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Targeted Taylor Rules: Some Evidence and Theory

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Abstract

Monetary theory and central bank doctrine generally prescribe a forceful reaction to demand-driven inflation and an attenuated response, if any, to supply-driven inflation. The Taylor–type rules used so far to describe central banks' reaction functions assume instead a uniform response of policy rates to inflation irrespective of its drivers. In this paper, we refine the specification of these monetary policy rules to allow for a different (targeted) reaction to demand- versus supply-driven inflation. Estimates of the new targeted rule for the United States show a fourfold larger response to demand-driven inflation than to supply-driven inflation. We use a textbook New Keynesian model to discuss the properties of the new type of monetary policy rule in terms of business cycle fluctuations and welfare.

Keywords: monetary policy trade–offs, targeted Taylor rules, inflation targeting

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> “*The response of monetary policy to higher prices stemming from an adverse supply shock should be attenuated because it would otherwise amplify the unwanted decline in employment.*”
>
> Powell (2023)

1 Introduction

Monetary theory and central bank doctrine generally prescribe a forceful reaction to demand-driven inflation and an attenuated response, if any, to supply-driven inflation.[1] The monetary policy rules used to describe the conduct of monetary policy in macroeconomic models and central banks' toolkits assume instead a “one-size fits all” reaction to inflation irrespective of its drivers (*e.g.* Taylor (1993), Clarida et al. (2000), Smets and Wouters (2007)).

In this paper, we propose a novel refinement of existing monetary policy rules that allows for a different (targeted) response to demand- versus supply-driven inflation. We refer to this new type of rule as a *targeted Taylor rule*. In the first part of the analysis, we use such a rule to summarize the conduct of monetary policy in the United States relying on recent methods to decompose inflation into its demand and supply factors (Eickmeier and Hofmann (2022), Shapiro (2022)). To do so, we estimate a Taylor (1993)–type rule where we replace overall inflation with its demand- and supply-driven components derived with these methods. In the second part of the analysis, we study the implications of monetary policy following such a targeted Taylor rule instead of a conventional (unconditional) one for business cycle fluctuations and welfare. For this purpose, we introduce the targeted Taylor rule into the textbook New Keynesian model with sticky prices and wages, and assume that business cycle fluctuations are driven by both demand and supply shocks. We model demand shocks as standard demand preference shocks, and supply shocks as technology shocks.

Our main findings are threefold.

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[1] According to monetary theory, the trade–offs faced by central banks between inflation and output stabilization around their desired levels are shock dependent. When the economy faces a demand shock, the central bank does not face any policy trade-off and can achieve the “first best” through *strict inflation targeting* — a result coined in the literature as the “divine coincidence” (Blanchard and Galí (2007)). By contrast, when the economy faces a supply shock, a simple rule whereby the central bank responds only moderately, if at all, to inflation — outperforms strict inflation targeting in terms of welfare (*see* Erceg et al. (2000) and Blanchard and Galí (2007) for a technology shock, and Bodenstein et al. (2008) and Nakov and Pescatori (2010) for an oil price shock).

First, our empirical analysis suggests that the conduct of monetary policy in the United States has over the past four decades or so been in line with the prescriptions of Federal Reserve doctrine as reflected in its official communications. Specifically, for the period following Paul Volcker's appointment as chairman of the Federal Reserve, the estimated reaction to demand-driven inflation is significantly larger than that to supply-driven inflation. For our baseline specification, the estimated response to demand-driven inflation is around four, while that to supply-driven inflation is slightly above one. The findings are robust across different Fed chairmanships.

Second, simulations from our textbook New Keynesian model show that aggregate output and inflation display very different business cycle properties when the central bank follows our estimated targeted Taylor rule instead of a conventional one. To compare business cycle fluctuations under the two alternative monetary policy rules, we set the non-policy parameters of the model at their textbook values in Galí (2015), and simulate time series data from the model conditional on monetary policy following either the baseline estimated targeted or conventional Taylor rule, subject to the same random series of (simultaneous) demand and supply shocks. According to this exercise, everything else equal, inflation is driven to a larger extent by supply shocks under the targeted Taylor rule than under the conventional Taylor rule, while output fluctuations are smaller and mainly driven by demand shocks. This finding reflects how the targeted Taylor rule counteracts more strongly the effects of demand (supply) shocks on inflation (output) than the conventional unconditional rule. These results suggest that imposing a conventional Taylor–type rule in macroeconomic models may not be without loss of generality if actual monetary policy decisions are taken in a targeted fashion.

Third, we find that a targeted Taylor rule can provide a better approximation of optimal policy than a conventional taylor rule when business cycle fluctuations are driven by both demand and supply factors. In the last part of our analysis, we derive the optimal monetary policy with commitment – still assuming concomitant demand and supply shocks[2]. We use the outcome under optimal policy as a benchmark for the evaluation of optimal conventional and targeted policy rules which central banks could follow in practice. The optimal targeted rule entails targeting aggressively demand-driven inflation, and reacting only weakly to supply-driven inflation. This rule is shown to always approximate better optimal policy in the presence of both demand and supply shocks than a conventional (unconditional) Taylor rule.

Hereafter, we proceed as follows. Section 2 highlights the contributions of the paper to the

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[2] According to the decomposition of inflation in demand and supply factors, this case is most often the relevant one in practice (*see e.g.* Figure 1 for instance for the decomposition based on the method in Shapiro (2022)).

literature. Section 3 estimates a targeted Taylor rule for the United States allowing for a different response to demand-driven versus supply-driven inflation. Section 4 presents a theoretical model featuring a targeted Taylor rule akin to that estimated in the previous section, and Section 5 analyzes the equilibrium of the model under this new rule. Section 6 compares business cycle fluctuations under the estimated targeted Taylor rule to those under the estimated conventional Taylor rule. Section 7 discusses the welfare merits of a targeted Taylor rule compared to those of a conventional one. A final section concludes.

2 Related literature

The paper is related to several strands of research.

The first strand of research concerns the empirical literature estimating and assessing the Federal Reserve's policy reaction function by means of simple monetary policy rules in the spirit of Taylor (1993). Such policy rules have been shown to be reasonable representations of how the Federal Reserve adjusts the federal funds rate in response to deviations of inflation from its medium-term target and of real activity from its potential level. This literature covers debates over how to estimate such policy rules (*e.g.* Carvalho et al. (2021)), about whether monetary policy in the U.S. has changed over time (*e.g.* Judd and Rudebusch (1998), Clarida et al. (2000), Orphanides (2004)), or whether the observed persistence in interest rates stems from policy inertia or persistent monetary shocks (*e.g.* Rudebusch (2002), Coibion and Gorodnichenko (2012)). In none of these analyses do monetary policy rules depend on the nature of the underlying aggregate shocks and, in particular, on the underlying drivers of inflation.

Our contribution to this literature is twofold. First, we provide empirical evidence that monetary policy in the United States has historically reacted much more forcefully to demand- than to supply-driven inflation. Second, we show that an asymmetric response as that embodied in a targeted Taylor rule can mimic more closely optimal policy than a conventional (unconditional) Taylor rule. In the process, we exploit the recent decompositions of inflation into its demand- and supply-driven components by Eickmeier and Hofmann (2022) and Shapiro (2022).

The second strand of related research is the companion normative literature which looks for simple policy rules that perform well across a wide range of monetary models and that central banks could follow in practice (*e.g.* Taylor (1993), McCallum (1999), Taylor (2007), Orphanides (2010), Taylor and Williams (2010)). Such "robust policy rules" were first derived from research on empirical monetary models with rational expectations and sticky prices in the

1970s and 1980s, and have been continuously refined and tested within a variety of newer and more rigorous models and policy evaluation methods. One notable policy rule derived within this line of research is the Taylor (1993) rule which calls for appropriate adjustments in the short-term interest rate in response to deviations of inflation and output from their respective targets. A central conclusion of this literature is that simple rules — in the spirit of the one proposed by Taylor (1993) — are generally more robust than model-specific fully optimal ones (McCallum (1988), Schmitt-Grohé and Uribe (2007), Taylor (2007), Taylor (2017)).

We contribute to this normative literature by highlighting that policy rules should not necessarily impose that monetary policy reacts in the same way to deviations of inflation from target, regardless of the nature of factors driving them – the standard premise of existing studies. Allowing for a shock-dependent response – in the spirit of the targeted Taylor rule – can improve welfare upon conventional (unconditional) Taylor rules.[3] Implementing such rules in practice depends, of course, on the central bank's ability to distinguish in real time between supply and demand disturbances. The measures of demand- and supply-driven inflation we have used became available only recently. Nonetheless, our empirical analysis suggests that the Federal Reserve has generally succeeded to infer similar information about the supply- versus demand-driven nature of inflation from their indicators, analytical toolboxes, judgment, and awareness of specific shocks buffeting the economy at a certain point in time (*e.g.* fiscal packages, oil price shocks). Going forward, the implementability of such targeted rules in practice will likely be further facilitated by the availability of (improved) methodologies to decompose inflation in demand and supply factors such as those used in our analysis.

Finally, our paper also relates more broadly to the inflation targeting literature (*e.g.* Kahn (1996), Fischer et al. (1996), Taylor et al. (1996), Posen et al. (1998), Cecchetti and Ehrmann (1999), Truman (2003), Svensson (2010), Hammond (2012), McCallum (2000), Taylor (2000)). The presence of trade–offs for certain types of shocks such as supply shocks is used in this literature to justify the choice of a flexible inflation targeting regime instead of a strict inflation targeting one (*e.g.* Bernanke and Mishkin (1997), Posen et al. (1998), Svensson (1999), Lomax (2004), Walsh (2009)). Flexible inflation targeting is defined as a regime where central banks not

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[3] More broadly, recent findings on monetary policy and financial stability — both theoretical and empirical (Boissay et al. (2021), Boissay et al. (2024)) — suggest that the targeted Taylor rules may have also merits in terms of financial stability. In these studies, the trade-off between price and financial stability depends on the nature of inflation drivers. For demand shocks, there is no such trade–off because strict inflation targeting avoids the build–up of financial vulnerabilities and associated financial stability risks. By contrast, a trade–off does exist for supply shocks: both strictly targeting inflation in the face of adverse supply shocks, or strictly fighting disinflation in response to expansionary supply shocks increase the probability of a financial crisis.

only aim at stabilizing inflation around a target but also put some weight, implicitly or explicitly, on stabilizing the real economy (Svensson (2010)). The monetary policy reaction function of this regime has been described by the means of conventional Taylor–type rules, whereby the central bank reacts to deviations of (aggregate) inflation from its target and of output from its desired level, and aims to fulfill its inflation target over the medium run as opposed to at each date.

Our paper contributes to this literature by showing that flexible inflation targeting can be thought as being implemented in a targeted fashion — with the monetary policy reaction function being different for supply versus demand shocks. We show that such a targeted reaction function has historically characterized the conduct of monetary policy by the Federal Reserve, whose monetary policy framework has aligned with all characteristic of flexible inflation targeting despite of being labeled as such only until more recently (Goodfriend (2007)).

Finally, our paper is marginally related to the literature discussing the merits of targeting core instead of headline inflation. This literature argues that central banks should "look through" the direct effects of energy and food prices on headline inflation and only respond to core inflation (Aoki (2001), Bodenstein et al. (2008)). The prescriptions of this literature are in line with both the doctrine of the Federal Reserve as reflected in its official communications (*e.g.* Mishkin (2007), Brainard (2022a)), as well as with recent estimates of the Federal Reserve's monetary policy reaction function which use as an operational inflation measure core instead of headline inflation (Carvalho et al. (2021)). Similar to the targeted Taylor rule, this literature prescribes a distinct monetary policy reaction function depending on the nature of shocks. The prescribed state-contingent nature is however different: in this literature, the response to commodity price shocks should be different than that to other shocks, in the sense that it should only concern their indirect effects on core inflation, ignoring the direct ones on headline inflation.

3 Federal Reserve's policy reaction function: some new evidence

In this section we estimate Taylor (1993)–type rules to summarize the Federal Reserve's monetary policy reaction function. We first estimate a conventional Taylor rule whereby the Federal Reserve is assumed to adjust the federal funds rate in response to deviations of aggregate inflation and output from their respective targets. We then proceed to estimate a targeted version of this policy rule, in which we replace aggregate inflation by its supply– and demand–driven components.

3.1 A conventional Taylor Rule

We begin with a conventional specification for the monetary policy reaction function — as described by a Taylor–type rule allowing for interest rate smoothing :

$$i_t = i^* + \rho i_{t-1} + (1-\rho)\Big[\phi_\pi(\pi_t - \pi^*) + \phi_y \widehat{y}_t\Big] + \varepsilon_t \tag{1}$$

where i_t is the policy rate, π_t is inflation, π^* is the inflation target and $\widehat{y}_t$ is the output gap.

To estimate the policy rule above, we follow closely Carvalho et al. (2021)'s recent study. The latter paper estimates by OLS the following reduced form econometric specification:

$$i_t = \alpha + \rho i_{t-1} + \phi_\pi^{aux}\pi_t + \phi_y^{aux}\widehat{y}_t + \varepsilon_t$$

in order to obtain $\widehat{\rho}$, $\widehat{\phi}_\pi^{aux}$ and $\widehat{\phi}_y^{aux}$, and then backs out the Taylor rule coefficients in (1) by computing $\widehat{\phi}_\pi = \frac{\widehat{\phi}_\pi^{aux}}{1-\widehat{\rho}}$, $\widehat{\phi}_y = \frac{\widehat{\phi}_y^{aux}}{1-\widehat{\rho}}$[4]. In our baseline estimation, we purposefully stay away from the zero lower bound period and use quarterly data from 1979Q3 to 2007Q4 – as in Carvalho et al. (2021). The policy rate is the federal funds rate, inflation is the year-on-year rate of change in core PCE, and the output gap is constructed using the Congressional Budget Office estimate of potential GDP.[5] All the data is downloaded from the St Louis FRED database. The only difference with respect to Carvalho et al. (2021)'s approach is that we use the most recent vintage of the data instead of real-time data. We do so for ease of comparison with the targeted Taylor rules analyzed in the next section, for which no real-time data is available.[6]

The estimated coefficients of the conventional Taylor rule (1) are reported in Table 1 (first row). The estimates have the expected sign, are highly statistically significant and their values are close to those reported in Carvalho et al. (2021). The point estimate of ρ equals 0.74, suggesting considerable interest rate inertia and confirming the conventional wisdom that the Federal Reserve smooths adjustments in the fed funds rate. Moreover, the estimated response

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[4] Carvalho et al. (2021) show that even though Ordinary Least Squares (OLS) estimation of monetary policy rules produces potentially inconsistent estimates of policy parameters, the related bias is likely very small. Furthermore, the paper finds that the bias of OLS estimates almost disappears when the true policy parameter is close to the limit imposed by the Taylor principle, and that it is negative for larger coefficients (See Figure 2 and related discussion in Section 2.2. in their paper). In the context of our analysis, this implies that the OLS estimate for the response coefficient to supply-driven inflation (which is slightly higher than one) is likely unbiased, while the strong response to demand-driven inflation (which is slightly below four) may be even higher.

[5] We follow Carvalho et al. (2021) and use core inflation as opposed to headline inflation as the inflation measure in our baseline regressions. Even though the inflation target is stated in terms of headline inflation, the Federal Reserve uses core inflation as its operational target (see for *e.g.* Mishkin (2007) or Bodenstein et al. (2008)).

[6] While using real–time data would admittedly be more in line with the Fed's information set at the time of policy rate decisions, Carvalho et al. (2021) note that estimates based on historical data are similar to those based on real time data (see footnote 19).

coefficient to inflation is slightly above 2, while that of the output gap is around 0.25 consistent with the Taylor principle being satisfied during our baseline estimation period.

Table 1: Estimated Taylor rules

	ρ	ϕ_π	ϕ_π^d	ϕ_π^s	ϕ_y
Taylor rule	0.74***	2.11***			0.26***
	(0.04)	(0.18)			(0.10)
Targeted Taylor rule	0.72***		3.75***	1.02**	0.22***
	(0.04)		(.60)	(0.40)	(0.05)

Notes: Values are expressed in quarterly rates. Standard errors derived by the Delta method are reported in parentheses. Statistical significance at 5%/1% level indicated with **/*** respectively. The difference between the estimated responses to demand–driven and supply–driven inflation in the targeted Taylor rule specification is statistically significant at 1% level. The Taylor rule specification is described by (1), while that of the targeted Taylor rule by (2).

3.2 A targeted Taylor Rule

As a next step, we re-estimate the monetary policy rule described in (1) but replace the year–on–year core PCE inflation rate π_t with its demand– and supply–driven components π_t^d and π_t^s – as derived by Shapiro (2022) and shown in Figure 1:[7]

$$i_t = \alpha + \rho i_{t-1} + (1-\rho)\Big[\phi_\pi^d(\pi_t^d - \pi_d^*) + \phi_\pi^s(\pi_t^s - \pi_s^*) + \phi_y \widehat{y}_t\Big] + \varepsilon_t \tag{2}$$

where $\pi_d^* + \pi_s^* = \pi^*$[8]. We choose the inflation decomposition based on the method proposed by Shapiro (2022) because it is available for core inflation. We use however the inflation decomposition based on the method proposed by Eickmeier and Hofmann (2022) — which is currently available only for headline inflation — to check the robustness of our findings.

Following the same approach as for the conventional Taylor rule, we estimate the policy rule in (2) by applying OLS to the reduced form econometric specification

$$i_t = \alpha^{aux} + \rho i_{t-1} + \phi_\pi^{d,aux}\pi_t^d + \phi_\pi^{s,aux}\pi_t^s + \phi_y^{aux}\widehat{y}_t + \varepsilon_t,$$

and we then back out the structural monetary policy rule coefficients of equation (2) as follows: $\widehat{\phi}_\pi^d = \frac{\widehat{\phi}_\pi^{d,aux}}{1-\widehat{\rho}}$, $\widehat{\phi}_\pi^s = \frac{\widehat{\phi}_\pi^{s,aux}}{1-\widehat{\rho}}$, $\widehat{\phi}_y = \frac{\widehat{\phi}_y^{aux}}{1-\widehat{\rho}}$.

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[7] The decomposition of inflation in demand and supply factors proposed by Shapiro (2022) is based on the sectoral decomposition of the PCE index. Inflation is demand-driven in a given sector if prices and quantities move in the same direction in that specific area of consumption. If, on the other hand, inflation tends to be supply-driven, prices and quantities should move in different directions. The method thus identifies periods that have been dominated by either supply or demand shocks for each consumption area. This is done with the aid of estimated equations. Weights for the different categories are then used to calculate the supply and demand-related contributions to aggregate price growth.

[8] The constants π_d^* and π_s^* stand the (possibly different) targets for demand- and supply-driven inflation.

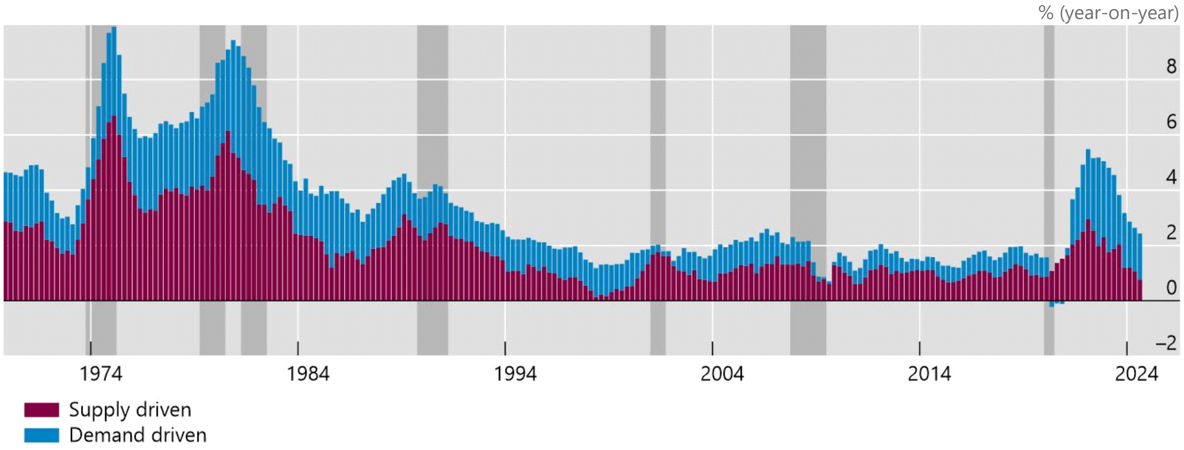

Figure 1: Decomposition of year-on-year core PCE inflation in demand and supply components
Notes: Inflation decomposition based on the method proposed by Shapiro (2022).

The estimated coefficients of the targeted Taylor rule described in equation (2) are reported in Table 1 (second row). The estimates of the interest rate smoothing coefficient (column two) and of the output gap coefficients (column six) are essentially those of the conventional Taylor rule. The estimated response to demand–driven inflation (column “ϕ_π^d”) is around four and almost four times larger than that to supply–driven inflation (column “ϕ_π^s”) which is slightly above one. The difference between the two is significant at 1% level.

3.3 Robustness analysis

In this section, we check the robustness of our results along several dimensions. We re-estimate the targeted Taylor–rule (1) over varied sample periods; (2) using headline instead of core inflation; (3) using Eickmeier and Hofmann (2022)'s alternative inflation decomposition into demand– and supply– factors; and (4) using lagged instead of current values for inflation and output gap. Our results carry through all these checks.

Alternative sample periods. We first rerun our estimation distinguishing between different Federal Reserve Governors' tenures as in Carvalho et al. (2021). Our estimates have been remarkably stable since Paul Volcker's chairmanship (2), with the Fed's response to demand-driven inflation being consistently around fourfold that to supply-driven inflation.

Second, we run our analysis on an extended sample, including the most recent period up to 2024Q2. The sample includes the post-GFC period where the zero lower bound (ZLB) was occasionally binding. Since our focus is on conventional monetary policy, we estimate the policy rule excluding those observations. We do so by conditioning the policy rates to be above

0.5 percent (or smaller, but positive).[9] Compared to baseline estimates reported in Table 1, we obtain very similar reactions to both demand-driven inflation (3.79 instead of 3.75) and supply-driven inflation (1.37 instead of 1.02), and slightly higher interest rate smoothing (0.82 instead of 0.72) and output gap coefficients (0.3 as opposed to 0.22) (Table 2).[10]

Finally, we run our analysis over the pre–Volcker Burns–Miller chairmanship (1969Q4–1979Q2). Results in this case are essentially opposite our baseline. During that period, the Federal Reserve responded particularly aggressively to supply–driven inflation and did not respond to demand–driven inflation (Table 2). This finding is consistent with the Federal Reserve reacting strongly to supply shocks such as oil price shocks as they were seen as potential causes of wage-price spirals (Kilian and Lewis (2011), Bernanke (2006)).[11]

Alternative measures of inflation We re–estimate the monetary policy rule (1) using headline instead of core inflation. The results are reported in Table 3. For both the conventional and the targeted Taylor rules, the estimated smoothing parameter is slightly higher when using headline instead of core inflation: it equals around 0.83-0.92 against 0.72-0.74 when using core inflation (see Table 2). For the targeted Taylor rule, the estimated coefficients of demand–driven inflation, supply–driven inflation and output gap are all very similar to those based on core inflation.[12]

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[9] We also considered alternative thresholds such as 0.1 or 0.25 and results do not change.

[10] In alternative exercises, we used the Wu and Xia (2020) shadow interest rate when the policy rate was in the vicinity of its effective lower bound (i.e when the funds rate was below 0.5 percent, or below lower, but positive thresholds). In those cases, we obtained a slightly higher interest rate smoothing parameter (0.88 instead of 0.72), a stronger reaction to demand-driven inflation (4.49 instead of 3.75) and a smaller statistically insignificant response to supply-driven inflation (0.69 instead of 1.02). Similar results obtained when we used the funds rate, ignoring that the ZLB was occasionally binding during this period. We also performed a similar exercise using the alternative shadow rate series from Krippner (2013) which are available until 2019Q3. In that specification, we obtained results very close to our baseline: an estimated response to demand-driven inflation of 3.72, one to supply-driven inflation equal to 1.43, with the difference between the two highly statistically significant, as well as both being highly statistically significant from zero; an output gap coefficient equal to 0.31 (quarterly) and an interest rate smoothing coefficient equal to 0.83.

[11] Bernanke (2006) notes that *"In the past, notably during the 1970s and early 1980s, both the first-round and second-round effects of oil-price increases on inflation tended to be large, as firms freely passed on rising energy costs to consumers, workers reacted to the surging cost of living by ratcheting up their wage demands, and longer-run expectations of inflation moved up quickly. In this situation, monetary policy-making was extremely difficult because oil-price increases threatened to result in a large and persistent increase in the overall inflation rate. The Federal Reserve attempted to contain the inflationary effects of the oil price shocks by engineering sharp increases in interest rates, actions which had the consequence of sharply slowing growth and raising unemployment, as in the recessions that began in 1973 and 1981. Since about 1980, however, the Federal Reserve and most other central banks have worked hard to bring inflation and expectations of inflation down. An important benefit of these efforts is that the second-round inflation effect of a given increase in energy prices has been much reduced. To the extent that households and business owners expect that the Fed will keep inflation low, firms have both less incentive and less ability to pass on increased energy costs in the form of higher prices, and likewise workers have less incentive to demand compensating increases in their nominal wages."*

[12] Notably, however, the R–squared of the specification with headline inflation is lower than that for core inflation, suggesting that the latter is a better description of the monetary policy reaction function in line with narratives of the Federal Reserve's policy reaction function (*see e.g.* Mishkin (2007)).

Table 2: Robustness analysis: alternative samples

	ρ	ϕ_π	ϕ_π^d	ϕ_π^s	ϕ_y
Baseline sample					
1979Q3-2007Q4					
Taylor rule	0.74***	2.11***			0.26***
	(0.04)	(0.18)			(0.05)
Targeted Taylor rule	0.72***		3.75***	1.02**	0.22***
	(0.04)		(0.60)	(0.40)	(0.05)
Volcker-Greenspan					
1979Q3-2005Q4					
Taylor rule	0.74***	2.10***			0.27***
	(0.04)	(0.19)			(0.06)
Targeted Taylor rule	0.72***		3.73***	1.03**	0.22***
	(0.04)		(0.62)	(0.42)	(0.05)
Greenspan-Bernanke					
1987Q3-2007Q4					
Taylor rule	0.80***	2.18***			0.38***
	(0.02)	(0.22)			(0.04)
Targeted Taylor rule	0.83***		4.62***	1.26**	0.34***
	(0.02)		(0.95)	(0.42)	(0.04)
Full-sample					
1979Q3-2024Q2					
Taylor rule	0.88***	2.14***			0.35***
	(0.02)	(0.37)			(0.13)
Targeted Taylor rule	0.82***		3.79***	1.37**	0.30***
	(0.03)		(0.85)	(0.59)	(0.08)
Pre-Volcker					
1969Q4-1979Q2					
Taylor rule	0.84***	0.83***			0.33***
	(0.06)	(0.26)			(0.13)
Targeted Taylor rule	0.69***		-0.65	1.69***	0.37***
	(0.0)		(1.14)	(0.50)	(0.09)

Notes: Standard errors are reported in parentheses. Statistical significance at 5%/1% level indicated with **/*** respectively. Differences between the estimated responses to demand–driven and supply–driven inflation in the targeted Taylor rule specification are statistically significant at 1% level. The Taylor rule specification is described by (1), while that of the targeted Taylor rule by (2). Estimates for the full-sample exercise are conditional on the (annualized) policy rate being strictly higher than 0.5%, and hence away from the close vicinity of the ZLB.

Alternative decomposition of demand– and supply–driven inflation. Next, we check whether our results hold when using Eickmeier and Hofmann (2022)'s decomposition of inflation into demand and supply factors. This methodology relies on the same basic conceptual consideration as in Shapiro (2022) that demand factors move inflation and output in the same direction, while supply factors move them in opposite direction, but in the context of a very different econometric model and type of data. Specifically, the methodology relies on the estimation of a factor model with sign restrictions using more than 140 quarterly macro-economic time series of aggregate inflation and real activity measures. The decomposition delivers a decomposition of quarter-on-quarter standardized headline PCE inflation. The year-on-year transformation of those series is reported in Figure A2 in the Appendix. The results based on this alternative decomposition are consistent with our baseline (row (vi) versus (iv)). They point to a strong and highly statistically significant response to demand–driven inflation and to a weak response to fluctuations in supply–driven inflation.

Table 3: Robustness analysis: alternative variables

	ρ	ϕ_π	ϕ_π^d	ϕ_π^s	ϕ_y
Headline inflation					
Taylor rule	0.84***	1.89***			0.26**
	(0.03)	(0.29)			(0.10)
Targeted Taylor rule					
Shapiro (2022)	0.83***		3.36***	1.09**	0.22**
	(0.03)		(0.94)	(0.54)	(0.09)
Eickmeier and Hofmann (2022)	0.84***		3.53***	0.75**	0.10
	(0.03)		(0.69)	(0.39)	(0.10)

Notes: Standard errors are reported in parentheses. Statistical significance at 5%/1% confidence level indicated with **/*** respectively. The differences between the estimated responses to demand–driven and supply–driven inflation in the targeted Taylor rule specification are statistically significant at 1% level. The Taylor rule specification is described by (1), while that of the targeted Taylor rule by (2). Baseline sample excluding the ZLB period running from 1979Q3 to 2007Q4.

Backward–looking specification We complete our robustness analysis by reporting the estimates for backward-looking rules where we use lagged values for inflation and output gap measures in our policy rules.[13] All the qualitative features of our baseline specification estimates seem to hold here as well: the demand inflation coefficient equals 2.72, that of supply inflation equals 1.4, the difference between the two is significant at 1% level and both are statistically significant at 1% level. The output gap coefficient equals 0.17, while the interest rate smoothing coefficient equals 0.7.

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[13] According to Taylor (2007), Bennet McCallum has argued that it was not realistic to assume that policy can respond to current-quarter values as assumed by the Taylor (1993) rule. Taylor (2007) does not fully support this statement, as policymakers have some current-period information available when they make interest rate decisions. To account however for this potential critique, we check the robustness of our results in backward–looking specifications of the monetary policy rules.

3.4 Reasons underlying the targeted monetary policy response

Official communications by the Federal Reserve mention two distinct reasons for reacting less to supply- than to demand-driven inflation. One is the macroeconomic stabilisation trade-off between inflation and real activity induced by supply shocks.[14] The other is the transitory nature of certain categories of supply shocks such as commodity price shocks.[15]

Our baseline specification expressed in terms of core inflation already accounts for the Federal Reserve's "look through" approach with respect to direct inflationary effects of transitory energy and food price shocks. Thus, the estimated asymmetric response to supply- versus demand-driven core inflation should necessarily reflect distinct concerns about the macroeconomic trade-offs implied by the two types of shocks. The high correlation of the demand and supply components of core inflation with the one-quarter ahead and the one-year ahead (Consensus and/or Greenbook) forecasts (Table A1) is also consistent with supply-driven inflation not being entirely transitory during the estimation period.[16].

In what follows, we incorporate the targeted Taylor rule in a textbook monetary model. In the model, the central bank faces a macro-economic stabilization (welfare) trade-off between inflation and real activity only in response to supply shocks. By contrast, conditional on demand shocks, there is no such trade-off and strictly targeting inflation allows to reach the "first best". We use this theoretical framework to study the implications for business cycle fluctuations and welfare of monetary policy following a targeted Taylor rule instead of a conventional one when the economy is subject (simultaneously) to both demand and supply shocks.

4 Model

The analytical framework of our analysis is a textbook closed economy version of the New Keynesian model with staggered price and wage setting, without capital accumulation or a fiscal

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[14] See for instance the citation from a speech by the Fed Governor Jerome Powell on page 2.

[15] "The standard monetary prescription is to "look through" commodities price shocks." (Brainard (2022b))

[16] As shown in Table A1, all correlation coefficients are above 0.7 and statistically significant at 1% level. Ideally, to the extent that the Federal Reserve accounts in its monetary policy decisions for the lags of monetary policy transmission and responds (also) to future inflation (as measured by the inflation forecast), one would like to add in the specification of the targeted Taylor rule (2) the forecasts of the demand- and supply-driven components of inflation. No decomposition of the inflation forecasts in demand- and supply-driven factors is however currently available. When adding the aggregate inflation forecasts as additional variables in our regressions, the coefficient of demand-driven inflation remains positive while that of supply-driven inflation turns negative consistent with the hypothesis that, everything else equal, the Federal Reserve tended to react more strongly (weakly) to inflation the higher its contemporaneous demand (supply) component. Since the inflation forecasts became available only until recently, these regressions are run on the entire sample using the Wu and Xia (2020) shadow rate when the policy rate was in the vicinity of the ZLB.

sector.[17] We consider a version of the model with two types of shocks: demand shocks – modeled as demand preference shocks, and supply shocks – modeled as technology shocks.

4.1 Non–policy block

The non-policy block of the model -and our exposition thereof- is the same as in Galí (2015), Chapter 6. All equations are log-linearized around a steady state with zero price and wage inflation. We assume a constant wage subsidy (financed through lump-sum taxes) that exactly offsets the distortions resulting from price and wage markups in the steady state -which is thus efficient. We present first the supply side and then turn to the demand side of the model.

The supply side of the economy is described by the following three equations representing the dynamics of price and wage inflation, π_t and π_t^w,

$$\pi_t = \beta E_t\{\pi_{t+1}\} + \chi_p \tilde{y}_t + \lambda_p \tilde{\omega}_t \tag{3}$$

$$\pi_t^w = \beta E_t\{\pi_{t+1}^w\} + \chi_w \tilde{y}_t - \lambda_w \tilde{\omega}_t \tag{4}$$

$$\tilde{\omega}_t \equiv \tilde{\omega}_{t-1} + \pi_t^w - \pi_t - \Delta\omega_t^n \tag{5}$$

where $\tilde{y}_t \equiv y_t - y_t^n$ and $\tilde{\omega}_t \equiv \omega_t - \omega_t^n$ denote, respectively, the output and wage gaps, with y_t^n and ω_t^n representing the (log) natural output and (log) natural wage (i.e. their corresponding equilibrium values in the absence of nominal rigidities).[18] The *natural* output and wage are given by (ignoring constant terms):

$$y_t^n = \psi_{ya} a_t$$

$$\omega_t^n = \psi_{\omega a} a_t$$

where $\psi_{ya} \equiv \frac{1+\varphi}{\sigma(1-\alpha)+\varphi+\alpha}$, $\psi_{\omega a} \equiv \frac{1-\alpha\psi_{ya}}{1-\alpha}$, and a_t is a technology parameter following an exogenous AR(1) process with autoregressive coefficient ρ_a. In addition, we note that $\chi_p \equiv \frac{\alpha\lambda_p}{1-\alpha}$, $\chi_w \equiv \lambda_w\left(\sigma + \frac{\varphi}{1-\alpha}\right)$, $\lambda_p \equiv \frac{(1-\theta_p)(1-\beta\theta_p)}{\theta_p}\frac{1-\alpha}{1-\alpha+\alpha\epsilon_p}$, where $\theta_p \in [0,1)$ and $\theta_w \in [0,1)$ are the Calvo indexes of price and wage rigidities, while $\epsilon_p > 1$ and $\epsilon_w > 1$ denote the elasticities of substitution

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[17] The reader may wonder why we did not use the basic New Keynesian model with sticky prices instead, with supply shocks being defined as cost push shocks. A technical reason underpins our decision: as showed by Boehm and House (2019), despite an inflation-output stabilization trade-off characterizing cost-push shocks in the basic model with sticky prices only, the optimal simple rule in that framework implies an infinite response to both inflation and output conditional on such shocks. That implies that the same policy rule is optimal for both demand and cost-push shocks in this basic framework, and hence allowing for a targeted response to demand versus supply (cost push) shocks would not help improve welfare upon the optimal conventional (unconditional) Taylor rule.

[18] Derivations can be found in Galí (2015), Chapter 6. Note that, compared to the textbook model, we denote *price* inflation by π_t instead of π_t^p. We do so to ease notation in the specifications of the targeted Taylor rules where additional superscripts are needed to distinguish between the demand and supply components of inflation.

among varieties of goods and labor services respectively. Parameters σ, φ and β denote the household's coefficient of relative risk aversion, the curvature of labor disutility and the discount factor respectively. Parameter α denotes the degree of decreasing returns to labor in production. As shown in Galí (2015), equations (1) and (2) can be derived from the aggregation of price and wage setting decisions of workers and firms, in an environment in which such re-optimization takes place with probabilities $1-\theta_p$ and $1-\theta_w$ respectively.

The demand side of the economy is described by the dynamic IS equation:

$$\tilde{y}_t = E_t\{\tilde{y}_{t+1}\} - \frac{1}{\sigma}(i_t - E_t\{\pi_{t+1}\} - r_t^n) \tag{6}$$

where i_t is the nominal interest rate and r_t^n is the efficient rate of interest. Under our assumptions, the latter is given by $r_t^n = \rho + (1-\rho_z)z_t + \sigma E_t\{\Delta y_{t+1}^n\}$, where $\rho \equiv -log\beta$ is the discount rate and z_t is a discount factor shifter (which we refer to as "demand" shock) which follows an exogenous AR(1) process with autoregressive coefficient ρ_z.[19] Note that in the absence of nominal rigidities, demand shocks have no effect on output or employment; they only affect the real interest rate.[20]

4.2 Monetary policy

In our analysis we consider three alternative monetary policy regimes. The first regime is described by a conventional Taylor–type rule given by:

$$i_t = \rho + \phi_\pi \pi_t + \phi_y \widehat{y}_t \tag{7}$$

where $\widehat{y}_t \equiv log(Y_t/Y)$ denotes the log deviation of output from its steady-state and where ϕ_π and ϕ_y are assumed to satisfy the standard determinacy condition:

$$\phi_\pi + \phi_y \left(\frac{1-\beta}{\sigma + \frac{\alpha+\varphi}{1-\alpha}}\right)\left(\frac{1}{\lambda_p} + \frac{1}{\lambda_w}\right) > 1 \tag{8}$$

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[19] The demand shock can be thought as a fiscal shock (see Clarida et al. (1999), footnote 11). Specifically, it can stand for a function of expected (exogenous) changes in government purchases relative to expected changes in potential output.

[20] In the absence of nominal rigidities, the demand shock bares no effect on output or employment. The reason has to do with the particular way in which it is introduced in the model, namely as a shock to the discount factor, which changes in the same proportion the marginal disutility of labor and the marginal utility of consumption. As a result, labor supply does not change. Labor demand does not change either, so employment and output do not change, they are fully pinned down by the supply block of the model. Only the real rate adjusts in order to keep consumption unchanged. With nominal rigidities, there is no longer a simple mapping between the real wage and employment (because the markup is variable). Instead employment and output are determined by the aggregate demand for goods, which changes in response to the discount factor shock, as long as monetary policy does not offset it fully. See chapters 2 and 3 in Galí (2015) for details.

This rule has been traditionally viewed as capturing in a parsimonious way the behavior of central banks in many advanced economies in the absence of a binding zero lower bound constraint on the policy rate[21]. The monetary policy rule in (7) can be rewritten in terms of the output gap as

$$i_t = \rho + \phi_\pi \pi_t + \phi_y \widetilde{y}_t + \nu_t \tag{9}$$

where $\nu_t \equiv \phi_y \widehat{y}_t^n$. Equations (3) through (9) describe the equilibrium of the model under a conventional Taylor rule.

The second regime we consider corresponds to a modified version of the Taylor rule in (7), where we replace aggregate price inflation π_t with its demand-driven and supply-driven components (π_t^d and π_t^s, respectively), akin to the targeted Taylor rule estimated in Section 3.2. The targeted Taylor rule in the model is given by

$$i_t = \rho + \phi_\pi^d \pi_t^d + \phi_\pi^s \pi_t^s + \phi_y \tilde{y}_t + \nu_t \tag{10}$$

with $\pi_t \equiv \pi_t^d + \pi_t^s$, where π_t^d and π_t^s are the demand and supply components of inflation. The details of the equilibrium determination in this case are deferred to Section 5.

Finally, the third regime we consider corresponds to the optimal policy under commitment in the presence of (simultaneous) demand and supply shocks. That policy is a state contingent plan that maximizes the representative household's welfare, subject to a sequence of private sector constraints given by equations (3) through (6), all for $t = 0, 1, 2, \ldots$. That optimal policy problem is described formally in Section 7.1 and gives rise to a set of difference equations which, together with equations (3) through (6), describe the equilibrium under the optimal policy with commitment.

4.3 Baseline parametrization

The baseline parametrization for the non-policy block of the model is summarized in Table 4.

The non-policy block is parametrized following Galí (2015). We set the discount factor β to 0.99, implying a (annualized) steady-state real interest rate of 2%. We set $\sigma = 1$, $\varphi = 5$ and $\alpha = 0.25$. Elasticity of substitution parameters ϵ_p and ϵ_w are set to 9 and 4.5, respectively,

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[21] In the original Taylor (1993) rule, the "output gap" is assumed to be measured by output relative to a deterministic trend. In more recent empirical studies, the trend measure is the one constructed by Congressional Budget Office (CBO) (*e.g.* Clarida et al. (2000), Carvalho et al. (2021)), as we also assume in our analysis. These trend measures conventionally map into the basic New-Keynesian framework into the steady-state level of output (*e.g.* Galí (2015)). As explicitly pointed out by Woodford (2001), this measure is very different from the (welfare relevant) output gap that is relevant for welfare.

implying a steady-state subsidy $\tau = 0.31$.[22] We set $\theta_p = \theta_w = 0.75$, consistent with an average duration of price and wage spells of one year. We choose a higher persistence of the demand shock than the textbook value (0.9 as opposed to 0.5) to help match better the persistence of demand-driven inflation in the model with that observed in the data (Figure 1, blue line). Our findings, however, carry over when using the textbook value of the parameter as well.

Table 4: Baseline parametrization: non-policy block

Parameter	*Description*	*Value*
β	Discount factor	0.99
σ	Curvature of consumption utility	1
φ	Curvature of labor disutility	5
$1-\alpha$	Index of decreasing returns to labour	0.25
ϵ_p	Elasticity of substitution of goods	9
ϵ_w	Elasticity of substitution of labor types	4.5
θ_p	Calvo index of price rigidities	0.75
θ_w	Calvo index of wage rigidities	0.75
ρ_z	Persistence demand preference shock	0.9
ρ_a	Persistence technology shock	0.9

Notes: : Values are shown in quarterly rates.

5 Equilibrium under a *targeted* Taylor Rule

To implement the targeted Taylor rule, we first represent the equilibrium conditions by means of a system of difference equations with an unique equilibrium.

Recall the non-policy block of the economy is described by equations (3), (4), (5), (6), while the targeted Taylor rule is described by (10). Assume the central bank can observe inflation in a shadow economy with supply shocks only and denote it by π_t^s. Under this assumption, using the (definition of the) inflation decomposition in demand and supply components $\pi_t \equiv \pi_t^d + \pi_t^s$, we can rewrite the policy rule (10) as a function of aggregate inflation π_t and inflation in the shadow economy with supply shocks only π_t^s as

$$\widehat{i}_t = \phi_\pi^d \pi_t + (\phi_\pi^s - \phi_\pi^d)\pi_t^s + \phi_y \tilde{y}_t + \nu_t \tag{11}$$

where π_t^s solves the following dynamic system of equations describing the shadow economy with

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[22] The optimal steady-state subsidy satisfies $\tau = 1 - \frac{1}{\mathscr{M}_p \mathscr{M}_w}$, where $\mathscr{M}_p \equiv \frac{\epsilon_p}{\epsilon_p - 1}$ and $\mathscr{M}_w \equiv \frac{\epsilon_w}{\epsilon_w - 1}$. See chapter 6 in Galí (2015) for details.

supply shocks only

$$\pi_t^s = \beta E_t\{\pi_{t+1}^s\} + \chi_p \widetilde{y}_t^s + \lambda_p \widetilde{\omega}_t^s \tag{12}$$

$$\pi_t^{w,s} = \beta E_t\{\pi_{t+1}^{w,s}\} + \chi_w \widetilde{y}_t^s - \lambda_w \widetilde{\omega}_t^s \tag{13}$$

$$\widetilde{\omega}_t^s \equiv \widetilde{\omega}_{t-1}^s + \pi_t^{w,s} - \pi_t^s - \Delta\omega_t^{n,s} \tag{14}$$

$$\widetilde{y}_t^s = E_t\{\widetilde{y}_{t+1}^s\} - \frac{1}{\sigma}\left(\widehat{i}_t^s - E_t\{\pi_{t+1}^s\} - \widehat{r}_t^{n,s}\right) \tag{15}$$

$$\widehat{i}_t^s = \phi_\pi^s \pi_t^s + \phi_y \widetilde{y}_t^s + \nu_t^s \tag{16}$$

where $\widehat{r}_t^{n,s} = \sigma\psi_{\omega a}(1-\rho_a)a_t$, $\nu_t^s = \phi_y \psi_{ya} a_t$. Equations (3), (4), (5), (6), (11), (12) – (16) describe a system of ten difference equations with ten unknowns.

To determine the equilibrium of the system, we first solve separately for the equilibrium of the shadow economy with supply shocks only described by equations (12) – (16). The latter equilibrium is unique if the nominal determinacy condition (8) is satisfied for $\phi_\pi = \phi_\pi^s$. If this is the case, one can determine the unique equilibrium in the shadow economy using the method of undetermined coefficients. Applying this method, we obtain

$$\pi_t^s = \delta_{\pi^{p,s}}^a a_t \tag{17}$$

with $\delta_{\pi^s}^a$ a constant which is a function of the structural parameters of the model. Using the value of π_t^s at each date t given by (17), we can now solve for the equilibrium of aggregate inflation π_t, output gap $\widetilde{y}_t$, real wage gap $\widetilde{\omega}_t$, wage inflation π_t^w, nominal interest rate $\widehat{i}_t$ described by the system of the five difference equations (3), (4), (5), (6), (11). The equilibrium of the latter system is unique if the nominal determinacy condition (8) is satisfied for $\phi_\pi = \phi_\pi^d$.

Proposition 1. *The equilibrium of the model is unique if the response coefficients to both demand–driven and supply–driven inflation (ϕ_π^d, ϕ_π^s) satisfy the Taylor principle given the response coefficient to the output gap (ϕ_y).*

If Proposition (1) is satisfied, we can now apply again the method of undetermined coefficients to compute the equilibrium paths of π_t, π_t^w, $\tilde{y}_t$ and $\tilde{\omega}_t$[23].

Notably, the equilibrium of the model can be written as the sum of the two shadow economies with supply shocks only and with demand shocks only. To verify this result, one can compute the

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[23] The system of ten equations (3), (4), (5), (6), (11), (12) – (16) can be solved also numerically using Dynare, Matlab or a similar software.

residual demand component π_t^d from the definition of the decomposition of inflation $\pi_t^d \equiv \pi_t - \pi_t^s$, using the expressions previously derived for aggregate inflation π_t and for inflation in the shadow economy with supply shocks only π_t^s. The residual demand component of inflation is equal to inflation in the shadow economy with demand shocks only[24]. The result implies that, up to a first order approximation, the model-based counterparts of the demand- and supply-driven inflation series plotted in Figure 1 are the inflation series in the shadow economies with demand shocks only and, respectively, with supply shocks only.

Proposition 2. *The equilibrium of the model with demand and supply shocks can be written as the sum of the two shadow economies with demand shocks only and with supply shocks only.*

Following a similar approach, one can write the dynamics of all other aggregate variables in our model as the sum of their dynamics in the shadow economies with demand and supply shocks only.[25] Thus, hereafter, anytime we refer in our analysis to the demand (supply) component of a variable, one may think of it as being equal to the level of that variable in a shadow economy with demand (supply) shocks only.

6 Business cycle fluctuations

What are the business cycle implications of monetary policy following a targeted —rather than a conventional— Taylor rule. One way to answer this question is to compare, for a given series of demand *and* supply shocks, the dynamics of our model under the two monetary policy regimes.

For the purpose of the experiment, we add an interest rate smoothing term in both the targeted and conventional rules and set the parameters of the monetary policy rules consistent with the estimated values in our empirical analysis – see Table 5 below. Furthermore, we set the variance of the technology shock to 1% and that of the demand shock to 5%. These values ensure that the variations in the demand and supply components of inflation under the targeted Taylor rule in our model are broadly consistent with those observed in the data. The dynamics of inflation, output, and policy rates under the two alternative monetary policy regimes, as well as the series of demand and supply shocks are reported in Figure 2.

Several findings stand out from the comparison of the simulated dynamics under the two monetary policy regimes.

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[24] This result can be easily verified using Dynare.

[25] For instance, one can write $\widehat{y}_t = \widehat{y}_t^d + \widehat{y}_t^s$ where $\widehat{y}_t^d$ ($\widehat{y}_t^s$) is the deviation of output from its steady state value in the shadow economy with demand (supply) shocks only, etc.

Table 5: Parametrization: monetary policy rules

Parameter	*Description*	*Value*
Taylor–type rule:		
ρ	Interest-rate smoothing	0.7
ϕ_π	Response to aggregate inflation	2
ϕ_y	Response to the output gap	0.2
Targeted Taylor–type rule:		
ρ	Interest-rate smoothing	0.7
ϕ_π^d	Response to demand-driven inflation	4
ϕ_π^s	Response to supply-driven inflation	1.01
ϕ_y	Response to the output gap	0.2

Notes: : Values are shown in quarterly rates.

Inflation The composition of inflation differs markedly across the two monetary regimes. Under the targeted Taylor rule, overall inflation is driven to a larger extent by supply factors than under the conventional rule. This is because the demand component of inflation is more subdued (Figure 2, top panel, blue), while that of supply is more prominent (red). These dynamics reflect a more forceful policy rate response to demand–driven inflation (4 versus 2) and a weaker response to supply–driven inflation (1.01 versus 2) under the targeted rule compared to the conventional rule.

Output The overall output volatility is smaller under the targeted Taylor rule, with both the demand and supply components of output being less responsive to the business cycle (Figure 2, middle panels). Under the targeted rule, output fluctuations in response to supply shocks are more muted because the economy adjusts to such shocks mainly through changes in prices (Figure 3). The component of output driven by demand shocks is also more subdued because the stronger reaction to demand–driven inflation simultaneously counteracts the demand–driven fluctuations in output (Figure 4). This is because the central banks does not face an inflation/output stabilization trade–off, i.e. the “divine coincidence” holds for demand shocks.

Nominal interest rates Despite material differences in the composition and levels of aggregate inflation and output under the two monetary regimes, the change in nominal interest rates, as well as their drivers, are very similar in the two cases (Figure 2, third row). This is consistent with the similar responses of policy rates under the targeted and conventional rules to both a supply shock (Figure 3) and a demand shock (Figure 4).

Finally, the variances of macro-variables under the two monetary regimes confirm these

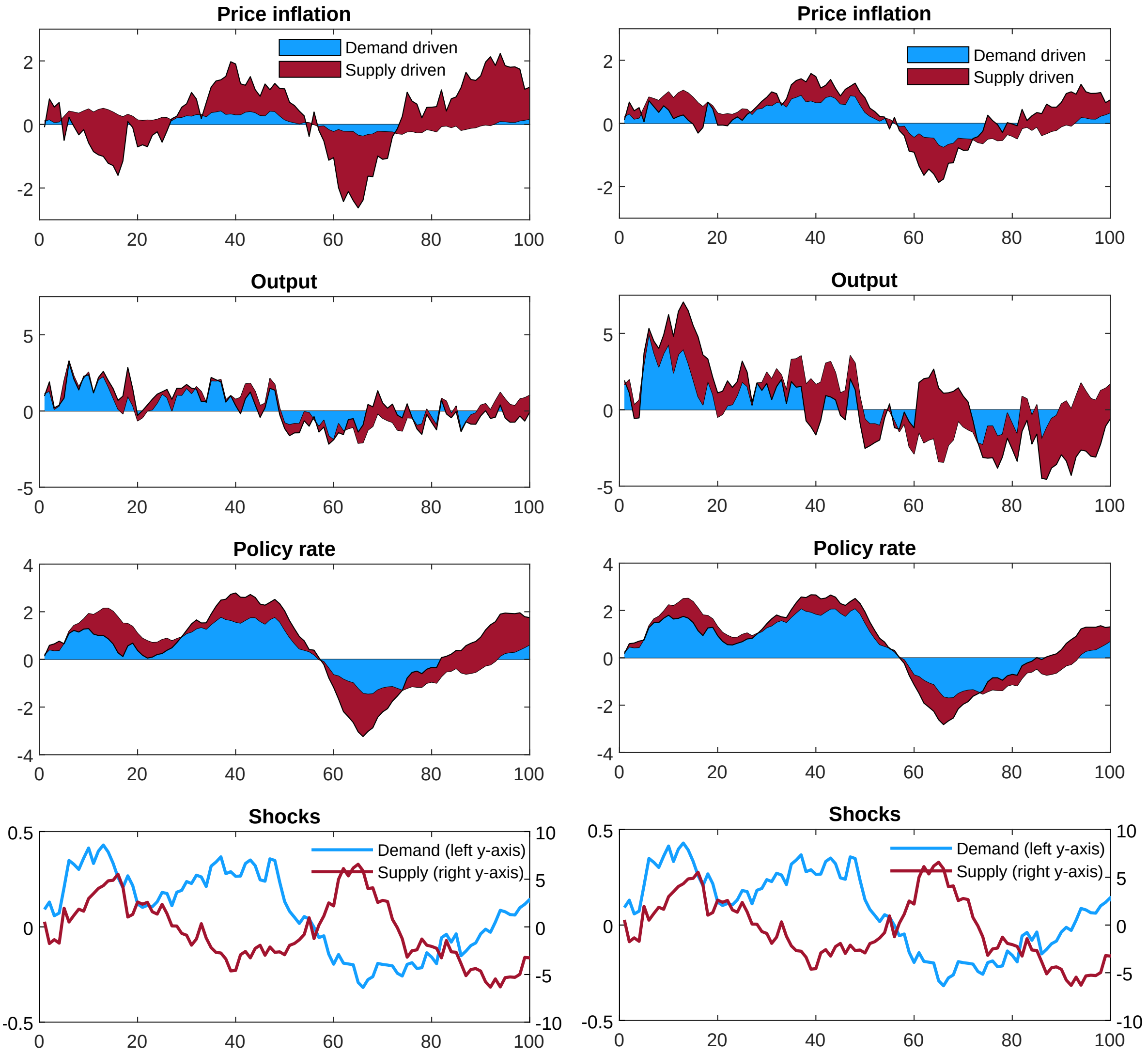

Figure 2: Simulated dynamics: targeted Taylor rule (left) versus conventional Taylor rule (right)

patterns (Table 6). In particular, under the targeted Taylor rule (second row), the relative variance of supply–driven inflation is higher, the variance of aggregate output is lower, while the variance of the interest rate is very similar to that under the conventional rule (first row).

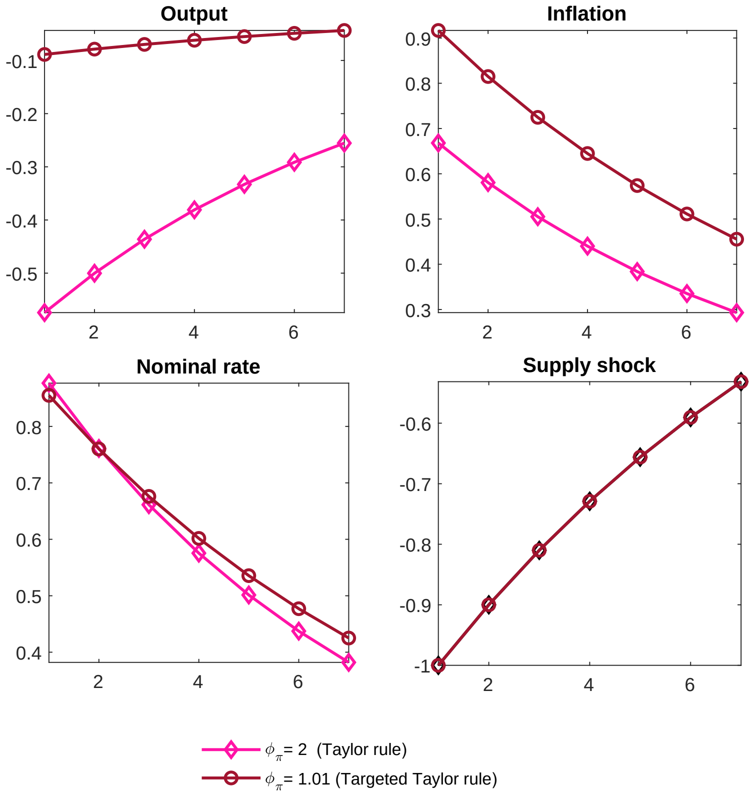

Figure 3: Dynamic responses to a technology shock

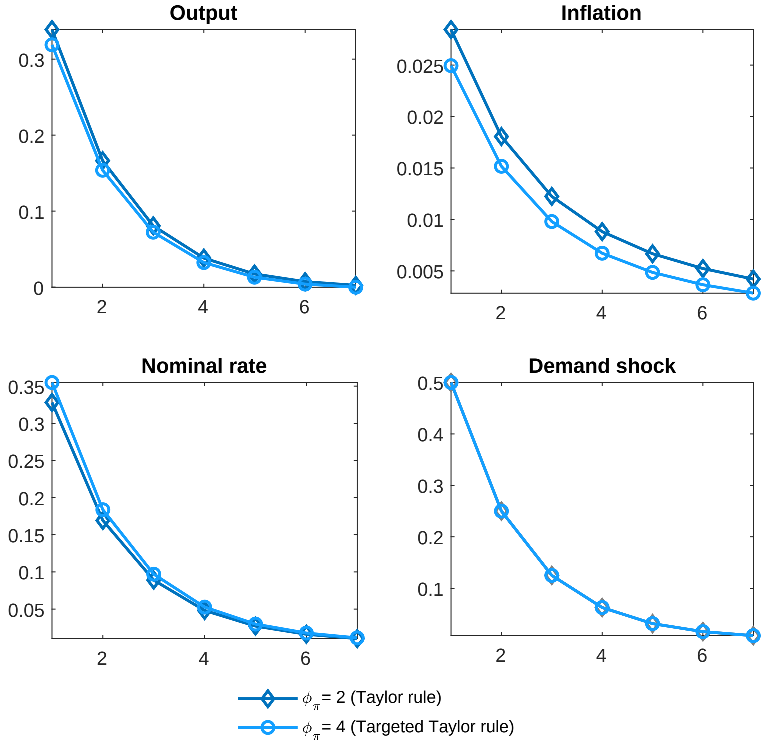

Figure 4: Dynamic responses to a demand preference shock

Table 6: Volatility of output, inflation and policy rates

	σ^2_y	σ^2_π	$\sigma^2_{\pi^d}$	$\sigma^2_{\pi^s}$	$\sigma^2_{y,d}$	$\sigma^2_{y,s}$	σ^2_i	$\sigma^2_{\pi^s}/\sigma^2_\pi$
Taylor rule	4.14	0.23	0.07	0.09	5.05	1.21	0.99	39%
Targeted Taylor rule	2.44	0.26	0.02	0.18	2.69	0.12	0.94	70%

Notes: Model-based variances of macroeconomic variables under the targeted Taylor–type rule versus the conventional Taylor–type rule. σ^2 stands for variance. Its subscript denotes a specific macroeconomic variable.

7 Welfare evaluation

The aim of this section is to derive optimal simple policy rules and evaluate welfare in our model economy. One novelty of our analysis is that we derive such rules in the presence of both demand and supply shocks — as opposed to each shock taken separately. Another novelty is that we compare the merits of following *targeted* Taylor–type rules relative to those of following conventional (unconditional) Taylor–type rules.

We start our analysis by deriving the optimal monetary policy with commitment when the economy is subject to both demand and supply shocks simultaneously. We then consider this hypothetical optimal policy as the relevant benchmark to assess the welfare implications of more operational ("simple") monetary policy rules. The welfare comparison across alternative monetary policy regimes is based on the average period welfare losses implied by each monetary policy regime given by:[26]

$$\mathbb{L} = \frac{1}{2}\left[\left(\sigma + \frac{\varphi+\alpha}{1-\alpha}\right)var(\tilde{y}_t) + \frac{\epsilon_p}{\lambda_p}var(\pi_t) + \frac{\epsilon_w(1-\alpha)}{\lambda_w}var(\pi^w_t)\right] \tag{18}$$

7.1 Optimal policy under commitment with demand *and* supply shocks

The optimal monetary policy under commitment when the economy faces simultaneously demand and supply shocks is characterized by the interest rate path which minimizes at each date

$$\frac{1}{2}E_0\sum_{t=0}^{\infty}\beta^t\left[\left(\sigma + \frac{\varphi+\alpha}{1-\alpha}\right)\tilde{y}^2_t + \frac{\epsilon_p}{\lambda_p}\pi^2_t + \frac{\epsilon_w(1-\alpha)}{\lambda_w}(\pi^w_t)^2\right]$$

subject to equations (3)–(6).

Note that conditions (3)–(5) do not depend on the demand shock. Thus, with the exception

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[26] For derivation details, see chapter 6 in Galí (2015).

of the path of the interest rate $\widehat{i}_t$, the paths of all other variables under optimal policy in the presence of both demand and supply shocks are identical to those in the presence of supply shocks only. As described in Galí (2015), Chapter 6.4, the paths of π_t, π_t^w, $\tilde{y}_t$, $\tilde{\omega}_t$ conditional on supply shocks only are the solution of the following dynamic system of equations:

$$\left(\sigma + \frac{\varphi + \alpha}{1 - \alpha}\right)\tilde{y}_t + \chi_p \xi_{1,t} + \chi_w \xi_{2,t} = 0 \tag{19}$$

$$\frac{\epsilon_p}{\lambda_p}\pi_t^p - \Delta\xi_{1,t} + \xi_{3,t} = 0 \tag{20}$$

$$\frac{\epsilon_w(1-\alpha)}{\lambda_w}\pi_t^w - \Delta\xi_{2,t} - \xi_{3,t} = 0 \tag{21}$$

$$\lambda_p \xi_{1,t} - \lambda_w \xi_{2,t} + \xi_{3,t} - \beta E_t\{\xi_{3,t+1}\} = 0 \tag{22}$$

for $t = 0, 1, 2, ...$, where $\{\xi_{1,t}\}$, $\{\xi_{2,t}\}$, $\{\xi_{3,t}\}$ denote the sequence of Lagrange multipliers associated with the previous constraints, together with the constraints (3)–(5), given $\xi_{1,-1} = \xi_{2,-1} = 0$ and an initial condition for $\tilde{\omega}_{-1}$. We hereafter index the solution path of the variables by the star symbol. Given the optimal paths of the output gap $\tilde{y}_t^*$ and price inflation π_t^*, we can now compute the optimal path of the interest rate $\widehat{i}_t^*$ as

$$\widehat{i}_t^* = \sigma E_t\{\Delta\tilde{y}_{t+1}^*\} + E_t\{\pi_{t+1}^*\} + \widehat{r}_t^n$$

for $t = 0, 1, 2, ...$, where $\widehat{r}_t^n = (1 - \rho_z)z_t + \sigma\psi_{\omega a}(1 - \rho_a)a_t$, which is a function of both supply and demand shocks.

Optimal policy completely insulates the economy from the effect of demand shocks, and solves efficiently the stabilization trade-off between inflation and output gap in the case of supply shocks so as to minimize their associated welfare losses. Table 7 reports the average welfare losses, as well as the variances of price inflation, wage inflation and of the output gap under optimal policy conditional on technology shocks only (rows 3 to 6), demand shocks only (rows 9 to 12), and both types of shocks (rows 15 to 18). The standard deviations of the technology σ_a and the demand σ_z innovations are both set to one percent as in Galí (2015), Chapter 6. The remaining parameters equal their baseline values summarized in Table 4.

The outcome under optimal policy is reported in the second column of Table 7. With technology shocks only, the welfare losses under optimal policy equal those reported in Table 6.1 in Galí (2015). Notably, the standard deviations of the welfare relevant output gap and of wage inflation are three times smaller than that of price inflation. This suggests that, in response to technology shocks, the central bank should not strictly stabilize price inflation. Results are very different for demand shocks only, where the optimal monetary policy response is compatible with the full stabilization of price inflation. The welfare losses and standard deviations under optimal policy when the economy is subject to both types of shocks at the same time are the sum of losses in the case with technology shocks only and with demand shocks only. According to our findings, if the central bank chose to strictly target (aggregate) price inflation in the case with shocks, it would exacerbate the inefficient fluctuations in response to technology shocks moving away from optimal policy.

	Optimal	*Strict targeting*	*Flexible targeting:*	
			unconditional	*targeted*
Technology shocks				
$\sigma(\pi)$	0.11	0	0.14	0.14
$\sigma(\pi^w)$	0.03	0.26	0.10	0.10
$\sigma(\tilde{y})$	0.04	3.41	0.78	0.78
$\mathbb{L}$	0.033	0.79	0.12	0.12
Demand shocks				
$\sigma(\pi)$	0	0	0.01	0
$\sigma(\pi^w)$	0	0	0.04	0
$\sigma(\tilde{y})$	0	0	0.96	0
$\mathbb{L}$	0	0	0.04	0
Both shocks				
$\sigma(\pi)$	0.11	0	0.15	0.14
$\sigma(\pi^w)$	0.03	0.26	0.14	0.10
$\sigma(\tilde{y})$	0.04	3.41	1.74	0.78
$\mathbb{L}$	0.033	0.79	0.16	0.12

Table 7: Welfare outcomes: optimal policy versus simple rules

Notes: As in Galí (2015), the standard deviations of the technology shock and the demand shock equal 1%.

The optimal monetary policy under commitment does not have a simple characterization, requiring instead that the central bank follow a complicated target rule satisfying simultaneously the optimality conditions described by (19) to (22). Thus, it is of interest to know to what extent simple monetary policy rules — understood as rules that a central bank could arguably adopt in practice — may be able to approximate the optimal policy, an issue that is attended to next.

7.2 Evaluation of simple monetary policy rules

In what follows, we first consider conventional Taylor–type rules (7) and then turn to targeted Taylor–type rules (10).[27]

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[27] Notably, Erceg et al. (2000) shows that the optimal policy response to a supply shock can be well approximated by targeting the *output gap*. A practical difficulty with implementing such a policy is that the output gap is

Taylor–type rules The specification of conventional Taylor–type rules described by $i_t = \rho + \phi_\pi \pi_t + \phi_y \widehat{y}_t$ nests the description of strict inflation targeting (SIT) and the conventional (unconditional) description of flexible inflation targeting (FIT).

In particular, SIT is characterized by $\phi_\pi \to \infty$ and $\phi_y = 0$, and implies that price inflation is zero, and hence on target at all times (Svensson (1999)). Table 7 (column three) shows that such a regime avoids welfare losses in the presence of demand shocks, but exacerbates losses with respect to optimal policy in the presence of supply shocks. In particular, welfare losses in response to supply shocks are up to twenty four times higher under SIT than under optimal policy. In the presence of both types of shocks, the order of magnitude of welfare losses compared to optimal policy is the same as in response to supply shocks only since welfare losses subject to demand shocks are zero under SIT.

The description of FIT conventionally entails finite positive values for $\phi_\pi \geq 0$, $\phi_y \geq 0$, and allows price inflation to temporary deviate from its medium-run target (Svensson (1999)). The two policy response coefficients may be optimally chosen to minimize welfare losses with respect to those under optimal policy. For the purpose of our exercise, we set them so as to minimize welfare losses in response to the supply shock in our model[28].

Our findings reported in Table 7 (column four) show that welfare losses due to inefficient fluctuations subject to supply shocks can be substantially mitigated under the conventional FIT-rule relative to the SIT-rule (compare welfare outcomes under unconditional FIT and SIT for supply shocks only). Specifically, under our baseline calibration, welfare losses are reduced by more than six and a half times (i.e. from 0.79 to 0.12). The welfare gains with respect to SIT due to an improved response to supply shocks come at a welfare cost due to more inefficient fluctuations subject to demand shocks (compare welfare outcome under unconditional FIT and SIT for demand shocks only). Thus, in the case with both types of shocks, the net welfare gains under conventional-FIT with respect to SIT will generally depend on the relative variance of supply shocks compared to that of demand shocks.

As long as the relative variance of supply shocks is high enough (as in the experiment

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not an observable variable. Since our analysis focuses on simple policy rules which central banks could *a priori* implement in practice, we consider rules where the central bank may respond to deviations of observable variables such as the deviation of inflation from its medium term target (here, the steady-state level of inflation) and of output from its deterministic trend (here, the steady-state level of output).

[28] For simplicity, we describe supply disturbances by the means of a technology shock. In practice, however, several types of supply disturbances may buffet the economy (e.g. technology shocks, oil supply shocks, labor supply shocks, market power shocks), and the optimal response coefficient to supply-driven inflation will depend on the mix of these shocks. Nevertheless, since strictly targeting inflation is not optimal for none of these shocks, the conclusions of our analysis remain qualitatively the same.

reported in Table 7 where it equals that of the demand shock), conventional-FIT will perform better than SIT. In this case, the deviation of inflation from target under FIT allows to improve overall welfare in the presence of both types of shocks. But this is not a general result. As shown in Figure 5, for large variances of demand shocks, SIT may improve welfare upon the optimal conventional-FIT rule. In those cases, the welfare gains of conventional-FIT subject to the relative small supply shocks are more than offset by the welfare losses incurred in the face of the large demand shocks.

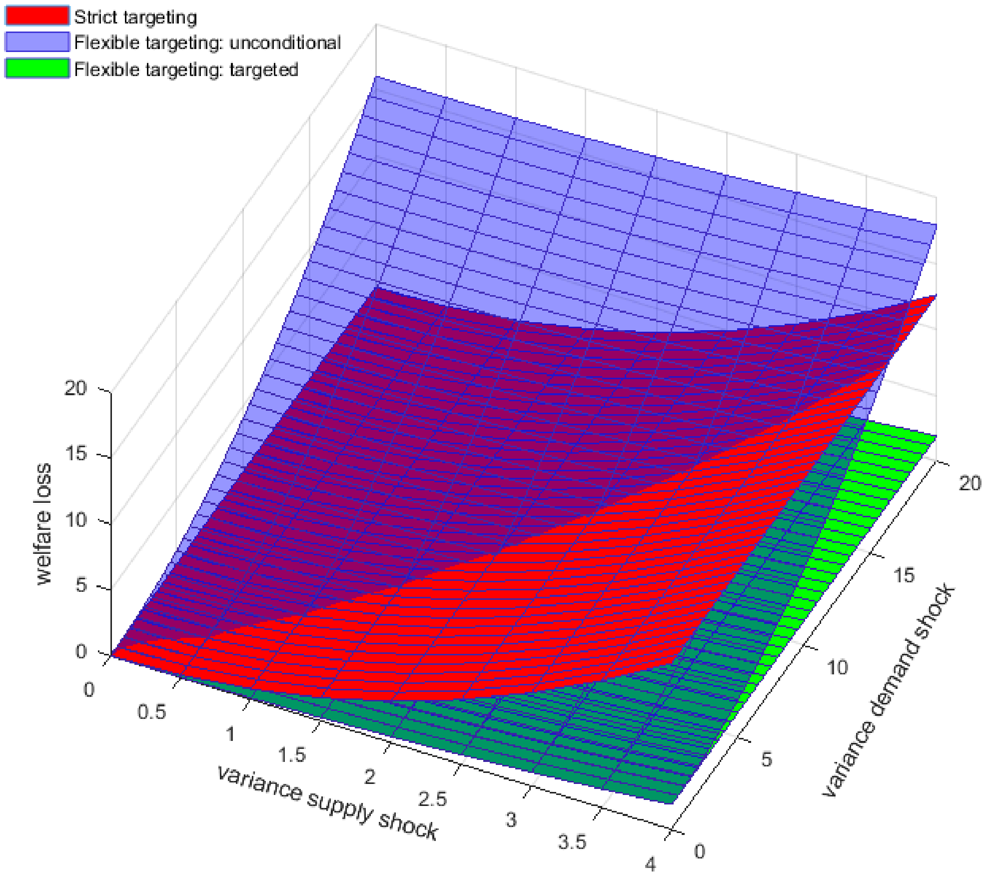

Figure 5: Welfare losses and the variances of shocks: Taylor rules versus targeted Taylor rules

Notes: The relative welfare gains of conventional unconditional flexible targeting compared to strict targeting increase in the relative standard deviation of supply shocks compared to that of demand shocks. Targeted flexible targeting always outperforms strict targeting and conventional unconditional flexible targeting regardless of the variance of the two types of shocks.

Targeted Taylor–type rules We now turn to the targeted Taylor–type rules described by

$$i_t = \rho + \phi_\pi^d \pi_t^d + \phi_\pi^s \pi_t^s + \phi_y \widehat{y}_t \tag{23}$$

These rules allow to tailor the monetary policy response to the nature of inflation drivers.

Consistent with the shock dependent nature of optimal monetary policy derived in Section 7.1, the optimal coefficients of the targeted policy rule (23) are characterized by: (i) a strong reaction to demand-driven inflation (i.e. $\phi_{\pi}^{d} \to \infty$) that insulates the economy from inefficient fluctuations in response to demand disturbances; (ii) a finite and moderate response to supply-driven inflation described by the optimal response in the case with supply shocks only.[29] Since the monetary policy regime described by a targeted Taylor–type rule (23) also satisfies the definition of flexible inflation targeting, we label it as *targeted flexible inflation targeting* (TA-FIT).

As shown in Table 7, this targeted way to conduct monetary policy mimics more closely optimal policy than both SIT or conventional FIT in the presence of both types of shocks. This is because the central bank can adjust optimally the policy response to demand (supply) shocks, without constraining its response to supply (demand) shocks. As a result, the welfare outcome is characterized by the linear combination of outcomes in an economy subject to demand shocks only where the central bank responds optimally to such shocks by strictly targeting inflation, and those in an economy subject to supply shocks only where the central bank responds optimally to such shocks by flexibly targeting inflation. This result holds irrespective of the variance of the two types of shocks (Figure 5).

Implementing such rules in practice depends, of course, on the central bank's ability to distinguish in real time between supply and demand disturbances. The measures of demand- and supply-driven inflation we have used became available only recently. Nonetheless, our empirical analysis suggests that the Federal Reserve has generally succeeded to infer similar information about the supply- versus demand-driven nature of inflation from their indicators, analytical toolboxes, judgment, and awareness of specific shocks buffeting the economy at a certain point in time (*e.g.* fiscal packages, oil price shocks). Going forward, the availability of direct measures of demand– versus supply–driven inflation could further improve the implementability of such targeted rules.

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[29] The optimal response coefficient to supply-driven inflation (ϕ_{π}^{s}) equals $3.5 < \phi_{\pi}^{d} \to \infty$ in our stylized model, while the policy response coefficient to the deviation of output from steady-state (ϕ_y) equals 0. More generally, the optimal value of this parameter will vary with the composition of different types of supply shocks, as well as with the presence of additional real and financial frictions. Notably, optimal Taylor coefficients for aggregate inflation derived within richer medium-scale macroeconomic models are in the ballpark of $1.2 - 2$ (*e.g.* Levin et al. (2005), Taylor (2007), Adjemian et al. (2007)), suggesting that the conditional optimal response to supply-driven inflation is lower than $1.2 - 2$ and hence closer to the empirical estimates based on US data.

8 Conclusion

In this paper we refine the specification of Taylor–type rules — conventionally used to describe the conduct of monetary policy — to allow for a different (targeted) reaction to demand- versus supply-driven inflation. We refer to the new type of rule as a "targeted Taylor rule". This new specification is in line with the doctrine of the Federal Reserve as reflected in its official communications, which calls for a more attenuated monetary response when inflation is driven by supply factors. Our contribution to the literature on monetary policy rules is both empirical and theoretical.

In the first part of the analysis, we show empirically that, starting with Paul Volcker's tenure at the Federal Reserve, monetary policy in the United States responded significantly more aggressively to demand-driven inflation than to supply-driven inflation. These findings are based on an otherwise standard Taylor–type rule estimation (*e.g.* Carvalho et al. (2021), Clarida et al. (2000)) in which we replace aggregate inflation with its demand–driven and supply–driven components, as identified in recent studies by Eickmeier and Hofmann (2022) and Shapiro (2022).

In the second part of our analysis, we highlight that our empirical findings have important implications for business cycle fluctuations and welfare. By design, a targeted rule counteracts to a larger extent the effects of demand (supply) shocks on inflation (output) than a conventional (unconditional) Taylor rule. Accordingly, simulations of a textbook New Keynesian model with both demand and supply shocks indicate that, all else equal, aggregate inflation is driven to a larger extent by supply factors when the central bank follows a *targeted* Taylor rule than when it follows a conventional unconditional Taylor rule. On the flip side, aggregate output is less volatile and mostly driven by demand factors. Finally, we show that the net effect on welfare of following the optimal targeted Taylor rule compared to the optimal conventional unconditional Taylor rule is unambiguously positive when business cycle fluctuations are driven by both demand and supply shocks.

Our analysis is meant as a first pass at this research question. In the future, one may want to revisit our empirical question using real time data on the demand–driven and supply–driven components of inflation, as well as their forecasts. To this end, developing forecasts of demand/supply–driven inflation would be highly welcome.

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9 Appendix

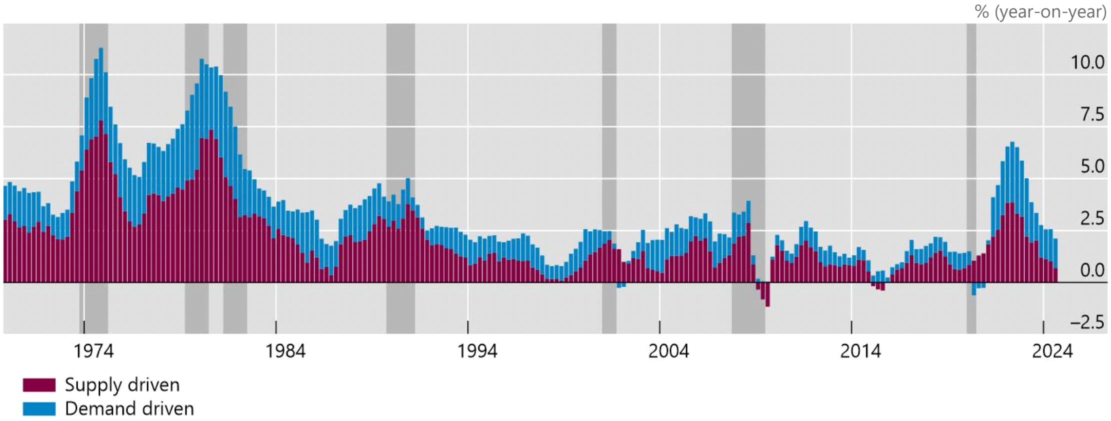

Figure A1: Decomposition of year-on-year headline PCE inflation in demand and supply factors

Notes: Inflation decomposition based on the method proposed by Shapiro (2022).

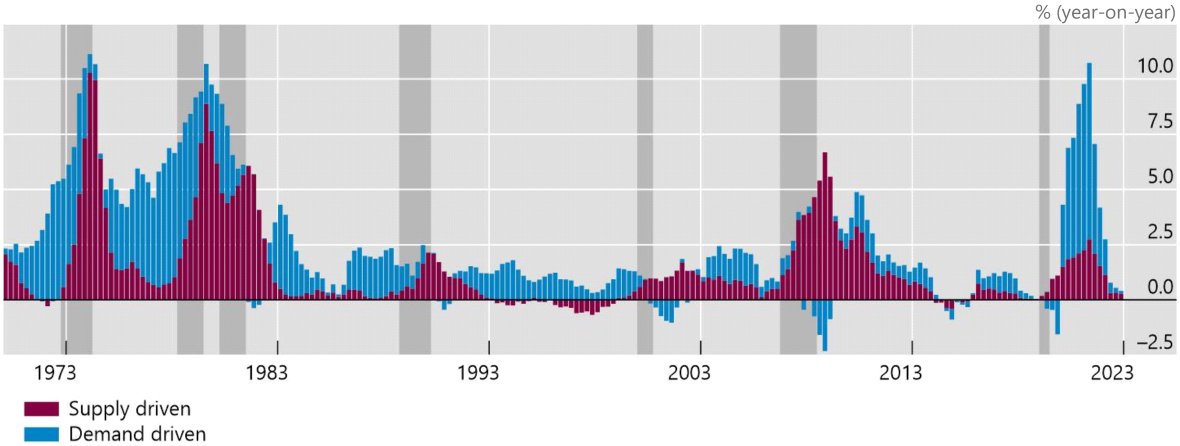

Figure A2: Decomposition of year-on-year standardized headline PCE inflation in demand and supply factors

Notes: Inflation decomposition (standardized) based on the method proposed by Eickmeier and Hofmann (2022).

	Inflation forecasts		
	Consensus	Greenbook	
Inflation component	1 year ahead	1 quarter ahead	1 year ahead
Demand–driven	0.739***	0.801***	0.817***
Supply–driven	0.743***	0.789***	0.716***

Table A1: Correlation demand and supply factors of core PCE inflation with inflation forecasts

Notes: Statistical significance at 1% level indicated with ***. Inflation decomposition based on Shapiro (2022), year-on-year changes. Greenbook forecasts: available for 1986Q1:2018Q4, core CPI inflation (higher correlations for both components when using forecasts of headline CPI inflation; all corelation coefficients above 0.83). Consensus forecasts: available for 1989Q4:2024Q4, headline CPI inflation (core CPI unavailable, core PCE starting in 2018).

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