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BUSINESS LOAN CHARACTERISTICS AND INFLATION SHOCKS TRANSMISSION IN THE EURO AREA

by Valentina Michelangeli* and Fabio Massimo Piersanti*

Abstract

This paper investigates how business loan characteristics, such as rate type and maturity, affect the transmission of inflation shocks. We exploit a DSGE model with a banking sector to show that longer maturity loans stabilize business cycles by dampening inflation induced fluctuations, while adjustable-rate loans exacerbate recessions. A local projection model using inflation surprises in euro area countries supports these theoretical results. We find that countries with higher shares of adjustable-rate loans would benefit from less reactive monetary and less procyclical fiscal policies, highlighting the potential effectiveness of fiscal policy fine-tuning in closing the welfare gap between fixed and adjustable-rate economies.

JEL Classification: E32, E43, E44, E52, E62, G21.

Keywords: banks, DSGE model, long-term loans, rate type, inflation, monetary policy, fiscal policy.

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1 Introduction[1]

After nearly a decade of subdued inflation in much of the developed world, in the wake of the COVID-19 pandemic price pressures surged to levels last seen in the 1980s (European Central Bank, 2022; Bank of International Settlement, 2022; International Monetary Fund, 2022; Bank of Italy, 2022). This upsurge was largely driven by energy inflation, but other supply chain problems, as captured by backlogs of goods and services, also played a significant role (Ball et al., 2022). In this changing environment, the vast literature studying the impact of inflation shocks has experienced a deep revival.[2] Nevertheless, the evidence on how loan characteristics mediate the transmission of inflationary pressures remains scant.

The euro area is a highly integrated economic system where member countries share many similarities such as the conduct of a common monetary policy, the strong reliance on imported energy goods, and thus the exposition towards common exogenous macroeconomic shocks. However, the structure of their economies also differs from many perspectives concerning both the real and financial side. This paper focuses on the euro area as case-study to investigate how business loan characteristics, such as interest rate type and maturity, have affected the transmission of inflation shocks across euro area countries. The region's diverse mix of long-term and adjustable-rate loans provides a unique opportunity to fit our purpose. Indeed, figure 1 shows a great extent of cross-country heterogeneity in both business loan rate fixation conventions and recourse to long-term loans. Furthermore, given the observed heterogeneity in loan characteristics, we study which is the most appropriate policy response considering both monetary and fiscal policy.

We begin by providing a theoretical framework to analyze the mechanisms at play. While the macro-finance literature has highlighted the importance of financial frictions in the propagation of

[1]We thank Carlo Altavilla, Paolo Angelini, Simone Auer, Alessandro Cantelmo, Francesco Furlanetto, Alessandro Lin, Stefano Pica, Federico Maria Signoretti, Luigi Federico Signorini, Gianluca Violante for their useful comments and suggestions, as well as the participants to the Heterogeneous Households, Firms and Financial Intermediaries: Theorethical Insights and Validation with Microdata Conference, Norges Bank, Oslo 10-11 September 2024 and to the 10^{th} Research Workshop of the Task Force on Banking Analysis for Monetary Policy, Oesterreichische National Bank, Vienna 21-22 October 2024. All remaining errors are our own.

[2]See Del Negro et al. (2015); Bodenstein et al. (2008); Christiano et al. (2018) for a review and Reis (2022); Candia et al. (2021); Ascari et al. (2023); Harding et al. (2023) for more recent contributions.

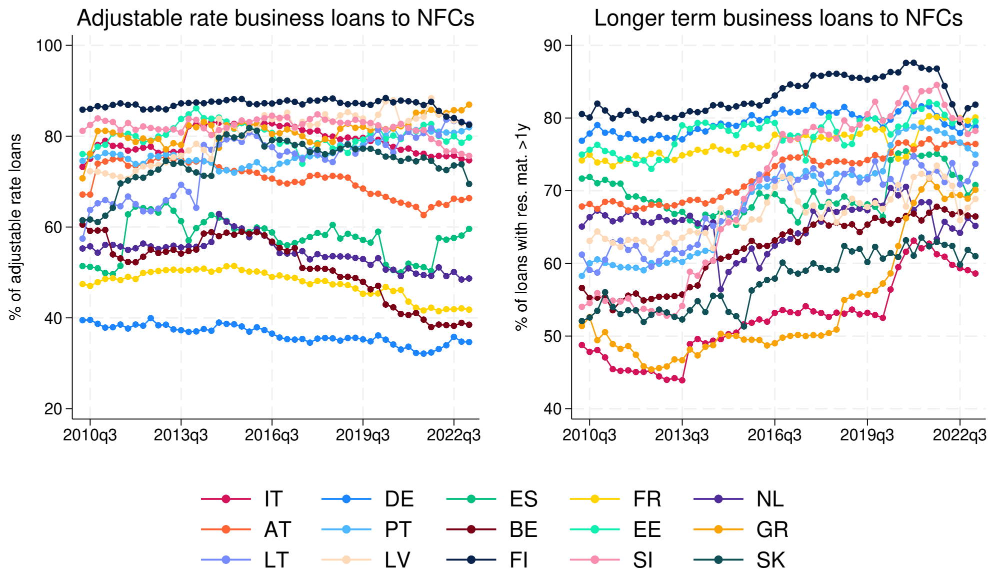

Figure 1 Business loan characteristics across countries.
Source: BSI. Longer term loans have a maturity above one year.

shocks (Kiyotaki and Moore, 1997; Bernanke et al., 1999), the role of maturity transformation in shaping business cycle dynamics has been investigated only to a very limited extent. Disregarding this factor may lead to bias in the study of the transmission of inflationary shocks. The vast majority of DSGE models with a banking sector focuses on loans with quarterly maturity, where banks receive one-period deposits that are instantaneously passed on to firms as one-period loans, thereby excluding maturity transformation and overlooking differences between fixed and adjustable-rate loans. While this assumption simplifies general equilibrium computations, it does not accurately reflect the actual business model of banks. Building on Andreasen et al. (2013), we examine the role of maturity transformation in shaping business cycle dynamics in the face of inflation shocks. Our model provides theoretical insights into how varying maturity and rate types (adjustable or fixed) of bank loans to firms affect the transmission of such shocks. We find that longer-term loans dampen business cycle fluctuations, while adjustable-rate loans have an amplifying effect.

Then, we empirically validate these theoretical mechanisms using a local projection model to study the transmission of unexpected inflation shocks across euro area countries.

Finally, we exploit the theoretical model to identify the most effective policy tools for mitigating disparities in the transmission of inflation shocks across countries with different business loan characteristics. We find that economies with a higher prevalence of adjustable-rate loans would benefit from a less reactive monetary policy to align welfare losses with those in fixed-rate economies, particularly for longer loan maturities. However, since monetary policy diversification based on loan characteristics is not viable in the euro area, we explore the role of fiscal policy in mitigating the adverse effects of inflationary shocks in these countries.

More in detail, in the first step of our study, we develop a DSGE model that features a frictional banking sector (Gertler and Kiyotaki, 2010; Gertler and Karadi, 2011) and allows for different possible configurations of business loan characteristics. In our model, firms borrow from banks to fully finance their acquisition of capital input. In this respect, long-term loans imply that the capital stock remains fixed for the whole loan contract duration as in Andreasen et al. (2013). We extend this framework by allowing long-term loans to be also at adjustable-rate, a peculiar loan arrangement fitting the working of credit relationships in several European countries. We then simulate six alternative economies with predetermined maturity (equal to one, six or twelve quarters)[3] and interest rate type (fixed or adjustable-rate), i.e. in our setup we do not allow firms to modify their loans' length or to switch from fixed to adjustable-rate loans.

While loan characteristics can be endogenously determined, our modeling choice allows us to keep the model computationally tractable. As actual economies typically fall somewhere in between these extreme cases, our approach allows us to clearly identify the main drivers of inflation shock transmission across different financial structures, providing valuable insights into real-world economies. The inflation shock is modeled as a cost push shock (Smets and Wouters, 2007, 2005), capturing the unexpected rise in prices due to supply-side factors like rising production costs and/or higher raw material prices.

We show that longer loan maturity dampens business cycle fluctuations triggered by inflation shocks, echoing results from (Andreasen et al., 2013) for technology shocks. Loan maturity affects

[3] A one-quarter maturity is included for comparison with existing literature, while longer maturities are similar to those considered, for instance, in Andreasen et al. (2013).

banks' asset structure, particularly by limiting changes in leverage. After an inflation shock, only a fraction of all loans is reset to reflect the lower price of capital. Intermediate producers modify their credit demand to a lesser extent compared with the case of one-period contracts. This, in turn, implies that also the responses of investment, consumption and other real variables are weaker and the overall impact on the business cycle turns out to be more muted.

Moreover, with longer maturity, the impact of business cycle fluctuations in response to an inflation shock also depends on loan interest rate type. Firms with a fixed-rate long-term loan maintain the same rate until capital is re-optimized: both total loan amount and loan installments remain constant over time (the capital share is reimbursed at the end of the contract, while interests are paid periodically), cushioning the decline in GDP. In contrast, firms with adjustable-rate loans face instead a state contingent interest rate that rises with monetary policy rates following an inflation shock. Such a spike in the cost of loans, along with a quantity of capital to be held fixed for many periods, forces firms to balance their budget by hiring less and reducing capital demand. This induces a more severe slump in consumption and investment, and the recession turns out to be deeper as a result.[4]

In the second part of our research, we seek to validate our theoretical findings using aggregate bank data at the country level, focusing on the euro area. Unlike in the US, where companies largely rely on capital markets, this region serves as an ideal case study as bank loans are the primary source of funding for firms. Moreover, while US banks predominantly offer adjustable-rate loans to businesses (as noted by Faulkender, 2005, Vickery, 2008, Ippolito et al., 2018), the structure of loans across euro area countries is highly heterogeneous. To work out a proxy of unexpected increases in inflation, we exploit a measure of inflation surprise. This allows us to assess the impact of inflation shocks on GDP, considering the financial structures of banking and corporate systems. To the extent of our knowledge, we are the first to study the impact of inflation surprises on macroeconomic variables and how it is mediated by business loan characteristics. In brief, we evaluate the cross-sectional impact of inflation surprises on GDP across euro area countries that differ in their share of fixed- vs adjustable-rate loans and maturity, using

[4]Although our model does not account for potential nonlinearities, such as those related to the size of the inflation shock or the initial inflation level (Ascari and Haber, 2022), it offers general insights into how different economic structures affect the transmission of inflation shocks.

local projections à la Jordà (2005). Drawing on Fabiani and Piersanti (2024), we construct an inflation shocks as resembled by inflation surprises. Our measure is defined as the difference between the realized value of the inflation rate (measured as the annual growth of the HICP) and the median forecast for the euro area from a survey of professional forecasters compiled by Thomson Reuters. We first regress GDP and inflation on the inflation surprise and show that surprises proxy supply shocks by triggering a persistent recession and price increase. We then interact the inflation surprise with the share of loans with adjustable-rate and long-term maturity. Our empirical results qualitatively confirm the theoretical findings: longer-term loans are associated with milder recessions, while adjustable-rate loans exacerbate declines in GDP. Specifically, a one standard deviation increase in the share of long-term loans (with maturity above one year) reduces the severity of the recession by a 1 percent at the peak, while a one standard deviation increase in the share of adjustable-rate loans deepens the recession by an additional 1 percent at its trough. These effects are statistically significant and exhibit a notable degree of persistence.

Finally, we use our theoretical model to assess how monetary policy should be tailored in response to an inflationary supply shock, considering the varying characteristics of business loans. This question has gained increased attention, as highlighted by a 2024 speech from a Federal Reserve Governor:

"*But in the real world—which is not so simple—demand shocks are not the only forces that can drive economic fluctuations. Supply shocks not only exist, but they can also be large and persistent, as we have learned over the past several years... While a sharp reduction in demand reduces both economic activity and inflation, a sharp reduction in supply, such as a sudden loss of global oil supply, increases inflation and reduces economic activity. Trying to combat inflation by raising interest rates would further reduce economic activity and employment, while reducing interest rates to boost economic activity and employment raises inflation even higher. Therefore, counteracting a persistent supply shock with monetary policy tools may help with one side of the mandate but create even larger deviations from the other side of the mandate.*"

While many works have tried to address how monetary policy should respond to a supply shock (Bandera et al., 2023), we present new insights. In particular, given that euro area countries differ in their loan structure, we evaluate how the Taylor rule might be modified for prevailing adjustable-rate economies to narrow the welfare gap with fixed-rate countries. Our findings indicate that the response to inflation can be less aggressive for longer maturities, but in economies with a higher proportion of adjustable-rate business loans, monetary policy should be more persistent across all loan maturities.

Additionally, our analysis highlights the potential effectiveness of fiscal policy in mitigating the negative effects of recessions caused by inflationary pressures. In particular, in our framework, countries with business loans mostly priced at adjustable-rates could benefit from a less procyclical taxing policy. Ultimately, our results suggest that fiscal policy, especially in the context of long-term loans, might be a more effective tool than monetary policy for addressing these economic challenges.

Related literature. This paper builds on two main strands of literature, one empirical and one theoretical. Considering the empirical macroeconomic literature, our paper provides evidence of the transmission of inflationary shocks across euro area countries. Early attempts have been made to study inflation dynamics (see Fuhrer, 2010 for a survey). Many scholars have focused on empirically testing the predictions of the forward-looking New-Keynesian Phillips curve (Galı and Gertler, 1999), also with a narrower focus on European countries (Galı et al., 2001; Angeloni et al., 2006). Following the seminal contribution of Blanchard and Gali (2007), another strand of literature has studied the transmission of inflationary pressures following oil price shocks (see Choi et al., 2018; Caldara et al., 2019; Shapiro, 2024). Finally, other papers have studied the interplay of inflation dynamics and financial frictions in the context of the Great Recession (Gilchrist et al., 2017). None of these papers has studied how inflationary shocks propagate based on business loan characteristics such as maturity and interest rate type. To the extent of our knowledge, we are the first to analyze this relevant transmission channel.

Another stream of literature close to us regards the high-frequency identification of macroeconomic shocks. Some papers focus on the identification of monetary policy shocks using monetary policy surprises. In their seminal contribution, Gertler and Karadi (2015) show that monetary policy shocks identified using monetary policy announcements as external instruments produce reliable and well-behaved impulse responses of macroeconomic variables. Stock and Watson

(2018) show how and under which conditions the use of external instruments is fit for the identification of macroeconomic shocks (see also Ramey 2016 for an extensive literature review concerning the empirical identification of macroeconomic shocks). Bauer and Swanson (2023) show that monetary policy shocks identified employing external instruments work well also in the context of local projection models à la Jordà (2005). Furthermore, in the context of inflationary pressures, other papers study how changes in oil price expectations impact the economic system (see Känzig, 2021; Degasperi, 2023). Our paper is close to this literature as it exploits inflation surprises for the identification of cost-push shocks. Differently from them, we can directly observe the unexpected changes in inflation by exploiting survey evidence stemming from professionals' forecasts. In this respect, we do not need to resort to external instruments to gauge inflation shocks. Moreover, we are the first to study the impact of inflation surprises over the business cycle using local projections.

From the theoretical side, the paper contributes to the literature on long-term loans. Maturity transformation is a key feature of financial intermediation. Banks, as a part of their normal activity, take short-term sources of finance, such as deposits from savers, and turn them into long-term borrowings, such as mortgages. Despite the renowned importance of this critical task for banks, the theoretical literature that deals with the financial accelerator mechanism has been overall quite silent. Among the few papers that account for longer maturities, some focus on the intersection between monetary policy and long-term mortgage loans in DSGE models. Calza et al. (2013) show that mortgage loan maturity helps to rationalize some empirical facts across industrialized countries following monetary policy shocks. Garriga et al. (2017) find that monetary policy affects housing investment decisions through the cost of new mortgage borrowing and real repayments of outstanding long-term debt. Bluwstein et al. (2020) estimate a model with multi-period loans, an occasionally binding constraint on new loans and a constraint on the borrowers' collateral to show that these features are paramount to understanding the dynamics of mortgage debt in the US. Other papers study businesses' long-term loans within a framework abstracting from the banking sector. Gomes et al. (2016) study the interconnection between long-term nominal corporate debt maturity and unanticipated inflation shocks in a general equilibrium model. Jungherr and Schott (2020) introduce long-term debt and endogenous maturity choice into a dynamic model of heterogeneous firms' production, financing and costly default. Jungherr and Schott (2021) show that accounting for long-term risky firms' debt is crucial for replicating the one-year lagged empirical correlation between business credit and GDP in the US. With respect to DSGE models with a financial sector, Andreasen et al. (2013) try to overcome the issue by introducing a stickiness in the quantity of capital that firms employ in their production process in a vein similar to Calvo (1983). With our model we contribute to the literature by showing that loans with longer maturity dampen the business cycle fluctuations when an inflation shock occurs, confirming the results of Andreasen et al. (2013) regarding a TFP shock, and, to our knowledge, we are the first to distinguish between fixed- and floating-rate loans. We show that the former ones smooth even more business fluctuations in the face of the shock. Finally, more recently, Ferrante et al. (2024) investigated how the cost of issuing equity mediates the transmission of monetary and financial shocks when firms have long-term debt. They find that, since equity issuance is costly, longer-term debt dampens the response to monetary policy and financial shocks.

Second, we contribute to the literature on policy responses to supply shocks. Gordon (1984) reviews the main issues that supply shocks pose for the conduct of monetary policy. Bandera et al. (2023) review the literature with a focus on a specific type of supply shock, a global increase in the price of energy, and then discuss how a succession of supply shocks could change the optimal policy response. Fornaro and Wolf (2023) study the effects of supply disruptions, such as due to energy price shocks or the emergence of a pandemic, in an economy with Keynesian unemployment and endogenous productivity growth. Scarring effects depress demand and equilibrium interest rates, amplifying the inflation rise triggered by supply disruptions. By reducing investment and future productivity, monetary tightenings may increase inflation in the medium run. In this work, we provide some insights into the monetary policy reaction in the face of inflation shocks in economies characterized by heterogeneous loan structures.

The debate on fiscal policy has often focused on estimating fiscal multipliers. While a strand of literature does not retain DSGE models fit for the purpose (Auerbach and Gorodnichenko, 2012), several attempts have been made to assess the role of fiscal policy as a stabilization tool in this class of models. Zubairy (2014) employs a medium-scale DSGE model to estimate fiscal multipliers of public spending and taxes on labor and capital in the US. She finds that public spending has a higher multiplier on impact, while the multiplier of labor and capital tax takes time to materialize and outpaces public spending only after 3-5 years. Drautzburg and Uhlig (2015) estimate small short-run and negative long-run fiscal multipliers of public spending and distortionary taxes using a DSGE model allowing for credit-constrained households, the zero lower bound, and government capital. Finally, McKay and Reis (2016) enrich a standard new Keynesian model with an incomplete market model of consumption and inequality. They find that tax and transfer programs can be more effective in stabilizing the business cycle, but the way they are implemented in the US has had little effect on aggregate output fluctuations despite stabilizing consumption. Also, the effectiveness of fiscal policy instruments is stronger when monetary policy is constrained by the zero lower bound. In this paper, we evaluate the ability of fiscal policy to stabilize the economic cycle according to business loan characteristics.

2 The model economy

We develop a dynamic stochastic general equilibrium model featuring nominal and financial frictions. Building on the work by Andreasen et al. (2013), we include long-term business loans, and, as a novelty of the model, we distinguish between fixed- and floating-rate loans. To keep the model tractable, we assume that firms know ex-ante how long the contract lasts on average as well as the interest rate type. Following Gertler and Kiyotaki (2010), our economy incorporates a detailed structure for the banking sector. In particular, on the one hand, banks' funding sources include net worth and one-period deposit contracts; on the other hand, banks' assets consist of long-term loans, issued to meet intermediate producers' needs. Banks thus face a more realistic maturity transformation problem than the one typically evaluated in the related literature, as two types of short term liabilities, i.e. deposits and bank capital, can be used to fund long-term business contracts with either fixed or floating loan rates.

Figure 2 summarizes the flows of payments in our economy.

The economy comprises five representative agents: workers, bankers, intermediate producers, final good-producers and capital-producing firms. We also include a central bank that sets the

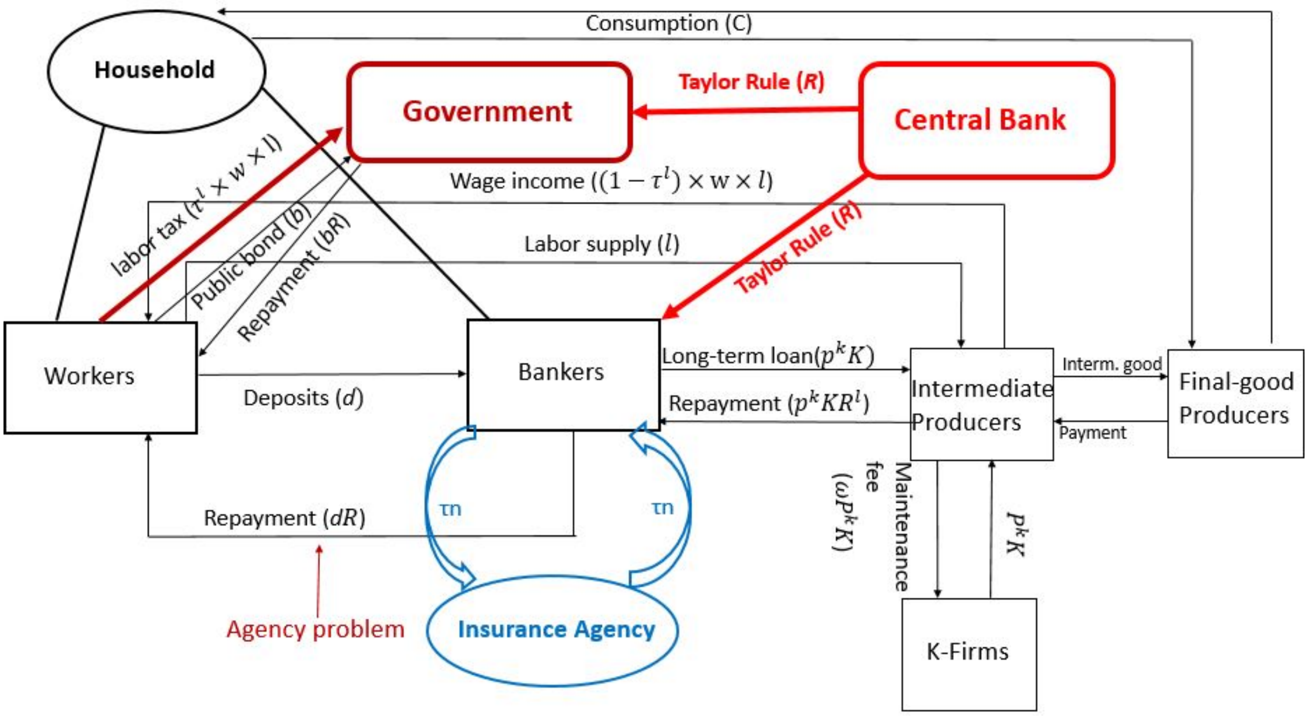

Figure 2 Flow of payments in the economy.

interest rate according to a Taylor rule and a government sector funding public expenditure and net debt emission via a distortionary tax on household's labor income.

Each household is made of a share of workers and a share of bankers. Workers supply labor to intermediate producers, receive wage income, consume and allocate their saving in both bank's deposits, funding the bankers' lending activity, and public bonds.

Bankers transfer funds from households to intermediate producers and, specifically, they issue corporate long-term loans. The banking sector structure draws from Gertler and Kiyotaki (2010). There is a simple agency problem constraining bank leverage and the provision of loans to intermediate producers. Bank sources of funds are: accumulated net wealth and short term deposits. At the end of each period, some banks exit from the economy redistributing accumulated wealth within their households. The transition from old to new bankers, with the same liability and asset structure, is managed by an insurance agency funded by a proportional contribution to banks' net wealth. This setup guarantees the existence of a representative bank in our economy along with long-term loans.

Intermediate producers adjust their capital stock only infrequently and, to sustain their investments, borrow from banks at a rental rate that can be fixed (i.e. it remains constant for the whole lending contract duration) or variable.

Final-good producers use intermediate goods as a production input and make a payment for that.

Capital-producing firms are the owners of capital stock and sell capital to intermediate producers. Capital exploited by intermediate producers needs maintenance; this service is provided by capital-good firms in exchange for a fixed fee. Also, good-producing and capital-producing firms' profits are redistributed lump sum to households.

Given the inclusion of the main features for households, firms and banks, this setup is properly equipped to study the impact of an inflation shock on business cycle fluctuations.

2.1 Households

We consider a representative household that is populated by a continuum of members of measure one. Within the household, there are $1-f$ workers and f bankers. In each period, the bankers face an exit risk with *iid* probability $1-\sigma$. When exiting, they redistribute accumulated wealth within their household. With probability $(1-f)\sigma$ a worker turns into a banker and with probability $f(1-\sigma)$ a banker becomes a worker. There is full consumption insurance within each household. Finally, as usual, it is assumed that workers fund with their savings some other households' owned bank.

The household optimally chooses consumption c, working hours l, and the allocation of saving between deposits d and public bonds b to maximize the following utility function, which is additively separable in consumption and labor with internal habits h in consumption:

$$\max_{c_t,l_t,d_t} \beta^{t+i} \sum_{i=0}^{+\infty} \left[\frac{(c_{t+i}-hc_{t+i-1})^{1-\gamma}}{1-\gamma} - \chi \frac{l_{t+i}^{1+\varphi}}{1+\varphi} \right] \tag{1}$$

subject to

$$c_{t+i} + d_{t+i} + b_{t+i} = (1-\tau_t^l) w_{t+i} l_{t+i} + R_{t+i} d_{t+i-1} + R_{t+i} b_{t+i-1} + \Pi_{t+i} \tag{2}$$

and the usual no-Ponzi game condition. Π is the net distribution of profits rebated to households by bankers and capital producing firms, w is the real wage paid for worked hours, R is the predetermined gross interest rate remunerating deposits and public bonds. Finally, τ^l is a distortionary, time varying, labor tax paid by workers and funding public expenditure as well as net public debt emissions.

The optimal conditions for consumption and labour are as follows:

$$\eta_t = (c_t - hc_{t-1})^{-\gamma} - h\beta \left(c_{t+1} - hc_t\right)^{-\gamma} \tag{3}$$

$$\chi l_t^{\varphi} = \eta_t w_t (1 - \tau_t^l) \tag{4}$$

$$E_t \left[\Lambda_{t,t+1}\right] R_{t+1} = 1 \tag{5}$$

Finally, let us define $\Lambda_{t,t+1} = \beta \frac{\eta_{t+1}}{\eta_t}$ as the stochastic discount factor.

2.2 Final-good producers

The final output in the economy is a CES bundle of differentiated retail goods:

$$y_t = \left[\int_0^1 y_{h,t}^{\frac{\varepsilon-1}{\varepsilon}} dh\right]^{\frac{\varepsilon}{\varepsilon-1}} \tag{6}$$

with $\varepsilon > 1$ and $y_{h,t}$ is the production of the retail firm h at time t.

From cost minimization, the standard demand function obtains

$$y_{h,t} = \left(\frac{P_{h,t}}{P_t}\right)^{-\varepsilon} y_t \tag{7}$$

where $P_{h,t}$ is the price of the retail good produced by firm h and the aggregate price level reads $P_t = \left[\int_0^1 P_{h,t}^{1-\varepsilon} dh\right]^{\frac{1}{1-\varepsilon}}$.

Retailers re-package the intermediate good with a linear production technology. To introduce price stickiness, the standard Calvo formulation is assumed. In each period, only a fraction $1-\zeta_p$

of firms is allowed to reset their price, P_t^*. The other ζ_p firms set $P_{h,t} = P_{h,t-1}$. Therefore, retail firms must solve the following maximization problem:

$$\max_{P_t^*} E_t \left\{ \sum_{i=0}^{+\infty} (\zeta_p \beta)^i \frac{\eta_{t+i}}{\eta_t} \left[\frac{P_t^*}{P_{t+i}} - p_{t+i}^m \right] y_{h,t+i} \right\} \tag{8}$$

subject to (7). p_t^m is the unitary price at which intermediate good firms sell their production to final good producers.

The log-linearized Phillips curve reads

$$\hat{\pi}_t = \frac{(1-\beta\zeta_p)(1-\zeta_p)}{\zeta_p} \hat{p}_t^m + \beta E \hat{\pi}_{t+1} + u_t \tag{9}$$

where

$$u_t = \rho^u u_{t-1} + \varepsilon_t^u, \text{ with } \varepsilon_t^u \sim \mathcal{N}(0, \sigma^u) \text{ and } \rho^u \in (-1, 1) \tag{10}$$

is a persistent cost-push shock.

2.3 Intermediate producers

There is a continuum of intermediate firms indexed by $i \in [0,1]$, whose production takes place by means of labor l_t and capital k_t. The production function has a Cobb-Douglas form:

$$y_{i,t} = a_t k_{i,t}^{\alpha} l_{i,t}^{1-\alpha} \tag{11}$$

where

$$a_t = \rho^a a_{t-1} + \varepsilon_t^a \tag{12}$$

is a standard exogenous processes describing the evolution of the TFP.

Following Andreasen et al. (2013), we assume that firms make lumpy investment decisions and, thus, choose their optimal level of capital with probability $1 - \zeta_k$ in each period. The probability $\zeta_k \in [0,1)$ takes the same value for all good-producing firms. As capital adjustments are infrequent, we assume that firms finance their capital stock by relying on long-term loans provided by banks. These contracts last for all periods with no capital re-optimization, which are ex-ante unknown for the single firm. The average duration of all loan contracts can, instead, be computed and it is equal to $\mathcal{D} = \frac{1}{1-\zeta_k}$.

Capital-producing firms supply physical capital to intermediate producers, who finance the acquisition of these capital services during the period of the contract by paying a fixed fee per capital unit, ω.

In each period, all intermediate producers choose also the optimal amount of labor, incurring in a cost equal to w_t for each unit. Given their homogeneity, all good-producing firms that re-optimize in period t choose the same amount of capital, $\bar{k}_t$. In a subsequent period $t+j$, all firms which lastly re-optimized their capital decision in t must choose the same amount of labor, $l_{t+j|t}$. Moreover, we also allow for two different interest rate types of long-term loan contracts. Indeed a long-term loan contract can be either at fixed or floating interest rate. We assume that firms and banks know ex-ante the loan interest rate type and loan maturity. This tractable setup allows to compare results across different assumptions.

2.4 Fixed-rate Type

For the whole duration of the credit contract, the rental (gross real) rate of capital R_t^l and the (real) market price of a capital unit p_{t-1}^k, as well as the quantity of capital, are kept fixed. The intermediate producers problem at time t can be described in real terms as follows:

$$\max_{\bar{k}_t} \sum_{j=0}^{+\infty} \zeta_k^j \Lambda_{t,t+j} \left\{ p_{t+j}^m a_{t+j} \bar{k}_t^{\alpha} l_{t+j|t}^{1-\alpha} - w_{t+j} l_{t+j|t} + \frac{p_{t-1}^k}{\pi_t \Pi_{i=1}^j \pi_{t+i}} \bar{k}_t (1-\omega) - R_t^l \frac{p_{t-1}^k}{\Pi_{i=1}^j \pi_{t+i}} \bar{k}_t \right\}. \quad (13)$$

where of course $R_t^l = \frac{R_t^{l,nom}}{\pi_t}$ is the real interest rate on loans at time t. Note that intermediate firm profits explicitly include the nominal adjustment of loans conditions to inflation evolution.

The optimal quantity of labor for firms that lastly re-optimized on capital in t, can be rewritten as:

$$l_{t+j|t} = \left(\frac{w_{t+j}}{p^m_{t+j} a_{t+j} (1-\alpha)} \right)^{-\frac{1}{\alpha}} \bar{k}_t. \tag{14}$$

The labor market is homogeneous, therefore no difference arises between the remuneration of hours worked in firms optimizing capital over different vintages. By exploiting the homogeneity in the labor market and the fact that all firms that lastly chose capital in t must have opted for the same amount of labor, we can substitute (14) back into (13) so that the optimal capital choice for each vintage can be easily determined. The first order condition for capital reads:[5]

$$\sum_{j=0}^{+\infty} \zeta_k^j \Lambda_{t,t+j} \left\{ \alpha \left(p^m_{t+j} a_{t+j} \right)^{\frac{1}{\alpha}} \left[\frac{w_{t+j}}{(1-\alpha)} \right]^{-\frac{1-\alpha}{\alpha}} - \left[R^l_t - \frac{1-\omega}{\pi_t} \right] \frac{p^k_{t-1}}{\Pi_{i=1}^j \pi_{t+i}} \right\} = 0. \tag{15}$$

This equation indicates that, on aggregate, the optimal capital and labor choices depend on aggregate prices.

The above condition can be rewritten recursively as

$$R^l_t p^k_{t-1} z_{2,t} = z_{1,t} + (1-\omega) \frac{p^k_{t-1}}{\pi_t} z_{3,t}, \tag{16}$$

where

$$z_{1,t} = \alpha \left(p^m_t a_t \right)^{\frac{1}{\alpha}} \left[\frac{w_t}{(1-\alpha)} \right]^{-\frac{1-\alpha}{\alpha}} + \zeta_k \Lambda_{t,t+1} z_{1,t+1}. \tag{17}$$

$$z_{2,t} = 1 + \zeta_k \Lambda_{t,t+1} \frac{z_{2,t+1}}{\pi_{t+1}}, \tag{18}$$

and $z_{3,t} = z_{2,t}$.[6]

[5] Similarly to Gertler and Karadi (2011), we assume that any profit earned is paid as dividends to households in each period. This assumption rules out the presence of any self-financing practice by good-producing firms and, as already pointed out by Andreasen et al. (2013), helps to single out the effect of long-term credit in the economy.

[6] The distinction between z_2 and z_3 is made to keep notation coherent with what is presented in the next section.

2.5 Adjustable-Rate Type

The contract setup for floating rate loans is basically the same as for fixed-rate ones. The only difference being that the loan interest rate carries a time varying subscript all over the sum. In fact, firms profits stream reads

$$\max_{\bar{k}_t} \sum_{j=0}^{+\infty} \zeta_k^j \Lambda_{t,t+j} \left\{ p_{t+j}^m a_{t+j} \bar{k}_t^{\alpha} l_{t+j|t}^{1-\alpha} - w_{t+j} l_{t+j|t} + \frac{p_{t-1}^k}{\pi_t \Pi_{i=1}^j \pi_{t+i}} \bar{k}_t (1-\omega) - R_{t+j}^l \frac{\pi_{t+j} p_{t-1}^k}{\pi_t \Pi_{i=1}^j \pi_{t+i}} \bar{k}_t \right\}. \tag{19}$$

Similarly to what we have previously seen, the capital FOC boils down to

$$\sum_{j=0}^{+\infty} \zeta_k^j \Lambda_{t,t+j} \left\{ \alpha \left(p_{t+j}^m a_{t+j} \right)^{\frac{1}{\alpha}} \left[\frac{w_{t+j}}{(1-\alpha)} \right]^{-\frac{1-\alpha}{\alpha}} - \left[\frac{R_{t+j}^l \pi_{t+j}}{\pi_t} - \frac{1-\omega}{\pi_t} \right] \frac{p_{t-1}^k}{\Pi_{i=1}^j \pi_{t+i}} \right\} = 0. \tag{20}$$

Also in this case the capital FOC can be rearranged as

$$\frac{p_{t-1}^k}{\pi_t} z_{2,t} = z_{1,t} + (1-\omega) \frac{p_{t-1}^k}{\pi_t} z_{3,t} \tag{21}$$

with

$$z_{2,t} = R_t^l \pi_t + \zeta_k \Lambda_{t,t+1} \frac{z_{2,t+1}}{\pi_{t+1}} \tag{22}$$

and

$$z_{3,t} = 1 + \zeta_k \Lambda_{t,t+1} \frac{z_{3,t+1}}{\pi_{t+1}} \tag{23}$$

Note that (21) and (16) are equivalent when $\zeta_k = 0$, i.e. loan maturity is 1 quarter.

2.6 Financial intermediaries

The banking sector is modeled following Gertler and Kiyotaki (2010) and Andreasen et al. (2013). We account for a simple agency problem between banks and households that, by constraining banks' leverage, limit the credit provided to producers. When bankers retire, they transfer their wealth to households. The transition from old to new bankers, with the same liability and asset structure, is managed by an insurance agency funded by a proportional contribution on banks' net wealth. This setup guarantees the existence of a representative bank in our economy.

Bank short term financial resources that can be used for making long-term loans to firms are of two types. The first one is retained earnings, i.e. net worth n_t, resulting from bank business activity. The second one is one-period deposits from households, d_t, remunerated at the predetermined rate R_{t+1}.

For the representative bank, the flow-of-funds constraint implies that in each period the amount of bank's lending, len_t, equals the total liabilities:

$$len_t = n_t + d_t, \tag{24}$$

Under our assumption that firms re-optimize their capital stock infrequently, bank's lending can be written as follows:

$$len_t = (1 - \zeta_k) p_t^k \bar{k}_{t+1} + \zeta_k \frac{len_{t-1}}{\pi_t}. \tag{25}$$

that is, a share $1 - \zeta_k$ of bank lending is attributable to firms that optimize for production in t, the share $\zeta_k(1 - \zeta_k)$ to those that have optimized for production in $t - 1$, the share $\zeta_k(1 - \zeta_k)^2$ in $t - 2$, and so on.

Banker's net worth is generated out of income flows, as follows:

$$n_t = (1 - \tau) \left[rev_{t-1} - R_t d_{t-1} \right], \tag{26}$$

where τ is the tax due to finance the insurance agency and rev are the proceedings accruing to banks from their lending activity. The evolution of banks' revenue mirrors (25) in the case of fixed-rate loan contracts:

$$rev_t = (1 - \zeta_k) R_{t+1}^l p_t^k \bar{k}_{t+1} + \zeta_k \frac{rev_{t-1}}{\pi_t}, \tag{27}$$

while it is as follows in the case of floating rate loan contracts

$$rev_t = R^l_{t+1} len_t, \tag{28}$$

as the whole loan stock proceedings simultaneously update to changes in the interest rate.

with the gross loan rate equal to $R^l_t = 1 + r^l_t$. Moreover, rearranging conditions (24) and (26), the law of motion of the banker's net worth is the following

$$n_t = (1-\tau)\left\{\left[\frac{rev_{t-1}}{len_{t-1}} - R_t\right] len_{t-1} + R_t n_{t-1}\right\} \tag{29}$$

Given the financing constraint, the banker finds it optimal to retain all its earnings until her exit from the market, which occurs with probability $(1-\sigma)$ in each period. At that point the banker pays the dividend to her own household. The expected present value of the future terminal dividends is thus

$$\mathcal{V}_t = E_t\left\{\sum_{j=0}^{+\infty} \sigma(1-\sigma)^j \Lambda_{t,t+j+1} n_{t+j+1}\right\}. \tag{30}$$

Following Gertler and Karadi (2011), we motivate the endogenous constraint on bank's capability of obtaining additional funds from households by introducing a simple agency problem. In each period, the banker can choose to divert a fraction of her funds from the project and transfer them back to the household to which she belongs. As households are aware of this possibility, they limit the funds lent to the bank. We assume that the share of funds that the bank can divert, Θ, is exogenous.

Upon diverting its assets, the banker defaults on its debt and creditors can claim only the fraction $(1-\Theta)$ of their assets. This possibility limits the amount households are willing to lend to banks.

To prevent the banker from diverting funds, the incentive compatibility constraint must hold:

$$\mathcal{V}_t(len_t, n_t) \geq \Theta len_t, \tag{31}$$

i.e. the maximized value of the bank's objective given a certain asset-liability configuration at the end of period t, $\mathcal{V}_t(len_t, n_t)$, cannot be lower than the proceedings the banker would obtain from diverting funds.

The franchise value of the bank accounts for the probability of exiting from the market and satisfies the following Bellman equation:

$$\mathcal{V}_{t-1}\left(len_{t-1}, n_{t-1}\right) = E\Lambda_{t-1,t}\left\{(1-\sigma)n_t + \sigma \max_{\bar{k}_{t+1}}\left[\mathcal{V}_t\left(len_t, n_t\right)\right]\right\}. \tag{32}$$

In each period, the banker thus chooses the optimal levels of $\bar{k}$ and x to maximize $\mathcal{V}_t\left(len_t, n_t\right)$ subject to (29) and (31).

We assume that the value function is a function of the components of the balance sheet:[7]

$$\mathcal{V}_t = \mu_{s,t} len_t + \nu_t n_t. \tag{33}$$

The internal leverage condition implies that the amount of credit lent out by the bank is limited by its net worth:

$$\phi_t = \frac{len_t}{n_t}, \tag{34}$$

where from the bank's optimization problem it follows that

$$\phi_t = \frac{\nu_t}{\Theta - \mu_{s,t}}, \tag{35}$$

with

$$\nu_t = (1-\tau)E\left[\Lambda_{t,t+1}\Omega_{t+1}\right] R_{t+1} \tag{36}$$

$$\mu_{s,t} = (1-\tau)E\left[\Lambda_{t,t+1}\Omega_{t+1}\left(\frac{rev_t}{len_t} - R_{t+1}\right)\right] \tag{37}$$

ν_t is the marginal saving in deposit costs from one additional unit of net worth funding and $\mu_{s,t}$ summarizes the excess value of assets over deposits.

[7] See Appendix A for the derivation and verification of this conjecture.

The shadow value of a net worth unit to the bank in the next quarter is given by:

$$\Omega_{t+1} = (1-\sigma) + \sigma E\left[\mu_{s,t+1}\phi_{t+1} + \nu_{t+1}\right] \tag{38}$$

The inside leverage, ϕ_t, is decreasing in the fraction of divertible funds, Θ, as it tightens the incentive compatibility constraint the banker is subject to. By contrast, it is increasing in ν_t and in the discounted excess value of bank's assets, $\mu_{s,t}$, as, by reducing the incentive of banks to divert funds, they make creditors willing to lend more.

2.6.1 Capital-producing firms

A representative capital-producing firm is the owner of the capital stock and is in charge of conducting investment. The capital stock is rented out to intermediate producers in exchange for a service and maintenance fee ω, which starts to be paid when the good-producing firm signs the loan contract. The capital-producing firm thus needs to keep track of the contracts signed by the intermediate producers to determine its income flows. More specifically, the actualized stream of profits equals:

$$\Pi_t^k = E_t \sum_{j=0}^{+\infty} \left\{\Lambda_{t,t+j}\left[\omega v_{t+j} - i_{t+j}\right]\right\}, \tag{39}$$

where $v_{t+j} = (1-\zeta_k)p_{t+j}^k \bar{k}_{t+j+1} + \zeta_k \frac{v_{t+j-1}}{\pi_{t+j}}$ is a recursive variable to keep track of the contracts signed by intermediate producers, and i are the resources allocated to investment by the capital-producing one. When maximizing profits, this latter firm is subject to the demand of capital

$$k_{t+1} = (1-\zeta_k)\bar{k}_{t+1} + \zeta_k k_t \tag{40}$$

and the law of motion of capital with adjustment costs

$$k_{t+1} = (1-\delta)k_t + i_t\left[1 - \frac{\gamma^I}{2}\left(\frac{i_t}{i_{t-1}} - 1\right)^2\right]. \tag{41}$$

2.7 Monetary policy, fiscal policy and market clearing

The central bank sets the nominal interest rate according to a standard Taylor rule:

$$R_t^{nom} = \rho R_{t-1}^{nom} + (1-\rho)\left[\phi_\pi \pi_t + \phi_y \log\left(\frac{p_t^m}{\frac{\varepsilon-1}{\varepsilon}}\right)\right] \tag{42}$$

where $\rho \in [0,1)$ is the interest rate smoothing parameter and $\frac{p_t^m}{\frac{\varepsilon-1}{\varepsilon}}$ is marginal cost deviations from steady state, i.e. a proxy for the output gap which can be more easily measured, especially in real times, by policymakers (see Galı and Gertler, 1999; Neiss and Nelson, 2005). The standard Fisher relationship holds

$$R_t = \frac{R_t^{nom}}{\pi_{t+1}}. \tag{43}$$

In equilibrium, capital demand and supply must be equal

$$k_t = \int_0^1 k_{i,t} di, \tag{44}$$

and also labor supply and demand

$$h_t = \int_0^1 h_{i,t} di. \tag{45}$$

The government budget constraint is such that the revenues from the distortionary labor tax and net public debt emissions fund government expenditure made of public consumption and public debt interest payments, i.e.

$$g_t + r_t b_{t-1} = \tau_t^l w_t l_t + b_t - b_{t-1} \tag{46}$$

where r_t is the net real rate, so that $R_t = 1 + r_t$.

The public sector adopts a fiscal policy rule tuning the distortive labor tax according to the deviation of public debt to GDP ratio from its steady state value

$$\tau_t^l = \bar{\tau}^l + \gamma_l \left[\log\left(\frac{b_t/y_t}{\bar{b}/\bar{y}}\right)\right] \tag{47}$$

where $\bar{\tau}^l$ is the steady state tax value and γ_l pins down the tax reaction based on deviations of the public debt to GDP ratio (b/y).

Finally, output is given by the sum of consumption, investment and public consumption:

$$y_t = \int_0^1 y_{i,t} di = c_t + i_t + g_t. \tag{48}$$

without any loss of generality, g follows a standard autoregressive process

$$g_t = (1 - \rho^g) \log(\bar{g}) + \rho^g g_{t-1} + \epsilon_t^g \tag{49}$$

where $\bar{g}$ is the steady state public consumption.

2.8 Calibration

Table 1 presents the values of the twenty-three calibrated parameters. Of them, twelve relate to standard preferences and technology, three refer to the banking sector, six concern the monetary and fiscal policy rule specification and the remaining two characterize the exogenous cost push shock.

Household preference parameters take standard values. The discount factor β is set to 0.99, the risk aversion γ to 1, and the intensity of habit h to 0.8. The inverse Frisch elasticity of labor supply φ is set equal to 2, a calibration choice that is specific to euro area countries (see Coenen et al., 2018). We calibrate the labor in the steady state to 8 hours worked each day.

Two parameters relate to good-producing firms. The capital share of income α equals 0.33, as it is standard in the DSGE literature. The probability that a firm does not adjust its capital ζ_k assumes a set of values $[0, 0.83, 0.92]$, corresponding to loan contract average duration $\mathcal{D} =$ 1, 6 and 12 quarters. The choice of this range of values does not aim to match the average business loan maturity of euro area countries, which we do not observe. Rather, it just gives the qualitative extent of the implications of longer-lasting loans for the transmission of the inflation shock in our model economy.

Considering final good producers, the production input elasticity of substitution is set to 4.167, to match a price mark-up equal to 24%. Finally, the Calvo parameter ζ_p, i.e. the unconditional probability of a retail firm not to reset its out price in the next period, is equal to 0.779, implying an average price duration of one year. Both are standard values in the DSGE literature.

The values chosen for the banking sector parameters are in line with those used in Andreasen et al. (2013). The banker survival rate σ is set to 0.92. The share of divertible funds parameter Θ is equal to 0.22. The financial spread, $R^l - R$, is set to 1% on an annual basis. Finally, the tax rate needed to fund the insurance agency τ is set to 0.02, which is pinned down by a bank leverage equal to 4.

The parameters defining the capital-producing firms are the capital depletion rate δ equal to 0.025, the investment adjustment cost γ^I equal to 3, and the service and maintenance fee ω equal to 0.025 to match an investment-to-GDP ratio of 12%.

The Taylor rule parameter calibration is fairly standard. We assume a moderate degree of interest rate smoothing, setting ρ equal to 0.85, while the inflation reaction parameter, ϕ^π, is set to 1.5 and the output gap reaction parameter ϕ^y is set to 0.125.

The fiscal policy parameters are also standard. We set the public debt-to-GDP ratio, $\bar{b}/\bar{y}$, equal to 50%, which pins down a steady state value of the distortionary labor tax equal to 2.5% of final production, as it is standard in DSGE models.[8] We impose a share of public consumption-to-GDP, $\bar{g}/\bar{y}$, to 20%. Finally, we set the fiscal policy reaction parameter, γ_l, equal to 0.5 so that fiscal policy is moderately procyclical.

We set the persistence parameter of the cost push shock, ρ^u, equal to 0.6, a value that is in line with estimates for the euro area from Del Negro et al. (2004) and Coenen et al. (2018). Finally we set the white noise error term standard deviation $\sigma(\varepsilon^u)$ to 0.5%, so that inflation on impact increases by 2% on an annual basis following the cost pust shock realization.

2.9 Impulse response functions

This section shows how the economy reacts in the face of a cost push shock, highlighting the differences by loan rate type and maturity. The model is solved using first order linear approxi-

[8]This value is relatively low as compared to what is observed in reality. However, DSGE models display determinacy issues with large values of public debt-to-GDP ratios.

Households	Value	Description	Target
β	0.99	Discount factor	4% annual interest rate
γ	1	Risk aversion	Andreasen et al. (2013)
h	0.8	Internal habit	Andreasen et al. (2013)
φ	2	Inverse Frisch elasticity of labor supply	Coenen et al. (2018)
$\bar{l}$	8	steady state labor	8 worked hours per day
Intermediate Producers			
α	0.33	Capital share of income	
ζ_k	$[0, 0.83, 0.92]$	Capital non-adjustment probability	
Final Producers			
ε	4.167	CES parameter	24% price mark-up
ζ_p	0.779	Calvo Parameter	Yearly price reset
Banks			
Θ	0.22	Share of divertible funds	Andreasen et al. (2013)
σ	0.92	Bankers survival rate	Andreasen et al. (2013)
τ	0.02	Insurance company fee	
Capital producing firms			
δ	0.025	Capital depreciation	Andreasen et al. (2013)
γ^I	3	Investment adjustment costs	Justiniano et al. (2011)
ω	0.025	Service and maintenance fee	$i/y = 15\%$
Taylor rule			
ρ	0.85	Interest rate smoothing	
ϕ^π	1.5	Inflation reaction	
ϕ^y	0.125	Output gap reaction	
Fiscal policy rule			
$\bar{b}/\bar{y}$	50%	public debt-to-GDP ratio	
$\bar{g}/\bar{y}$	20%	Public consumption-to-GDP ratio	
γ_l	0.5	Fiscal policy reaction	
Exogenous processes			
ρ^u	0.6	Cost push persistence	Del Negro et al. (2004); Coenen et al. (2018)
$\sigma(\varepsilon^u)$	0.5%	Cost push standard deviation	

Table 1 Parameter values

mation.

The standard mechanism is the following. When the inflation shock hits the economy, final good producers face an increase in their production cost and, consequently, demand less of the intermediate good. This fall in demand transmits to intermediate producers, which in turn demand less labor and reduce their loan demand for capital acquisition. Workers reduce consumption in face of a drop in labor income. The lower demand for capital makes capital firms reduce investment. Aggregate production falls as a result. Finally, the fall in hours worked brings down fiscal revenues. The public debt to GDP ratio increases as a result, and the distortionary labor tax must also increase due to the fiscal policy rule.

Given this standard mechanism, the reactions of economic variables differ by loan maturity. Figure 3 reports impulse response functions, expressed as percentage deviations from the steady state, of a positive cost push shock in economies with only fixed-rate loans. The red lines show the results for three economies characterized by different loan maturities D, equal to 1, 6, and 12 quarters respectively.

The longer is average loan maturity $\mathcal{D} = \frac{1}{1-\zeta_k}$, the smaller the share of the intermediate producers that cannot immediately reset their entire capital stock $(1 - \zeta_k)$. As the negative shock occurs, the price of capital (P^k) falls as firms entitled to optimize on capital demand less of it $(\bar{K})$. The initial fall is deeper the longer the loan maturity, but the impact on the overall capital stock (K) is more contained as most firms stick to the capital stock chosen in the past. This implies a more muted impact on aggregate bank lending, investment and, ultimately, GDP.[9] The shock propagation in the economy thus turns out to be weaker and the recession is milder compared to loans with shorter maturity. These results are in line with Andreasen et al. (2013), who evaluate a technological shock in a DSGE model with maturity transformation in the banking sector.

Figure 4 reports impulse response functions of a positive cost push shock in economies characterized by different maturities, but with only adjustable-rate loans. The dynamics are qualitatively the same as for the economies with fixed-rate loans.

Figure 5 allows to compare visually, for different maturities, the impulse responses of selected economic variables. The recession is deeper if loans are priced at adjustable-rate. This result follows from two main effects. First, with adjustable loan rates, the fall in the loan remuneration is far deeper on impact, as the loan return is then allowed to adjust in the aftermath of the shock for the whole loan portfolio. This implies that the shock is immediately transferred to banks, which are subject to an abrupt fall in real return on business loans. Thus, a larger net wealth depletion materializes, which then translates into lower lending, and therefore prompts the financial accelerator up. Second, the average interest rate paid by firms in the adjustable-rate

[9] Note that the real interest rate and inflation dynamics are similar independently on loan maturity. This is due to the relatively high degree of persistence in the Taylor rule and to the limited persistence, consistent with the empirical evidence, of the cost-push shock.

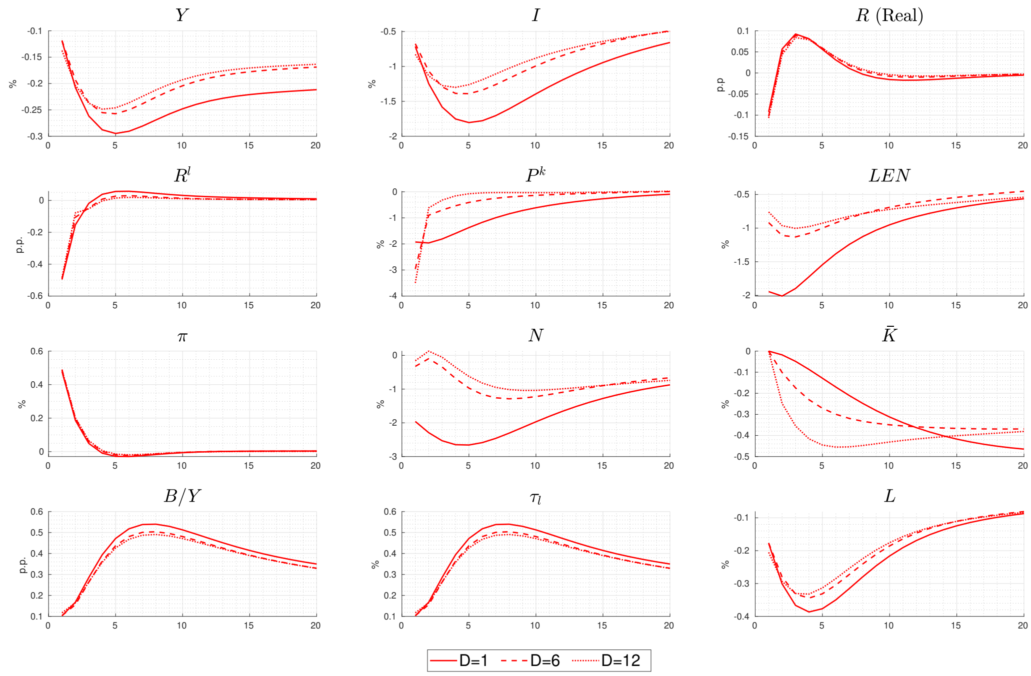

Figure 3 Impulse response functions to a recessionary cost-push shock for the fixed-rate model.
Note: vertical axis report percentage deviation from the steady state of the variable of interest.

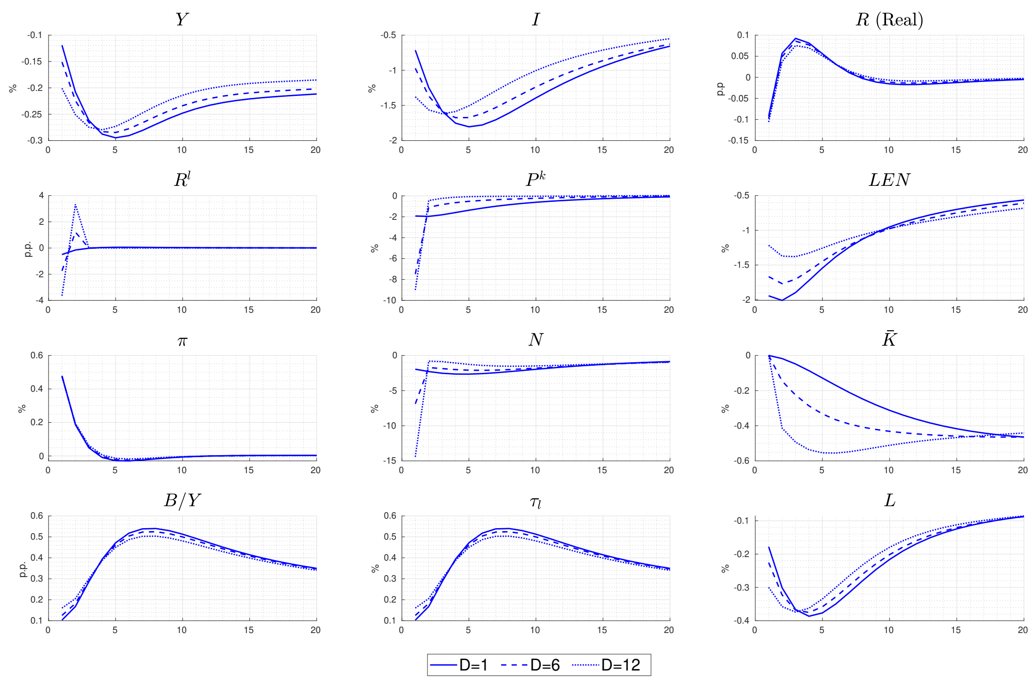

Figure 4 Impulse response functions to a recessionary cost-push shock for the adjustable-rate model.
Note: vertical axis report percentage deviation from the steady state of the variable of interest.

regime is higher than in the fixed-rate one in the aftermath of the shock realization. Since net wealth depletion is larger in the adjustable-rate economy, bank lending falls by more, inducing a demand excess that needs higher loan rates for market clearing. On the one hand, this limits new investment. On the other hand, intermediate producers go through an increase in interest expenditures without being able to adjust their capital stock accordingly. They cut hours worked as a result, given the need to balance their budget. Both these forces contribute to the more pronounced decline in GDP.

Summarizing our findings, the adjustable-rate model lays down two contrasting forces at play. On the one hand, there is the cushioning effect of the sticky adjustment of the capital stock that implies a weaker shock transmission as loan maturity increases. On the other hand, there is the misalignment between the loan maturity and the repricing of the loan rate which, if anything, strengthens the shock transmission as it affects all intermediate firms independently on when they have lastly chosen their optimal capital stock. Overall, the netting out of these two forces favors the former over the latter. This implies that adjustable-rate economies are subject to stronger inflation shocks transmission, and this effect is dampened at longer loan maturities.

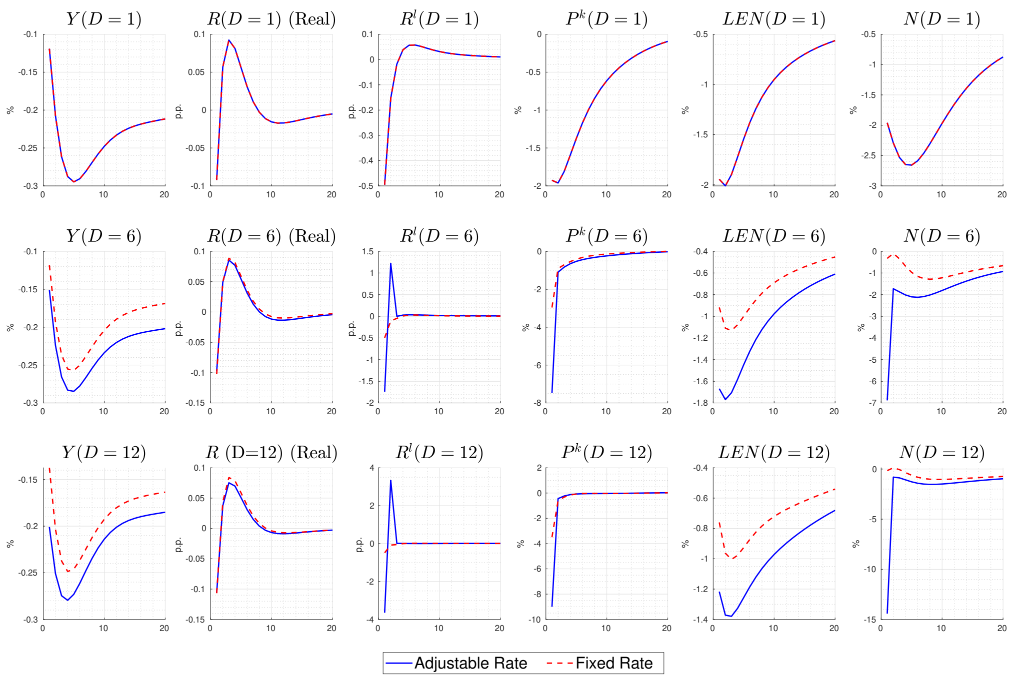

Figure 5 Impulse response functions to a recessionary cost-push shock, comparison between interest rate types.

Note: vertical axis report percentage deviation from the steady state of the variable of interest.

3 Empirical analysis

In the previous section, we have nailed down the theoretical mechanisms that explain the impact of an inflation shock on economies characterized by loans to firms with different maturity and rate type. In this section, we aim to empirically assess how an inflation shock is mediated by business loan characteristics.

3.1 Data

3.1.1 Loans and macroeconomic variables

We collect information on business loan amounts, maturity, and interest rate type for the main euro area countries, exploiting Balance Sheet Items (BSI) data from the European Central Bank. We have access to a panel of fifteen countries: Italy (IT), Germany (DE), Spain (ES), France (FR), the Netherlands (NL), Austria (AT), Portugal (PT), Belgium (BE), Estonia (EE), Greece (GR), Lithuania (LT), Latvia (LV), Finland (FI), Slovenia (SL) and Slovakia (SK).[10] More specifically, the BSI dataset provides information, among others, on the total amount of bank loans to businesses and households at the country level. Those loan amounts can be classified according to loan reimbursement and repricing maturity buckets. In particular, we exploit the partition of total loans into long-term loans expiring within a year (LT1y, i.e. loans with original maturity over one year and residual maturity up to one year), long-term loans expiring beyond the current year with interest rate reset within the current year (LTo1y, i.e. loans with original maturity over one year, residual maturity over one year and interest rate repricing within the next year) and short term loans (ST, i.e. loans with original maturity up to one year) to compute the shares of adjustable-rate and long-term loans for both businesses and households, respectively. In particular, we assume that all loans included in LTo1y do not have a fixed interest rate type

[10]Lithuania, Latvia and Estonia joined the Euro respectively in 2015, 2014 and 2011. All economic variables for these countries are expressed in euros even before they joined the monetary union. Ireland, Malta, Luxemburg, Cyprus, and Croatia are excluded due to data availability issues.

and thus define the share of adjustable-rate loans at any point in time as

$$\text{Share of AR loans}^x_{c,q} = \frac{LTo1y^x_{c,q} + ST^X_{c,q}}{TotalLoans^x_{c,q}} \times 100, \text{ where x} \in [NFC, HH]$$

and the share of longer-term loans, that is loans maturing beyond one year, as

$$\text{Share of LT loans}^x_{c,q} = \frac{TotalLoans^x_{c,q} - ST^x_q - LT1y^x_{c,q}}{TotalLoans^x_{c,q}} \times 100, \text{ where x} \in [NFC, HH]$$

Of course, the shares of adjustable-rate (AR) and long-term (LT) loans are not mutually exclusive but are two partially overlapping partitions of the same amount of loans at the country-time level.

Figure 1 shows a vast heterogeneity across countries both in the shares of adjustable-rate loans (left graph) and in the share of longer-term business loans (right graph). Concerning rate type, Germany is the country with the lowest share of adjustable-rate business loans (at around 40 percent), while Finland is the country with the highest share of these types of loans (above 80 percent). All the other countries fall in between these two extreme cases. Interestingly, for the vast majority of countries, the share of adjustable-rate loans varies only to a limited extent over time and the overall ranking is about stable in the period 2010-22. Also for loan maturity we find large heterogeneity across countries. The average share of loans with maturity above 1 year takes the highest value (above 80 percent) for Finland and the lowest value for Italy (around 45 percent in 2013). Over time, the share of loans with longer maturity is increasing for all countries. The increase was particularly pronounced during the Covid-19 crisis. Indeed, in many countries, to sustain the liquidity needs of the corporate sector and prevent a disruption of financial intermediation during the pandemic, State-guaranteed long-term loans were granted in favor of firms in difficulty (Li et al., 2020; Didier et al., 2021; Chodorow-Reich et al., 2022; Cascarino et al., 2022); the issuance of these loans accelerated a process already in place, i.e. the lengthening of business loan maturity. However, also in this case, the ranking across countries remained stable over time.

The other variables needed for our empirical analysis are extracted from FRED st. Louis and Eurostat (see appendix A for further details). The time span of our panel dataset ranges from 2010Q2 to 2022Q4.

3.1.2 Inflation surprises

Finally, to construct our proxy of inflation shock, we follow (Fabiani and Piersanti, 2024). In particular, we collect inflation expectations through the Thomson Reuters Poll of Professional Forecasters. This monthly poll surveys a team of professional forecasters from various financial institutions about the expected level of inflation in several countries and for the euro area as a whole. It is conducted before the release of inflation data (growth rate of the Harmonized Index of Consumer Prices) by the relevant national statistical institutes (and by Eurostat for euro area data) and covers both monthly and annual figures. The release of inflation data consists of two stages. First, there is a preliminary (or flash) release of inflation estimates; second, the statistical institutes of each country release the final inflation estimate, which could account for some minor adjustments. We compute a measure of inflation surprise using the flash releases for the euro area. We focus on flash releases as previous studies attribute inflation adjustments to flash estimates (Garcıa and Werner, 2021; Fabiani and Piersanti, 2024). More specifically, we compare the monthly realized HICP inflation in the euro area, labeled as π_t, with the expectations from professional forecasters. The difference between this latter variable and the median expected HICP inflation based on consensus forecast, $\hat{\pi}_t$, can be interpreted as a proxy of surprise inflation:

$$\varepsilon_t = \pi_t - \hat{\pi}_t \tag{50}$$

Given that our data on macroeconomic variables have quarterly frequency, we cumulate all monthly inflation surprises within a quarter and thus obtain a measure of quarterly inflation surprises.

Figure 6 displays inflation surprises for the euro area as a whole, represented by a line and bars indicating monthly and cumulative values, respectively. On average, inflation surprises are small, at around 7 basis points throughout the entire period, with a standard deviation equal to

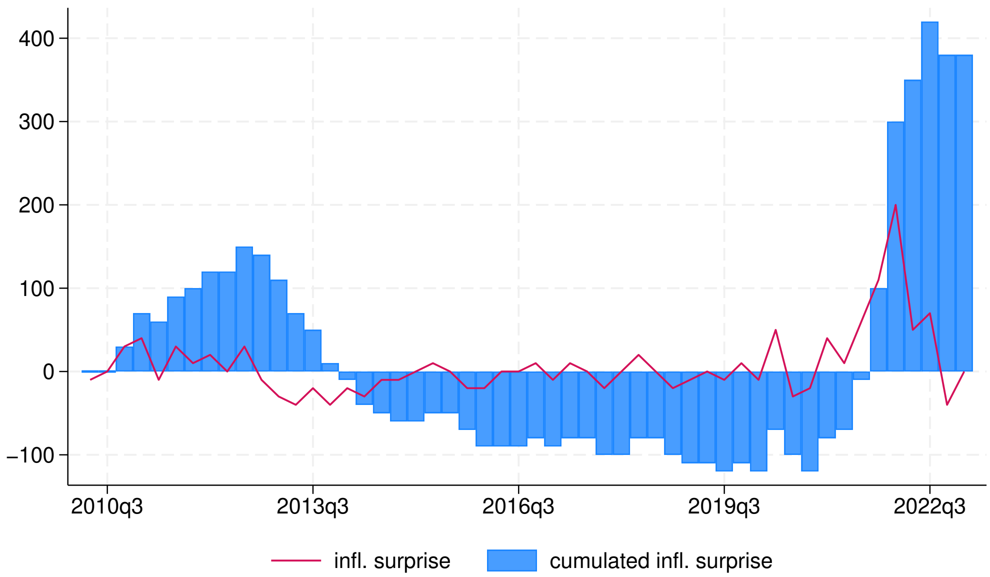

Figure 6 Inflation surprises evolution over time
Source: Thomson Reuters

40 basis points.

Differently from Fabiani and Piersanti (2024), we do not rely on first releasing country surprises as GDP is not expected to respond at high frequency to inflation surprises as stock market returns do. However, we identify unexpected changes in inflation using inflation surprises as they do but, differently from them, we evaluate the impact of those surprises on macroeconomic variables. In this respect, we must ensure that our measure of euro area-wide inflation surprise predicts inflation dynamics well across countries so that it can be credibly taken as a measure of unexpected inflation shocks. Figure 7 shows a scatter plot of country-specific inflation rates, proxied by first differences of price deflators, against euro area inflation surprises in each month. This chart reveals that inflation surprises are strongly positively correlated with inflation rates of euro area countries. In particular, a positive 100 basis point inflation surprise predicts an average inflation increase of 80 basis points across euro area countries. This relationship is strongly significant with an R-squared of 0.12. Therefore, despite the lack of cross-country heterogeneity, our euro-area measure of inflation surprise explains a non-negligible share of the country-specific inflation variability.

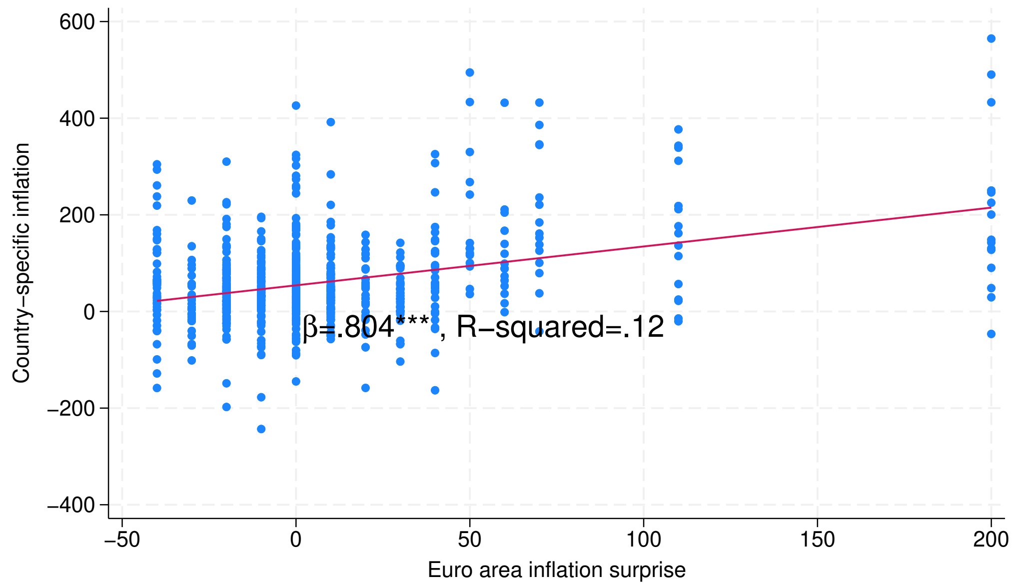

Figure 7 Country-specific inflation and euro area inflation surprises

3.2 Methodology: local projection

3.2.1 Cost push shock identification

The economic literature has tried to understand the most effective ways of identifying macroeconomic shocks driving business cycle fluctuations (Ramey, 2016). In particular, a strand of literature has relied on high-frequency monetary policy surprises as instruments to identify monetary policy shocks using either structural VARs (Gertler and Karadi, 2015; Stock and Watson, 2018), local projections à la Jordà (2005) (see Ramey 2016), or both (Bauer and Swanson, 2023). Differently from these studies, we restrict our focus on inflation surprises. In this respect, as we directly identify the unexpected changes in inflation, we do not need to resort to a two-stage estimation approach. Our measure of inflation surprise is directly retrieved from professional forecasters' expectations surveyed just before preliminary data on inflation were released, ruling thus out the presence of any confounding factor at play. However, we cannot state whether our measure of inflation surprises proxies demand or supply forces behind the unexpected change in prices. Therefore, we aim to ensure that inflation surprises trigger dynamics of macro variables compatible with those of the cost push shock in our theoretical model.

To test the DSGE model predictions, it is crucial to ensure that the proposed measure of inflation surprises is a proxy of supply shocks. To this end, we use local projections (Jordà, 2005) to track the dynamic response of real GDP per capita, real business loans per capita and inflation to a positive inflation surprise over a 10-quarter horizon. In practice, we sequentially estimate through OLS the regressions displayed in equation (51). That is, we regress the cumulative percentage growth in the country-specific outcome variable of interest from quarter $q-1$ to quarter $q+h$, $\Delta_h Y_{c,q,h}$, against our quarterly inflation surprise, ε_q. The coefficient β_h describes the impact of such inflation surprise on the cumulative h-quarters growth in the dependent variable, for h=0,1,2,. . . ,10. Hence, plotting the whole series of estimated coefficients β_h returns the impulse-response function over the horizon of interest.

$$\Delta_h Y_{c,q,h} = \beta_h \varepsilon_q + \delta \Gamma_{c,q-1} + \iota \Delta r_{q-1} + \sum_{h \neq 0} \zeta_h \varepsilon_{q+h} + \mu_c + u_{c,q} \tag{51}$$

We also include a set of lagged controls in the model, Γ_{q-1}, to account for country-specific macro-financial lagged characteristics. In particular, we include the ratio of public net borrowing to GDP ratio to account for the country-specific fiscal stance over the business cycle, the ratio of the net trade balance to GDP to account for country-specific trade shocks, first difference in 10Y country-specific sovereign yield, absorbing variation in country risk, and also the first difference in the country-specific price deflator.[11] Finally, Δr is the first difference in the 3-months Euribor to proxy changes in the policy rate and μ_c is a vector of country fixed effects. Moreover, given that including time fixed effects would saturate our measure of inflation surprises, we control (at horizons $t+h$) for surprises that occurred between quarter $q-1$ and $q+h$ (Teulings and Zubanov, 2014), which allows us to better identify the impact of surprises occurred in quarter q along the h-quarters horizon of interest. Finally, $u_{c,q}$ is an error term clustered at the time level.

We exclude the second and third quarters of 2020 from our estimation sample as Covid containment measures triggered an abrupt and sudden fall in economic activity that could confound our estimates.

[11] We exclude the price deflator from the set of controls when it is the dependent variable. This is done to rule out endogeneity issues given the panel structure of our data. However, results are unchanged if two lags of the growth of the dependent variable are included among the controls (results are available upon request).

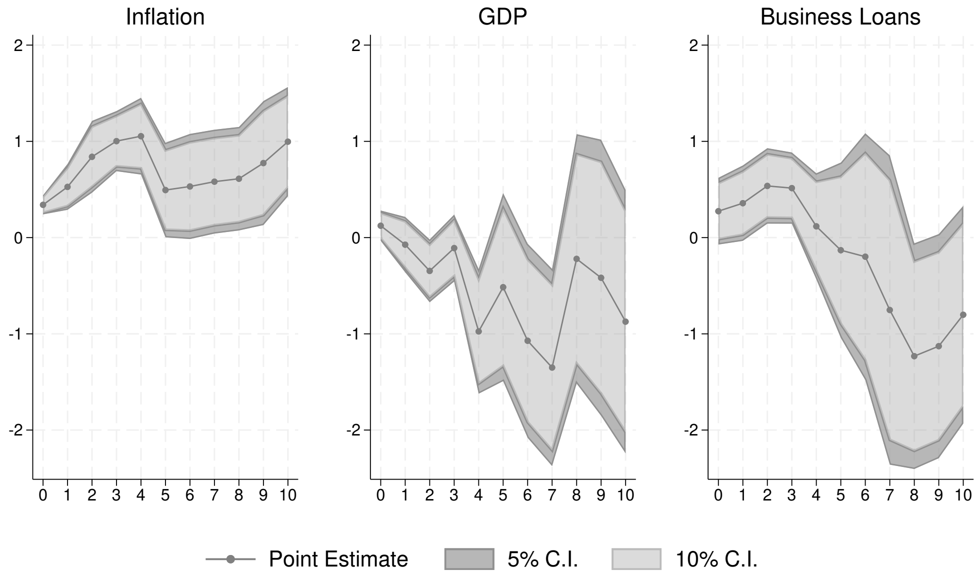

Figure 8 Empirical impulse response function to a standardized positive inflation surprise.
Note: This figure depicts the impulse response function of inflation (left graph), real GDP per capita (center graph) and real business loans per capita (right graph) to a positive one standard deviation inflation surprise over the period 2010-2022. All graphs show the coefficients β_h from the estimation of equation (51), h=0,1,2,...,10. The vertical axis reports the percentage growth rate of the dependent variable at time t+h with respect to its initial value at time t-1, i.e. $\Delta_h Y_{c,q,h}$, following a 40 basis point positive inflation surprise. The solid-dotted line reports the point estimates for β_h; the light gray and dark gray shaded areas depict the 95 percent and 90 percent confidence intervals, respectively. In all impulse responses we apply robust standard errors clustered at the time level.

Figure 8 shows that a positive one standard deviation inflation surprise triggers a dynamic response of macroeconomic variables in line with a cost push shock. All impulse responses are statistically significant at conventional levels. Indeed, inflation persistently rises on impact, peaking at 1 percent four quarters after the shock, against the backdrop of a hump-shaped fall in GDP with a trough at 1.5 percent after seven quarters. The loan quantity initially picks up slightly in response to the shock to steadily decline then since quarter four. The results show that the response of macroeconomic variables is consistent, at least qualitatively, with the model predictions about the transmission of a cost-push shock. In the next section, we analyze empirically how the transmission of an inflation shock is mediated by the heterogeneity of loan characteristics.

3.3 Loan characteristics and the transmission of inflation shocks

To evaluate the impact of different business loan characteristics on the transmission of an unexpected inflation shock (ε_q) to GDP and business loan quantities, we estimate the following local projection (LP) model:

$$\begin{aligned}\Delta_h Y_{c,q,h} =& \beta_h^1 \varepsilon_q \times \text{Sh. of AR loans}_{c,q-1} + \beta_h^2 \varepsilon_q \times \text{Sh. of LT loans}_{c,q-1} + \\ &+ \eta \varepsilon_q \times \Gamma_{c,q-1} + \iota \varepsilon_q \times \Delta r_{q-1} + \mu_c + \mu_t + u_{c,t}\end{aligned} \tag{52}$$

where our variables of interest are lagged shares of adjustable-rate loans (Sh. of AR Loans) and long-term loans (Sh. of LT Loans). Indeed, conditional on a positive one standard deviation inflation surprise, β_h^1 (β_h^2) identifies the additional impact of the shock on the dependent variable of a country with a standard deviation larger share of adjustable-rate (long-term) loans. On top of the controls already introduced in model (51), we include in the vector Γ also the lagged share of long-term and adjustable-rate loans for both non-financial companies and households and the ratio of total loans to GDP, respectively. Finally, when GDP is the dependent variable, we add the quarterly growth rates of loans to NFC and households. By contrast, when loans to NFCs is the dependent variable, we include the first log-difference of real GDP per capita among the controls. Variables describing the dynamics of households' loans are introduced to rule out that estimates are confounded by developments concerning the private financial sector as a whole, rather than specific to NFCs. The inflation surprise also interacts with the above vector of controls.[12] Finally, differently from before, we also add a vector of time fixed effects, μ_t, to the country fixed effects. This implies that the stand-alone inflation surprise coefficient is saturated, and so are the shocks possibly occurring between quarter $q-1$ and $q+h$. Therefore, β_h^1 and β_h^2 are identified by the cross-sectional variation within each quarter of loan characteristics across countries.

Figure 9 shows the results of the local projection model for real GDP per capita. Concerning

[12]Similarly to before, results are virtually unchanged if two lags of the growth rate of the dependent variable are included among the controls (results are available upon request).

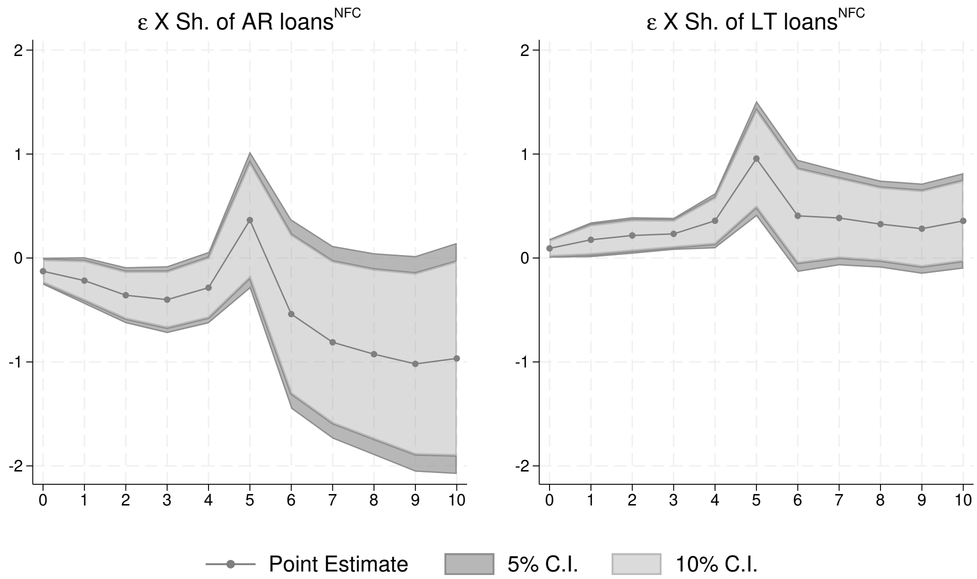

Figure 9 Empirical impulse response functions of GDP to a standardized positive inflation surprise across loan characteristics.
Note: This figure depicts the impulse response function of real GDP per capita to a positive one standard deviation inflation surprise as additional impact for countries with a standard deviation higher share of adjustable-rate loans (left graph) and countries with a standard deviation higher share of long-term loans (right graph) over the period 2010-2022. All graphs show the coefficients β_h from the estimation of equation (52), h=0,1,2,. . . ,10. The vertical axis reports the percentage growth rate of the dependent variable at time t+h with respect to its initial value at time t-1, i.e. $\Delta_h Y_{c,q,h}$, following a 40 basis point positive inflation surprise. The solid-dotted line reports the point estimates for β_h; the light gray and dark gray shaded areas depict the 95 percent and 90 percent confidence intervals, respectively. In all impulse responses we apply robust standard errors clustered at the time level.

the rate type, we find that a 1 std.dev. (15 per cent) increase in the share of adjustable-rate loans (from an average of 69 per cent) deepens the recession by an additional 9 per cent at the trough (quarter 9). For the business loan maturity, we find that a 1 standard deviation (10 per cent) increase in the share of long-term loans, i.e. with maturity above one year, (from an average of 67 per cent) cushions the recession by a 1 per cent at the peak (quarter 5). Once again, our estimates turn out to be statistically significant at conventional levels.

The local projection results confirm the theoretical findings: more adjustable-rate loans amplify the recession triggered by an unexpected in inflation shock, while longer loan maturity softens it.

Figure 10 shows that results for GDP, and so those from the theoretical model, are broadly confirmed when looking at business loans as a whole. Differently from before, however, coeffi-

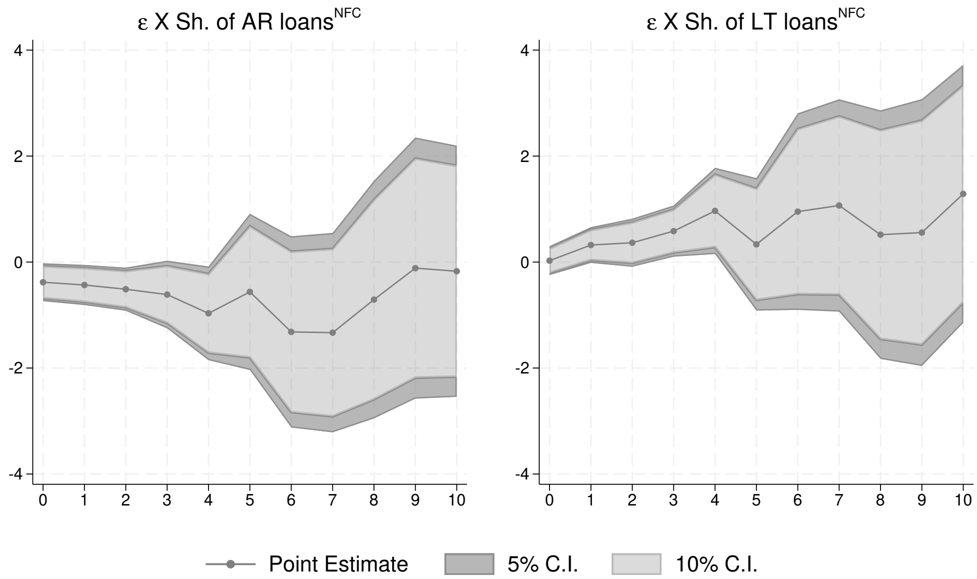

Figure 10 Empirical impulse response functions of Business loans to a standardized positive inflation surprise
Note: This figure depicts the impulse response function of real business loans per capita to a positive one standard deviation inflation surprise as additional impact for countries with a standard deviation higher share of adjustable-rate loans (left graph) and countries with a standard deviation higher share of long-term loans (right graph) over the period 2010-2022. All graphs show the coefficients β_h from the estimation of equation (52), h=0,1,2,. . . ,10. The vertical axis reports the percentage growth rate of the dependent variable at time t+h with respect to its initial value at time t-1, i.e. $\Delta_h Y_{c,q,h}$, following a 40 basis point positive inflation surprise. The solid-dotted line reports the point estimates for β_h; the light gray and dark gray shaded areas depict the 95 percent and 90 percent confidence intervals, respectively. In all impulse responses we apply robust standard errors clustered at the time level.

cient estimates are more noisy. We take this as qualitative evidence supporting the mechanism described by the model.

4 Policy response to inflation shocks

Our theoretical model and empirical evidence based on the major euro area countries show that adjustable-rate business loans imply deeper recessions than fixed-rate ones following an inflation shock. Varying degrees of business cycle fluctuations in turn lead to different welfare losses for households, depending on the maturity of their loans and the type of interest rates, assuming all other factors remain constant. We compute the welfare loss using a second order approximation around the steady state for the representative household's utility functions (see appendix B for further details):

$$\widetilde{\mathcal{W}}_{\mathcal{D}}^{\text{adj./fix}} = -\frac{1}{2}\frac{1}{(1-\beta)U}\left\{\gamma\left(C-hC\right)^{-\gamma-1}C^{2}\left[(1+h^{2})\sigma_{c}^{2}-2h\sigma_{c_{t},c_{t-1}}\right]+\chi\varphi L^{\varphi+1}\sigma_{l}^{2}\right\}$$

Figure 11 reports the welfare loss for households in economies with different interest rate types over increasing loan durations. When loan maturity is above 1 quarter, the losses of the two models diverge. As expected, the fixed-rate model (continuous red line) displays smaller welfare losses than the adjustable-rate model (continuous blue line) at all maturities. The gap narrows as loan maturity lengthens since the adjustable-rate model benefits from the greater dampening of business cycle fluctuations driven by longer loan terms with respect to shorter ones.

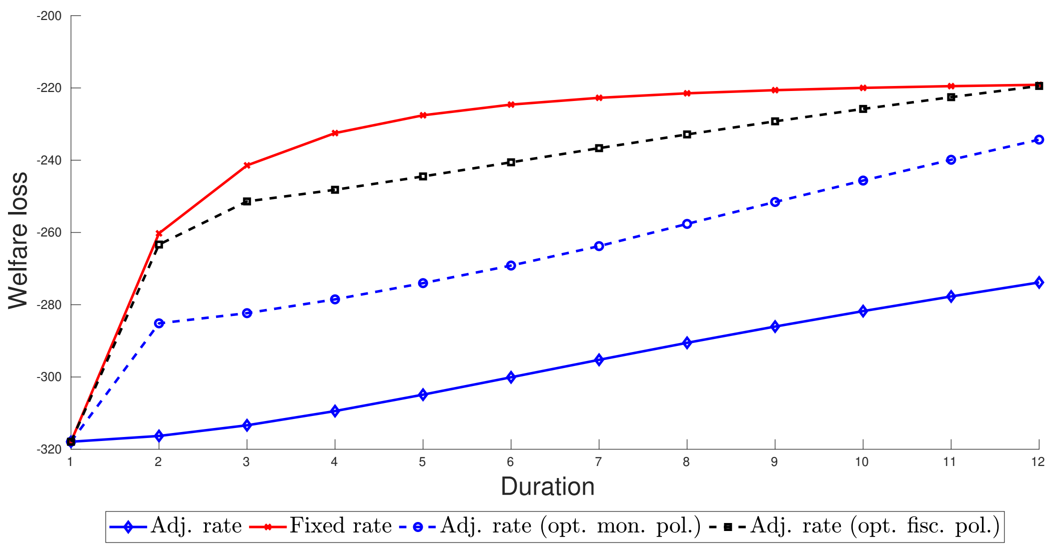

Figure 11 Evolution of welfare loss by loan characteristics

We then extend the analysis evaluating whether it is possible to narrow as much as possible the welfare gap between fixed and adjustable-rate models by manipulating either the Central Bank's or the fiscal policy authority's response to inflation.

We acknowledge that this exercise may not lead to optimal policies. First, everything is conditional on a single type of shock. Second, the policy rules parameters in the fixed rate economy are not optimally selected. Third, in the case of the monetary policy rule, the search for the welfare-improving values in the adjustable rate economy is done only under two out of the three Taylor rule parameters. However, this approach allows us to draw potentially useful comparisons for policy purposes within a stylized framework.

4.1 Monetary policy tuning

A potential implication of the heterogeneous shock transmission based on business loan characteristics is that monetary policy should be tuned differently based on loan characteristics. However, our baseline calibration of the Taylor rule parameters ρ^r and ϕ_π takes values equal to 0.85 and 1.5, respectively. This is independent of loan characteristics (see equation 42).

We set up a grid search method to select a couple of values of the Taylor rule parameters $[\rho^r, \phi_\pi]$ that minimize the distance of the welfare loss of the adjustable-rate model with that of the fixed-rate model, where ρ^r and ϕ_π take standard values (i.e. equal to 0.85 and 1.5, respectively) for each loan maturity.

This boils down to solving the following minimization problem

$$\min_{\rho^r,\phi_\pi} \left[\widetilde{\mathcal{W}}_{\mathcal{D}}^{fix} - \widetilde{\mathcal{W}}_{\mathcal{D}}^{adj}\right]$$
$$\text{s.t. } \widetilde{\mathcal{W}}_{\mathcal{D}}^{adj} \leq \widetilde{\mathcal{W}}_{\mathcal{D}}^{fix}$$

We set our grid search around a set of reasonable values of ρ^r and ϕ_π. In particular, we evaluate the interest rate stickiness (ρ^r) in the space between 0.8 and 0.95 and the inflation reaction coefficient (ϕ_π) in the space between 1 and 3. Figure 12 shows how the desirability of the Taylor rule calibration of the adjustable-rate model evolves along the parameters space. The darker the square color, the better the Taylor rule parametrization for the adjustable-rate model at a given loan maturity. Therefore, black squares identify the optimal calibration, at least according to our definition, for each maturity.

Our results show that the adjustable-rate model needs a stickier Taylor rule, for a wider set of values of ϕ_π, to close the welfare loss gap with the fixed-rate model. More specifically, the only values of ρ^r allowing for a welfare gain are 0.9 and 0.95. Interestingly, the longer the loan maturity, the less responsive to inflation the Taylor rule needs to be. Indeed, if by construction

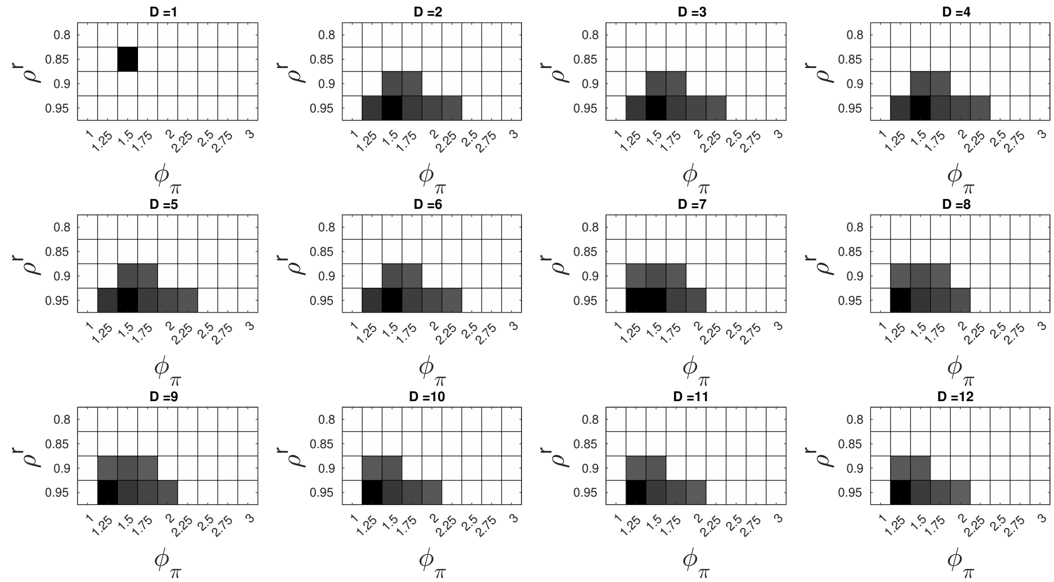

Figure 12 Monetary policy rule calibration and welfare losses

when $\mathcal{D} = 1$ both interest rate type models must be identical, when $\mathcal{D} \in [2, 7]$ the adjustable-rate model calls for a stickier Taylor rule. Moreover, when $\mathcal{D} > 8$ it also demands a less severe inflation reaction, as the optimal couple of values becomes $[\rho^r = 0.95, \phi_\pi = 1.25]$. Thus, the monetary policy response to the cost-push shock must be both stickier and milder than in the fixed-rate model. The gain in welfare loss is sizeable as the gap between the fixed-rate model and the adjustable-rate one is more than halved, as shown by the dashed blue line in Figure 11.

More in details, in Figure 13 we look at the impulse response functions with the newly defined Taylor rule. As before, the red dashed line stands for the fixed-rate model with the canonical Taylor rule (i.e. the one with $\rho^r = 0.85$ and $\phi_\pi = 1.5$), the blue continuous line for the adjustable-rate model with the same Taylor rule calibration, and the blue dashed lines for the adjustable-rate model with the selected calibration of the Taylor rule for each maturity according to the black squares in Figure 12.

For longer loan maturities, the Taylor rule suited for the adjustable-rate model implies a less strong reaction of the nominal rate. Indeed, at $\mathcal{D} = 12$, the GDP fall is less deep than with the standard calibration of the monetary policy rule earlier adopted, to levels akin to the fixed-rate models. By contrast, if anything, inflation dynamics are only marginally impacted by the new Taylor rule. Then, the two adjustable-rate models' impulse response functions tend to get closer

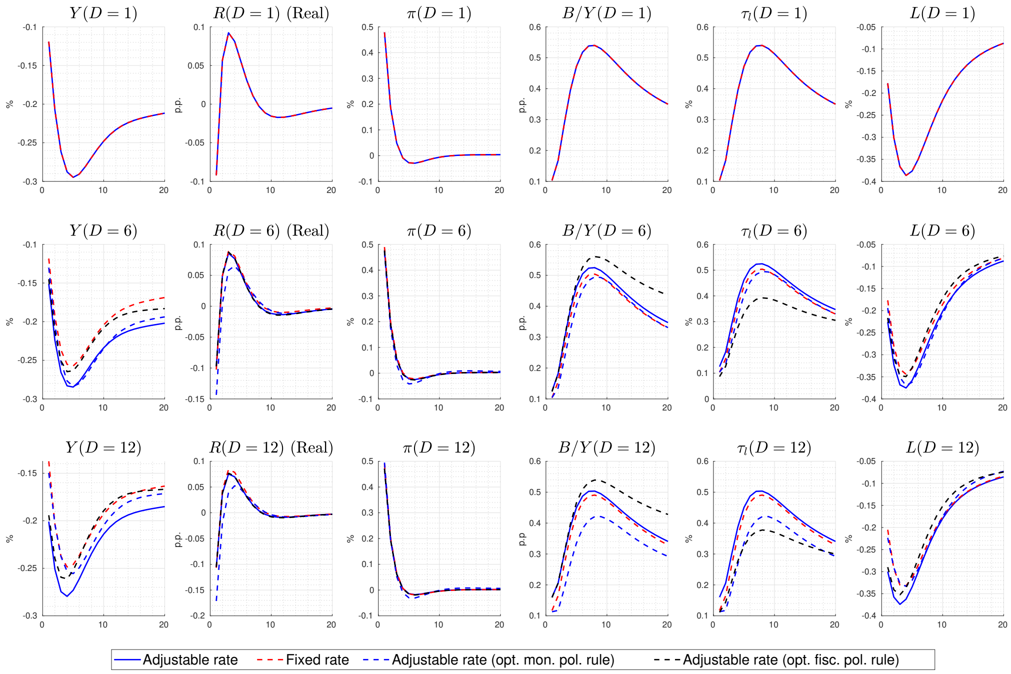

Figure 13 Impulse response functions to a recessionary cost-push shock for fine-tuned monetary policy and fiscal policy rule calibration.
Note: vertical axis report percentage deviation from the steady state of the variable of interest.

from quarter 6 onwards.

4.2 Fiscal policy tuning

Given the institutional setup of the euro area, monetary policy is unique for all union members and cannot be tailored according to country-level idiosyncrasies. In this section, we propose fiscal policy as an alternative tool to address the cross-country heterogeneity in the response to inflation shocks due to different business loan characteristics. In the same fashion as before, based on a grid search, we look for the calibration of the fiscal policy reaction parameter, γ_l, in the adjustable-rate model that narrows as much as possible the welfare loss gap between fixed- and adjustable-rate economies for each loan maturity (given the standard calibration of the fixed-rate model, i.e. γ_l=0.5).

We define our grid search around a set of reasonable values of γ_l over which a unique solution exists, that is $\gamma_l \in [0.2, 1]$. Figure 14 shows how the optimal fiscal policy rule calibration of the adjustable-rate economy evolves over loan maturities. That is, for $\mathcal{D} > 1$ the adjustable-rate

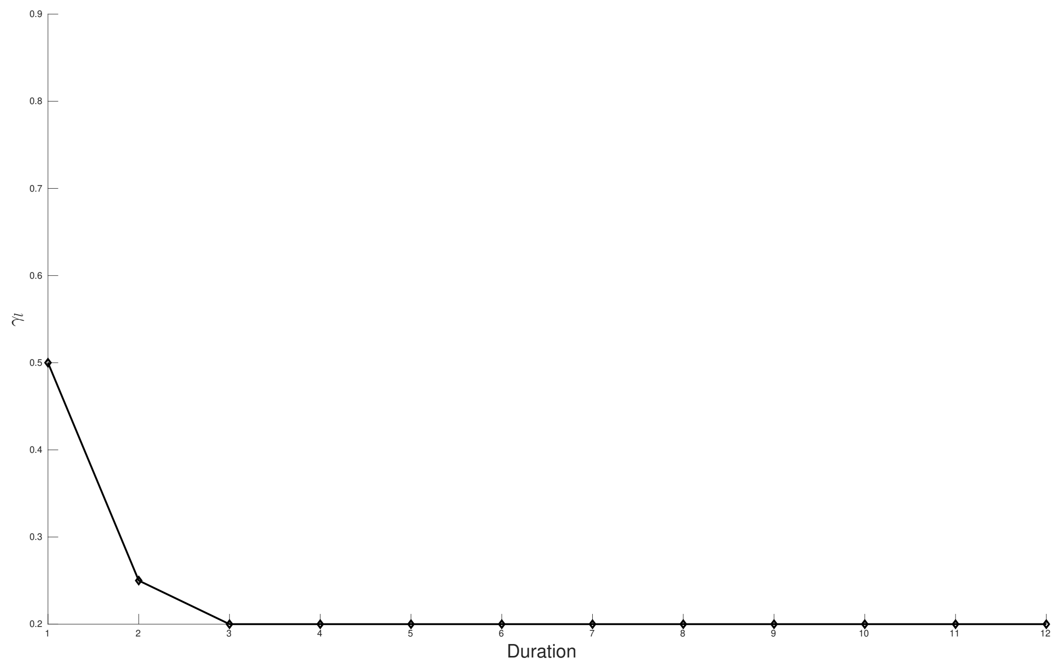

Figure 14 Fiscal policy rule calibration and welfare losses

model calls for a much more muted tax increase, i.e. $\gamma_l = 0.25$ for $\mathcal{D} = 2$ and $\gamma_l = 0.2$ for $\mathcal{D} > 2$ instead of 0.5 in the fixed-rate model. The black-dashed line in Figure 11 shows the evolution of the welfare loss in the adjustable-rate model with the optimal, at least according to our definition, fiscal policy rule. Interestingly, in our framework, the gain brought in by the enhanced fiscal policy is always above that of the optimal monetary policy rule (blue-dashed line). Therefore, it might also be able to entirely close the gap between the fixed and adjustable-rate loan models for $\mathcal{D} = 12$.

Black-dotted lines in Figure 13 display impulse response functions for the case of the enhanced fiscal policy in the adjusted rate economy, for different loan maturities, following a positive cost-push shock. First, as before, with $\mathcal{D} = 1$ no differences arise between fixed and adjustable-rates, and therefore both fiscal and monetary policy are unchanged. Second, fiscal policy is less able than monetary policy to cushion the recession in the early phase of the adjustment following the shock. Then, in line with Zubairy (2014), it sustains production much more over the medium-long-term, to finally converge with the fixed-rate model. These dynamics are more marked for $\mathcal{D} = 12$, as fiscal policy is more capable of improving welfare as shown in Figure 11. Differently from the optimal monetary policy, fiscal policy does not affect the policy rate feedback from the inflation shock. Indeed, the distortionary labor tax increases by less, thus sustaining economic activity, but at the cost of a persistently higher debt-to-GDP ratio.

Finally, this result should be interpreted cautiously for at least three reasons. First, the feasibility of such a shift in fiscal policy depends heavily on each country's debt-to-GDP ratio. In practice, allowing public debt to grow beyond typical levels in response to shocks may be undesirable, especially in the context of the Stability and Growth Pact. Second, we assume that both fixed and adjustable-rate economies follow the same fiscal policy rule ex-ante, though they may differ in their fiscal capacity to implement such a policy. More generally, halving tax revenues is extremely challenging in reality, making the significant fiscal policy adjustments suggested here potentially unfeasible. Lastly, for simplicity, we have not considered alternative fiscal measures, such as public investment or fiscal transfers, which could lead to different outcomes that are beyond the scope of this analysis. However, this experiment shows that fiscal policy might be, at least in principle, a more suited instrument than monetary policy to address differences in the transmission of inflationary shocks between countries with different business loan characteristics.

5 Conclusion

How do country-specific characteristics in loan structure affect the transmission of inflation shocks in the economy? This paper aims to answer this critical question by providing a theoretical foundation based on a rich DSGE model featuring maturity transformation and rate type heterogeneity. It also empirically tests the theoretical findings by exploiting a database containing information on the loan structure of the main euro area countries and inflation supply shocks derived from the Thomson Reuters survey of professional forecasters.

The local projection results confirm the theory: longer-term loans have a stabilizing role as they mitigate the impact of inflation shocks, adjustable-rate loans instead exacerbate the negative effects on GDP. Then, we fist evaluate how the Taylor rule should be calibrated to minimize the welfare losses for countries with a prevalence of adjustable-rate business loans. Our results suggest that these countries would need a softer stance to contrast inflation shocks. However, since euro area countries share a common monetary policy, we examine the effectiveness of a stylized fiscal policy as a tool for stabilizing the business cycle. Our findings show that, in our framework, fiscal policy might be more effective for this purpose, as a less procyclical fiscal policy outperforms a more accommodative monetary policy. To the best of our knowledge, this is the first paper to address all of these issues. In the current period of high inflationary pressures, monetary policy is active in reducing inflation, but fiscal policy could still play a relevant role.

The vast heterogeneity in business loan characteristics across countries plays a crucial role in shaping how unexpected price increases affect macroeconomic variables and cannot be overlooked.

Some relevant questions are not addressed in this paper and could be explored in future research. First of all, the paper also relates to the literature on misallocation. Indeed, the fact that in each period there is only a fraction of firms that adjust the capital stock could generate a misallocation of capital across firms. If that is the case, it would be relevant to evaluate whether there is a scope for monetary or fiscal policy to fix or reduce the welfare losses for a given length of loan maturities. Second, the role of business loan characteristics may differ for expansionary vs recessionary shocks. It would be then interesting to evaluate if non-linearities are important for the transmission of inflationary shocks.

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A Data Appendix

Data for the amounts of business loans to NFCs and households are collected from BSI statistics and those for inflation surprises are from the Thomson Reuters poll of professional forecasters. Both data sources are described in section 3.1.

We collect data on real GDP, labor force population, implicit price deflators, Euribo,r and the 10-Year public bond yields from FRED St. Louis.[13]. Finally, data for net government borrowing and net trade balance to GDP ratios are both from Eurostat.[14]

Real GDP per capita is defined as the ratio between real GDP and labor force population.

$$\text{RealGDPPC}_{c,q} = \frac{\text{RealGDPPC}_{c,q}}{\text{LabForPop}_{c,q}} \tag{A.1}$$

NFCs and households' loans per capita are defined as the respective loan amounts ($\text{TotalLoans}^x_{c,q}$ in sec 3.1), expressed in real terms, divided by the labor force population, that is

$$\text{RealTotalLoansPC}^x_{c,q} = \frac{\text{TotalLoans}^x_{c,q}}{\text{Deflator}_{c,q} \times \text{LabForPop}_{c,q}} \tag{A.2}$$

NFCs and households's loans to GDP ratio as defined as

$$\text{Loans2GDP}^x_{c_q} = \frac{\text{RealTotalLoanPCs}^x_{c,q}}{\text{RealGDPPC}_{c,q}} \tag{A.3}$$

[13]Labor force population for Slovakia is only available at quarterly frequency. This implies that this variable is assumed to be constant for all quarters within a year

[14]Data on net government borrowing to GDP ratio is only available at yearly frequency. This implies that this variable is assumed to be constant within each quarter.

B Welfare function approximation

B.1 Approximation

Given $f(x)$ where $x = (x^1, x^2, x^3)$ is a vector of variables, a second order approximation of $f(x)$ around $x_0 = (x_0^1, x_0^2, x_0^3)$ can be written as

$$f(x) \approx f(x_0) + \sum_{i=1}^{3} \frac{\partial f(x_0)}{\partial x_0^i}(x^i - x_0^i) + \frac{1}{2}\sum_{i=1}^{3}\sum_{j=1}^{3} \frac{\partial^2 f(x_0)}{\partial x_0^i \partial x_0^j}(x^i - x_0^i)(x^j - x_0^j)$$

Let us define $f'(x_0^i) = \frac{\partial f(x_0)}{\partial x_0^i}$ and $f''(x_0^{i,j}) = \frac{\partial^2 f(x_0)}{\partial x_0^i \partial x_0^j}(x^i - x_0^i)(x^j - x_0^j)$. Let us subtract and divide by $f(x_0)$ on both sides, the previous equation becomes

$$\frac{f(x) - f(x_0)}{f(x_0)} \approx \sum_{i=1}^{3} \frac{f'(x_0^i)}{f(x_0)}(x^i - x_0^i) + \frac{1}{2}\sum_{i=1}^{3}\sum_{j=1}^{3} \frac{f''(x_0^{i,j})}{f(x_0)}(x^i - x_0^i)(x^j - x_0^j)$$

Let us define $f(\widetilde{x}) = \frac{f(x)-f(x_0)}{f(x_0)}$ and $\widetilde{x}^i = \frac{x^i - x_0^i}{x_0^i}$, the above equation now reads

$$f(\widetilde{x}) \approx \sum_{i=1}^{3} \frac{f'(x_0^i)}{f(x_0)} x_0^i \widetilde{x}^i + \frac{1}{2}\sum_{i=1}^{3}\sum_{j=1}^{3} \frac{f''(x_0^{i,j})}{f(x_0)} x_0^i x_0^j \widetilde{x}^i \widetilde{x}^j \tag{B.1}$$

Equation (B.1) is a second order approximation of $f(x)$ around x_0.

B.2 First and second order derivatives

Let us consider the following utility function

$$U_t = \frac{(C_t - hC_{t-1})^{1-\gamma}}{1-\gamma} - \chi \frac{L_t^{1+\varphi}}{1+\varphi} \tag{B.2}$$

The set of first derivatives is

$$U'(C_t) = (C_t - hC_{t-1})^{-\gamma}$$

$$U'(C_{t-1}) = -h(C_t - hC_{t-1})^{-\gamma}$$

$$U'(L_t) = -\chi L_t^{\varphi}$$

The set of second order derivatives

$$U''(C_t, C_t) = -\gamma (C_t - hC_{t-1})^{-\gamma-1}$$

$$U''(C_{t-1}, C_{t-1}) = -\gamma h^2 (C_t - hC_{t-1})^{-\gamma-1}$$

$$U''(C_t, C_{t-1}) = \gamma h (C_t - hC_{t-1})^{-\gamma-1}$$

$$U''(L_t, L_t) = -\chi\varphi L_t^{\varphi-1}$$

B.3 Second order approximation of the utility function

Let us define

$$U = \frac{(C - hC)^{1-\gamma}}{1-\gamma} - \chi\frac{L^{1+\varphi}}{1+\varphi}$$

as the utility function evaluated around the steady state, i.e. around $C_t = C_{t-1} = C$ and $L_t = L$. Applying (B.1) to (B.2) yields and evaluation of a second order approximation fo the utility function around the steady state

$$\begin{aligned}\widetilde{U}_t \approx & \frac{(C-hC)^{-\gamma}}{U}C\widetilde{C}_t - h\frac{(C-hC)^{-\gamma}}{U}C\widetilde{C}_{t-1} - \chi\frac{L^{\varphi+1}}{U}\widetilde{L}_t - \frac{1}{2}\frac{\gamma(C-hC)^{-\gamma-1}}{U}C^2\widetilde{C}_t^2 + \\ & -\frac{1}{2}\frac{\gamma h^2 (C-hC)^{-\gamma-1}}{U}C^2\widetilde{C}_{t-1}^2 + \frac{\gamma h (C-hC)^{-\gamma-1}}{U}C^2\widetilde{C}_t\widetilde{C}_{t-1} - \frac{1}{2}\frac{\chi\varphi L^{\varphi-1}}{U}L^2\widetilde{L}_t^2\end{aligned}$$

Let us now define the households' welfare as the stream of expected utility functions, i.e.

$$\mathbf{W} = \sum_{i=0}^{+\infty}\beta^i U_{t+i} \Rightarrow E_t[\mathbf{W}] = E_t\left[\frac{U_t}{1-\beta}\right]$$

Given the expectation operator, under the assumption of unconditional expectations $\Rightarrow E_t\left[\widetilde{X}_t\right] = 0$, $E_t\left[\widetilde{X}_t^2\right] \equiv E_t\left[\widetilde{X}_{t-1}^2\right] = \sigma_x^2$, and $E_t\left[\widetilde{X_t X_{t-1}}\right] = \sigma_{x_t,x_{t-1}}$. Thus, equation the above equation boils down to

$$\widetilde{U}_t \approx -\frac{1}{2}\frac{\gamma\left(C-hC\right)^{-\gamma-1}}{U}C^2\sigma_c^2-\frac{1}{2}\frac{\gamma h^2\left(C-hC\right)^{-\gamma-1}}{U}C^2\sigma_c^2+$$
$$+\frac{\gamma h\left(C-hC\right)^{-\gamma-1}}{U}C^2\sigma_{c_t,c_{t-1}}-\frac{1}{2}\frac{\chi\varphi L^{\varphi-1}}{U}L^2\sigma_l^2$$

As a result, we can write down the following welfare loss approximation

$$\widetilde{\mathbf{W}} = -\frac{1}{2}\frac{1}{(1-\beta)U}\left\{\gamma\left(C-hC\right)^{-\gamma-1}C^2\left[(1+h^2)\sigma_c^2-2h\sigma_{c_t,c_{t-1}}\right]+\chi\varphi L^{\varphi+1}\sigma_l^2\right\} \tag{B.3}$$

C List of equations

C.1 Households

We consider a representative household that is populated by a continuum of members of measure one. Within the household, there are $1-f$ workers and f bankers. In each period, the bankers face an exit risk with iid probability $1-\sigma$. When exiting, they redistribute accumulated wealth within their household. Each period $f(1-\sigma)$ workers become bankers so that the total number of members in each occupation does not change.

The household maximization problem is

$$\max_{c_t,l_t,e_t,d_t} \beta^{t+i} \sum_{i=0}^{+\infty} \left[\frac{(c_{t+i} - hc_{t+i-1})^{1-\gamma}}{1-\gamma} - \chi \frac{l_{t+i}^{1+\varphi}}{1+\varphi} \right]$$

s.t.

$$c_{t+i} + d_{t+i} + = w_{t+i} l_{t+i} + R_{t+i} d_{t+i-1} + t_{t+i}$$

The Lagrangean reads

$$\begin{aligned}
\mathcal{L} =& \beta^t \left[\frac{(c_t - hc_{t-1})^{1-\gamma}}{1-\gamma} - \chi \frac{l_t^{1+\varphi}}{1+\varphi} \right] - \beta^t \eta_t \left[c_t + d_t - w_t l_t - R_t d_{t-1} - t_t \right] + \\
& \beta^{t+1} \left[\frac{(c_{t+1} - hc_t)^{1-\gamma}}{1-\gamma} - \chi \frac{l_{t+1}^{1+\varphi}}{1+\varphi} \right] + \\
& - \beta^{t+1} \eta_{t+1} \left[c_{t+1} + d_{t+1} - w_{t+1} l_{t+1} - R_{t+1} d_t - t_{t+1} \right] + ...
\end{aligned}$$

Then, FOCs read

$$\frac{\partial \mathcal{L}}{\partial c_t} = 0 \Longleftrightarrow \eta_t = (c_t - hc_{t-1})^{-\gamma} - h\beta \left(c_{t+1} - hc_t \right)^{-\gamma} \tag{C.1}$$

$$\frac{\partial \mathcal{L}}{\partial l_t} = 0 \Longleftrightarrow \chi l_t^{\varphi} = \eta_t w_t \tag{C.2}$$

$$\frac{\partial \mathcal{L}}{\partial d_t} = 0 \Longleftrightarrow \beta \frac{\eta_{t+1}}{\eta_t} R_{t+1} = 1 \tag{C.3}$$

Finally, let us define $\Lambda_{t,t+1} = \beta \frac{\eta_{t+1}}{\eta_t}$ as the stochastic discount factor.

C.2 Final-good producers

The final output in the economy is a CES bundle of differentiated retail goods:

$$y_t = \left[\int_0^1 y_{h,t}^{\frac{\varepsilon-1}{\varepsilon}} dh \right]^{\frac{\varepsilon}{\varepsilon-1}} \tag{C.4}$$

with $\varepsilon > 1$ and $y_{h,t}$ is the production of the retail firm h at time t.

From cost minimization, the standard demand function obtains

$$y_{h,t} = \left(\frac{P_{h,t}}{P_t} \right)^{-\varepsilon} y_t \tag{C.5}$$

where $P_{h,t}$ is the price of the retail good produced by firm h and the aggregate price level reads $P_t = \left[\int_0^1 P_{h,t}^{1-\varepsilon} dh \right]^{\frac{1}{1-\varepsilon}}$.

Retailers re-package the intermediate good with a linear production technology. To introduce price stickiness, the standard Calvo formulation is assumed. In each period, only a fraction $1-\zeta_p$ of firms is allowed to reset their price, P_t^*. The other ζ_p firms set $P_{h,t} = P_{h,t-1}$. Therefore, retail firms must solve the following maximization problem:

$$\max_{P_t^*} E_t \left\{ \sum_{i=0}^{+\infty} (\zeta_p \beta)^i \frac{\eta_{t+i}}{\eta_t} \left[\frac{P_t^*}{P_{t+i}} - p_{t+i}^m \right] y_{h,t+i} \right\} \tag{C.6}$$

subject to (C.5). p_t^m is the unitary price at which intermediate good firms sell their production to final good producers.

The first order condition reads

$$P_t^* = \frac{\varepsilon}{\varepsilon - 1} \frac{\sum_{i=0}^{+\infty} (\beta \zeta_p)^i \eta_{t+i} P_{t+i}^{\varepsilon} p_{t+i}^m y_{t+i}}{\sum_{i=0}^{+\infty} (\beta \zeta_p)^i \eta_{t+i} P_{t+i}^{\varepsilon-1} y_{t+i}}$$

that can be rearranged as

$$P_t^* = \frac{\varepsilon}{\varepsilon - 1}\frac{x_{1,t}}{x_{2,t}} \tag{C.7}$$

with

$$x_{1,t} = P_t^{\varepsilon} p_t^m y_t \eta_t + \zeta_p \beta x_{1,t+1} \tag{C.8}$$

and

$$x_{2,t} = P_t^{\varepsilon-1} y_t \eta_t + \zeta_p \beta x_{2,t+1} \tag{C.9}$$

Let us define $\bar{x}_{1,t} = \frac{x_{1,t}}{P_t^{\varepsilon}}$ and $\bar{x}_{2,t} = \frac{x_{2,t}}{P_t^{\varepsilon-1}}$. Thus we can rewrite (C.8) and (C.9) as

$$\bar{x}_{1,t} = p_t^m y_t \eta_t + \zeta_p \beta \bar{x}_{1,t+1} \pi_{t+1}^{\varepsilon} \tag{C.10}$$

and

$$\bar{x}_{2,t} = y_t \eta_t + \zeta_p \beta \bar{x}_{2,t+1} \pi_{t+1}^{\varepsilon-1} \tag{C.11}$$

Therefore we rearrange (C.7) as it follows

$$P_t^* = \frac{\varepsilon}{\varepsilon - 1}\frac{x_{1,t}}{P_t^{\varepsilon}}\frac{P^{\varepsilon-1}}{x_{2,t}} P_t \equiv \frac{\varepsilon}{\varepsilon - 1}\frac{\bar{x}_{1,t}}{\bar{x}_{2,t}} P_t \Rightarrow \pi_t^* = \frac{\varepsilon}{\varepsilon - 1}\frac{\bar{x}_{1,t}}{\bar{x}_{2,t}} \pi_t \text{ with } \pi_t^* = \frac{P_t^*}{P_{t-1}} \tag{C.12}$$

Let us note that $P_t^{1-\varepsilon} = \int_0^1 P_{h,t}^{1-\varepsilon} d_h$, but a fraction $1 - \zeta_p$ of these firms will update their price to the same reset price, P_t^*. By contrast, the remaining fraction ζ_p will charge the price they charged in the last period. Since firms' ordering does not matter, we have that $P_t^{1-\varepsilon} = \int_0^{1-\zeta_p} P_{h,t}^{1-\varepsilon} d_h + \int_{1-\zeta_p}^1 P_{h,t}^{1-\varepsilon} d_h = (1-\zeta_p) P_t^{*1-\zeta_p} + \int_{1-\zeta_p}^1 P_{h,t}^{1-\varepsilon} d_h$. Now, because the firms who get the update are randomly chosen, and because there is a large number of firms, the integral of individual prices over some subset of the unit interval is proportional to the integral over the entire unit interval, where the proportion is equal to the subset of the unit interval over which the integral is taken. Thus, $\int_{1-\zeta_p}^1 P_{h,t}^{1-\varepsilon} d_h = \zeta_p \int_0^1 P_{h,t}^{1-\varepsilon} d_h = \zeta_p P_{t-1}^{1-\varepsilon}$. Therefore we have that

$$P_t^{1-\varepsilon} = (1-\zeta_p)\, P_t^{*1-\varepsilon} + \zeta_p P_{t-1}^{1-\varepsilon} \Rightarrow \pi_t^{1-\varepsilon} = (1-\zeta_p)\, \pi_t^{*1-\varepsilon} + \zeta_p \tag{C.13}$$

C.3 Intermediate Producers

There is a continuum of good-producing firms indexed by $i \in [0,1]$, whose production occurs through labor l_t and capital k_t. The production function has a Cobb-Douglas form:

$$y_{i,t} = a_t \left(k_{i,t}\right)^{\alpha} l_{i,t}^{1-\alpha}, \tag{C.14}$$

where

$$a_t = \rho^a a_{t-1} + \varepsilon_t^a, \text{ with } \varepsilon_t^a \sim \mathcal{N}\left(0, \sigma^a\right) \text{ and } \rho^a \in (-1,1) \tag{C.15}$$

is a standard exogenous process describing the evolution of the TFP.

Following Andreasen et al. (2013), we assume that firms make lumpy investment decisions and, thus, choose their optimal level of capital with probability $1-\zeta_k$ in each period. The probability $\zeta_k \in [0,1)$ takes the same value for all good-producing firms. As capital adjustments are infrequent, we assume that firms finance their capital stock by relying on long-term loans provided by banks. These contracts last for all periods with no capital re-optimization, which are ex-ante unknown for the single firm. The average duration of all loan contracts can, instead, be computed and it is equal to $\mathcal{D} = \frac{1}{1-\zeta_k}$.

Capital-producing firms supply physical capital to good-producing firms, who finance the acquisition of these capital services during the period of the contract by paying a fixed fee per capital unit, ω.

In each period, all good-producing firms choose also the optimal amount of labor, incurring in a cost equal to w_t for each unit. Given their homogeneity, all good-producing firms that re-optimize in period t choose the same amount of capital, $\bar{k}_t$. In a subsequent period $t+j$, all firms which lastly re-optimized their capital decision in t must choose the same amount of labor, $l_{t+j|t}$. Moreover, we also allow for two different interest rate type of long-term loan contracts. Indeed a long-term loan contract can be either at fixed or at adjustable interest rate. By assumption, we impose the interest rate type on the loan contract so that neither the firm nor the bank can choose the interest rate type as well as the loan length.

Finally, note that intermediate good firms sell their production to final good producers at the unitary price p_t^m.

C.3.1 fixed-rate Type

For the whole duration of the credit contract, the rental (gross real) rate of capital R_t^l and the (real) market price of a capital unit p_{t-1}^k, as well as the quantity of capital, are kept fixed. Their problem at time t can be described as follows:

$$\max_{\bar{k}_t} \sum_{j=0}^{+\infty} \zeta_k^j \Lambda_{t,t+j} \left\{ \frac{P_{t+j}^m}{P_{t+j}} a_{t+j} \bar{k}_t^{\alpha} l_{t+j|t}^{1-\alpha} - \frac{W_{t+j}}{P_{t+j}} l_{t+j|t} + \frac{P_{t-1}^k}{P_{t+j}} \bar{k}_t (1-\omega) - R_t^{l,nom} \frac{P_{t-1}^k}{P_{t+j}} \bar{k}_t \right\}.$$

In order to express everything in real terms we can rewrite the former as

$$\max_{\bar{k}_t} \sum_{j=0}^{+\infty} \zeta_k^j \Lambda_{t,t+j} \left\{ p_{t+j}^m a_{t+j} \bar{k}_t^{\alpha} l_{t+j|t}^{1-\alpha} - w_{t+j} l_{t+j|t} + \frac{p_{t-1}^k}{\Pi_{i=0}^j \pi_{t+i}} \bar{k}_t (1-\omega) - R_t^{l,nom} \frac{p_{t-1}^k}{\Pi_{i=0}^j \pi_{t+i}} \bar{k}_t \right\}.$$

where $\frac{P_{t-1}^k}{P_{t+j}} \equiv p_{t-1}^k \frac{P_{t-1}}{P_{t+j}} \equiv \frac{p_{t-1}^k}{\Pi_{i=0}^j \pi_{t+i}}$ with $p_{t-1}^k = \frac{P_{t-1}^k}{P_{t-1}}$.

Note also that $\Pi_{i=0}^j \pi_{t+i} \equiv \pi_t \Pi_{i=1}^j \pi_{t+i}$. Exploiting this, we can express the loan interest rate in real terms within the stream of profits

$$\max_{\bar{k}_t} \sum_{j=0}^{+\infty} \zeta_k^j \Lambda_{t,t+j} \left\{ p_{t+j}^m a_{t+j} \bar{k}_t^{\alpha} l_{t+j|t}^{1-\alpha} - w_{t+j} l_{t+j|t} + \frac{p_{t-1}^k}{\pi_t \Pi_{i=1}^j \pi_{t+i}} \bar{k}_t (1-\omega) - R_t^l \frac{p_{t-1}^k}{\Pi_{i=1}^j \pi_{t+i}} \bar{k}_t \right\}. \quad \text{(C.16)}$$

where of course $R_t^l = \frac{R_t^{l,nom}}{\pi_t}$ is the real interest rate on loans at time t. Now intermediate firm profits are expressed in real terms and explicitly includes the nominal adjustment of loans to inflation.

The optimal quantity of labor for firms that lastly re-optimized on capital in t, can be rewritten as:

$$\frac{\partial \mathcal{L}}{\partial l_{t+j}} = 0 \Longleftrightarrow l_{t+j|t} = \left(\frac{w_{t+j}}{p^m_{t+j} a_{t+j} (1-\alpha)}\right)^{-\frac{1}{\alpha}} \bar{k}_t. \tag{C.17}$$

The optimal condition for capital is:[15]

$$\frac{\partial \mathcal{L}}{\partial \bar{k}_t} = 0 \Longleftrightarrow \sum_{j=0}^{+\infty} \zeta_k^j \Lambda_{t,t+j} \left\{ \alpha p^m_{t+j} a_{t+j} \bar{k}_t^{\alpha-1} l_{t+j|t}^{1-\alpha} - \left[R^l_t - \frac{1-\omega}{\pi_t}\right] \frac{p^k_{t-1}}{\Pi_{i=1}^j \pi_{t+i}} \right\} = 0. \tag{C.18}$$

Plugging (C.17) into the latter reads

$$\sum_{j=0}^{+\infty} \zeta_k^j \Lambda_{t,t+j} \left\{ \alpha \left(p^m_{t+j} a_{t+j}\right)^{\frac{1}{\alpha}} \left[\frac{w_{t+j}}{(1-\alpha)}\right]^{-\frac{1-\alpha}{\alpha}} - \left[R^l_t - \frac{1-\omega}{\pi_t}\right] \frac{p^k_{t-1}}{\Pi_{i=1}^j \pi_{t+i}} \right\} = 0. \tag{C.19}$$

This equation indicates that, on aggregate, the optimal capital and labor choices depend on aggregate prices.

The above can be broken down into three addends

$$\sum_{j=0}^{+\infty} \zeta_k^j \Lambda_{t,t+j} \alpha \left(p^m_{t+j} a_{t+j}\right)^{\frac{1}{\alpha}} \left[\frac{w_{t+j}}{(1-\alpha)}\right]^{-\frac{1-\alpha}{\alpha}} - \sum_{j=0}^{+\infty} \zeta_k^j \Lambda_{t,t+j} R^l_t \frac{p^k_{t-1}}{\Pi_{i=1}^j \pi_{t+i}} + \sum_{j=0}^{+\infty} \zeta_k^j \Lambda_{t,t+j} \frac{1-\omega}{\pi_t} \frac{p^k_{t-1}}{\Pi_{i=1}^j \pi_{t+i}} = 0.$$

The first addend can be written recursively as

$$z_{1,t} = \alpha \left(p^m_t a_t\right)^{\frac{1}{\alpha}} \left[\frac{w_t}{(1-\alpha)}\right]^{-\frac{1-\alpha}{\alpha}} + \zeta_k \Lambda_{t,t+1} z_{1,t+1}. \tag{C.20}$$

The second addend reads

$$R^l_t p^k_{t-1} z_{2,t}. \tag{C.21}$$

The third addend can be written as

[15]Similarly to Gertler and Karadi (2011), we assume that any profit made by firms is paid as dividends to household in each period. This assumption rules out the presence of any self-financing practice by good-producing firms and, as already pointed out by Andreasen et al. (2013), helps to single out the effect of long-term credit in the economy.

$$(1-\omega)\frac{p^k_{t-1}}{\pi_t}z_{3,t}, \tag{C.22}$$

with

$$z_{2,t} = 1 + \zeta_k \Lambda_{t,t+1}\frac{z_{2,t+1}}{\pi_{t+1}}, \tag{C.23}$$

and $z_{3,t} = z_{2,t}$.[16]

So the intermediate firms FOC reads

$$R^l_t p^k_{t-1} z_{2,t} = z_{1,t} + (1-\omega)\frac{p^k_{t-1}}{\pi_t}z_{3,t} \tag{C.24}$$

C.3.2 adjustable-rate Type

The contract set-up is basically the same as before. The only difference being that the loan interest rate carries a time varying subscript all over the sum. In fact, firms profits stream reads

$$\max_{\bar{k}_t}\sum_{j=0}^{+\infty}\zeta^j_k\Lambda_{t,t+j}\left\{p^m_{t+j}a_{t+j}\bar{k}^\alpha_t l^{1-\alpha}_{t+j|t} - w_{t+j}l_{t+j|t} + \frac{p^k_{t-1}}{\Pi^j_{i=0}\pi_{t+i}}\bar{k}_t(1-\omega) - R^{l,nom}_{t+j}\frac{p^k_{t-1}}{\Pi^j_{i=0}\pi_{t+i}}\bar{k}_t\right\}.$$

Defining $R^l_{t+j} = \frac{R^{l,nom}_{t+j}}{\pi_{t+j}}$ and multiplying and dividing the last addend by π_{t+j} we have

$$\max_{\bar{k}_t}\sum_{j=0}^{+\infty}\zeta^j_k\Lambda_{t,t+j}\left\{p^m_{t+j}a_{t+j}\bar{k}^\alpha_t l^{1-\alpha}_{t+j|t} - w_{t+j}l_{t+j|t} + \frac{p^k_{t-1}}{\Pi^j_{i=0}\pi_{t+i}}\bar{k}_t(1-\omega) - R^l_{t+j}\frac{\pi_{t+j}p^k_{t-1}}{\Pi^j_{i=0}\pi_{t+i}}\bar{k}_t\right\}.$$

Similarly to what we have previously seen, the capital FOC boils down to

$$\sum_{j=0}^{+\infty}\zeta^j_k\Lambda_{t,t+j}\left\{\alpha\left(p^m_{t+j}a_{t+j}\right)^{\frac{1}{\alpha}}\left[\frac{w_{t+j}}{(1-\alpha)}\right]^{-\frac{1-\alpha}{\alpha}} - \left[\frac{R^l_{t+j}\pi_{t+j}}{\pi_t} - \frac{1-\omega}{\pi_t}\right]\frac{p^k_{t-1}}{\Pi^j_{i=1}\pi_{t+i}}\right\} = 0. \tag{C.25}$$

[16]The distinction between z_2 and z_3 is made to keep notation coherent with what is presented in the next section.

As before, this can be broken down into three components

$$\sum_{j=0}^{+\infty} \zeta_k^j \Lambda_{t,t+j} \alpha \left(p_{t+j}^m a_{t+j}\right)^{\frac{1}{\alpha}} \left[\frac{w_{t+j}}{(1-\alpha)}\right]^{-\frac{1-\alpha}{\alpha}} - \sum_{j=0}^{+\infty} \zeta_k^j \Lambda_{t,t+j} \frac{R_{t+j}^l \pi_{t+j}}{\pi_t} \frac{p_{t-1}^k}{\Pi_{i=1}^j \pi_{t+i}} + \sum_{j=0}^{+\infty} \zeta_k^j \Lambda_{t,t+j} \frac{1-\omega}{\pi_t} \frac{p_{t-1}^k}{\Pi_{i=1}^j \pi_{t+i}} = 0.$$

The first addend is the same as (C.20). The second addend reads

$$\frac{p_{t-1}^k}{\pi_t} z_{2,t} \tag{C.26}$$

with $z_{2,t} = R_t^l \pi_t + \zeta_k \Lambda_{t,t+1} \frac{z_{2,t+1}}{\pi_{t+1}}$.

The third one can be written as

$$(1-\omega) \frac{p_{t-1}^k}{\pi_t} z_{3,t}, \tag{C.27}$$

where $z_{3,t} = 1 + \zeta_k \Lambda_{t,t+1} \frac{z_{3,t+1}}{\pi_{t+1}}$.

So, in this case the capital FOC reads

$$\frac{p_{t-1}^k}{\pi_t} z_{2,t} = z_{1,t} + (1-\omega) \frac{p_{t-1}^k}{\pi_t} z_{3,t} \tag{C.28}$$

Equation (C.28) says that when optimally choosing capital, the intermediate firm takes into account the expected evolution of loan rates.

Note that (C.28) and (C.24) are equivalent when $\zeta_k = 0$, i.e. loan maturity is 1 quarter.

C.4 Capital Firms

Capital firms own the stock of capital, sell it to the intermediate firm, repair the capital throughout the whole loan contract duration, are paid a maintenance fee ω, and produce investment needed in the economy.

Let v_{t+j} be a recursive variable taking into account the several loan vintages.

The capital firms maximization problem goes as follows

$$\max_{k_{t+1},\bar{k}_{t+1},i_t,v_t} \sum_{j=0}^{+\infty} [v_{t+j} - (1-\omega)v_{t+j} - i_{t+j}]$$

s.t.

$$\begin{aligned}
v_t \leq &(1-\zeta_k)p_t^k \bar{k}_{t+1} + \zeta_k \frac{v_{t-1}}{\pi_t} \\
k_{t+1} \leq &(1-\delta)k_t + \left[1 - \frac{\gamma^I}{2}\left(\frac{i_t}{i_{t-1}} - 1\right)^2\right] i_t \\
k_{t+1} \geq &(1-\zeta_k)\bar{k}_{t+1} + \zeta_k k_t
\end{aligned}$$

The Lagrangean reads

$$\begin{aligned}
\mathcal{L} = &\omega v_t - i_t - u_{1,t}\left[v_t - (1-\zeta_k)p_t^k \bar{k}_{t+1} - \zeta_k \frac{v_{t-1}}{\pi_t}\right] + u_{3,t}\left[k_{t+1} - (1-\zeta_k)\bar{k}_{t+1} - \zeta_k k_t\right] + \\
&- q_t \left\{k_{t+1} - (1-\delta)k_t - \left[1 - \frac{\gamma^I}{2}\left(\frac{i_t}{i_{t-1}} - 1\right)^2\right] i_t\right\} + \\
&- \Lambda_{t,t+1} u_{1,t+1}\left[v_{t+1} - (1-\zeta_k)p_{t+1}^k \bar{k}_{t+2} - \zeta_k \frac{v_t}{\pi_{t+1}}\right] + \\
&+ \Lambda_{t,t+1} u_{3,t+1}\left[k_{t+2} - (1-\zeta_k)\bar{k}_{t+2} - \zeta_k k_{t+1}\right] + \\
&- \Lambda_{t,t+1} q_{t+1} \left\{k_{t+2} - (1-\delta)k_{t+1} - \left[1 - \frac{\gamma^I}{2}\left(\frac{i_{t+1}}{i_t} - 1\right)^2\right] i_{t+1}\right\} + ...
\end{aligned}$$

The FOCs read

$$\frac{\partial \mathcal{L}}{\partial v_t} = 0 \Longleftrightarrow u_{1,t} = \omega + \zeta_k \Lambda_{t,t+1} \frac{u_{1,t+1}}{\pi_{t+1}}$$

$$\frac{\partial \mathcal{L}}{\partial \bar{k}_{t+1}} = 0 \Longleftrightarrow p_t^k = \frac{u_{3,t}}{u_{1,t}}$$

$$\frac{\partial \mathcal{L}}{\partial k_{t+1}} = 0 \Longleftrightarrow q_t = u_{3,t} + \Lambda_{t,t+1} q_{t+1}(1-\delta) - \zeta_k \Lambda_{t,t+1} u_{3,t+1}$$

$$\frac{\partial \mathcal{L}}{\partial i_t} = 0 \Longleftrightarrow 1 = q_t \left[1 - \frac{\gamma^I}{2} \left(\frac{i_t}{i_{t-1}} - 1 \right)^2 - \gamma^I \left(\frac{i_t}{i_{t-1}} - 1 \right) \frac{i_t}{i_{t-1}} \right] + \gamma^I \Lambda_{t,t+1} q_{t+1} \left(\frac{i_{t+1}}{i_t} - 1 \right) \left(\frac{i_{t+1}}{i_t} \right)^2$$

C.5 Banks

The banking sector is modeled following Gertler et al. (2012) and Andreasen et al. (2013). We account for a simple agency problem between banks and households that, by constraining banks' leverage, limit the credit provided to good-producing firms. When bankers retire, they transfer their wealth to households. The transition from old to new bankers, with the same liability and asset structure, is managed by an insurance agency funded by a proportional contribution on banks' net wealth. This setup guarantees the existence of a representative bank in our economy.

Bank short term financial resources that can be used for making long-term loans to firms are of two types. The first one is retained earnings, i.e. net worth n_t, resulting from bank business activity. The second one is one-period deposits from households, d_t, remunerated at the predetermined rate R_{t+1}.

For the representative bank, the flow-of-funds constraint implies that in each period the amount of the bank's lending, len_t, equals the total liabilities:

$$len_{t+1} = n_t + d_t, \tag{C.29}$$

Under our assumption that firms re-optimize their capital stock infrequently, bank's lending can be written as follows:

$$len_t = (1-\zeta_k)p^k_{t-1}\bar{k}_t + \zeta_k \frac{len_{t-1}}{\pi_t}. \tag{C.30}$$

that is, a share $1-\zeta_k$ of bank lending is attributable to firms that optimize for production in t, the share $\zeta_k(1-\zeta_k)$ to those that have optimized for production in $t-1$, the share $\zeta_k(1-\zeta_k)^2$ in $t-2$, and so on.

Banker's net worth is generated out of income flows, as follows:

$$n_t = (1-\tau)\left[rev_t - R_t d_{t-1}\right], \tag{C.31}$$

where τ is the tax due to finance the insurance agency. rev_t are the proceedings accruing to banks from their lending activity. The evolution of banks ' revenue mirrors (C.30) in the case of fixed-rate loan contract:

$$rev_t = (1-\zeta_k)R^l_t p^k_{t-1}\bar{k}_t + \zeta_k \frac{rev_{t-1}}{\pi_t}, \tag{C.32}$$

while it is as follows in the case of adjustable-rate loan contracts

$$rev_t = R^l_t len_t, \tag{C.33}$$

as the whole loan stock proceedings simultaneously update to changes in the interest rate.

with the gross loan rate equal to $R^l_t = 1 + r^l_t$. Moreover, rearranging conditions (C.29) and (C.31), the law of motion of the banker's net worth is the following

$$n_t = (1-\tau)\left\{\left[\frac{rev_t}{len_t} - R_t\right] len_t + R_t n_{t-1}\right\}, \tag{C.34}$$

Given the financing constraint, the banker finds it optimal to retain all its earnings until its exit from the market, which occurs with probability $(1-\sigma)$ in each period. At that point the banker pays the dividend to her own household. The expected present value of the future terminal dividends is thus

$$\mathcal{V}_t = E_t \left\{ \sum_{j=0}^{+\infty} \sigma(1-\sigma)^j \Lambda_{t,t+j+1} n_{t+j+1} \right\}. \tag{C.35}$$

Following Gertler and Kiyotaki (2010), we motivate the endogenous constraint on the bank's capability of obtaining additional funds from households by introducing a simple agency problem. In each period, the banker can choose to divert a fraction of its funds from the project and transfer them back to the household to which it belongs. As households are aware of this possibility, they limit the funds lent to the bank.

Upon diverting its assets, the banker defaults on its debt, and creditors can claim only the fraction $(1-\Theta$ of their own assets. This possibility limits the amount households are willing to lend to banks.

To prevent the banker from diverting funds, the incentive compatibility constraint must hold:

$$\mathcal{V}_t(len_{t+1}, n_t) \geq \Theta len_{t+1}, \tag{C.36}$$

i.e. the maximized value of the bank's objective given a certain asset-liability configuration at the end of period t, $\mathcal{V}_t(len_t, n_t)$, cannot be lower than the proceedings the banker would obtain from diverting funds.

The franchise value of the bank accounts for the probability of exiting from the market and satisfies the following Bellman equation:

$$\mathcal{V}_{t-1}\left(len_t, n_{t-1}\right) = E\Lambda_{t-1,t} \left\{ (1-\sigma)n_t + \sigma \max_{\bar{k}_{t+1}} \left[\mathcal{V}_t\left(len_{t+1}, n_t\right) \right] \right\}. \tag{C.37}$$

In each period, the banker thus chooses the optimal levels of $\bar{k}$ and x to maximize $\mathcal{V}_t\left(len_t, n_t\right)$ subject to (29) and (31).

Following Gertler et al. (2012) we assume that the value function is a function of the components of the balance sheet:[17]

$$\mathcal{V}_t = \mu_{s,t} len_{t+1} + \nu_t n_t. \tag{C.38}$$

[17]See Appendix A for the derivation and verification of this conjecture.

The internal leverage condition implies that the amount of credit lent out by the bank is limited by its net worth:

$$\phi_t = \frac{len_{t+1}}{n_t}, \tag{C.39}$$

where from the bank's optimization problem it follows that

$$\phi_t = \frac{\nu_t}{\Theta - \mu_{s,t}}, \tag{C.40}$$

with

$$\nu_t = (1-\tau)E\left[\Lambda_{t,t+1}\Omega_{t+1}\right]R_{t+1} \tag{C.41}$$

$$\mu_{s,t} = (1-\tau)E\left[\Lambda_{t,t+1}\Omega_{t+1}\left(\frac{rev_t}{len_t} - R_{t+1}\right)\right] \tag{C.42}$$

ν_t is the marginal saving in deposit costs from one additional unit of net worth funding, $\mu s, t$ summarizes the excess value of assets over deposits.

The shadow value of a net worth unit to the bank in the next quarter is given by:

$$\Omega_{t+1} = (1-\sigma) + \sigma E\left(\mu_{s,t+1}\phi_{t+1} + \nu_{t+1}\right) \tag{C.43}$$

The leverage, ϕ_t, is decreasing in the fraction of divertible funds, Θ, as it tightens the incentive compatibility constraint the banker is subject to. By contrast, it is increasing in ν_t and in the discounted excess value of the bank's assets, $\mu_{s,t}$, as, by reducing the incentive of banks to divert funds, they make creditors willing to lend more.

The inside leverage is negatively correlated with risk perception. In particular, the banker evaluates expected returns by means of a composite discount factor, i.e. $\Lambda_{t,t+1}\Omega_{t+1}$, which varies countercyclically as both the household stochastic discount factor $\Lambda_{t,t+1}$ and the shadow value of net worth Ω_{t+1} are countercyclical. When uncertainty increases, the counter-cyclical behavior of the composite discount factor reduces the excess value of banks' assets, i.e. $\mu_{s,t}$, and its continuation value. Then, the leverage ratio decreases, and consequently, the bank's ability to obtain funds is more contained.

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