. These definitions imply that the just derived first order conditions become:

$$1 + \lambda_t^{\texttt{LIA}} = \mathbf{E}_t[\mathbb{M}_{t,t+1}r_{L,t+1}], \tag{A.43}$$

$$(1+\chi\lambda_t^{\texttt{LIA}})p_t^I = q_t\left[1 - \frac{\phi_I}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2 - \phi_I\left(\frac{I_t}{I_{t-1}} - 1\right)\left(\frac{I_t}{I_{t-1}}\right)\right] + \mathbf{E}_t\left[q_{t+1}\mathbb{M}_{t,t+1}\phi_I\left(\frac{I_{t+1}}{I_t} - 1\right)\left(\frac{I_{t+1}}{I_t}\right)^2\right], \tag{A.44}$$

$$q_t = \mathbf{E}_t\left[\mathbb{M}_{t,t+1}\left(\frac{\Phi_{t+1}\alpha Y_{t+1}}{K_{t+1}} + (1-\delta)q_{t+1}\right)\right], \tag{A.45}$$

$$w_t = \Phi_t(1-\alpha)Y_t/N_t, \tag{A.46}$$

$$\mathbf{E}_t\left[\mathbb{M}_{t,t+1}\phi_p Y_{t+1}\Pi_{t+1}\left(\Pi_{t+1} - \tilde{\Pi}_{t+1}\right)\right] = \phi_p Y_t\Pi_t\left(\Pi_t - \widetilde{\Pi}_t\right) - \epsilon_p\Phi_t(\mathbb{P}_t)^{-\epsilon_p}Y_t - (1-\epsilon_p)(\mathbb{P}_t)^{1-\epsilon_p}Y_t. \tag{A.47}$$

Moreover, normalizing the loan-in-advance constraint and the definition of the Rotemberg price adjustment cost function yields by applying the definition $\Phi_{p,t} = \Phi^n_{p,t}/P_t$ for real price adjustment costs:

$$\ell_t = \chi p^I_t I_t, \tag{A.48}$$

$$\Phi_{p,t} = \frac{\phi_p Y_t}{2}\left(\Pi_t - \widetilde{\Pi}_t\right)^2. \tag{A.49}$$

Finally, the real retail loan return definition also needs to be included in the equilibrium system in the following way:

$$r_{L,t} = R_{L,t-1}/\Pi_t. \tag{A.50}$$

A.7.3 Investment goods producers

Applying the definition of the real relative price of investment $p^I_t = P^I_t/P_t$ in Equation (A.21) yields:

$$p^I_t = (A_{I,t})^{-1}. \tag{A.51}$$

A.7.4 Banks

Bank equity in real terms is denoted and defined by $K_{b,t} = K^n_{b,t}/P_t$, the bank start-up fund by $\Phi_{b,t} = \Phi^n_{b,t}/P_t$, and bank deposits by $d_t = D_t/P_t$. This implies the following equilibrium conditions in real terms:

$$(1 - \mu^{\mathtt{icc}}_t)v_t = \mathbf{E}_t[\mathbb{M}_{t,t+1}\Omega_{t+1}r_{d,t+1}], \tag{A.52}$$

$$K_{b,t} + d_t = \ell_t, \tag{A.53}$$

$$K_{b,t} = \theta\left(\frac{(r_{\ell,t} - r_{d,t})\ell_{t-1}}{K_{b,t-1}} + r_{d,t}\right)K_{b,t-1} + \Phi_{b,t-1}, \tag{A.54}$$

$$\Phi_{b,t} = \varphi K_{b,t}. \tag{A.55}$$

The retail loan branch's first order condition in real form is given by:

$$\mathbf{E}_t\left[\mathbb{M}_{t,t+1}\left(\frac{\phi_\ell}{\epsilon_\ell - 1}\right)\left(\frac{\ell_{t+1}}{\ell_t}\right)\left(\frac{R_{L,t+1}}{R_{L,t}}\right)^2\left(\frac{R_{L,t+1}}{R_{L,t}} - 1\right)\right] = \frac{\phi_\ell}{\epsilon_\ell - 1}\left(\frac{R_{L,t}}{R_{L,t-1}}\right)\left(\frac{R_{L,t}}{R_{L,t-1}} - 1\right) + 1 - \frac{\epsilon_\ell}{\epsilon_\ell - 1}\left(\frac{\mathbb{R}_t R_{\ell,t}}{R_{L,t}}\right). \tag{A.56}$$

The retail deposit branch's first order condition in real form is given by:

$$\mathbf{E}_t\left[\mathbb{M}_{t,t+1}\left(\frac{\phi_d}{1 - \epsilon_d}\right)\left(\frac{d_{t+1}}{d_t}\right)\left(\frac{R_{D,t+1}}{R_{D,t}}\right)^2\left(\frac{R_{D,t+1}}{R_{D,t}} - 1\right)\right] - 1 = \frac{\epsilon_d}{1 - \epsilon_d}\left(\frac{\mathbb{D}_t R_{d,t}}{R_{D,t}}\right) + \frac{\phi_d}{1 - \epsilon_d}\left(\frac{R_{D,t}}{R_{D,t-1}}\right)\left(\frac{R_{D,t}}{R_{D,t-1}} - 1\right) + \tau_b\left[\left(\frac{\epsilon_d}{\epsilon_d - 1}\right)\left(\frac{i_t}{R_{D,t}}\right) - 1\right]. \tag{A.57}$$

Finally, the real wholesale loan and deposit return definition also needs to be included in the equilibrium system in the following way:

$$r_{\ell,t} = R_{\ell,t-1}/\Pi_t, \tag{A.58}$$

$$r_{d,t} = R_{d,t-1}/\Pi_t. \tag{A.59}$$

The real aggregate net interest income of the banking sector is given by:

$$\text{profit}_t^B = r_{L,t}\ell_{t-1} - r_{D,t}d_{t-1}. \tag{A.60}$$

A.7.5 Central bank

The real monetary policy rate is given by:

$$r_t = i_{t-1}/\Pi_t. \tag{A.61}$$

A.8 Formal definition of equilibrium

The formal definition of the equilibrium in my model involves **42** variables that obey **42** equations. The equilibrium can be formally defined as follows:

1. The household-specific variables w_t (real wage), $\mathbb{W}_t$ (wage mark-up shock process), $\Pi_{w,t}$ (wage inflation), $\widetilde{\Pi}_{w,t}$ (wage indexing-adjusted wage inflation), N_t (labor hours), λ_t (real marginal utility), C_t (consumption), $R_{D,t}$ (nominal retail deposit return), $r_{D,t}$ (real retail deposit return), and $\mathbb{M}_{t,t+1}$ (real stochastic discount factor) – in total, **10** variables – satisfy the following equations: (4), (7), (A.37), (A.38), (A.39), (A.40), (A.41), (A.42) – in total, **8** equations.

2. The general production sector variables $A_{Y,t}$ (aggregate technology / aggregate total factor productivity), $\Phi_{p,t}$ (real total menu costs), $\tilde{\Pi}_t$ (price indexing-adjusted inflation), $\mathbb{P}_t$ (price mark-up shock process), $\lambda_t^{\texttt{LIA}}$ (relative shadow price of the loan-in-advance constraint), $R_{L,t}$ (nominal retail loan return), $r_{L,t}$ (real retail loan return), K_t (capital stock), I_t (capital investment), q_t (real marginal Tobin's Q), Φ_t (relative shadow price of production technology), ℓ_t (real loan stock), p_t^I (relative real price of investment), and Y_t (final goods output) – in total, **14** variables – satisfy the following equations: (11), (14), (17), (A.19), (A.20), (A.43), (A.44), (A.45), (A.46), (A.47), (A.48), (A.49), (A.50) – in total, **13** equations.

3. The investment-specific variables X_t (final goods input for investment goods production), $A_{I,t}$ (investment-specific technology / investment-specific total factor productivity) – in total, **2** variables – satisfy the following equations: (19), (A.22), (A.51) – in total, **3** equations.

4. The bank-specific variables $K_{b,t}$ (aggregate real bank net worth), d_t (real bank deposits), v_t (bank value function), Ω_t (modification term for bank stochastic discount factor), $\Phi_{b,t}$ (real bank start-up fund), $\mathbb{R}_t$ (retail loan interest rate mark-up shock process), $R_{\ell,t}$ (nominal wholesale loan return), $r_{\ell,t}$ (real wholesale loan return), $\mathbb{D}_t$ (retail deposit interest rate mark-down shock process), $R_{d,t}$ (nominal wholesale deposit return), and $r_{d,t}$ (real wholesale deposit return) – in total, **11** variables – satisfy the following equations: (24), (29), (32), (A.24), (A.52), (A.53), (A.54), (A.55), (A.56), (A.57), (A.58), (A.59) – in total, **12** equations.

5. The fiscal variables G_t (real government consumption) and T_t (real lump-sum tax) – in total, **2** variables – satisfy the following equations: (37), (38) – in total, **2** equations.

6. The central bank-specific variables i_t (nominal monetary policy rate) and r_t (real monetary policy rate) – in total, **2** variables – satisfy the following equations: (39), (40), (A.61) – in total, **3** equations.

7. The aggregate variable Π_t (gross aggregate inflation rate) – in total, **1** variable – satisfies the following equation: (45) – in total, **1** equation.

B Data

In this appendix, I provide details on the euro area data used for the calibration of the model.

Macroeconomic variables All macroeconomic growth rates are calculated by computing the quarterly log growth rate using the following data:

1. real GDP Y – "gross domestic product at market prices";
2. consumption C – "household and NPISH final consumption expenditure";
3. investment I – "gross fixed capital formation";
4. public consumption G – "Final consumption expenditure of general government".

All these variables are measured using chain linked volumes (2015), millions of euro, seasonally and calendar adjusted data, euro area – 19 countries (from 2015) and have been downloaded from Eurostat. The ratios I/Y, C/Y, and G/Y are computed using the same data.

Inflation Π is given by the monthly data series "harmonized index of consumer prices (HICP) - all items, measured by growth rate on previous period (t/t-1), neither seasonally adjusted nor calendar adjusted data, euro area – 19 countries (from 2015)", from Eurostat.

Financial time series The retail deposit interest rate $R_{D,t-1}$ is identified in the data by using the monthly time series "euro area (changing composition), annualized agreed rate (AAR)/narrowly defined effective rate (NDER), credit and other institutions (MFI except MMFs and central banks) reporting sector – Overnight deposits, total original maturity, new business coverage, non-financial corporations and households (S.11 and S.14 and S.15) sector, denominated in euro", available at the ECB Statistical Data Warehouse, only from 2003:M1 onward though.

The retail loan interest rate $R_{L,t}$ is identified in the data by using the monthly time series "euro area (changing composition), annualized agreed rate (AAR) / narrowly defined effective rate (NDER), credit and other institutions (MFI except MMFs and central banks) reporting sector – loans, total original maturity, outstanding amount business coverage, non-financial corporations (S.11) sector, denominated in euro", available at the ECB Statistical Data Warehouse, only from 2003:M1 onward though.

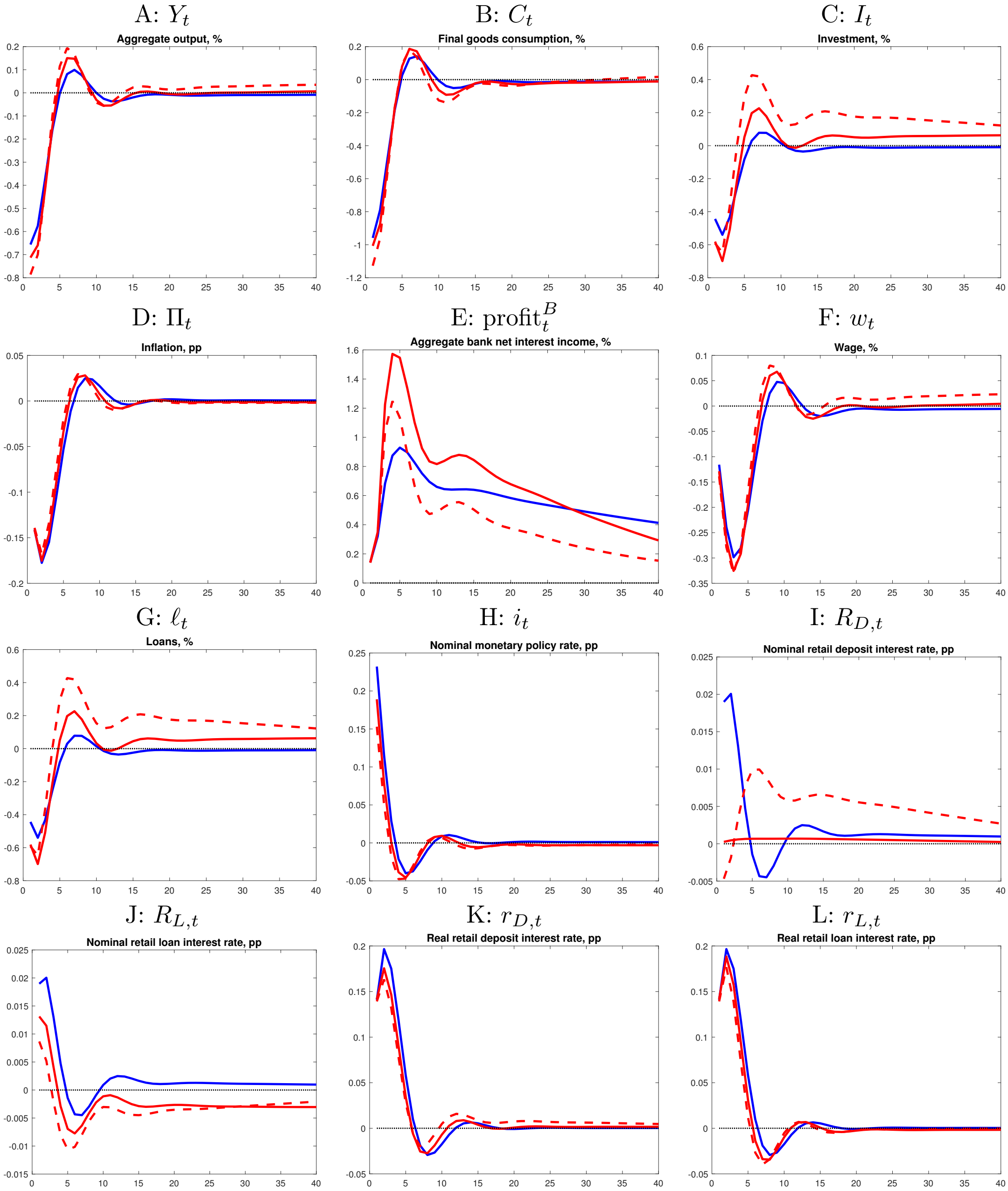
The monetary policy rate i_t is identified in the data by using the daily time series "ECB interest rate on deposit facility", available at the ECB Statistical Data Warehouse. The daily series is converted into a monthly series by averaging all daily observations for each month.

The loan to annualized GDP ratio $L/(4Y)$ is computed using quarterly data for nominal GDP Y, i.e. "gross domestic product at market prices, current prices, millions of euro, seasonally and calendar adjusted data, euro area – 19 countries (from 2015)", from Eurostat and quarterly data on "euro area (changing composition), outstanding amounts at the end of the period (stocks), MFIs excluding ESCB reporting sector – loans, total maturity, all currencies combined – domestic (home or reference area) counterpart, non-MFI sector, denominated in euro, data neither seasonally nor working day adjusted, end of period (E), millions of euro" from the ECB Statistical Data Warehouse. Similarly, for the deposit to annualized GDP ratio $D/(4Y)$, I use the following series from the ECB Statistical Data Warehouse to identify deposits in the data: "Overnight deposits vis-a-vis euro area Non-MFIs excl. central gov. reported by MFIs, central gov. and POGIs in the euro area (stocks), Euro area (changing composition), End of period (E), Millions of Euro".

Leverage of financial intermediaries is computed as the weighted average leverage ratio of MFI and non-MFI leverage using quarterly data from Eurostat on "Financial balance sheets".

C Additional Results

Figure C.1: Impulse response functions after positive monetary policy shocks with the same inflation response



Notes: This figure depicts impulse response functions for a positive shock to the monetary policy rate. The shock occurs in period 1, with no further shocks simulated thereafter. The blue solid lines correspond to the benchmark full pass-through regime with $\rho_{di} = 0$ and no bank excess net interest income tax applied (i.e. $\tau_b = 0$), while the red solid and dashed lines correspond to the slow pass-through regime with $\rho_{di} = 0.995$ without and with the tax ($\tau_b = 0$ vs. $\tau_b = 0.60$). For the blue solid lines, the original shock size has been used, while for the red solid lines the shock size has been reduced to 86% of the original value and for the red dashed lines the shock size has been reduced to 74% of the original value.