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Abstract

This paper investigates the costs of disinflation in an otherwise standard DSGE model with borrowing constraints and credit frictions, augmented with macroprudential authority. Analyzing the real and welfare effects of a permanent change in the inflation rate, we study the role of macroprudential policy and its interaction with monetary policy in ensuring financial stability. Results show that when macroprudential authority intervenes actively in order to improve financial stability, disinflation costs are limited. As for the welfare effects, disinflation is welfare improving for savers but welfare costly for borrowers and banks.

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Keywords: Disinflation, Macroprudential policy, Loan-to-value ratio, Monetary policy, Sacrifice ratio, Welfare effects

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1 Introduction

Inflation is currently the main topic of debate among policymakers and a long-standing issue in macroeconomics. According to the Federal Reserve and the European Central Bank, the increase in inflation we are witnessing nowadays should come back to central banks targets within one or two years. However, the risk that inflation remains persistently high for longer is not null. The department 's Bureau of Labor Statistics in 2021 reports an increase of 7% of the consumer price index in the US increased by 7% (Figure 1).

Fig. 1 - US Consumer price index, percent change from a year ago (Cox, 2022).

Such a climb was the fastest increase in the US since 1982. Afterall, price-driving factors are temporary in principle but can reinforce each other, influencing inflation dynamics permanently (Beckmann et al., 2021). In that context, disinflationary policies go back to being a forefront economic policy tool in the macroeconomic debate.

Economic literature unanimously argues that disinflation entails short-run output losses. On empirical side, disinflation costs are measured by the Sacrifice Ratio (SR, henceforth) defined as the cumulative output losses the economy has to sacrifice to achieve one percentage point reduction of inflation. SR measures can be affected by different estimation methods, different historical periods and countries considered. According to the empirical evidence, a credible range for SRs values is between 0.5 and 3. Mankiw (2000) finds that the SR for the US economy during the Volcker disinflation is equal to 2.8, while Corbo et al. (2001) estimates a SR of 0.6 for a large group of inflation-targeting countries. For Euro-area countries, Durand et al. (2008) estimate much lower values of SR, between 0.2-0.8, while Collard et al. (2007) and Fève et al. (2010) find an average SR of 4.3.

On theoretical side, and consistently with the stylized facts, Dynamic Stochastic General Equilibrium (DSGE, herefter) models can explain a costly disinflation. Relatively to the US economy, Ascari and Ropele (2012 a, b) simulate a permanent change in the inflation rate focusing on costs of a cold-turkey disinflation. Ascari and Ropele (2013) measure disinflation costs comparing different monetary policy rules, i.e. nominal money supply rule *vs* interest rate rule. In a framework with homogeneous agents these contributions show that, despite the costs on real economy, disinflation produce gains from a welfare viewpoint. In a Two-Agent New Keynesian (TANK) model for the US economy Ferrara and Tirelli (2020) evaluate the redistributive and welfare effects of a monetary policy regime change according to different price-setting mechanisms and show that disinflation is always welfare improving for asset holders. However, ambiguous welfare results come out for the non asset holders, who face important consumption losses during the transition[1].

However, the literature on disinflationary policies ignores an important issue already come out in the afterrmath of 2007 financial crisis: guaranteeing the financial stability and avoiding possible systemic risks in the financial system. These aims turn out to be even more relevant in the actual context of recovery after pandemic to support banks to lend more to the borrowers harmed by the recent economic crisis. Exactly here is the role of the macroprudential policies aiming to limit the propagation of financial risks. The main front of the literature on macroprudential DSGE models considers two macroprudential policy instruments: capital requirements and loan-to-value ratio (LTV ratio, henceforth). In this context, several contributions evaluate the cooperation between monetary and macroprudential policies with a focus on price and financial stability trade-off. When the central bank directly responds to financial variables as well, a trade-off between its primary objective of price stability and the financial stability objective can emerge. Indeed, such monetary policy could dampen financial risks, but at the cost of higher price instability (Fouejieu et al., 2019). In light of that, a disinflationary policy would be more difficult to implement. However theoretical literature assesses the trade-off between inflation and financial stability in the presence of macroprudential policies as well. Angelini et al. (2011, 2014a) analyze the role of the two macroprudential tools to assess the trade-off between price and financial stability. They suggest that when the economy is hit by financial shocks, which are important drivers of macroeconomic fluctuations, macroprudential policy contributes effectively to guarantee macroeconomic stability. Rubio and Carrasco-Gallego (2016) study the interaction between Basel I, II and III regulations with monetary policy and demonstrate that the countercyclical capital buffer stated by Basel III promotes stability and reduces systemic risk. Likewise, Rubio and Yao (2019) show how macroprudential policy can simultaneously contribute to financial and macroeconomic stability. They analyze the implementation of macroprudential policies in a low-interest rate environment with occasionally binding Zero Lower Bound, by considering different LTV rules. Also Christensen and Meh (2011) emphasize the important goal of macroprudential policies to mitigate risks to the financial system and to reduce real losses in terms of economic performance. They demonstrate that in the face of a financial shock, a countercyclical LTV is a more effective tool for stabilization than monetary policy. Millard et al. (2021) examine the interaction of macroprudential policies with monetary policy considering a third macroprudential tool, that is the affordability constraints on mortgage borrowing, in addition to the LTV ratio and the capital requirements on banks. They find that macroprudential policy help monetary policy to achieve its primary objective.

This paper contributes to the literature that analyzes the trade-off between monetary and financial stability and focuses on the role of macroprudential policy when a disinflationary policy

[1] For Chinese economy, disinflation produces output losses, as well; although the policy is less costly when the monetray policy regime follows an extended Taylor rule with money (Ferrara et al., 2020). In addition, disinflationary policies impact differently on households' ability to smooth consumption, producing important redistributive effects.

operates. To our purposes, we ask the following questions: 1) how much costly is disinflation under different macroprudential and/or monetary policy interventions?; 2) what are the welfare and redistributive effects? We answer these questions simulating a permanent monetary policy shock in a DSGE model with borrowing constraints and credit frictions à la Rubio and Carrasco-Gallego (2016). In particular, we evaluate the real and welfare effects during a disinflation process working with an active macroprudential policy, namely an increasing LTV ratio. Thereby the macroprudential authority makes the collateral constraint less binding, allowing borrowers to access more credit. On the contrary, a non-active macroprudential policy namely with a fixed LTV ratio more constrains borrowers in accessing credit. The analysis is also carried out taking into account different monetary policy rules which change according to a response of the interest rate to different variables including inflation, output gap, house prices, and loans.

We do think this is an interesting issue to investigate because, as far as we know, there are no contributions analyzing the disinflation topic in a macroprudential framework and credit frictions. In addition, the question appears even more relevant in the current context of the continuous rise in inflation which is igniting the today's macroeconomic debate.

Our results can be summarized as follows. First, disinflation produces short-run output costs but when macroprudential authority intervenes actively in order to improve the financial stability, losses are limited. Indeed, the obtained SR is always higher when the LTV is a constant. Second, disinflation costs are lower when the central bank pursues the goals both of price and output stability. Indeed the SR as well is lower than in the other monetary policy scenarios. The reason lies in the fact that under this monetary policy, inflation takes more quarters to reach the new steady-state level, and thus the disinflation process is slower.

Third, disinflation is always welfare improving for savers but welfare costly for borrowers and banks. However, while savers and banks benefit from an active intervention of the macroprudential authority, borrowers are harmed by the increase in LTV ratio because of increasing borrowing costs. Furthermore, welfare costs are lower for borrowers and banks when monetary policy pursues the goals both of price and output stability. Indeed, they prefer high inflation environments and thus a slower disinflation process. On the contrary, savers prefer price stability and so a faster disinflation process.

The rest of the paper is organized as follows. Section 2 shows a summary of the model. Section 3 describes the disinflation experiment. The calibration of the model is reported in Section 4. The transition dynamics of the main macroeconomic and financial variables are explained in Section 5. In the same section, we also investigate the real and welfare effects of the disinflation experiment. Section 6 concludes and discusses policy implications.

2 A summary of the model

Starting from the seminal paper of Iacoviello (2015), we employ an extended version of the DSGE New Keynesian model with the housing market and macroprudential policy developed in Rubio and Carrasco-Gallego (2016). The economy includes households, banks, firms, and two authorities, the central bank.and the macroprudential regulator.

Households work and consume both consumption goods and housing. We model two types of households: savers and borrowers. The former, who are patient agents, deposit their savings in the bank, while borrowers are impatient, and borrow from the bank. Banks intermediate funds among households, and are credit constrained in borrowing from savers. Instead, impatient agents are credit constrained in borrowing from banks. Firms convert household labor into the final good and prices are sticky à la Calvo (1983) with indexation. The monetary authority follows different Taylor rules in setting the interest rate, while the macroprudential authority follows a Taylor-type rule in setting loan-to-value ratio. In what follows, we focus on monetary and macroprudential policy rules, while the full model will be discussed in Appendix A.

2.1 Monetary policy

In this subection, we show different scenarios according to which the central bank implements the monetary policy. Specifically, we consider five alternative rules, as follows:

Scenario 1. A standard Taylor-type monetary policy rule where the nominal interest rate targeting rule responds only to inflation target:

$$\frac{R_{s,t}}{R_s} = \left(\frac{\pi_t}{\pi}\right)^{\phi_\pi^R}, \tag{1}$$

where $\phi_\pi^R \geq 0$ measures the response of the interest rate to inflation gap;

Scenario 2. The monetary policy instrument responds both to inflation target and output gap, in order to pursue the objective of price stability. According to this Taylor rule, the short-term nominal interest rate increases in reaction to both the inflation and the output gap:

$$\frac{R_{s,t}}{R_s} = \left(\frac{\pi_t}{\pi}\right)^{\phi_\pi^R} \left(\frac{y_t}{y}\right)^{\phi_y^R}, \tag{2}$$

where $\phi_y^R \geq 0$ indicates the response of the interest rate to output gap;

Scenario 3. A Taylor rule which responds to inflation target and output gap with interest rate smoothing:

$$R_{s,t} = (R_{s,t-1})^\rho \left(\left(\frac{\pi_t}{\pi}\right)^{\phi_\pi^R} \left(\frac{y_t}{y}\right)^{\phi_y^R}\right)^{1-\rho}, \tag{3}$$

where $0 \leq \rho \leq 1$ is the interest rate inertia;

Scenario 4. An augmented Taylor rule with an argument whereby the short-term nominal interest rate increases in reaction to the housing prices gap:

$$R_{s,t} = (R_{s,t-1})^\rho \left(\left(\frac{\pi_t}{\pi}\right)^{\phi_\pi^R} \left(\frac{y_t}{y}\right)^{\phi_y^R} \left(\frac{q_t}{q}\right)^{\phi_q^R}\right)^{1-\rho}, \tag{4}$$

where $\phi_q^R \geq 0$ represents the response of the interest rate to the housing gap;

Scenario 5. A countercyclical monetary policy vis-a-vis household debt, where the policy rate directly responds to the growth rate in household debt as well:

$$R_{s,t} = (R_{s,t-1})^\rho \left(\left(\frac{\pi_t}{\pi}\right)^{\phi_\pi^R} \left(\frac{y_t}{y}\right)^{\phi_y^R} \left(\frac{b_t}{b_{t-1}}\right)^{\phi_b^R}\right)^{1-\rho}, \tag{5}$$

where $\phi_b^R \geq 0$ measures the response of the interest rate to credit growth.

2.2 Macroprudential policy

We assume that the macroprudential policy instrument is the LTV ratio, à la Rubio and Yao (2019). Specifically, we consider a simple macroprudential Taylor-type rule whereby the LTV ratio κ_t, reacts inversely to the deviation of credit from its steady-state, by moderating credit booms. When the macroprudential authority increases κ_t the collateral constraint is less tight, implying that borrowers can borrow as much as they are allowed. Viceversa, when the authority reduces the LTV ratio, the borrowing constraint is tighter, implying that borrowers can obtain fewer loans. The LTV ratio rule follows:

$$\kappa_t = (\kappa)\left(\frac{b_t}{b}\right)^{-\phi_b}, \tag{6}$$

where κ denote a steady-state value for the LTV, and ϕ_b represents the response of the LTV ratio to the credit gap.

3 Disinflationary policy experiment

This section explains the disinflation experiment we carry out. Following Ascari and Ropele (2012b), we implement the disinflation experiment reducing the inflation rate permanently. To do that, we simulate transition dynamics from a high-inflation steady-state to a low-inflation steady-state. Specifically, we set the first inflation target π^*_{old} to 8%, and the second inflation target π^*_{new} to 2%[2]. The new inflation target value is very close to the actual objective of many central banks including, for example, the European Central Bank, the Bank of England, and the Bank of Canada. Moreover, it is in line with recent estimates of the Federal Reserve's implicit inflation target (Ascari and Ropele, 2012b).

To analyze the pure role of monetary policy during the disinflation process, we replicate the permanent reduction in inflation experiment for each of the five Taylor rules shown above. In addition, to study the pure role of macroprudential policy, for each monetary policy rule, we repeat the disinflation experiment both assuming that the LTV ratio follows the equation 6 and that it is equal to a fixed value. In the first case, the macroprudential authority increasing the LTV ratio makes the collateral constraint less binding, allowing borrowers to access more credit. On the opposite, a non-active macroprudential policy more constrains borrowers in accessing credit.

4 Calibration

This section reports the quarterly calibration of monetary and macroprudential policies' parameters[3]. Table 1 shows their description and details.

[2] We numerically solve the nonlinear model in Dynare using perfect foresight. Dynare is a software platform for handling a wide class of economic models including Dynamic Stochastic General Equilibrium (DSGE) models. For more details, see https://www.dynare.org/.

[3] The baseline calibration of structural parameters follows Rubio and Carrasco-Gallego (2016) and is consistent with the US data. Appendix B reports the details.

As for the monetary policy, to simulate the disinflation experiment we set the initial steady state value of inflation equal to 8% and the second steady state value equal to 2% in the spirit of Ascari and Ropele (2012b). For each Taylor rule shown in Subsection 2.7, the parameter governing inflation stabilization ϕ_π^R is set to 1.5 according to Ascari and Ropele (2012b). Instead, the parameter governing the output stabilization ϕ_y^R is calibrated at 0.5 in equations 2 - 5 consistently with the classical Taylor rule specification. The parameter denoting the coefficient for interest rate smoothing ρ is fixed at 0.8 in equations 3 - 5, following Rubio and Carrasco-Gallego (2016). Finally, the parameter governing the response of the monetary policy rule to house prices ϕ_q^R is set to 0.1 in 4 as in Rubio and Carrasco-Gallego (2015) and the parameter denoting the response of the monetary policy rule to borrowers debit ϕ_b^R is calibrated at 0.1 in 5 as in Alpanda and Zubairy (2017).

As for the macroprudential rule, we fixed the parameter denoting the LTV ratio κ at 0.9 while the policy parameter ϕ_b at 0.43, consistently with Rubio and Yao (2019). Furthermore, the parameter γ representing the fraction of banks' assets that cannot be exceed by liabilities, is set at 0.895[4].

Table 1

Monetary and Macroprudential policies' Parameters Values

Parameter	Value	Description
Monetary Policy		
π^*_{old}	8%	Inflation (old target)
π^*_{new}	2%	Inflation (new target)
ϕ_π^R	1.5	Inflation stabilization
ϕ_y^R	0.5	Output stabilization
ρ	0.8	Coefficient for interest rate smoothing
ϕ_q^R	0.1	TR response to house prices
ϕ_b^R	0.1	TR response to debit
Macroprudential Policy		
κ^*	0.9	Steady-state LTV ratio
ϕ_b	0.43	Policy parameter for the LTV response
γ	0.895	1 - CRR for Basel III (10.5%)

5 Results

In this section, we analyze the short-run effects of a disinflation process during which the central bank reduces inflation from 8% to the target level of 2%. Then, we compute the Sacrifice Ratio to measure disinflation costs in terms of output loss. Finally, we compute the Welfare-based Sacrifice Ratio (WRs, henceforth) to study the welfare effects of permanent reduction in inflation.

Moreover, to investigate the role of the macroprudential authority, we implement the disinflation experiment by assuming first that the LTV ratio follows a policy rule, and, then, that LTV is a parameter. Instead, to evaluate the role of the monetary policy we consider the five scenarios shown in Section 2. Therefore, we analyze the effects of the disinflation process from two different

[4] This value is given by $1 - CRR$. Following Rubio and Carrasco-Gallego (2016), we calibrate CRR parameter value at 10.5% in equation A.12, consistently with the Basel III regulations.

perspectives: on one hand, we compare the results considering both an active and a non-active intervention of macroprudential authority, for each monetary policy rule; on the other hand, we compare the results among different scenarios, being equal the macroprudential policy.

5.1 Transition dynamics

In this section, we assess the short-run effects of reducing inflation to its lower target level considering the monetary policy responds only to inflation as in equation 1[5]. Figures 2-3 show the transition dynamics of our disinflation experiment of the main macroeconomic and financial variables both in the case with the active intervention of macroprudential authority (red line) and not (blue line). In the first case, we let the LTV ratio increase via equation 6: thereby the macroprudential authority makes the borrowing constraint less tight, to dampen the recessive effects of disinflation. In the second case, we consider the LTV ratio as a fixed parameter.

Disinflation causes short-run output losses. The rate of inflation gradually decreases towards the new steady-state level, lowering nominal interest rates on loans and deposits. In other words, inflation inertia increases real interest rates. As a result, wages and worked hours reduce, causing a loss of income which, in turn, involves a reduction in households' consumption in the short run. However, while borrowers - who are liquidity-constrained households - consume their labor income period by period, savers are able to smooth their consumption. Indeed, Fig. 2 shows that the negative effects on their consumption are limited.

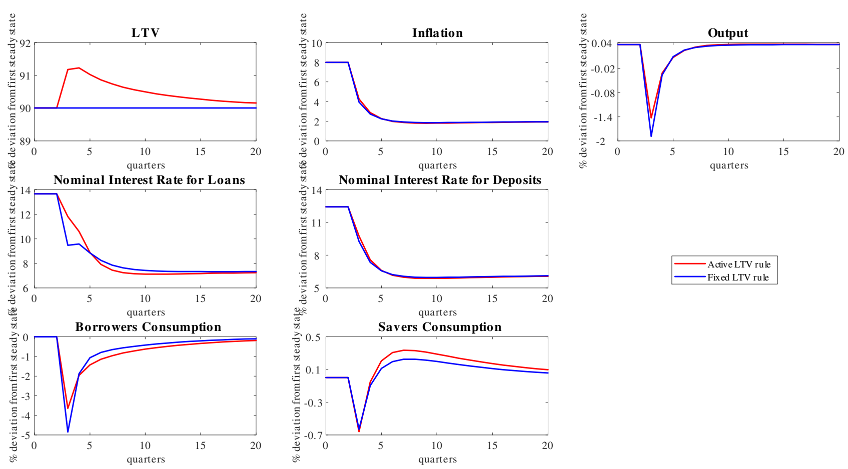

Fig. 2 - Short run effects of dinsinflation with and without active LTV rule

Furthermore, due to their lower-income, borrowers invest less in housing shares (Fig. 3). Thus, given the reduction in collateral and the increase in the real interest rate on the loans, they borrow less. Therefore, the loans decrease. On the other hand, savers, who are patient agents, expect that in the future, house prices increase and their housing shares will be worth more in the medium- and

[5] The short-run effects of the disinflation experiment are qualitatively the same for each monetary policy scenario (see equations 1 - 5). Therefore, for the sake of brevity, in this section, we only refer to the first scenario.

long-run[6]. Indeed, house prices, which are expressed in terms of consumption units, only initially decrease as a result of the reduction in both savers' and borrowers' consumption, and then increase, following the reduction in the nominal interest rate[7]. In other words, savers, who suffer less the costs of disinflation, prefer to invest in housing shares rather than to deposit, even if the real interest rate on deposits increases. Disinflation also impacts banks' consumption following the reduction in loans and deposits. Finally, banks have to face an increase in the real interest rate on deposits, larger than the one in the real interest rate on loans[8].

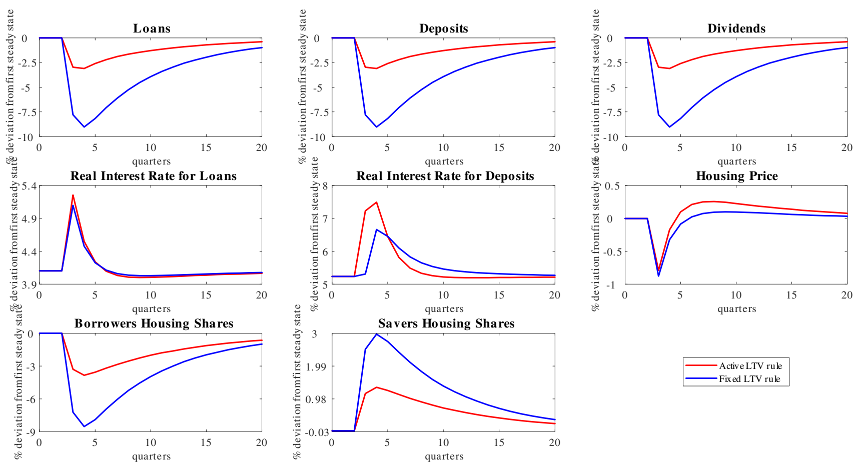

Fig. 3 - Short run effects of dinsinflation with and without active LTV rule

These results are qualitatively the same both in the case when the LTV ratio increases and not. However, an active intervention of the macroprudential authority aimed at facing the negative effects of disinflation improves financial stability. As a result, the transition dynamics of the main macroeconomic and financial variables are smaller than in the case in which the loan-to-value ratio is held constant.

5.2 Sacrifice Ratios

In this section we investigate the real effects of disinflation process by computing the model-consistent Sacrifice Ratio for output, in the spirit of Ascari and Ropele (2012a,b). We use the following formula:

$$SR = -\frac{1}{\pi^*_{old} - \pi^*_{new}} \sum_{t=0}^{T} \left(\frac{Y_t - Y^*_{old}}{Y^*_{old}} \right), \tag{7}$$

where the difference between π^*_{old} and π^*_{new} measures the size of disinflation in percentage points, Y^*_{old} is the steady-state value of output when the steady-state level of inflation is greater, and T is the number of periods required by inflation to reach the new steady-state level. Since the Sacrifice

[6] In addition, since the housing supply is fixed, if borrowers reduce their housing shares, savers invest more in them.

[7] This result is consistent with Rubio (2016). Indeed house prices, being an asset price, move inversely with the nominal interest rate.

[8] Real interest rate on loans together with loans represent the source of funds for banks, that are used to pay back depositors at a cost that is the real interest rate on deposits. In our model, this latter represents also the policy rate.

Ratio represents the cost of disinflation in the short-term, it is higher if the disinflation process is faster.

For comparison purposes, we first compute the SR within the same Scenario focusing on the pure role of the macroprudential policy, both by assuming that the LTV ratio is fixed and not; then, we calculate the costs of disinflation for each Scenario, investigating the role of the monetary policy, being equal the macroprudential policy. Results are shown in Table 2.

Table 2

Sacrifice Ratios, Percentage Variations

	Scen. 1	Scen. 2	Scen. 3	Scen. 4	Scen. 5
κ_t	0.47 (T=5)	0.34 (T=7)	0.48 (T=3)	0.47 (T=3)	0.45 (T=3)
κ	0.54 (T=5)	0.39 (T=8)	0.60 (T=4)	0.58 (T=4)	0.51 (T=4)

Note - We use κ_t for the active LTV rule and κ for the LTV parameter.

We show in parenthesis the timing of disinflation process.

Consider the role of the macroprudential policy first. When the loan-to-value ratio is a fixed parameter, the costs of disinflation are higher. Therefore, the absence of an active macroprudential rule worsens the transitional output costs of disinflation. This result confirms the importance of active intervention by macroprudential authority and its supportive role as a built-in stabilizer[9]. Indeed, the increase in the loan-to-value ratio by the macroprudential authority via equation 6 softens the financial accelerator mechanism related to the collateral constraint for borrowers. This, in turn, facilitates the stabilization of inflation, and so the aim of the monetary policy authority[10]. As a result, with the active LTV rule, the disinflation process is less costly, although faster.

As for the role of the monetary policy, by comparing different Scenarios and being equal the macroprudential policy, the timing of the disinflation process is relevant. The Sacrifice Ratio is lower when the nominal interest rate responds both to the inflation target and output gap to pursue the objective of price stability (see eq. 2). The reason lies in the fact that, in this case, inflation takes more quarters to reach the new steady-state level (T is equal to 7 and 6 with and without active LTV rule, respectively). Instead, a Taylor Rule which does not include the response to output as in equation 1, amplifies the financial accelerator mechanism represented by collateral constraint[11], entailing a greater SR. On the other hand, when the nominal interest rate rule includes the smoothing term as in equations 3 - 5, the faster reduction in inflation entails the higher SRs. However, among these inertial monetary policy rules, the Sacrifice Ratio is lower when the Taylor rule also responds to credit growth (Scenario 5) compared to the case in which it responds only to output (Scenario 3). This happens because the augmented Taylor Rule represents a proxy for the macroprudential instrument and, therefore, it contributes to the financial stability of the economy[12]. Similarly, disinflation costs are lower when the Taylor rule also responds to houses prices (Scenario

[9] See, for instance, Angelini et al., 2011, 2014 and Rubio et al. 2016, 2017, 2019, 2020a.

[10] In line with Beau et al., 2012.

[11] In other words, the central bank aims at implementing disinflation only and it does not intervene when output falls.

[12] In other words, the reason why the SR is lower when monetary policy follows 5 than 3 lies in the existence of a direct link between the policy rate and the borrowing rate which allows the authority to pursue the objectives of both macroeconomic and financial stability (consistently with Rubio (2017), and Alpanda and Zubairi (2017)).

4) compared to the case in which it responds only to output (Scenario 3). Indeed, the augmented monetary policy rule 4, being macroprudential itself, improves the economic stability[13].

5.3 Welfare Analysis

This section shows in Table 3 the welfare effects of the disinflation experiment for each monetary policy scenario both assuming active macroprudential policy and not. Following Ascari and Ropele (2012a), we compute the Welfare-based Sacrifice Ratio (hereafter WRs) by using the Consumption Equivalent Measure (CEM)[14].

Overall, disinflation is always welfare improving for savers, and welfare costly for borrowers and banks. As for savers, the lower labor disutility and the greater housing shares compensate for the negative variation in consumption, and so their welfare improves. On the contrary, disinflation is costly in terms of welfare for the borrowers because the lower labor disutility does not compensate for the decrease in housing demand and consumption. As for banks, instead, the reason why disinflation is welfare costly lies in loans and deposits reduction entailing a decrease in bank capital, and in turn, in dividends representing banks' consumption.

Moreover, the presence in our model of three sources of distortions namely price rigidities, credit frictions, and loan frictions, influences welfare results. More specifically, savers, as firm owners, prefer a low inflation environment and benefit from price stabilization policies aimed to reduce price stickiness distortion, including disinflation policy. On the contrary, borrowers are harmed by disinflation, because they prefer situations with high inflation (Rubio and Yao, 2019). They are worried about credit frictions, coming directly from collateral constraint through house prices and credit[15]. As well, collateral constraint impacts banks' side through loan frictions. Finally, borrowers and banks are harmed by the increase in the real interest rates on loans and deposits, respectively[16]. Therefore, different agents are affected by the volatility of different variables: savers' and borrowers' welfare is mainly influenced by macroeconomic and financial variables fluctuations, respectively[17]; instead, banks' welfare is affected by both.

Let's now compare the WRs shown in the table above. As for macroprudential policy, for each policy Scenario, savers and banks always benefit from an active intervention of the authority[18]. Indeed, in this case, negative effects of disinflation are mitigated by a more stable financial system. On the contrary, borrowers are always harmed by the increase in LTV ratio because of increasing borrowing costs[19]. As for monetary policy, our results show that Scenario 3 and Scenario 4 are the best for savers in terms of WR, being equal the macroprudential policy (-0.021 and -0.019 with active LTV rule and fixed LTV, respectively). Quite the opposite, these Scenarios are the worst for

[13] This result is consistent with Rubio and Carrasco-Gallego (2015).

[14] The derivations of the CEM and of the Welfare-based Ratio are reported in Appendix C.

[15] Consistent with transition dynamics shown in subsection 5.1, disinflation reduces housing prices, affecting the value of housing shares, and so, the collateral needed for loans.

[16] The higher real interest rate on loans harms borrowers, while the higher real interest rate on deposits harms banks. However, while banks benefit from a higher interest rate on loans, borrowers don't benefit from a higher interest rate on deposits.

[17] See, for instance, Rubio and Yao (2020) and Rubio (2020a).

[18] These results are consistent with sacrifice ratio results.

[19] More specifically, disinflation causes real interest rates to rise, increasing borrowing costs. These higher costs imply that if borrowers can demand more loans today - as it happens with active macroprudential policy rule - they will have to pay back more in the future, and then, they can consume less. In light of that, the reason why WRs are better for borrowers when the LTV ratio is a fixed parameter lies in the fact that they are more constrained in accessing credit. This, in turn, causes borrowers to recover faster in terms of consumption (as in Rubio, 2020a).

borrowers and banks, who suffer higher costs of disinflation in terms of welfare (WR values are the highest among Scenarios and regardless the type of macroprudential policy). This result highlights the existing trade-off between the agents: for savers, who prefer price stability, a faster disinflation process represents a higher gain in terms of welfare; on the contrary, for borrowers and banks, who prefer high inflation environments, a slower disinflation process represents a lower cost in terms of welfare. Indeed, their WRs are lower in the Scenario 2, that is the one in which inflation takes more quartes to reach its new and lower target level.

Table 3

WRs, Percentage Variations

π^*_{old} 8%	π^*_{new} 2%	Savers κ_t	Savers κ	Borrowers κ_t	Borrowers κ	Banks κ_t	Banks κ
Scen. 1		-0.018	-0.017	0.077	0.076	0.091	0.270
Scen. 2		-0.013	-0.011	0.053	0.049	0.066	0.187
Scen. 3		-0.021	-0.019	0.091	0.086	0.106	0.301
Scen. 4		-0.021	-0.019	0.091	0.084	0.106	0.295
Scen. 5		-0.020	-0.017	0.087	0.075	0.102	0.268

6 Conclusion and policy discussion

This paper investigates the real and welfare effects of a disinflationary policy in a model with borrowing constraints and credit frictions. To analyze the pure role of monetary policy, we design a disinflation policy experiment under different Taylor rules. In addition, to evaluate the pure role of macroprudential policy, we replicate the experiment both assuming the LTV ratio increases and it is equal to a fixed value. Our results show that under monetary policy rule that responds both to inflation and output gap, disinflation is less costly. Not by chance, such Taylor rule is the best formula that describers the Fed's dual mandate pursuing the goals of price stability and maximum employment[20]. Moreover, an active macroprudential policy namely an increasing LTV ratio, even more reduces disinflation costs in terms of output losses and positively affects savers' and banks' welfare.

In light of that, this paper wants to provide a threefold policy message. First, we suggest that the policymakers should implement a disinflationary policy stabilizing also the output. Second, the

[20]The Taylor rule can be written in terms of the gap between the actual level of the unemployment rate and the level of the unemployment rate that corresponds to full employment. An empirical relationship between output and the unemployment rate is known as Okun's law.

macroprudential authority should intervene actively during a disinflation process to minimize its costs and the financial instability that derives from it. Third, the central bank and the macroprudential regulator should pursue the goals of financial stability and price stability separately. Indeed, when the central bank directly responds to financial variables as well, a trade-off between price and financial stability objectives can emerge. As a result, disinflation is more costly. Finally, a countercyclical monetary policy that is macroprudential itself - pursuing both goals of price and financial stability - is redundant in the presence of a macroprudential authority. Thus, we suggest that both authorities have to intervene with an active rule, but each one has to focus on its own policy goal (Beau et al (2012), Rubio and Carrasco-Gallego (2015), Svensson (2018), Kannan et al. (2012)).

Our paper is the first attempt to study the effects of a permanent inflation target reduction in a deterministic model characterized by credit frictions and borrowing constraints. In addition, our model takes into account banks and emphasizes the primary role of macroprudential regulation. However, our work leaves out several important features as the wage-setting mechanisms. Moreover, it would be interesting to analyze the effects of softening of borrowers' collateral constraint through other macroprudential instruments including capital requirement ratio. We leave these extensions for future research.

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Appendix A: The model

6.1 Savers

Households choose consumption ($C_{S,t}$), housing shares ($H_{S,t}$) and working hours ($N_{S,t}$). Specifically, their utility function is increasing in consumption and housing shares, while it is decreasing in working hours:

$$\max E_0 \sum_{t=0}^{\infty} \beta_S^t \left[\log C_{S,t} + j \log H_{S,t} - \frac{(N_{S,t})^{\eta}}{\eta} \right],$$

where $\beta_S \in (0,1)$ is the patient discount factor. $1/(\eta - 1)$ represents the labor supply elasticity, where $\eta > 0$. Instead, $j > 0$ represents the relative weight of housing in the utility function.

Their budget constraint is:

$$C_{S,t} + d_t + q_t \left(H_{S,t} - H_{S,t-1}\right) = \frac{R_{S,t-1} d_{t-1}}{\pi_t} + w_{S,t} N_{S,t} + \frac{X_t - 1}{X_t} Y_t, \tag{A.1}$$

where d_t are bank deposits, $R_{S,t}$ is the gross return from deposits, q_t denotes the housing price in units of consumption, and $w_{S,t}$ represents the real wage rate. X_t is the markup of the firm, Y_t is the output and the term $\frac{X_t - 1}{X_t} Y_t$ represents firms profits, which are paid back to savers.

The first order conditions to the problem are the following:

$$\frac{1}{C_{S,t}} = \beta_S E_t \left(\frac{R_{S,t}}{\pi_{t+1} C_{S,t+1}} \right) \tag{A.2}$$

$$\frac{q_t}{C_{S,t}} = \frac{j}{H_{S,t}} + \beta_S E_t \left(\frac{q_{t+1}}{C_{S,t+1}} \right) \tag{A.3}$$

$$w_{S,t} = \left(N_{S,t}\right)^{\eta - 1} C_{S,t}, \tag{A.4}$$

where the first equation is the Euler equation, which is the intertemporal condition for consumption, the second represents the intertemporal condition for housing and the last equation is the labor-supply condition.

6.2 Borrowers

Impatient households choose consumption ($C_{B,t}$), housing shares ($H_{B,t}$) and working hours ($N_{B,t}$). Also their utility function is increasing in consumption and housing share, while it is decreasing in working hours as follows:

$$\max E_0 \sum_{t=0}^{\infty} \beta_B^t \left[\log C_{B,t} + j \log H_{B,t} - \frac{(N_{B,t})^{\eta}}{\eta} \right],$$

where $\beta_B \in (0,1)$ represents the impatient discount factor.

Borrowers face the following period-by-period budget constraint:

$$C_{B,t} + \frac{R_{B,t-1} b_{t-1}}{\pi_t} + q_t \left(H_{B,t} - H_{B,t-1}\right) = b_t + w_{B,t} N_{B,t}. \tag{A.5}$$

The collateral constraint is:

$$b_t \leq E_t \left(\frac{1}{R_{B,t}} \kappa_t q_{t+1} H_{B,t} \pi_{t+1} \right), \tag{A.6}$$

where b_t denotes bank loans, $R_{B,t}$ represents the gross interest rate, and κ_t is the loan-to-value ratio. The borrowing constraint states that borrowing is limited to the present discounted value of their housing holdings.

The first order conditions are the following:

$$\frac{1}{C_{B,t}} = \beta_B E_t \left(\frac{R_{B,t+1}}{\pi_{t+1} C_{B,t+1}} \right) + \lambda_{B,t} \tag{A.7}$$

$$\frac{j}{H_{B,t}} = \frac{q_t}{C_{B,t}} - \beta_B E_t \left(\frac{q_{t+1}}{C_{B,t+1}} \right) - \lambda_{B,t} E_t \left(\frac{1}{R_{b,t}} \kappa_t q_{t+1} \pi_{t+1} \right) \tag{A.8}$$

$$w_{B,t} = \left(N_{B,t}\right)^{\eta-1} C_{B,t}, \tag{A.9}$$

where $\lambda_{B,t}$ denotes the multiplier on the borrowing constraint. These equations represent the Euler equation, the intertemporal condition for housing, and the labor-supply condition, respectively.

6.3 Banks

Banks maximize dividends ($\text{div}_{f,t}$), that are fully consumed by bankers, so that $C_{f,t} = \text{div}_{f,t}$. Their utility is a convex function of dividends, that represent the residual income of the banker after depositors have been repaid and loans have been issued (Iacoviello, 2015). Banks' maximization problem is the following:

$$\max E_0 \textstyle\sum_{t=0}^{\infty} \beta_f^t \left[\log \text{div}_{f,t}\right],$$

where $\beta_f \in (0,1)$ denotes the bankers discount factor.

Their budget constraint is:

$$\text{div}_{f,t} + \frac{R_{S,t-1} d_{t-1}}{\pi_t} + b_t = d_t + \frac{R_{B,t-1} b_{t-1}}{\pi_t}, \tag{A.10}$$

where the term $d_t + \frac{R_{B,t-1} b_{t-1}}{\pi_t}$ represents deposits by households and repayments from borrowers on previous loans, as sources of funds for the banks. Banks use these funds for paying back savers and extending new loans, or for increasing their own consumption.

Banks are constrained by the amount of assets minus liabilities: this introduces the capital requirement ratio (CRR), according to the Basel regulation.

The fraction of capital ($b_t - d_t$) with respect to assets has to be larger than a certain ratio. The collateral constraint is defined as:

$$\frac{b_t - d_t}{b_t} \geq CRR, \tag{A.11}$$

that is

$$d_t \leq (1 - CRR)b_t. \tag{A.12}$$

If we set γ equal to $(1 - CRR)$, where $\gamma \leq 1$, we can say that banks liabilities cannot exceed a fraction of its assets, which can be used as collateral:

$$d_t \leq \gamma b_t, \tag{A.13}$$

The first order conditions for deposits and loans are respectively given by:

$$\frac{1}{\text{div}_{f,t}} = \beta_f E_t \left(\frac{R_{S,t}}{\text{div}_{f,t+1}\, \pi_{t+1}} \right) + \lambda_{f,t} \tag{A.14}$$

$$\frac{1}{\text{div}_{f,t}} = \beta_f E_t \left(\frac{R_{B,t}}{\text{div}_{f,t+1}\, \pi_{t+1}} \right) + \gamma\lambda_{f,t}, \tag{A.15}$$

where $\lambda_{f,t}$ denotes the multiplier on the bankers borrowing constraint.

6.4 Final goods producers

The final goods firms operate under perfect competition and flexible prices. They aggregate intermediate goods according to the following production function:

$$Y_t = \left[\int_0^1 Y_t\,(z)^{(\varepsilon-1)/\varepsilon}\, dz \right]^{\varepsilon/(\varepsilon-1)}, \tag{A.16}$$

where $\varepsilon > 1$ represents the elasticity of substitution between intermediate goods. The final good firm chooses $Y_t(z)$ to minimize its costs, resulting in demand of intermediate good z:

$$Y_t(z) = \left(\frac{P_t(z)}{P_t} \right)^{-\varepsilon} Y_t. \tag{A.17}$$

The price index is then given by:

$$P_t = \left[\int_0^1 P_t(z)^{1-\varepsilon} dz \right]^{1/(\varepsilon-1)}. \tag{A.18}$$

6.5 Intermediate goods producers

Intermediate firms compete monopolistically producing goods according to the following technology:

$$Y_t(z) = N_{S,t}(z)^{\alpha} N_{B,t}(z)^{(1-\alpha)}, \tag{A.19}$$

where $\alpha \in [0, 1]$ measures the relative size of each group in terms of labor.

Labor demand is represented by:

$$w_{S,t} = \frac{1}{X_t}\alpha\frac{Y_t}{N_{S,t}} \tag{A.20}$$

$$w_{B,t} = \frac{1}{X_t}(1-\alpha)\frac{Y_t}{N_{B,t}}, \tag{A.21}$$

where X_t denotes the markup, or the inverse of marginal cost. The price-setting problem for the intermediate good producers follows the standard Calvo-Yun setting. In each period an intermediate firms sells its good at price $P_t(z)$ and faces a constant probability, $1-\theta \in [0,1]$, of being able to choose the sale price.

The optimal price $P_t^*(z)$ is chosen in order to maximize the discounted value of expected future profits. The firms' maximization problem is the following:

$$\max_{P_t^*(z)} E_t \sum_{s=0}^{\infty}(\theta\beta_S)^s \frac{P_t}{\lambda_t}\frac{\lambda_{t+s}}{P_{t+s}}\left(P_t^*(z)\prod_{k=1}^{s}\pi_{t+k-1}^{\chi}\pi^{1-\chi} - P_{t+s}mc_{t+s}\right)Y_{t+s}^*(z) = 0$$

subject to:

$$Y_{t+s}^*(z) = \left(\frac{P_t^*(z)\prod_{k=1}^{s}\pi_{t+k-1}^{\chi}\pi^{1-\chi}}{P_{t+s}}\right)^{-\varepsilon} Y_{t+s}^d$$

where mc_t is the marginal cost, or the inverse of the markup X_t. $\frac{\lambda_{t+s}}{\lambda_t}$ denotes the stochastic discount factor of savers[21], who own the firms, and Y_t^d represents the aggregate demand.

The first order condition respect to $P_t^*(z)$ is:

$$E_t \sum_{s=0}^{\infty}(\theta\beta_S)^s \frac{\lambda_{t+s}}{\lambda_t}\left(\frac{\prod_{k=1}^{s}\pi_{t+k-1}^{\chi}\pi^{1-\chi}}{\prod_{k=1}^{s}\pi_{t+k}}\right)^{-\varepsilon} Y_{t+s}^d \left(\frac{P_t^*(z)}{P_t}\right)^{-\varepsilon-1}\left[\left(\frac{P_t^*(z)}{P_t}\right)\left(\frac{\prod_{k=1}^{s}\pi_{t+k-1}^{\chi}\pi^{1-\chi}}{\prod_{k=1}^{s}\pi_{t+k}}\right) + \frac{\varepsilon}{1-\varepsilon}mc_{t+s}\right]$$

where the term $\frac{\varepsilon}{1-\varepsilon}$ indicates the mark up in the absence of price stickiness.

By writing this first-order condition recursively, we can define:

$$x_t^1 = \left(\frac{P_t^*(z)}{P_t}\right)^{-\varepsilon-1} E_t \sum_{s=0}^{\infty}(\theta\beta_S)^s \frac{\lambda_{t+s}}{\lambda_t}\left(\frac{\prod_{k=1}^{s}\pi_{t+k-1}^{\chi}\pi^{1-\chi}}{\prod_{k=1}^{s}\pi_{t+k}}\right)^{-\varepsilon} Y_{t+s}^d mc_{t+s}$$

$$x_t^2 = \left(\frac{P_t^*(z)}{P_t}\right)^{-\varepsilon} E_t \sum_{s=0}^{\infty}(\theta\beta_S)^s \frac{\lambda_{t+s}}{\lambda_t}\left(\frac{\prod_{k=1}^{s}\pi_{t+k-1}^{\chi}\pi^{1-\chi}}{\prod_{k=1}^{s}\pi_{t+k}}\right)^{1-\varepsilon} Y_{t+s}^d.$$

By expressing recursively:

$$x_t^1 = Y_t^d mc_t P_t^*(z)^{-\varepsilon-1} + E_t\left[(\theta\beta_S)\frac{\lambda_{t+1}}{\lambda_t}\left(\frac{P_t^*(z)}{P_{t+1}^*(z)}\right)^{-\varepsilon-1}\left(\frac{\pi_t^{\chi}\pi^{1-\chi}}{\pi_{t+1}}\right)^{-\varepsilon} x_{t+1}^1\right] \tag{A.22}$$

[21] Where λ_t is equal to $\frac{1}{C_{S,t}}$.

$$x_t^2 = Y_t^d P_t^*(z)^{-\varepsilon} + E_t \left[(\theta\beta_S) \frac{\lambda_{t+1}}{\lambda_t} \left(\frac{P_t^*(z)}{P_{t+1}^*(z)} \right)^{-\varepsilon} \left(\frac{\pi_t^{\chi} \pi^{1-\chi}}{\pi_{t+1}} \right)^{1-\varepsilon} x_{t+1}^2 \right]. \tag{A.23}$$

It is possible to rewrite the price setting equation as follows:

$$x_t^1 = \frac{\varepsilon - 1}{\varepsilon} x_t^2. \tag{A.24}$$

6.6 Equilibrium

The market clearing condition for the goods is:

$$Y_t = Y_t^d * s_t \tag{A.25}$$

where Y_t^d represents the aggregate consumption:

$$Y_t^d = C_{S,t} + C_{B,t} + C_{f,t}, \tag{A.26}$$

and s_t denotes the price dispersion in the Calvo model. It follows:

$$s_t = (1-\theta) P_t^*(z)^{(-\varepsilon)} + \theta \left(\frac{\pi_t}{\pi_{t-1}^{\chi} \pi^{(1-\chi)}} \right)^{\varepsilon} s_{t-1}, \tag{A.27}$$

where P_t^* is the aggregate price level that satisfies the following equation:

$$1 = \theta \pi_t^{(\varepsilon-1)} \left(\pi_{t-1}^{\chi} \pi^{(1-\chi)} \right)^{(1-\varepsilon)} + (1-\theta) P_t^*(z)^{(1-\varepsilon)}. \tag{A.28}$$

The total housing supply is fixed and normalized to unity, as follows:

$$H_{S,t} + H_{B,t} = 1. \tag{A.29}$$

The equilibrium in financial markets is given by:

$$D_t = (1 - CRR) b_t. \tag{A.30}$$

Finally, according to the Walras law, labor market also clears.

Appendix B: Baseline calibration

The baseline calibration of structural parameters follows Rubio and Carrasco-Gallego (2016) and is consistent with the US data. Table 4 summarizes structural parameters values and their description.

The parameter denoting the discount factor β is set equal to 0.99, 0.98 and 0.965 for savers, borrowers and banks, respectively. The steady-state weight of housing in the utility function j is calibrated at 0.1 such that the housing wealth-to-GDP ratio is close to 1.40 in steady state, in line with the US data. Parameter η is fixed at 2 so as to calibrate at 1 the labor supply elasticity. The labor income share for savers α, is fixed at 0.64 while the price elasticity of demand ε, is calibrated at 21 such that the steady-state markup X is equal to 1.05, as in Iacoviello (2005). Regarding the price-setting parameters, we set the Calvo price parameter θ at 0.75 as in Rubio and Carrasco-Gallego (2016), and the price indexation χ at 0.8, as in Benati (2008).

Table 4

Structural Parameters Values

Parameter	Value	Description
Households		
β_s	0.99	Discount factor for savers
β_b	0.98	Discount factor for borrowers
β_f	0.965	Discount factors for banks
j	0.10	Weight of housing
η	2	Parameter associated with labor elasticity
Firms		
α	0.64	Labor income share for savers
ε	21	Price elasticity of demand
θ	0.75	Calvo price
χ	0.8	Price indexation

Appendix C: Welfare-based Ratio

We compute the Welfare-based Ratio (WR^i, henceforth), following Ascari and Ropele (2012a). The intertemporal welfare function in recursive form is:

$$V_t^i = \ln C_{i,t} + j \ln H_{i,t} - \frac{(N_{i,t})^\eta}{\eta} + \beta E_t V_{t+1}^i; \tag{C.1}$$

we define

$$V_{old}^i = \frac{1}{1-\beta}\left[\ln C_{i,old}(1-\lambda^i) + j \ln H_{i,old} - \frac{(N_{i,old})^\eta}{\eta}\right], \text{ with } i = s, b, f, \tag{C.2}$$

as the steady-state value of V_t^i when the monetary authority does not implement the disinflation policy, and V_0 as the steady-state value of V_t^i when the disinflation is implemented. Since the utility function is not cardinal, we need to find a measure that can represent welfare costs (or gains) of the disinflation. To do that, we measure the welfare effects caused by the disinflation in terms of Consumption Equivalent Measure (CEM, henceforth). CEM is defined as the constant fraction of consumption that households should give away in order to reduce the inflation rate permanently:

$$\frac{1}{1-\beta}\left[\ln C_{i,old}(1-\lambda^i) + j \ln H_{i,old} - \frac{(N_{i,old})^\eta}{\eta}\right] = V_0^i \tag{C.3}$$

$$\lambda^i = 1 - \exp\left[\left(1-\beta^i\right)\left(V_0^i - V_{old}^i\right)\right], \tag{C.4}$$

Then, we compute the WR^i as the ratio between the CEM and the difference between old and new inflation values:

$$WR^i = \frac{\lambda^i}{\pi_{old}^* - \pi_{new}^*}. \tag{C.5}$$

Disinflation is welfare improving when the WR is negative, and, thus, we read negative values as welfare gains.