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* Views expressed are those of the author and do not necessarily reflect official positions of De Nederlandsche Bank.

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Monetary policy in the Euro Area, when Phillips curves ... are curves*

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Abstract

We study monetary policy in an environment where price and wage Phillips curves exhibit true curvature. To this end, we propose a New Keynesian model with endogenous adjustment of price and wage setting frequencies, moving beyond the quasi-linear structure of standard nonlinear NK Phillips curves. Using euro area data from 1999Q1 to 2024Q4, we estimate and simulate the non-linear model, analyzing the recent inflation surge and the implications of state-dependent prices and wages for monetary policy. Unlike conventional models, our framework does not attribute inflation dynamics primarily to exogenous supply shocks. Instead, the impact of shocks is asymmetric and depends on their timing, size, and the business cycle. Consequently, the inflation–output stabilization trade-off is state-dependent: monetary policy is more effective in curbing inflation, and supply shocks have larger effects during periods of high inflation.

***Keywords*:** New Keynesian Phillips Curve, non-linearity, inflation, monetary policy.
***JEL codes*:** C51, E31, E47, E52.

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'The relation between unemployment and the rate of change of wage rates is therefore likely to be highly non-linear.'

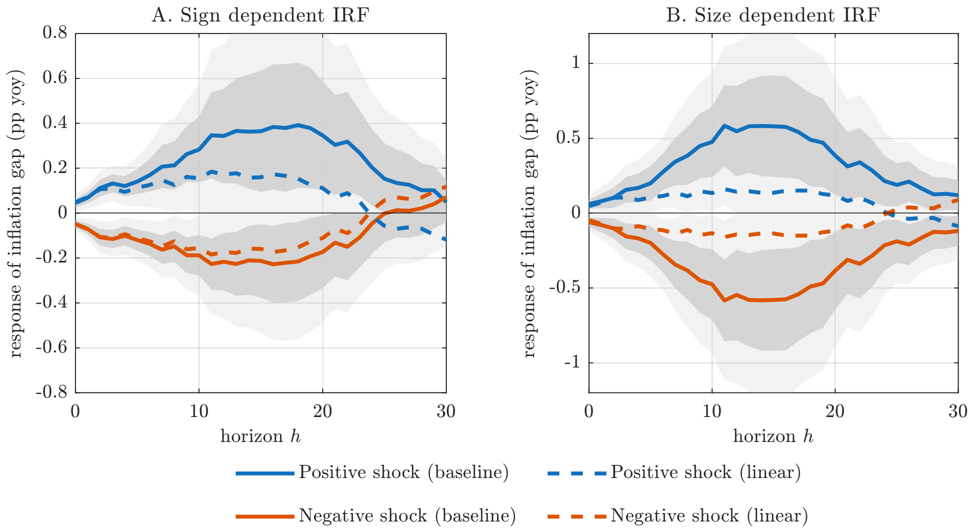
(Phillips, 1958, p. 283)

1. Introduction

The 2021–2022 inflation surge across advanced economies has renewed fundamental questions about the mechanisms governing price and wage adjustment. Inflationary pressures were not confined to consumer prices but were accompanied by a marked acceleration in wage inflation, suggesting changes in firms' and workers' price- and wage-setting behavior. Yet, despite the magnitude and persistence of the inflationary episode, inflation was brought down without triggering a deep recession in most advanced economies. Both the European Central Bank and the Federal Reserve appear to have achieved a so-called *"soft landing"*, stabilizing inflation while avoiding a sharp contraction in real activity. Understanding how nominal adjustment mechanisms operate in high-inflation environments is therefore central to explaining this episode.

A natural interpretation of the recent disinflation is that nominal rigidities respond endogenously to economic conditions. In particular, price and wage adjustment may intensify during inflationary episodes, helping absorb large shocks without generating persistent real misallocation. This view is supported by a growing body of microeconomic evidence documenting state-dependent nominal adjustment. Firms are found to adjust prices more frequently during inflation surges, consistent with a non-linear activation of the extensive margin of price setting (see, e.g., Gautier et al., 2026; Montag and Vallenas, 2023). Similarly, Gödl and Gödl-Hanisch (2024) show that wage-setting frequencies increase during periods of elevated inflation. These findings suggest that nominal adjustment responds asymmetrically to economic conditions, becoming more frequent in high-inflation states while remaining comparatively inert in low-inflation environments.

Consistent with these micro-level findings, macroeconomic data also exhibit pronounced sign and size dependence in inflation dynamics. Figure 1 presents evidence from local projections for the euro area, showing that inflation responses depend both on the sign *and* size of oil supply shocks. Panel A illustrates sign dependence: inflationary supply shocks generate stronger and more persistent inflationary responses than dis-inflationary shocks of comparable magnitude. Panel B highlights size dependence and shows that larger shocks induce disproportionately stronger inflation responses, indicating a clear departure from linearity in shock size. Taken together, the micro- and macro-level evidence points to a common pattern: nominal adjustment reacts nonlinearly to both the sign and the size of shocks, intensifying in inflationary states while remaining relatively unresponsive during disinflationary episodes.



Note: Monthly local projections for year-on-year HICP inflation spanning 1997M1-2024M9. For each horizon $h = 0, 1, \ldots, H$, we estimate $\pi_{t+h} = \alpha_h + \sum_{\ell=0}^{11}(g_h(z_{t-\ell}) + \delta_{\ell,h}\pi_{t-1-\ell}) + \varepsilon_{t+h}$, where π_t denotes year-on-year inflation and z_t is the monthly oil supply shock constructed by Känzig (2021). The function $g_h(\cdot)$ captures horizon-specific nonlinearities. Panel A (sign dependence) uses $g_h(z) = \beta_{1,h}z + \beta_{2,h}z^2$, while Panel B (size dependence) uses $g_h(z) = \beta_{1,h}z + \beta_{2,h}z|z|$. Dashed lines report the estimate from a linear benchmark $g_h(z) = \beta_{1,h}z$. Shaded area reports the 90% and 68% confidence intervals. Appendix A provides further details.

Figure 1: Inflation Impulse Response Functions to a one standard deviation supply shock

These patterns stand in sharp contrast with the predictions of the standard New Keynesian (NK) model, which remains the workhorse framework for monetary policy analysis. In its canonical formulation, the NK model relies on time-dependent pricing and wage-setting mechanisms, such as Calvo contracts, under which adjustment occurs with a constant probability independent of economic conditions (Calvo, 1983). This model can not replicate the non-linearity in macroeconomic data shown in Figure 1. Moreover, once estimated, the model typically implies relatively flat and state-invariant price and wage Phillips curves, so that inflation dynamics are largely driven by exogenous supply shocks, while demand shocks and monetary policy play a limited role (see, e.g., Fratto and Uhlig, 2020). In this environment, disinflation requires sizable and persistent output losses, making soft landings difficult to reconcile with the model's implications.

Against this background, the paper makes three main contributions. First, we develop a New Keynesian model in which both price- and wage-adjustment frequencies vary endogenously with economic conditions. Second, we propose a nonlinear estimation strategy that allows us to quantify these state-dependent nominal rigidities using aggregate euro area data. Our estimated model— on euro area data—reproduces the main facts reported above: endogenous increase in frequency as in the micro data, sign and size dependence of the effects of shocks. Third, we use the estimated model to study how state-dependent adjustment frequencies shape the inflation–real activity trade-off and its implications for monetary policy, with a particular focus on the recent inflation surge.

Regarding the first contribution, we introduce a novel mechanism in which pricing agencies optimally determine the fraction of products and labor types that are allowed to re-optimise prices and wages. Firms and unions face a discrete choice problem in which the expected gains from adjustment are weighed against adjustment costs, capturing the extensive margin of price and wage setting. This framework applies the rational inattention foundations of Matějka and McKay (2015) to a joint price–wage setting environment, encompassing and generalizing the state-dependent pricing mechanism of Gasteiger and Grimaud (2023). As inflation rises, the expected benefits from re-optimization increase, leading endogenously to higher adjustment frequencies for both prices and wages.

In the model, adjustment frequencies respond more strongly when firms and unions have incentives for price and wage increases, i.e., when inflation is high. This asymmetric response is embedded in a broader framework with endogenous adjustment frequencies, which gives rise to non-linear price and wage Phillips curves, a central implication of state-dependent pricing models. Consequently, the model's Phillips curve slopes and stabilization trade-off are state-dependent. Such state-dependence addresses a key shortcoming of the standard NK model: the quasi-linearity of the structural relationship between inflation and real activity, even in its non-linear form. This quasi-linearity limits the model's ability to generate state-dependent inflation dynamics and stabilization trade-off. However, empirical evidence suggests that this trade-off is, in fact, state-dependent and was historically low during the last inflation surge (Forbes et al., 2025; Zlobins, 2024). Beyond this standard implication of state-dependent pricing, adjustment frequencies in our model respond asymmetrically across states: firms and unions react more strongly to incentives for price and wage increases than to incentives for reductions. This asymmetry is consistent with recent micro-level evidence showing that price increases are more likely than equally sized price decreases (see, e.g., Karadi, Schoenle and Wursten, 2024; Luo and Villar, 2021).[1]

Our second contribution is methodological. Since the central mechanism of the model operates through state-dependent price and wage adjustment frequencies, estimating a linearized version of the model would mechanically suppress these nonlinearities by imposing symmetry between upward and downward adjustments. We therefore move beyond standard perturbation methods and adopt a numerical solution that preserves the full nonlinear propagation mechanisms of the model. Specifically, we follow the approach of Adjemian and Juillard (2024) and Sahuc et al. (2025), building on the extended path method originally proposed by Fair and Taylor (1983), and we estimate the nonlinear model using an inversion filter that treats the model itself as the data-generating process. This macro-to-micro approach exploits information in aggregate data to infer the endogenous price and wage adjustment frequencies directly from euro area macroeconomic time series. The estimated

[1]While many state-dependent pricing models generate non-linear dynamics, they typically imply responses that are symmetric across signs (see, e.g., Blanco et al., 2024; Ghassibe and Nakov, 2025; Karadi, Schoenle and Wursten, 2024).

adjustment frequencies, although identified only from aggregate dynamics, align with existing micro-level evidence, reconciling macroeconomic dynamics and changes in micro price- and wage-setting behavior.

Finally, our third contribution is to use the estimated nonlinear model to analyze the monetary policy implications of state-dependent price and wage setting. We characterize how the stabilization trade-off varies across economic states and show that it changed markedly during the recent inflation surge in the euro area. We further conduct counterfactual policy experiments to evaluate whether monetary policy should have "looked through" the inflationary shocks, shedding new light on policy design in the presence of nonlinear nominal rigidities.

Our findings have important implications for monetary policy. Our model interprets the recent inflation surge in the euro area as an episode of steepening price and wage Phillips curves. This steepening is driven by time-varying price- and wage-setting frequencies, which play a central role in shaping inflation dynamics. As a direct consequence, also the stabilization trade-off becomes state-dependent, meaning that the cost of disinflation in the euro area varies depending on macroeconomic conditions. From a dynamic perspective, firms adjust prices faster than wages during the surge, with wages gradually catching up, resulting in a lagged yet persistent wage response. With the benefit of hindsight, our analysis suggests that monetary policy could have responded more aggressively during the early stages of the inflation surge, with relatively low output costs. Overall, our results indicate that the size of supply shocks is crucial in determining the appropriate policy response. Large cost-push shocks cannot be ignored, because state-dependent price- *and* wage-setting can quickly thrust inflation.

To conclude, first, we propose a tractable method for incorporating non-linearities arising from state-dependent price and wage adjustment frequencies in a non-linearly estimated NK-DSGE model. Second, our estimated quantitative non-linear model provides a more accurate account of recent euro area inflation dynamics by emphasizing the importance of this new mechanism. Third, we study how the stabilization trade-offs faced by monetary policy vary with inflationary conditions, providing new insights into the policy debate on the effectiveness of monetary policy in curbing inflation, especially in periods of high inflation. Given the significance of the recent inflationary episode in the euro area, our method should prove valuable for future structural macroeconomic studies on the euro area.

Related literature. Our paper is obviously connected to the very large literature on state-dependent pricing that has flourished over the past two decades with the growing availability of micro-level data on prices – less so on wages. It has generated several seminal contributions that have enhanced our understanding of the distribution, dynamics and drivers of price changes. A comprehensive survey is beyond the scope of this paper; see Costain and Nakov (2024) for a recent and thorough overview. Of course, our modeling approach, based on Gasteiger and Grimaud (2023), cannot – and does not aim at – reproducing the distribution of price (or wage) changes. It provides a short-cut way to take into account some insights from this recent literature, and make them operational in estimating large NK models.

Early menu-cost models imply strong selection effects, whereby price adjustments following aggregate shocks are concentrated among the most misaligned firms (e.g., Golosov and Lucas, 2007). However, a growing body of micro-level evidence suggests that this is not a dominant feature of observed price-setting behavior. Costain and Nakov (2024) stress this point and argue in favor of a shift toward a more general class of state-dependent pricing frameworks in which adjustment probabilities rise smoothly with firms' incentives to adjust. In these models, state-dependence operates primarily through movements in the gross extensive margin – i.e., the increased fraction of adjusting prices – rather than through a strong selection effect – i.e., large price adjustment from firms more distant from their desired price – implying larger real effects of monetary policy. Recent evidence on the distribution of price changes (Alvarez et al., 2016; Midrigan, 2011) and on adjustment hazards conditional on price gaps (Carvalho and Kryvtsov, 2021; Gagliardone et al., 2025; Karadi, Schoenle and Wursten, 2024) supports this view. Our modeling choice is designed to capture this smooth state-dependent behavior in adjustment frequencies and should therefore be interpreted as abstracting from selection effects, in line with the empirical literature.

Moreover, state-dependent models, which match patterns from microdata, share many of the macro implications of the Calvo model when the latter is accordingly recalibrated.[2] However, the key difference identified by Costain and Nakov (2024) between the state-dependent models and the standard Calvo model is that the former imply rapid and flexible price changes in some circumstances, as for high inflation (Alvarez et al., 2019), for large shocks (Cavallo et al., 2024; Karadi and Reiff, 2019), making the Phillips curve slope state-dependent (Karadi, Nakov, Nuno, Pasten and Thaler, 2024).

While admittedly using a short-cut relative to a microfounded state-dependent model that features a selection effect, we provide a tractable way to incorporate state-dependent price- *and* wage- setting into the standard model. "Tractable way" has a very precise meaning for us: a way that allows us to estimate a non-linear quantitative NK model with state-dependent price- *and* wage-setting with a non-linear method. This is particularly important as fully microfounded state-dependent models, while able to match the micro data, are still computationally quite far away from being incorporated in a non-linearly estimated NK model. To the best of our knowledge, this paper is the first one that includes state-dependent price- *and* wage-setting in a non-linear NK model, non-linearly estimated on aggregate euro area data, to provide policy analysis and counterfactuals.

[2]As shown by Auclert et al. (2024), the first-order approximation of a wide class of state-dependent models shares many macro-implications with the Calvo framework. This motivates our focus on a fully non-linear environment, where such first-order equivalence breaks down and state-dependence becomes quantitatively relevant.

From this same perspective, Blanco et al. (2024) is the closest paper to ours. Developed independently and in parallel, they propose a different but related mechanism where the fraction of price changes evolves endogenously, as in state-dependent models, while retaining the tractability of time-dependent models for empirical and policy analysis. In their model, multiproduct firms can reset their prices in every period subject to an adjustment cost, as in standard menu costs models. However, they can choose how many prices to adjust, but not which ones. This main assumption allows to solve the model without the need to keep track of the entire distribution of price changes. Moreover, they perform a Bayesian estimation of the aggregate shock parameters, as well as some of the price-setting parameters, on US data using a third-order approximation of the non-linear model. Despite relying on a different mechanism, their model shares several key implications with ours that are characteristic of state-dependent pricing: an endogenous extensive margin of price adjustment, an amplification of inflation response in a high-inflation environment and a more favorable stabilization trade-off when inflation is elevated. At the same time, the two approaches are complementary since they abstract from state-dependent wage setting and from additional elements – such as habit persistence or price and wage indexation – that have been shown to be important for empirical analysis, and estimates a more limited subsets of parameters using US data. By contrast, our framework incorporates these features while being applied to euro area data.

Reiter and Wende (2024) is another recent paper that proposes a yet different mechanism, based on a generalization of the Rotemberg pricing model. The mechanism is based on the assumption that marginal cost follows a sigmoid function, and it is then embedded in a calibrated DSGE model to show that it has similar aggregate implications as the menu cost models in Costain and Nakov (2019).

Our paper also relates to recent studies on optimal monetary policy in nonlinear calibrated state-dependent models. Karadi, Nakov, Nuno, Pasten and Thaler (2024) find that central banks should respond to major cost-push shocks with a more aggressive anti-inflation policy, since the more favorable stabilization trade-off reduces the economic cost of controlling inflation. Additionally, they find that in the case of an aggregate productivity shock, which does not create any trade-off, the optimal policy emphasizes strict price stability. In a multisector economy with menu costs, Caratelli and Halperin (2025) find that optimal policy should, instead, allow inflation to move after sectoral productivity shocks, with inflation and output move in opposite direction. The optimal policy prescription in their model entails nominal wage targeting, i.e., nominal wages, rather than inflation, should be stabilized, despite wages being flexible.

Finally, our work relates to a large empirical research dealing with non-linear inflation dynamics and its implications for monetary policy. Some studies provide empirical evidence of non-linearity in the aggregate response of inflation to shocks, that are consistent with state-dependent price- and wage-setting (see, e.g., Alvarez et al., 2017; Ascari and Haber, 2022; Cavallo et al., 2024; de Veirman, 2023). Non-linearity in the Phillips curve could arise for different reasons than state-dependent pricing. Harding et al. (2022, 2023) show that the non-linear standard Calvo model with a Kimball aggregator gives rise to a non-linear Phillips curve, and then study the implications for monetary policy under de- or accelerating inflation. Erceg et al. (2024) extend this framework by allowing for endogenous indexation of prices and wages, whereby the share of backward-looking price and wage setting by firms and households increases with the level and persistence of above-target inflation. Benigno and Eggertsson (2023) and Gitti (2025) provide evidence suggesting that the Phillips curve is strongly non-linear in the vacancy-to-unemployment ratio, as a measure of labor market tightness. Faber and Züllig (2025) present similar evidence for a panel of 18 euro area countries, using unemployment as measure of labor market slack. However, Beaudry et al. (2024, 2025) argue that this evidence is fragile, and that non-linearities may only reflect shifts in short-run inflation expectations. This is in line with evidence for the US in Gorodnichenko and Coibion (2025), and for Europe in Acharya et al. (2023).

2. The model

In this section, we first describe the main features of the model in Subsection 2.1 and then describe the non-linear solution in Subsection 2.2.

2.1 Structure of the model

The model is a standard New Keynesian model with no capital, consumption habits, where wages and prices are sticky and they are both indexed to lagged inflation. The model departs from the standard Calvo (1983) setup by allowing state-dependent sticky prices and wages following Gasteiger and Grimaud (2023). The state-dependency allows for intensive *and* extensive margin adjustments in prices and wages. Given that the model is otherwise standard, its detailed description and derivations are confined in Appendix B, while here we just sketch its structure and focus on how we introduce state-dependency into the model.

The lifetime utility of household features multiplicative external consumption habits and disutility from labor. The representative household owns the firms and receives dividends. Two exogenous AR(1) processes, $\varepsilon_{w,t}$ and $\varepsilon_{d,t}$, are introduced to generate variations in distortionary taxes—or subsidies—on wages and on bond income. These processes are introduced for estimation purposes. They effectively represent a labor supply shock ($\varepsilon_{w,t}$) and a demand shock ($\varepsilon_{d,t}$) creating a wedge between the central bank's policy rate and the return on assets held by households, similar to Smets and Wouters's (2007) risk premium shock.

Production is divided into several layers. A representative wholesale firm hires labor from the labor packer and produces output, which is sold to a continuum of retail firms at price

$P_{w,t}$, subject to exogeneous AR(1) supply shock ($\varepsilon_{p,t}$). Each retail firm $i \in [0,1]$ repackages wholesale output, and sells it, at the price $P_t(f)$, to a competitive final goods firm which transforms retail output into a final output good according to a standard CES function, sold at the price P_t .

Retailers are price-setters. Following Gasteiger and Grimaud (2023), the price-setting problem is:

$$\max_{P_t(f)} \mathbb{E}_t \sum_{j=0}^{\infty} \left(\prod_{k=0}^{j} \phi_{p,t+k} \right) \phi_{p,t}^{-1} \Lambda_{t,t+j} \times \\ \times \left\{ P_t(f)^{1-\epsilon_p} (P_{t+j}/\Pi_{t,t+j}^{\varrho_p})^{\epsilon_p - 1} Y_{t+j} - P_{w,t+j} P_t(f)^{-\epsilon_p} (P_{t+j}/\Pi_{t,t+j}^{\varrho_p})^{-\epsilon_p} Y_{t+j} \right\},$$

where $\Lambda_{t,t+j}$ is the stochastic discount factor of the household between period t and $t+j$, Y_t is final output good output that determines the demand for retail goods, $p_{w,t} = P_{w,t}/P_t$ represents retailers' real marginal costs, $0 \leq \varrho_p < 1$ is a parameter governing indexation to past inflation and:

$$\Pi_{t,t+j} \equiv \begin{cases} \frac{P_{t+1}}{P_t} \times \frac{P_{t+2}}{P_{t+1}} \times \ldots \times \frac{P_{t+j}}{P_{t+j-1}} & \text{for } j = 1, 2, \ldots \\ 1 & \text{for } j = 0. \end{cases}$$

This price-resetting problem is the same as the one in a standard Calvo framework, with one key difference: the probability of not-being able to adjust the price in a future period—and so the implied price-resetting frequency in equilibrium—is time varying, i.e., $\phi_{p,t+k}$. All the price-resetting firms are symmetric and face the same problem. So we can define the optimal reset price as $P_t^{\#}$, because it is the same for all the firms and it does not depend on the index f. The first-order condition is recursively given by

$$x_{1,t} = p_{w,t} Y_t + \mathbb{E}_t \phi_{p,t+1} \Lambda_{t,t+1} \left(\frac{\pi_{t+1}}{\pi_t^{\varrho_p}} \right)^{\epsilon_p} x_{1,t+1}$$

$$x_{2,t} = Y_t + \mathbb{E}_t \phi_{p,t+1} \Lambda_{t,t+1} \left(\frac{\pi_{t+1}}{\pi_t^{\varrho_p}} \right)^{\epsilon_p - 1} x_{2,t+1}$$

$$p_t^{\#} = \frac{\epsilon_p}{\epsilon_p - 1} \frac{x_{1,t}}{x_{2,t}}$$

with $p_t^{\#} = P_t^{\#}/P_t$. Again, these equations defined the first-order condition also in the standard model, the only difference being the Calvo probability of not-adjusting being time-varying.

Price-resetting agency. In the price-setting problem above, firms recognize that the probability of not adjusting prices is time-varying but independent of their own decisions. Consequently, this time variation cannot depend on firm-specific variables and must instead be driven solely by aggregate conditions. This assumption is key for tractability.

We formalize this mechanism by introducing a price-resetting agency that authorizes firms to adjust prices. Firms that are not authorized must keep their existing prices (which we allow to be partially indexed automatically). All firms comply with the agency's decision, so in each period the agency effectively chooses the fraction of firms that are unable to reset prices, that is, the non-resetting probability $\phi_{p,t}$. The agency is owned by the representative household, which also owns the continuum of intermediate-goods firms. As a result, the agency internalizes firm profits, and any net payoff is rebated lump-sum to households.

We assume that it is costly for the agency to process information about individual firms, including their prices and their profit implications of price changes. As a consequence, the agency allocates price-adjustment permissions randomly across firms. In making its decision, the agency evaluates the expected continuation value of the future profits. Firms granted permission to reset prices share a common expected continuation value, $V^{\#}_{p,t}$, net of a menu cost of changing price, τ_p. By contrast, firms that are not allowed to reset prices have heterogeneous continuation values, reflecting differences in their inherited prices. However, because permissions are allocated randomly, the agency uses as a proxy the expected continuation value of future profits of a non-adjusting firm that keeps its price equal to the aggregate price level in the previous period. The agency then chooses the optimal fraction of firms permitted to adjust prices, taking into account a cost of processing information.

Formally the agency would solve the following problem. It chooses $\phi_{p,t}$ to maximize

$$\max_{\phi_{p,t}} \left\{ \phi_{p,t} V^{f}_{p,t} + (1-\phi_{p,t})(V^{\#}_{p,t} - \tau_p) - \frac{1}{\gamma_p}\Omega(\phi_{p,t}) \right\},$$

where $\Omega(\phi_{p,t})$ is an information-processing cost and $\gamma_p > 0$ is the inverse marginal cost of information processing. Under an entropy-based information cost and a symmetric prior, Matějka and McKay (2015, Theorem 1) shows that the first-order condition yields the logit policy

$$\phi_{p,t} = \frac{\exp\left(\gamma_p V^{f}_{p,t}\right)}{\exp\left(\gamma_p V^{f}_{p,t}\right) + \exp\left(\gamma_p (V^{\#}_{p,t} - \tau_p)\right)}. \tag{1}$$

In each period t, the agency authorizes a fraction $(1-\phi_{p,t})$ of firms to reset their price to $P^{\#}_t$, while the remaining firms have to keep their old prices (partially indexed to the average inflation). Equation (1) implies that the non-resetting share $\phi_{p,t}$ is a smooth, state-dependent function of the difference between the continuation values of non-adjustment and adjustment. The fixed burden $\tau_p > 0$ shifts the adjustment value $V^{\#}_{p,t} - \tau_p$ downward and therefore raises $\phi_{p,t}$, all else equal. The intensity of choice parameter $\gamma_p > 0$ governs the strength of state contingency. When γ_p is small, information is expensive and the agency responds weakly to movements in $V^{f}_{p,t}$ and $V^{\#}_{p,t}$; adjustment becomes nearly random and $\phi_{p,t}$ is close to a constant, delivering the Calvo benchmark as $\gamma_p \to 0$. As γ_p increases, information becomes cheaper, the agency conditions more sharply on the state, and $\phi_{p,t}$ varies more with the underlying present values. In the limit $\gamma_p \to \infty$, choices become nearly deterministic: the agency puts almost all probability on the higher-value action, so price adjustment becomes effectively state-dependent. For any finite γ_p, adjustment remains probabilistic and prices are therefore rigid in the sense that a positive mass of firms does not re-optimize each period.[3]

Labor market. The labor market structure mirrors the one of production and consists of three layers. There is a continuum of labor unions index by $l \in [0,1]$. They purchase labor from households at MRS_t and repackage it for sale to a representative labor packer $W_t(l)$. The labor packer combines differentiated labor inputs into final labor, $L_{d,t}$, using a CES technology with elasticity of substitution $\epsilon_w > 1$. Labor unions are wage setters, and their problem is symmetric with respect to the one just described for firms. In each period t, a wage-setting agency chooses the fraction of unions that can re-optimize their wage, but not which unions adjust. The wage-setting agency authorizes a, randomly chosen, fraction $(1-\phi_{w,t})$ of unions to reset their wage to $W_t^{\#}$, while the remaining unions must keep their old wages. Resetting entails a fixed non-pecuniary cost $\tau_w > 0$, while non-reset wages are partially indexed to past inflation. The agency evaluates the expected continuation value of adjusting unions, $V_{w,t}^{\#}$, and that of a representative non-adjusting union that has the wage equals to the average wage from the previous period, $V_{w,t}^{f}$. Under an entropy-based information cost, the implied non-resetting share follows the multinomial-logit form (Matějka and McKay, 2015):

$$\phi_{w,t} = \frac{\exp\left(\gamma_w V_{w,t}^{f}\right)}{\exp\left(\gamma_w V_{w,t}^{f}\right) + \exp\left(\gamma_w \left(V_{w,t}^{\#} - \tau_w\right)\right)},$$

where $\gamma_w > 0$ is the intensity of choice, i.e., the inverse marginal cost of information processing.

Finally, monetary policy follows a standard Taylor rule and features a monetary policy shock ε_t^r. All shocks follow a stationary AR(1) processes.

[3] Similar devices to our assumed agency have been widely employed in the literature to circumvent heterogeneity and ensure tractability. Classic examples include the indivisible labor assumption (see Hansen, 1985; Rogerson, 1988) and the household–union (insurance) construct commonly used in New Keynesian models—as our labor packer, see below—with heterogeneity in wages or labor supplies across households (see Woodford, 2011). A closely related logic also appears in Blanco et al. (2024). They assume gigantic multiproduct firms that produce all the products in the economy and are able to choose how many prices to adjust in each period, but not which ones; price adjustments are then assigned randomly across products. In this sense, their multiproduct firm plays exactly the same role as our agency. By aggregating firms in this way, the model abstracts from the selection effects that arise when adjustment decisions depend on firm-level variables, allowing adjustment shares to be treated as probabilities without tracking the cross-sectional composition of adjusters. Our model differs from theirs in the way the problem is formulated. In particular, we follow the rational inattention approach to discrete choice developed in Matějka and McKay (2015), which results in a different first-order condition governing the evolution of the fraction of price-resetting firms.

2.2 The extended path solution method

This paper explores the non-linearities of the Phillips curve and the interactions between the intensive and extensive margins of inflation. A first-order linearization is inadequate for approximating the model, as it fails to capture the state-dependent dynamics driven by asymmetric profit functions. The state-dependent adjustment frequencies for prices and wages generate essential nonlinearities and asymmetries in inflation and wage responses to shocks, requiring a fully nonlinear estimation approach. To accurately capture these non-linearities, we solve the model using the extended path method developed by Fair and Taylor (1983), following the recent implementation by Adjemian and Juillard (2024); Sahuc et al. (2025). This method provides a nonlinear solution under rational expectations, responding to MIT-type shocks without aggregate uncertainty.[4] Specifically, agents are assumed to be surprised by contemporaneous shocks, but consistently expect future shocks to be zero, consistent with rational expectations. The numeric solution can be expressed as follows:

$$y_t = \mathbb{E}_{t,t+S}\left\{g_\Theta\left(y_{t-1},\bar{y},\eta_t\right)\right\}, \tag{2}$$

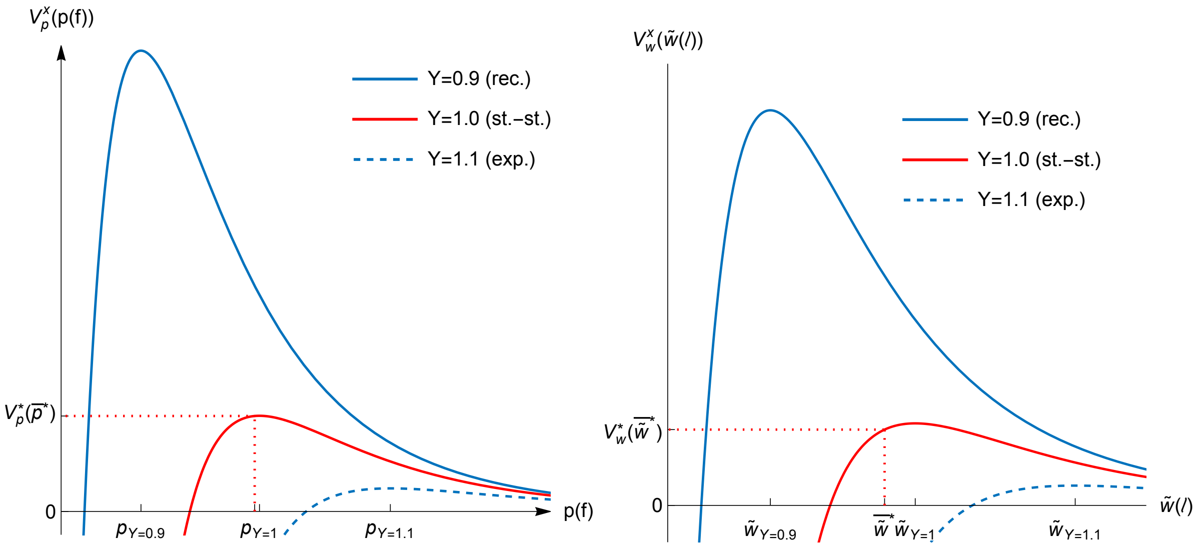
where y_t denotes the vector of endogenous variables, $g_\Theta(\cdot)$ is the nonlinear transition function implied by the structural equations, Θ represents the set of structural parameters, and shocks are normally distributed as $\eta_t \sim N(0,\Sigma_\eta)$. The expectation operator $\mathbb{E}_{t,t+S}$ implies a sequence-space approximation of expected fluctuations over a horizon of S periods, beyond which the economy has fully returned to steady state $\bar{y}$. We choose a sequence-space horizon of 10 years ($S = 40$ quarters), as extending this horizon further does not significantly alter the likelihood. Importantly, this numerical solution explicitly accounts for endogenous variations in the Calvo adjustment probabilities, which are central to our model.

3. Monetary policy under non linear Phillips curves

We begin by calibrating the model to match a small-scale setup[5] to build intuition about the role of endogenous versus exogenous price and wage setting frequencies. Section 3.1 contrasts the shape of both the price and wage New Keynesian Phillips curves when the econ-

[4]Explicit integration over future uncertainty would offer limited additional accuracy given the CRRA specification of the utility function and does not justify the significant computational cost involved.

[5]We assume that the discount factor is set to $\beta = 0.995$, and the curvature of consumption utility is set to $\sigma = 2$. To neutralize the effects of price and wage dispersion on labor supply and marginal cost, we impose $\chi = 0$. The Taylor rule follows standard values for the euro area, with coefficients $\{\theta_\pi,\theta_y,\rho\} = \{2, 0.125, 0.8\}$. The gross steady-state inflation rate is set to $\overline{\pi} = 1.005$. The elasticities of demand for individual goods and labor are set to $\varepsilon_p = \varepsilon_w = 9$. The steady-state shares of firms and unions not optimally resetting prices and wages are calibrated to $\{\overline{\phi}_p,\overline{\phi}_w\} = \{0.75, 0.85\}$, consistent with standard values used in the literature on Calvo pricing. We follow Gasteiger and Grimaud (2023) and set the state-dependency parameters to $\gamma_\pi = \gamma_w = 10$. The autoregressive coefficients of the exogenous shocks are set to $\rho_d = \rho_p = \rho_w = 0.8$, while monetary policy shocks are assumed to be purely i.i.d. Finally, to simplify the analysis and focus on the role of state-dependency, we shut down most sources of endogenous persistence by setting $h = \varrho_\pi = \varrho_w = 0$.



(a) Firms

(b) Unions

Figure 2: **Asymmetry in wage and price setting decisions.** The lines depict the present values of firms (Panel (a)) and unions (Panel (b)), as a function of output and their relative price and wage (atomistic firm and union in partial equilibrium)

omy is hit by demand and supply shocks. Section 3.2 compares state-dependent IRFs in response to different shocks, depending on the value of the underlying inflation processes. Finally, Section 3.3 shows how the sign and the size of the shocks matter for their propagation.

3.1 Implied Phillips curves and intuition

This subsection provides the intuition behind wage and price setting in the model, emphasizing the differences between fixed and endogenous adjustment frequencies. We extend the analysis in Gasteiger and Grimaud (2023), who focused exclusively on price-setting and demand shocks, to include both price and wage adjustments and supply shocks. We show that endogenous price- and wage-setting frequencies give rise to non-linear New Keynesian Phillips curves that are steeper for positive demand shocks and flatter for negative demand shocks for both price and wage. This result arises because of the asymmetry in the price and wage setting decision. For a given updating cost, the benefits of increasing prices and wages, following an increase in demand or in prices and wages, are larger than the benefits of decreasing them, when demand or prices and wages decrease.

Asymmetry in price and wages setting decisions. Panel 2a depicts firm f's present value in steady state as a function of its relative price $p(f) = P(f)/P$. The depicted present value measures the firm f's benefit in partial equilibrium, i.e., holding all other variables at their steady state (red line). The blue solid line and blue dashed line depict the present value for a lower or higher output level.

Two observations stand out. First, the relative price associated with the present value's peak is higher, if the output level is higher. The latter is because firm f's present value depends on current and future expected pro-cyclical marginal costs. Thus, higher output creates an incentive to increase the price and lower output creates an incentive to cut the price.

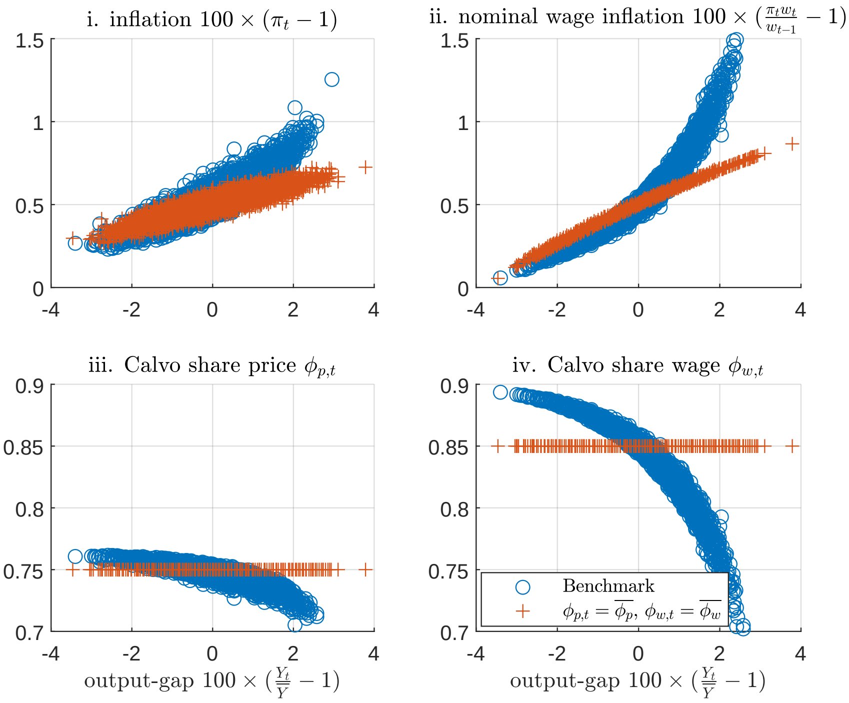
Second, the present value exhibits asymmetry, which is due to the nonlinear profit functions given the Dixit and Stiglitz (1977) monopolistic competition setting. As discussed in greater detail in Gasteiger and Grimaud (2023), because of this asymmetry in the present value, low relative prices imply relatively larger reductions in the present value. The opportunity cost is mainly in terms of profit per unit. In contrast, high relative prices imply relatively smaller reductions in the present value. The opportunity cost is mainly in terms of foregone quantity. Hence, the asymmetry of the present value undermines the incentive to cut the price when demand falls and strengthens the incentive to increase the price when demand increases.

Finally, recall that Panel 2a depicts firm f's present value as a function of its relative price. Thus, all else equal, any increase in the aggregate price level, say due to an inflationary supply shock, implies a decrease in firm f's relative price. Inspection of the depicted present value clarifies that this again creates a strong incentive to increase the price because of the aforementioned asymmetry. However, again the opposite is less true in case of a disinflationary supply shock.

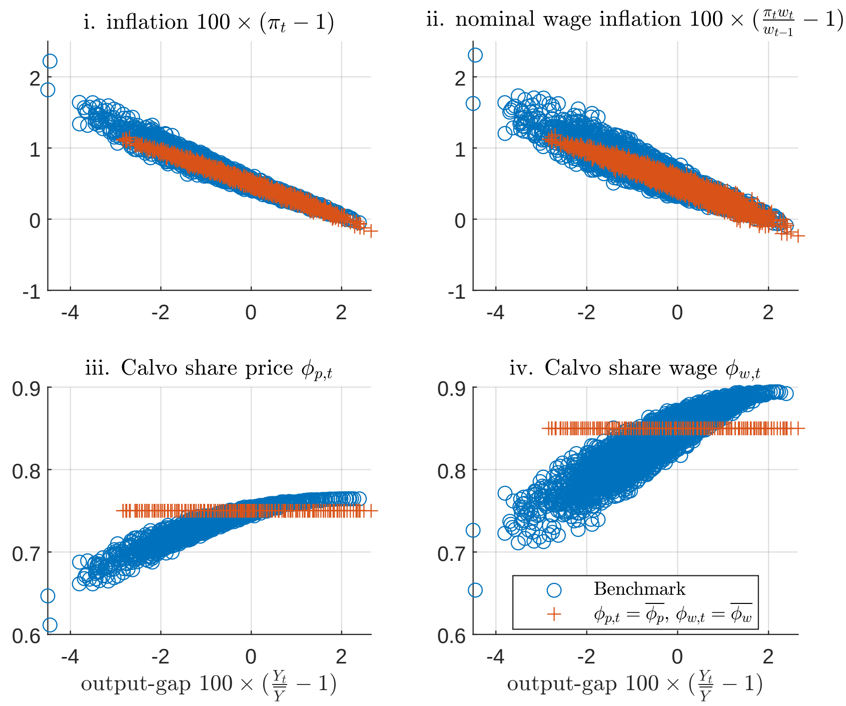
In analogy to Panel 2a above, Panel 2b depicts union l's present value in steady state as a function of its relative wage $\tilde{w}(l) = W(l)/W$. The case of union l parallels the previous case of firm f. First, as in the case of firm f, the relative wage associated with the peak of the present value is higher for union l, if the output level is higher. In the case of union l, this is because its present value depends on current and future expected pro-cyclical marginal rates of substitution. Second, also union l's present value is asymmetric. Hence, higher demand (or an inflationary aggregate shock) creates an incentive to increase the wage, while lower demand (or a disinflationary aggregate shock) creates an incentive to reduce the wage. However, given the aforementioned asymmetry in the present value, the incentives to reduce wages are low, whereas the incentives to increase wages are strong.

Non-linear Phillips Curves. Figure 3 visualizes the implications of the asymmetry in price and wage decisions for the response of the model after a demand shock and a supply shock. Each panel displays as dots the simulation of 10,000 periods conditional to stochastic monetary policy and labor supply shocks in our benchmark model (blue circle) and the standard Calvo model (red plus).[6] Figure 3a reports results for monetary policy shocks, one of the model's demand-side shocks. Demand shocks move both output and inflation in the same direction. The blue circles reveal the non-linear dynamics of the model under state-dependent price and wage-setting. The non-linear behavior of the Phillips curve in

[6] In the absence of habit and indexation, the degree of endogenous persistence is relatively modest, allowing us to clearly decompose the conditional Phillips curves. These conditional Phillips curves can be interpreted as proxies for the underlying aggregate demand and supply curves (see Bergholt et al., 2024).



(a) Monetary policy shocks



(b) Labor supply shocks

Figure 3: **Phillips curves are curves.** The dots show the results of stochastic simulated runs of the output gap and of (i) price inflation, (ii) wage inflation, (iii) the share of not-adjusting firms; (iv) the share of not-adjusting unions, respectively, in the case of monetary policy shocks (Panel (a)) and labor supply shocks (Panel (b)).

Notes: The distribution of Gaussian shocks follows the estimated volatility of the monetary policy (top panels), and labor supply shock (bottom-panels), respectively. For the sake of brevity, we refer to the share of non-reoptimized wages or prices displayed in the chart as the Calvo shares.

our model is driven by the interaction of two distinct channels: (i) on the intensive margin, higher demand increases the optimal resetting price for firms, directly raising inflation (as in a Calvo model), (ii) on the extensive margin, higher demand boosts the present discounted value of resetting prices, further amplifying inflation by increasing the frequency of price adjustments. The same mechanisms apply to labor unions' wage-setting decisions. Note that, in general equilibrium, the non-linearity of wage and price setting decisions reinforce each other. Higher price level reduces real wages, increasing the marginal rate of substitution and therefore the incentive for unions to reset nominal wages upward. This adjustment pushes up marginal costs, reinforcing inflationary pressures through a feedback loop. Consequently, both price *and* wage Phillips curves exhibit convexity, linking inflation dynamics across the goods and labor markets. In other words, as demand shocks, monetary policy shocks in Figure 3a trace out, therefore, non-linear aggregate supply curves.

Without state-dependency (i.e., setting $\gamma_p, \gamma_w \to 0$), the model reverts to the standard NK model, which produces a quasi-linear relationship between output and price or wage inflation in response to demand-side shocks, as shown by the red pluses in Figure 3a.

Figure 3b presents similar simulations conditional on only labor supply shocks, as an example of supply disturbances. The shocks move price and wage inflation in the same direction and output in opposite directions, generating negative sloped (wage and price) Phillips curves. Labor supply shocks in Figure 3a trace out actually an aggregate demand relationship.

By reducing labor supply, the shocks drive up real wages, increasing marginal costs and, ultimately, prices. In the standard NK model (red pluses), these shocks generate a quasi-linear relationship between marginal costs, inflation, and output. In contrast, in the state-dependent model, the extensive margin creates non-linear effects due to the asymmetry analyzed above, which is evident when comparing the effects of inflationary and deflationary supply shocks. Inflationary supply shocks, which raise marginal costs, lead to more frequent price and wage resets (see Panel (iii) and (iv) in Figure 3b), thus generating strong upward pressures on prices and wages. On the contrary, deflationary shocks have weaker effects, as adjustment frequencies are less responsive to falling prices. As a result, the blue circles in Panel (i) and (ii) in Figure 3b stretch (and fan) out the red pluses when inflation is on the upside, while they lie over the red pluses when inflation is on the downside. The extensive margin amplifies the inflationary pressure of adverse supply shocks, but this effect is not symmetric: deflationary pressure of benign supply shocks is not amplified with respect to the standard Calvo model.

In sum, Figure 3 visualizes the strong correlation between inflation and the frequency of price and wage resets that our model generates. During periods of high inflation, price and wage resets increase, reflecting the state-dependent nature of the adjustment process. In the fixed adjustment probability model of Calvo (1983), these channels are deactivated, leading to constant adjustment frequencies, and quasi-linear price and wage Phillips curves under both demand and supply side shocks. In such a setting, inflationary responses to shocks are proportional to marginal cost fluctuations, and the rich interplay between the resetting frequency and inflation vanishes. This underscores the key role of state-dependency in shaping nonlinear inflation-output trade-offs observed in the price and wage Phillips curves.

Effect of Trend Inflation. Appendix C shows that higher steady-state inflation raises the frequency of wage and price adjustment, as both firms (and unions) choose to adjust prices (and wages) more frequently, thereby leading to a more flexible economy. Moreover, the Appendix illustrates that this feature of our model is both quantitatively and qualitatively consistent with results as in, e.g., L'Huillier and Schoenle (2024) for the US. Finally, Figure C.2 displays the effect of trend inflation on the IRFs to monetary and cost-push shocks, showing that the changes in first moments affects second moments, amplifying the effects of monetary policy shocks on inflation and the ones of cost-push shocks on output.

3.2 On the state-dependent effects of shocks

One of the main contributions of this paper is to show that the interaction between state-dependent price and wage setting, along with their implied non-linear Phillips curves, leads to state-dependency in the effects of exogenous shocks. As in the previous subsection 3.1, throughout the paper we will focus on the difference between monetary policy shocks, as a demand shock, and cost-push or labor supply shocks, as a supply shock. This allows us to investigate the effects of policy shocks moving prices and quantities in the same direction, as well as the trade-off generated by shocks moving them in the opposite way.

Unlike the quasi-linear standard NK Calvo model, where responses are uniform regardless of initial conditions, our model implies that the responses to shocks are state-dependent, meaning that they differ depending on the condition of the economy, that is, are contingent to the particular shocks the economy has been subject to.

Figure D.1 in Appendix D visualizes the state-dependency of IRFs to a monetary policy shock and a cost-push shock, after the economy has been subject to different inflationary shocks (see Appendix D for details). When starting from higher initial inflation levels, the economy exhibits greater flexibility in prices and wages (due to lower share of firms and unions not optimally updating the price and wage), leading to steeper Phillips curves. This increased steepness means that a given monetary policy shock will result in a more pronounced change in inflation and a smaller alteration in output. Additionally, high inflation environments lead to significantly steeper New Keynesian Phillips Curves (NKPCs) for both wages and prices, causing real wages to adjust more strongly and immediately to demand shocks, due to increased economic flexibility. However, this heightened flexibility also ensures that these real wage deviations are less persistent.

The mechanism behind cost-push shocks resembles that of monetary policy shocks, where

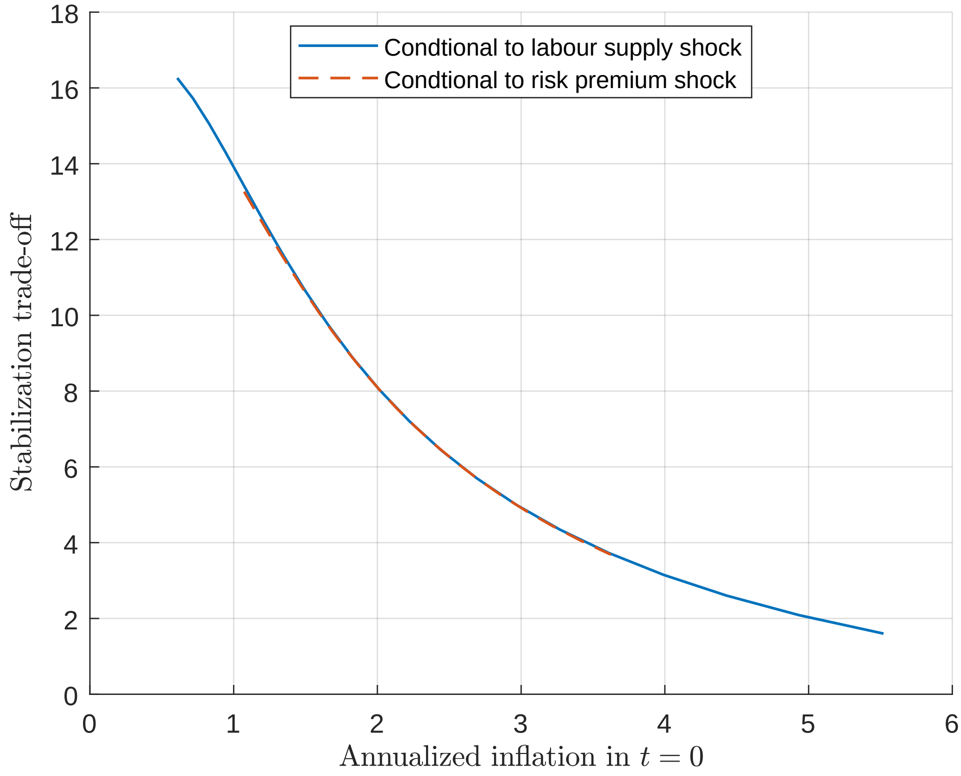


Figure 4: **The output-inflation stabilization trade-off for monetary policy depends on the level of inflation.** The lines decreases in the level of initial inflation, meaning that the higher the level of inflation, the more monetary policy affects inflation relative to output.
Notes: The stabilization trade-off is measured throughout this paper as the average ratio of cumulative output gap to inflation deviations over 20 quarters in response to +0.25% monetary policy shock.

higher inflation increases economic flexibility, amplifying the immediate impact of supply shocks on inflation and output. Initially, an adverse cost-push shocks trigger a divergence between price and wage inflation: firms raise prices, reducing demand and both nominal and real wages. This short-run decline in wage inflation weakens unions' incentives to adjust wages, leading to fewer wage resets. Over time, however, as inflation remains elevated, wage-setting becomes more responsive, with wages adjusting upward to match rising prices through a price-to-wage feedback loop. This interaction between different margins of wage and price flexibility makes the economic adjustment to negative supply shocks – via lower real wages and output – highly persistent, regardless of the initial inflation level.[7]

To underscore those dynamics, Figure 4 shows the output-inflation stabilization trade-off that monetary policy is facing, computed from simulations conditioned on different starting inflation levels (the solid blue line is the case in which we condition on labor supply shocks only, the red dashed line is with risk premium shocks only). The stabilization trade-off is defined throughout this paper as the average ratio of cumulative output gap deviations to cu-

[7] See again Appendix D for details. Figure F.2 in Appendix F present the IRFs to these two shocks originating from the steady state, with and without time-varying updating frequencies.

mulative inflation deviations over 20 quarters in response to a 0.25% monetary policy shock. The results are striking: at an annualized inflation rate of 0.5%, the stabilization trade-off is 7 times larger than at 5%. This indicates that monetary policy is more effective at controlling inflation when starting from high inflation levels, as the steeper Phillips curves amplify the response of inflation to monetary policy shocks. Notably, this effect holds regardless of whether underlying inflation is driven by labor supply or risk premium shocks.

3.3 Size and sign dependency

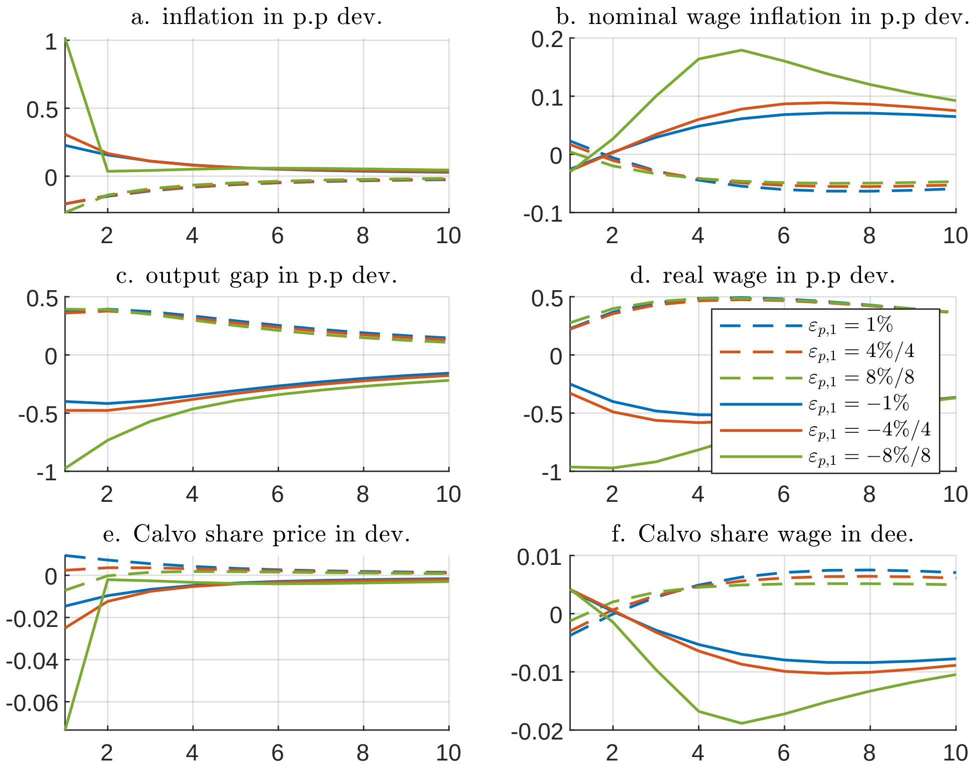


Figure 5: **Size and sign dependency in the response to a cost-push shock.** The different lines correspond to the scaled responses to different sizes of (positive and negative) cost push shocks

Notes: The responses to the shocks are rescaled such that shocks are normalized to a 1% cost-push shock. We refer to the share of non-reoptimized wages or prices displayed in the chart as the Calvo shares.

Given the model's inherent non-linearity, shock propagation is both sign- and size-dependent. This can have important implications for the question of whether central banks should look through supply shocks. Figure 5 displays rescaled IRFs to normalized positive and negative cost-push shocks, highlighting that larger inflationary shocks amplify the intensive margin response. This implies that price inflation reacts more strongly to large shocks but with lower persistence, as price adjustments accelerate in response to stronger inflationary pressures. Regarding wage inflation, we observe that a larger initial real wage loss leads to greater wage flexibility, which in turn amplifies the persistence of nominal wage inflation.

The underlying mechanism aligns with the state-dependent pricing intuition discussed earlier, where higher inflation triggers more frequent price and wage updates. In contrast to labor supply shocks, cost-push shocks exhibit a different propagation pattern, as the response of $\phi_{w,t}$ remains largely size-invariant on impact. This distinction arises because cost-push shocks directly alter firms' marginal costs, lowering pricing frictions, whereas labor supply shocks primarily shift wage-setting incentives inducing non-linear responses in wage adjustment frequencies on impact.

Furthermore, the asymmetry in firms' profit functions reinforces sign dependency. While inflationary shocks increase price-resetting frequency, disinflationary shocks exhibit weaker size effects, as firms are less inclined to reduce their price adjustment frequency significantly. This is evident in the muted response of price and wage resetting frequencies following deflationary shocks. As a result, large inflationary shocks make the economy more flexible by increasing price adjustment rates, while disinflationary shocks fail to generate a symmetric reduction in price-setting activity which implies linear scaling.[8]

4. A tale of two quantitative models

Building on the intuition of the small-scale model in Section 3, this section examines how time-varying updating frequencies affect the estimation of quantitative NK models, particularly focusing on the recent inflation surge period. To make the model more operational, we extend the framework to allow for consumption habits, as well as price and wage indexation to past inflation. We then estimate two specifications of this non-linear model. In the first specification, referred to as the benchmark model or the model with time-varying updating frequencies, the parameters γ_p and γ_w are estimated. In the second specification, called the model with fixed updating frequencies, we effectively remove state-dependency by setting $\gamma_p \to 0$ and $\gamma_w \to 0$. Both estimations rely on the same dataset and follow an identical estimation procedure. Additionally, the priors are consistently specified across both versions.

4.1 Estimation strategy

Filtering method. The state-dependent adjustment frequencies for prices and wages require a fully nonlinear estimation approach. To bring this nonlinear model to the data, we use the inversion filter developed by Cuba-Borda et al. (2019); Guerrieri and Iacoviello (2017) and adapted to the extended path context by Sahuc et al. (2025). Given the observed sample $\{\mathcal{Y}_t\}_{t=1}^T$, the inversion filter recursively recovers structural shocks $\{\eta_t\}_{t=1}^T$ from the model

[8] Figure F.1 compares local projection impulse responses to supply shocks with the impulse responses to a cost-push shock generated by the estimated model described in Section 4. The comparison shows that the model replicates both the sign and size asymmetries present in the data.

observation equations and nonlinear solution paths derived from equation (2). The observation equation is given by:

$$\mathcal{Y}_t = h_\Theta(y_t), \tag{3}$$

where $h_\Theta(y_t)$ is is the vector of measurement equations in (2) and Θ is the set of structural parameters. For a candidate vector of estimated parameters $\theta \subset \Theta$, the likelihood function of the model $L(\theta, \mathcal{Y}_{1:T})$ is evaluated from the filtered sequence of shocks $\{\eta_t\}_{t=1}^{T}$. Following standard Bayesian practice in the DSGE literature (An and Schorfheide, 2007), we combine likelihood with prior distributions. Parametric uncertainty is assessed numerically via Markov Chain Monte Carlo (MCMC) sampling using the Metropolis-Hastings algorithm. Specifically, we generate 400,000 posterior draws across eight parallel chains, each running 50,000 iterations after a burn-in period of 50,000 draws. The scale parameter of the proposal distribution is adjusted to achieve an acceptance rate close to 33%.

Observation equations and Data. Our dataset consists of four quarterly macroeconomic time series spanning the period from 1999Q1 to 2024Q4. The mapping between these observed variables and the model-implied quantities is summarized in the system of observation equations below, corresponding to an expanded version of (3):

$$\begin{bmatrix} \text{Real output growth per cap., lin. detrended} \\ \text{Inflation rate quarterly (HICP)} \\ \text{Quater. policy rate (Krippner SR) adj. lvl} \\ \text{Real hourly wage growth , lin. detrended} \end{bmatrix} = \begin{bmatrix} 100 \times (\frac{Y_t}{Y_{t-1}} - 1) + \mathbb{1}_{t=2020Q2}\alpha_{y,1} + \mathbb{1}_{t=2020Q3}\alpha_{y,2} \\ 100 \times (\pi_t - 1) \\ 100 \times (R_t - 1) + \overline{r} \\ 100 \times (\frac{w_t}{w_{t-1}} - 1) + \mathbb{1}_{t=2020Q2}\alpha_{w,1} + \mathbb{1}_{t=2020Q3}\alpha_{w,2} \end{bmatrix}.$$

We next discuss the data transformation. All data is based on EA changing composition. We first start with GDP transformation. We de-trend the real output growth series with linear trend to account for the fact that our model abstracts from exogenous long-run GDP growth. For prices and wages, we use HICP and real hourly wages – detrended nominal compensation of employee divided by total employment deflated by HICP – , respectively, and compute their quarterly growth rates. As for the interest rate, we adopt the shadow rate constructed by Krippner (2013), using the quarterly average of monthly values, to account for the constraints imposed by the Effective Lower Bound (ELB).

In the measurement equation, we introduce two types of measurement errors related to two events in our sample. First, our sample includes the COVID-19 outbreak, a major macroeconomic shock that violates the "all fluctuations are alike" principle of Lucas (1977).[9] Without specific treatment of this episode, the slope of the Phillips Curve would appear artificially flat, leading to a biased and downwardly distorted estimate of nominal rigidities. We therefore introduce $\alpha_{y,1}$ and $\alpha_{y,2}$ and $\alpha_{w,1}$ and $\alpha_{w,2}$, calibrated to average out the extreme recession and expansion caused by lockdown policies over those two quarters. Since we

[9]In particular, the COVID recession was marked by a sharp contraction in output without a corresponding decline in real wages, largely due to mitigation policies implemented by governments. This disconnect temporarily breaks the empirical relationship underpinning the New Keynesian Phillips Curve.

exclude 2020 from likelihood calculation, these two additional terms are automatically excluded from the likelihood computation and thus do not directly interfere with the identification of structural parameters.

The second event concerns the period at the Zero Lower Bound (ZLB), which requires the use of a shadow rate that pushes the average interest rate to very low levels. Without treatment, the estimated interest rate would be consistent with a near-one discount factor. We therefore introduce a correction term, $\overline{r}$, in the measurement equation for the interest rate. Given the low nominal rate environment and the presence of trend inflation, this adjustment ensures that the steady-state condition $\frac{\overline{\pi}}{\beta} - 1 + \overline{r}$ aligns with the observed average interest rate, while preserving the restriction $\beta < 1$.

Priors and posteriors estimate in the benchmark model. Table 1 reports the prior and posterior distributions for the estimated parameters. We first focus on the priors and benchmark model's posterior. Priors are chosen based on standard conventions in the literature under the constraint that the model dynamics are far more sensitive to parameter change than their usual linearized counterpart. In all the estimations in the paper, we assume that the discount factor is $\beta = 0.995$, the yearly inflation trend is 2% or $\overline{\pi} = 1.005$, and that the elasticity of good and labor demand are equal to $\varepsilon_p = \varepsilon_w = 9$. The autocorrelation of the monetary policy shock is never identified suggesting we could assume an i.i.d shock and $\rho_r = 0$. Results are not sensitive to change in those parameters but their identification is beyond the scope of this paper.

The standard deviations of the shocks $(\sigma_r, \sigma_d, \sigma_p, \sigma_w)$ are assigned inverse gamma priors with a mean of 0.001. Posterior means remain close to these priors, with, in the absence of the scaling generated by the linearization, higher values for the cost-push shock ($\sigma_p = 0.016$) and labor supply shock ($\sigma_w = 0.031$). The persistence of shocks, modeled through AR(1) parameters, exhibits significant posterior persistence, particularly for the risk premium shock ($\rho_d = 0.991$), the labor supply shock ($\rho_w = 0.9777$), and the price cost-push shock ($\rho_p = 0.988$) with posterior means close to the upper bound of the prior distribution.

The curvature of consumption utility (σ) and the disutility of labor (χ) follow gamma priors with means of 2 and 1, respectively. Posterior mode estimates indicate large increases for σ, with $\sigma = 4.825$ while the estimation for $\chi = 0.089$ implies a nearly linear curvature, as the exponent $1 + \chi$ in the disutility of labor approaches 1. The consumption habit prior follows a beta distribution with a mean at 0.5 and exhibits posterior distribution with a mode at $h = 0.679$.

In terms of the monetary policy rule, the inflation response parameter we found a posterior mean of $\theta_\pi = 1.948$, reflecting a strong monetary policy response to inflation deviations, while the mode of the output response parameter is $\theta_y = 0.111$ and the interest rate smoothing is $\rho = 0.935$, consistent with findings in the literature on interest rate inertia.

Parameters governing the steady-state price and wage stickiness ($\bar{\phi}_p, \bar{\phi}_w$) are estimated with priors centered at 0.7. We set tight priors consistent with the current practice for modeling the euro area business cycle in order to get a stable solution that is consistent with the micro evidence on wage and price setting. The posterior mode for steady-state price ($\bar{\phi}_p = 0.85$) and wage stickiness ($\bar{\phi}_w = 0.863$) suggest significant rigidities at the steady-state, aligning with standard macroeconomic models. However, the size of the price and wage state-dependency parameters ($\gamma_p = 9.280, \gamma_w = 9.715$) show posterior means consistent with priors, supporting the robustness of the model's endogenous wage and price-setting mechanisms. The intensities of choice are not different enough from their prior to claim strong identification, but they are in the realm of the Gasteiger and Grimaud (2023) estimates and the literature on discrete choice models following Matějka (2016). Moreover, the intensities of choice for price state-dependency parameter is very close to Gautier et al. (2026) estimated value of a Gasteiger and Grimaud (2023) model estimated on EU micro data. For the indexation parameters with priors centered at 0.5 both prices and wages show values between 0.2 and 0.4, indicating 20% to 40% indexation to last quarter's price inflation.

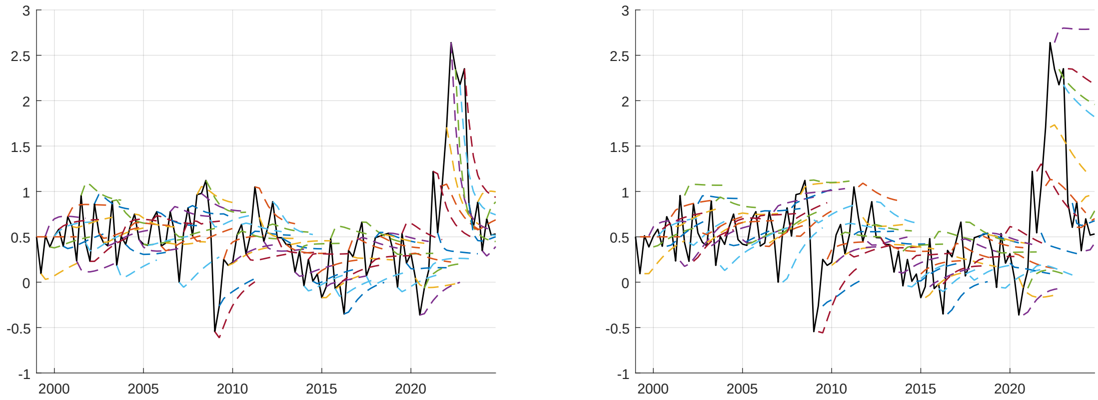
Comparison with the fixed updating frequency model. The log posterior value of the version with fixed updating frequencies is lower than in the quantitative benchmark model with endogenous frequency. This suggests that wage and price indexation help to address some data features, but the full setup with endogenous state-dependency outperforms a traditional quantitative DSGE model. To formally compare the two alternative representations of the data, we assume equal prior probabilities over the two competing specifications taking the fixed frequency model as baseline. The Bayes factor is 78 for our specification, which implies the data are approximately 78 times more likely under the benchmark model than under the fixed-frequency model. The posterior probability of our new pricing mechanism is 0.987, it is nearly 99% likely to be the correct specification, relative to the simpler model without state-dependent price and wage setting.

Comparing the parameters in the two quantitative models reveals some differences. First, the standard deviations of labor supply and cost-push shocks are larger in the version with fixed updating frequencies. Hence, without state-dependent wage and price setting, and with relatively flat Phillips curves, the model requires larger supply shocks to match observed price and wage inflation dynamics. Second, the curvature of the disutility of labor, χ, is small in both models but more than twice as large in the version with fixed updating frequencies, making marginal cost steeper.[10] Finally, the wage resetting frequency is smaller in the model with fixed updating frequencies compared to the steady state one of the benchmark model. This is due to the fact that in the absence of time variation, the former does need higher

[10] In this setup, a larger χ drives a stronger non-linear relationship between output and marginal costs, potentially overstating the steepness of the Phillips curve in normal times. In the *Endogenous Calvo model*, χ plays a critical role in explaining the present value of unions and firms. A large χ in this model would risk creating excessive state-dependency.

		Prior Distribution			Benchmark model $\phi_{p,t}$, $\phi_{w,t}$ - Posterior Distribution			Fixed updating freq. model ϕ_p, ϕ_w - Posterior Distribution		
		Shape	Mean	Std	Mode	Mean	[5%:95%]	Mode	Mean	[5%:95%]
Panel A: Shock processes										
Monetary policy shock std	σ_r	$\mathscr{IG}_2$	0.001	1	0.001	0.001	*[0.001:0.001]*	0.001	0.001	*[0.001;0.001]*
Risk premium shock std	σ_d	$\mathscr{IG}_2$	0.001	1	0.002	0.002	*[0.002;0.002]*	0.002	0.002	*[0.002;0.002]*
Cost-push shock std	σ_p	$\mathscr{IG}_2$	0.001	1	0.016	0.017	*[0.014;0.020]*	0.018	0.018	*[0.016;0.022]*
labor supply shock std	σ_w	$\mathscr{IG}_2$	0.001	1	0.031	0.032	*[0.027;0.039]*	0.038	0.041	*[0.033;0.052]*
AR(1), risk premium shock	ρ_d	$\mathscr{B}$	0.5	0.1	0.991	0.990	*[0.983;0.994]*	0.992	0.990	*[0.984;0.994]*
AR(1), cost-push shock	ρ_p	$\mathscr{B}$	0.5	0.1	0.988	0.986	*[0.976;0.992]*	0.993	0.993	*[0.990;0.995]*
AR(1), labor supply shock	ρ_w	$\mathscr{B}$	0.5	0.1	0.977	0.977	*[0.962;0.987]*	0.946	0.937	*[0.911;0.958]*
Panel B: Structural parameters										
Curvature consumption utility	σ	$\mathscr{G}$	2	1	4.825	5.058	*[4.091;6.183]*	4.726	4.786	*[3.785;5.943]*
Curvature disutility of labor	χ	$\mathscr{G}$	2	1	0.089	0.116	*[0.041;0.262]*	0.217	0.200	*[0.076;0.376]*
Consumption habit	h	$\mathscr{B}$	0.5	0.1	0.679	0.673	*[0.595;0.750]*	0.687	0.681	*[0.601;0.762]*
Inflation stance	θ_π	$\mathscr{G}$	2	0.05	1.948	1.940	*[1.856;2.023]*	1.940	1.932	*[1.847;2.016]*
Output stance	θ_y	$\mathscr{G}$	0.125	0.01	0.111	0.111	*[0.095;0.128]*	0.115	0.112	*[0.095;0.128]*
Interest rate smoothing	ρ	$\mathscr{B}$	0.5	0.1	0.935	0.934	*[0.920;0.947]]*	0.938	0.935	*[0.921;0.948]*
Panel C: Price and wage setting										
Price Calvo share	$\overline{\phi}_p$	$\mathscr{B}$	0.7	0.02	0.850	0.848	*[0.828;0.864]*	0.819	0.816	*[0.807;0.823]]*
Intensity of choice price	γ_p	$\mathscr{N}$	10	0.5	9.280	9.323	*[8.436;10.191]*			
Price indexation	ϱ_p	$\mathscr{B}$	0.5	0.1	0.225	0.232	*[0.166;0.301]*	0.162	0.165	*[0.109;0.234]*
Wage Calvo share	$\overline{\phi}_w$	$\mathscr{B}$	0.7	0.02	0.863	0.867	*[0.846;0.886]*	0.805	0.809	*[0.790;0.826]*
Intensity of choice wage	γ_w	$\mathscr{N}$	10	0.5	9.715	9.682	*[8.845;10.538]*			
Wage indexation	ϱ_w	$\mathscr{B}$	0.5	0.1	0.374	0.375	*[0.280;0.473]*	0.376	0.370	*[0.309;0.397]*
Log posteriors						475.923			471.5637	

Table 1: Priors and posteriors of the quantitative models. Sample: 1999Q1-2024Q4



(a) Benchmark

(b) Fixed updating frequency

Figure 6: **In sample inflation forecast at the posterior mode** Panel (a): for the benchmark model, Panel (b) for the model with fixed updating frequencies.

flexiblity to explain the price to wage feedback loop during the inflation surge.

Finally, Figure 6 shows all those effects by plotting the in sample forecast for inflation in both models. Because our contribution focuses on pricing mechanisms, we specifically report the forecast for inflation. Prior to 2020, forecast are relatively similar for both models, as state-dependent price and wage setting mechanisms do not significantly impact the dynamics during this period. This aligns with the view that state-dependencies become more pronounced only during periods of high inflation.

Both models struggle to capture the initial inflation surge in the short run and subsequently produce large errors. The benchmark model produces a slightly larger forecast error during the persistent run-up of inflation. This is due to both a lower estimated persistence of cost-push shocks and state-dependency, which makes the economy more flexible, so that the effects of shocks becomes less persistent. However, for the same reasons, the model with fixed updating frequencies yields very large forecast errors in the run-down of inflation. The near-unit-root behavior of supply shocks driving inflation in this model (see Subsection 4.2), combined with flat and autocorrelated NKPCs drive these errors. Indeed, under a time-invariant and flat New Keynesian Phillips Curve (NKPC), interactions between macroeconomic conditions, other aggregate shocks, and inflation are very limited. As a result, in the fixed updating frequency framework, supply shocks persistence account for most of the observed dynamic in inflation. On the contrary, errors are strikingly close to zero for the benchmark model, which takes into account that the higher flexibility of the economy yields a faster adjustment to shocks and more interaction with the rest of macro development.

In order to quantify the inflation forecast errors, we compute the RMSE for four-quarter-ahead inflation forecasts at the posterior mode in both models. Over the full sample, the benchmark model exhibits an RMSE of 0.54, whereas the fixed updating frequency model performs worst, with an RMSE of 0.60. Restricting the sample to the high-inflation period (i.e., 2021Q1–2023Q4), not surprisingly the average error increases, but importantly the gap between the models increases, with the benchmark model yielding an RMSE of 0.97 and the fixed updating frequency model performing worse at 1.16.[11] To further assess the performance of the models, we split the sample based on inflation regimes: a low inflation regime ($100 \times (\pi_t - 1) < 0.25$), a regime with inflation around target ($0.25 < 100 \times (\pi_t - 1) < 0.75$), and a target overshoot regime ($100 \times (\pi_t - 1) > 0.75$). The benchmark model exhibits RMSEs of [0.4991, 0.3927, 0.8727] across the three regimes, respectively. In comparison, the Fixed Updating Frequency model yields RMSEs of [0.5216, 0.4109, 1.0167]. These results indicate that the benchmark model delivers notably better forecasting performance during periods of elevated inflation.

4.2 Drivers of inflation in both models

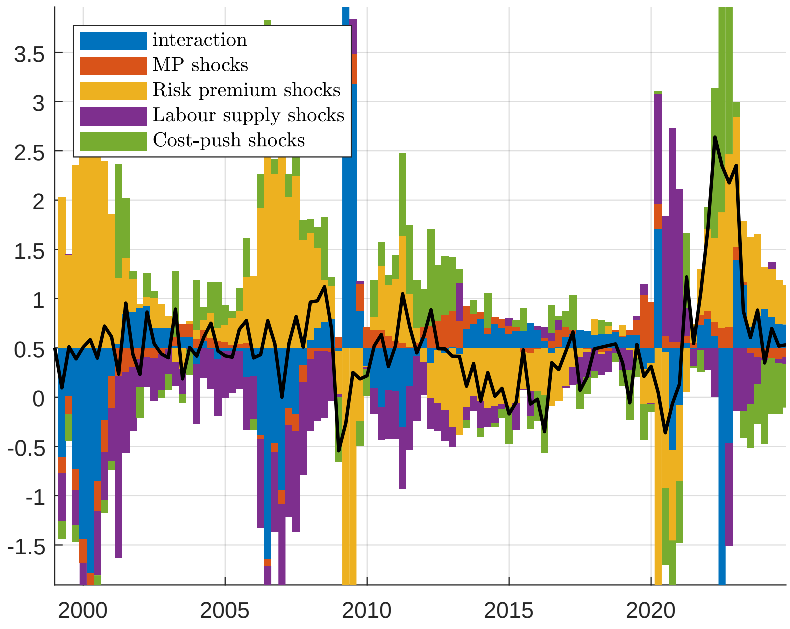
One of our key findings is that for most of the sample the version with time-varying updating frequency explains price and wage inflation by interactions of several shocks. In contrast, the version with fixed updating frequency explains the dynamics with hardly any interaction of shocks. This insight stems from a historical decomposition of inflation dynamics.

The historical decomposition identifies the contributions of the specific shocks to the historical dynamics of the variables. However, due to the non-linear nature of the model, the sum of individual shock effects does not fully reconstruct the endogenous path when all shocks act simultaneously. To address this issue, a residual (blue bar) is included in the decomposition, capturing non-linear interactions among shocks that cannot be attributed to a single shock in isolation.[12]

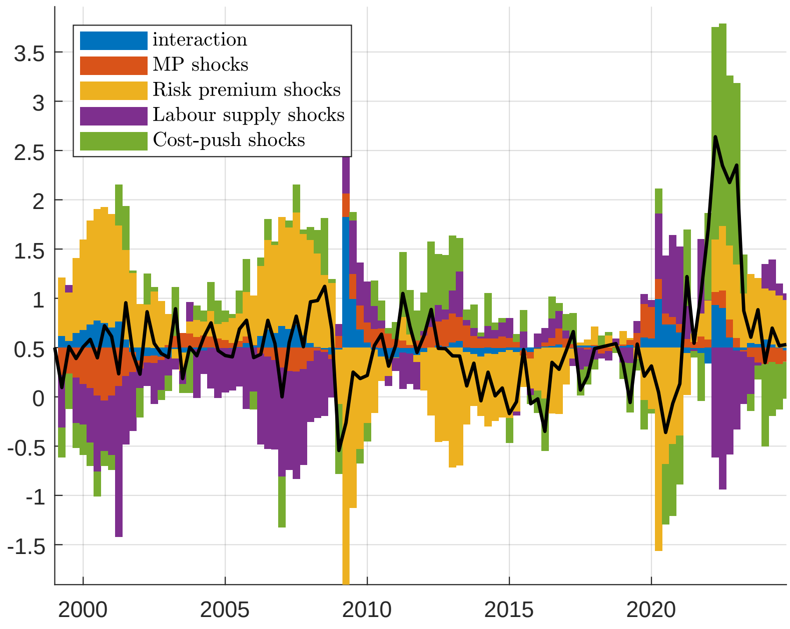
Figure 7 highlights striking differences between the two versions of the model. The inflation decomposition in the version with time-varying updating frequencies in Figure 7a shows that for most of the sample, inflation is not just explained by supply-side shocks. Shock interactions play an important role, which reflects a high degree of non-linearity in this version of the model. Moreover, this version also attributes a notable role to demand-side shocks. While supply-side shocks are predominant at the onset of the recent surge in inflation, the persistence of inflation appears to have been supported by subsequent demand shocks. The mechanism driving this episode is as follows: the initial cost-push shock steepened the

[11] For one-quarter-ahead forecast errors, the results are less clear-cut. The benchmark model exhibits an RMSE of 0.42, whereas the fixed updating frequency model performs marginally better at 0.41. During the high-inflation period, the gap between the models does not widen significantly, with the benchmark model at 0.66 and the fixed updating frequency model at 0.63.

[12] This residual reflects the complexity of non-linear dynamics and varies based on the specific shocks and the model's state-dependent structure. Its presence highlights a key limitation: the decomposition is inherently imperfect and should be interpreted as an approximation rather than a definitive breakdown of drivers. As model non-linearity increases, interaction terms become more significant, further reducing the clarity of the decomposition.



(a) Benchmark



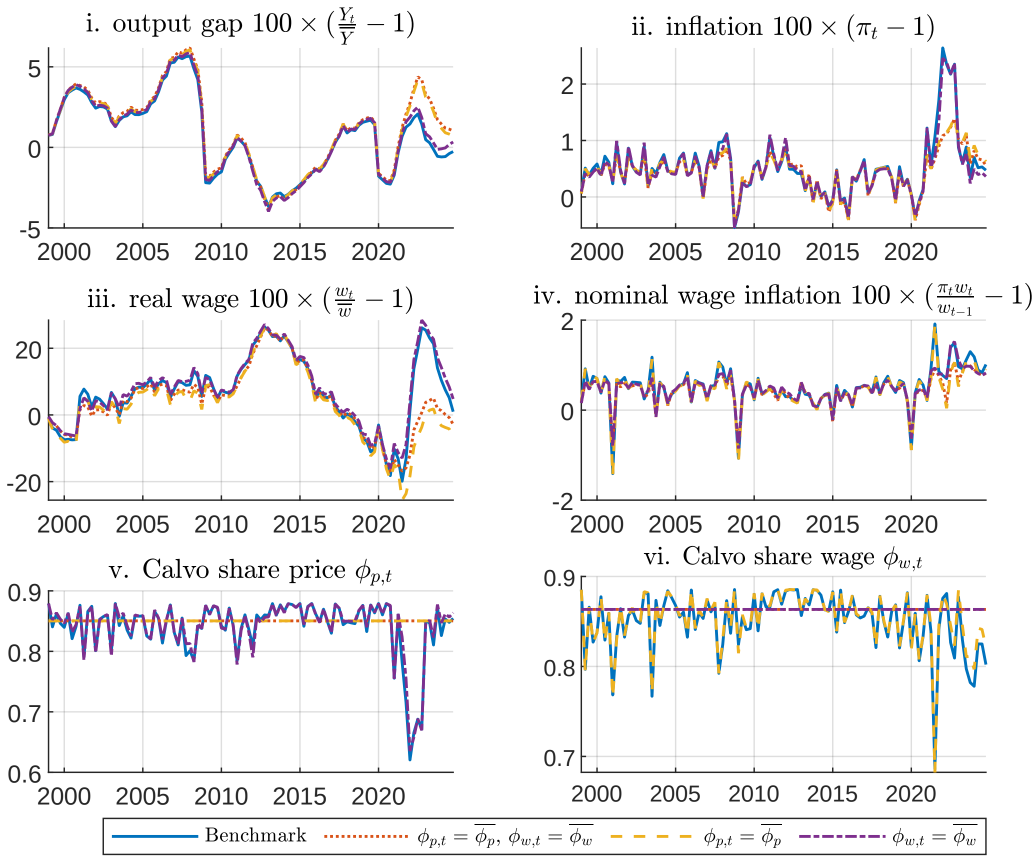
(b) Fixed updating frequencies

Figure 7: **Historical decomposition of price inflation in both model specifications.** Panel (a): HD for the benchmark model, Panel (b) HD for a model with fixed updating frequencies.
Notes: The decompositions are obtained by simulating each shock separately and adding them together thereafter. Due to the non-linear nature of the models, the sum of individual effects does not fully reconstruct the endogenous path when all shocks act together. The residual (blue bar) captures non-linear interactions among shocks that cannot be attributed to a single shock in isolation.

Phillips curves, while demand shocks contributed to the amplification of the inflationary impact of supply-side shocks due to a stronger price-wage interaction.

In comparison, the historical inflation decomposition in the version with fixed updating frequencies in Figure 7b attributes hardly any role to shock interactions. Prior to 2021, inflation is primarily driven by demand-side and labor supply shocks, with cost-push shocks contributing to short-term, high-frequency fluctuations. In the post-pandemic period, inflation is largely explained by cost-push shocks, which account for roughly two-thirds of the total. Positive demand-side shocks play a more limited role, contributing approximately one-third relative to the benchmark model. Similar insights can be gained from the wage inflation decomposition of this version of the model relegated to Figure F.5 of Appendix F.

4.3 Inflation channels in the benchmark model



(a) Full sample

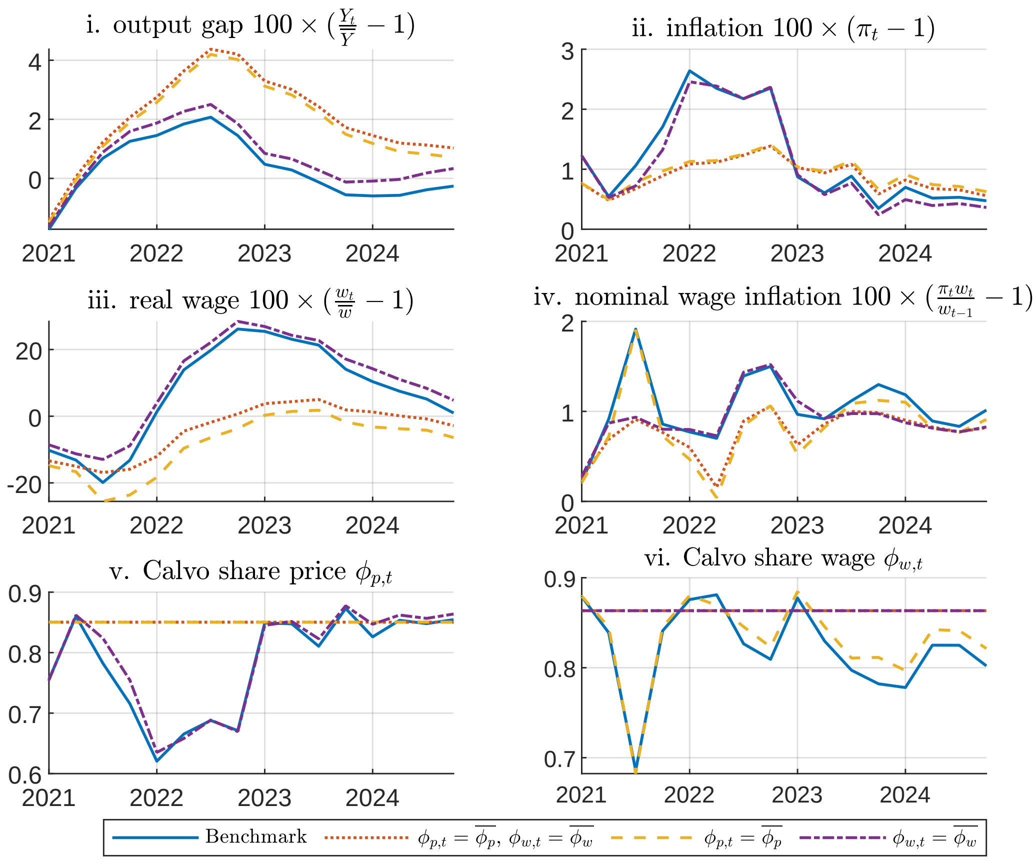
Figure 8: **Contribution of state-dependent price and wage setting to the dynamics of selected variables.** Counterfactual exercise switching off the state-dependency in wage and/or price setting. Dotted red lines: fixed updating frequencies, dashed yellow lines: only *wage* updating frequency is time-varying, dash-dotted purple lines: only *price* updating frequency is time-varying. We refer to the share of non-reoptimized wages or prices displayed in the chart as the Calvo shares.

We now turn to counterfactuals that demonstrate the crucial role of time-varying price- *and* wage-updating frequencies in explaining euro area data from 2021 onwards. Figure 8 reports the benchmark simulation with time-varying price- and wage-adjustment frequencies (blue solid line, coinciding with the data by construction) next to the counterfactuals. The red dotted line is the counterfactual with both adjustment frequencies fixed. The yellow dashed line is the counterfactual with time-varying wage-adjustment only. Finally, the purple dash-dotted line is the counterfactual with time-varying price-adjustment frequency only.

Panel 8a exhibits the simulated paths for all scenarios over the entire sample. Up to 2021, the counterfactual predicted paths deviate only slightly from the data. This suggests that time-varying price- and wage-adjustment frequencies play only a minor role in explaining the data during the pre-2021 period. The adjustment frequencies show only little variation around their posterior mode in the benchmark as well in the counterfactual simulations.

However, Panel 8b makes clear that time-varying price- *and* wage-adjustment frequencies play a crucial role in explaining the data from 2021 onwards. On the one hand, to generate the surge in inflation, as well as the dynamics of employment and the real wage, the model relies to a large extent on the time-varying price-adjustment frequency, which seems relatively more important than endogenous wage setting frequency. In particular, state-dependent wage setting alone cannot capture the dynamics of nominal wage inflation and real wages from 2022 onward. On the other hand, to capture the initial spike in nominal wage inflation at the end of 2022, the model depends crucially on the time-varying wage-adjustment frequency. Thus, the model relies crucially on the interaction of time-varying price- *and* wage-adjustment frequencies to explain the data during times of large shocks. Finally, without this mechanism the model fails to explain the data (red dotted lines).

Finally, we benchmark our model-implied extensive margin of price adjustment against euro area micro evidence. Appendix Figure F.3 compares the latent share of re-optimized prices in the quantitative model, $1-\phi_{p,t}$, with the share of changed prices reported by Gautier et al. (2026) over their common sample (2012–2024). The two series comove strongly, with a correlation of 0.6146 (90% confidence interval: [0.4609, 0.7325]). Strikingly, the model-generated share of re-optimized prices closely aligns with the share of price changes in the data. Before the 2021–2022 inflation surge, these shares are around 0.15 (model) and 0.23 (data). Both series display a sharp acceleration in price adjustment during the inflation episode, with the increase occurring about one quarter earlier in the model. A natural interpretation is composition: our model-based series pertains to headline HICP and therefore includes energy items, whose adjustment frequency rose abruptly already in late 2021 as energy prices began to surge, while Gautier et al. (2026) exclude energy from their micro-data coverage. Accordingly, the data series picks up the broad-based increase in price changes with a short delay, once non-energy components adjust more strongly. This consistency suggests that our model captures key features of the extensive margin of price adjustment during the recent



(b) Recent sample

Figure 8: (Cont.) **Contribution of state-dependent price and wage setting to the dynamics of selected variables.** Counterfactual exercise switching off the state-dependency in wage and/or price setting. Dotted red lines: fixed updating frequencies, dashed yellow lines: only *wage* updating frequency is time-varying, dash-dotted purple lines: only *price* updating frequency is time-varying. We refer to the share of non-reoptimized wages or prices displayed in the chart as the Calvo shares.

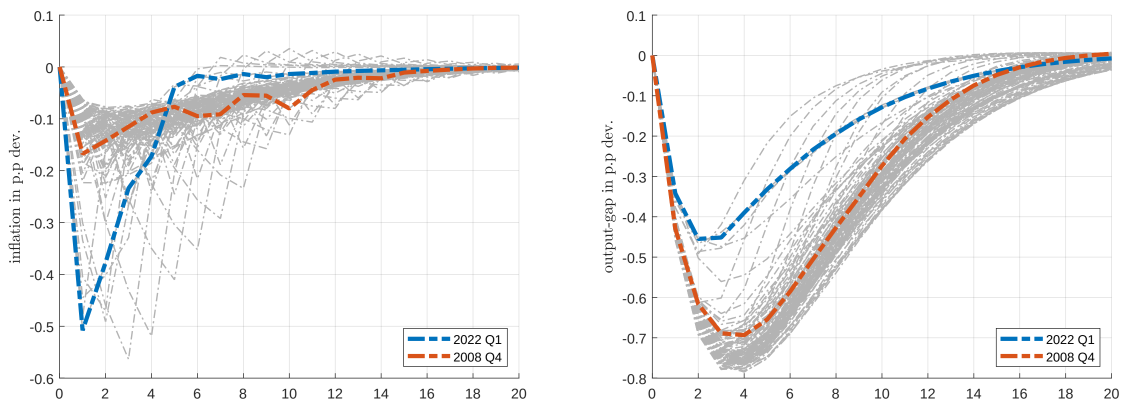
inflation episode.

5. Policy implications

Next, we analyze the policy implications of our model. We investigate three main questions. First, we examine how the transmission of shocks varied over the sample period, depending on the state of the business cycle and the estimated shocks. Second, we ask what the outcome would have been under alternative monetary policy choices. We also investigate whether time-varying price and wage adjustment frequencies can help explain the recently observed soft landing.

5.1 Shock transmission over the business cycle

We now examine how the transmission of shocks varied conditional on the euro area business cycle, i.e., conditional on the filtered shocks from the estimated quantitative model. First, we focus on monetary policy shocks and then we look at supply shocks. To compute IRFs conditional on the business cycle, we simulate the path of the endogenous variables in our model, in response to the filtered shocks, which provides the observed data. We then run a second simulation, adding a monetary policy (or a cost-push) shock of fixed size to the filtered shocks for each quarter in the sample. The difference between these two simulations yields the IRFs to the monetary policy (or cost-push) shock conditional on the business cycle. Hence, for each quarter in our sample, we obtain a different IRF to the same shock, allowing us to analyze how the transmission of these shocks varied over time along the euro area business cycle. Note that a linearized version of the model (e.g., Smets and Wouters, 2007), these IRFs would all be identical, while in the nonlinear version IRFs are state-dependent.



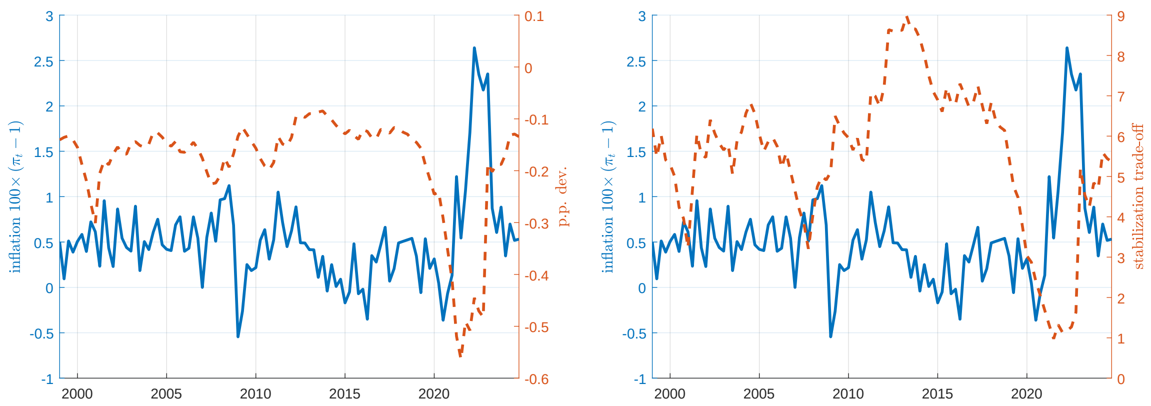
(a) Inflation responses

(b) Output responses

Figure 9: **IRFs to a +** 0.25% **monetary policy shock as function of the state** Panel (a): Inflation. Panel (b): Output. State-dependent IRFs are calculated by comparing the IRFs from all filtered shocks, with the IRFs from those filtered shocks plus an additional contemporaneous monetary policy shock. This isolates the effect of the monetary policy shock conditional on the initial state.

Figure 9 shows the responses of inflation and output to a contractionary monetary policy shock for each quarter, highlighting the IRFs corresponding to periods associated with the peak and trough of quarterly inflation. This figure nicely visualizes how the effects of monetary policy shocks in the euro area differed in our sample according to our estimates. In 2008Q4 – orange dashed line – a monetary policy would have had a strong contractionary impact on output with little effect on inflation. In contrast, during the peak of the recent inflation surge, in 2022Q1, a contractionary monetary policy shock would have largely affected inflation and much less output.

These differing IRFs naturally translate into a state-dependent inflation-output stabilization trade-off, summarized by Figure 10. Panel 10a presents the path of quarterly HICP inflation in the euro area (solid blue line, scale on the left axis) alongside the trough response of inflation along the IRFs (dashed red line, scale on the right axis) to a fixed-size contractionary monetary policy shock. The trough of the IRFs is simply the minimum inflation response over all quarters of the IRFs. The results indicate that inflation declines more sharply in response to a contractionary monetary policy shock when initial inflation is high.



(a) Trough response of inflation

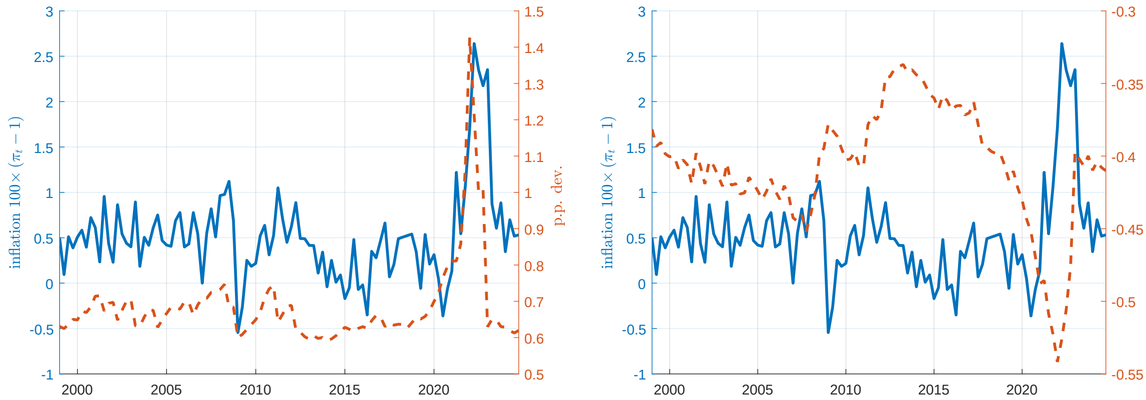
(b) Stabilization trade-off

Figure 10: **State-dependent inflation and stabilization trade-off responses to 0.25% contractionary monetary policy in the euro area over the business cycle.** Panel (a) Solid blue line is HICP inflation, scale on the left axis; dashed red line is the trough response of inflation along the IRFs, scale on the right axis. Panel (b): Solid blue line is HICP inflation, scale on the left axis; dashed red line is the the stabilization trade-off along the IRFs, scale on the right axis.

Notes: Stabilization trade-off is computed as the sum over 20 quarters of the ratio of the IRFs of output gap divided by the sum of the IRFs of inflation in response to a 0.25% monetary policy shock.

Panel 10b goes one step further, and examines the inflation-output trade-off over time. Here, the dashed red line represents the sum over 20 quarters of the ratio of the IRFs of the output gap to inflation, effectively capturing the cost of reducing inflation in terms of output. We find that, when inflation is high, the trade-off improves substantially, making it less costly to bring inflation down. In contrast, when inflation is low, the trade-off worsens, implying higher output costs to achieve the same reduction in inflation. These findings are consistent with the intuitions developed in the context of the small model in Section 3. The mechanism behind this pattern is that high inflation raises the relative benefit of adjusting prices for firms and wages for unions, leading to more frequent price and wage adjustments. This increased flexibility steepened the price and wage Phillips curves during the recent inflation surge in the euro area. In consequence, the effects of monetary policy shocks on inflation were stronger, and the inflation-output trade-off - in response to monetary policy shocks -

improved. Put differently, the increase in the frequency of adjustment appears to have made it less costly to reduce inflation for the ECB during the post-pandemic inflation surge. In contrast, as inflation started to decline as of 2023, the trade-off increased again.



(a) Peak response of inflation

(b) Average real wage deviation

Figure 11: **State-dependent inflation and average real wage responses to a 0.5% cost-push shock in the euro area over the business cycle.** Panel (a): Solid blue line is HICP inflation, scale on the left axis; dashed red line is the peak response of inflation along the IRFs, scale on the right axis. Panel (b): Solid blue line is HICP inflation, scale on the left axis; dashed red line is the average real wage deviation from steady state over 20 quarters IRFs, scale on the right axis.

Next, we turn to the transmission of cost-push (supply-side) shocks (Figure 11).[13] For this analysis, we repeat the above exercise, using a fixed-size cost-push instead of a monetary policy shock. Specifically, we compute the IRFs as the difference between a simulation using the filtered shocks alone and one with the addition of a cost-push shock for each period in the sample. In Panel 11a, the peak response of inflation to the cost-push shock is shown in dashed red, while the observed inflation data are in solid blue. We find that cost-push shocks have a stronger effect on inflation when inflation is high. The steepening of the price and wage Phillips curves at the onset of the inflation surge therefore likely made cost-push shocks more inflationary, such that the nonlinearity amplified the initial rise in inflation.

Panel 11b reports the average real wage deviation over 20 periods (red dashed line) conditional on the business cycle, in response to a cost-push shock. When inflation (solid blue line) is around 0.5%, the average real wage deviation is around -0.4%. When inflation is even lower, the value increases to around -0.33% reflecting a stronger response of nominal wages relative to prices. However, during episodes of high inflation, the response of nominal wages relative to prices is weaker, while prices react strongly. Finally, as inflation declines,

[13] Figure F.4 show the responses of inflation and output to an inflationary cost-push shock for each quarter, as Figure 9 does for monetary policy shocks.

the response of nominal wages relative to prices becomes stronger. These findings can be rationalized by the very same mechanism as discussed right above (see Panel (b) in Figure 8). Price- and wage-adjustment frequencies are at the heart of the mechanism. As can be seen in Panels (v.) and (vi.) in Figure 8, the price-adjustment frequency rose sharply during 2021 and 2022 leading to relatively weaker responses of nominal wages. The wage-adjustment frequency increased more gradually and persistently, while the price-adjustment frequency already declined in 2023. Put differently, in the euro area, price inflation accelerated before wage inflation, initially leading to a sharp decrease in real wages in 2021 that was only gradually reversed.

5.2 Policy stance and stabilization trade-offs

This section examines how the shape of the price and wage Phillips curves influences the trade-off between inflation and output, and how this can lead to different macroeconomic outcomes under alternative monetary policy stances. Counterfactual simulations are used to illustrate how recent dynamics might have evolved under different policy settings.

Specifically, in this subsection, we investigate how policy counterfactuals change between models with endogenous and fixed price and wage adjustment frequencies. Figure 12 compares the effects of different monetary policy stances toward inflation for the output gap, inflation, nominal wage inflation, and the policy rate. Solid lines represent the paths of variables when all parameters are at the posterior mode, i.e., the baseline scenarios. By construction, the simulated paths coincide with the data in both cases.

The counterfactual simulations during the 2021Q1–2024Q4 period use the same model-specific filtered shocks as in the baseline scenarios. However, the counterfactuals consider inflation reaction coefficients (θ_π) adjusted by ±10%.[14]

Under a tighter monetary policy stance ($\theta_\pi + 10\%$, dashed lines), the two models exhibit markedly different outcomes. In this counterfactual, both models predict comparable price inflation, as expected, below the baseline.[15] However, in the model with fixed adjustment frequencies (red lines), the slight decrease in inflation comes at the cost of generating a longer-lasting recession with a more persistent negative output loss relative to the benchmark model (blue lines), whose output gap behavior, instead, almost coincides with the baseline. In sum, the model with fixed adjustment frequencies predicts a less favorable output-inflation trade-off, i.e., flatter Phillips curves relative to the benchmark model. Therefore this model suggests that a more aggressive monetary policy would have led to a deeper recession during this episode of high inflation. In contrast, the benchmark model predicts that a more aggressive monetary policy stance could have reduced price and wage inflation by more during this episode of high inflation with only limited additional output cost. The

[14] To save space, we omit the pre-2021 period, where no significant deviations are observed.

[15] At times, the model with fixed adjustment frequencies predicts lower wage inflation than the benchmark.

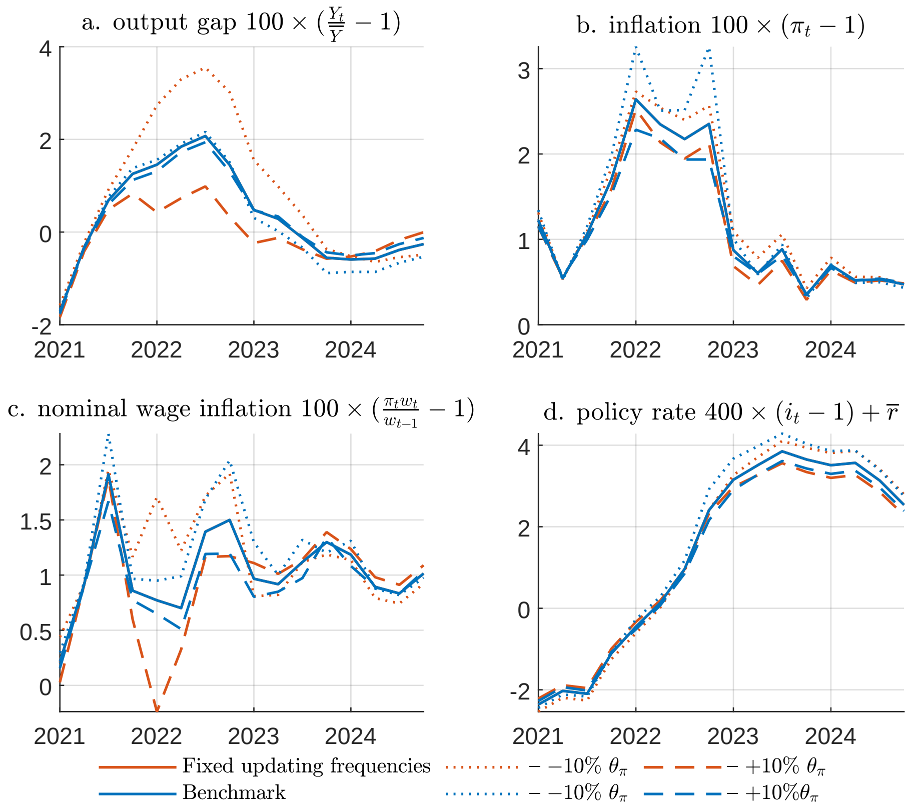


Figure 12: **Impact of the monetary policy stance on output and inflation in the euro area recent inflation surge.** Counterfactual exercise varying the monetary policy stance in the benchmark and fixed updating frequencies models. Red lines: fixed updating frequencies, blue lines: benchmark model. Dotted lines: decrease of the inflation reaction coefficient in the Taylor rule parameter by 10%, Dashed lines: increase of the same parameter by 10%.
Notes: Counterfactual simulations in the benchmark model (blue lines) and the model with fixed adjustment frequencies (red lines) during the 2021Q1-2023Q4 period, with different monetary policy stance. The dotted lines correspond to cases with a change −10% to the estimated reaction of the deviation of inflation to the target in the Taylor rule, the dashed lines are cases with a change +10% to the same parameter.

latter is true, because in the benchmark model the Phillips curves are steeper when inflation is high, which improves the output-inflation trade-offs.

Finally, notice from Figure 12 that the counterfactual with a more passive monetary policy stance ($\theta_\pi - 10\%$, dotted lines), suggests opposite conclusions compared to a more aggressive monetary policy stance. The model with fixed adjustment frequencies predicts a counterfactual expansion at the cost of moderately higher price and wage inflation. In contrast, the benchmark predicts hardly any difference in output relative to baseline, but much higher price and wage inflation.

The takeaway from these counterfactuals is that, through the lens of the benchmark model, a more proactive monetary policy during 2021Q1–2024Q4 could have helped moderate inflation with relatively minimal impact on output. In contrast, a more dovish monetary policy would have led to higher inflation.[16]

[16] A caveat is that the analysis primarily captures nonlinearities in price and wage setting, while abstracting

The difference in monetary policy effectiveness between the two models, just described above, would affect the optimal policy prescriptions. Appendix E extends the analysis by considering a real-time optimal strict inflation targeting exercise, revealing the following important differences across the two models. The fixed-updating frequency model implies highly persistent inflation, due to persistent cost-push shocks, and a flat Phillips curve. Hence, it calls for an aggressive tightening during the 2021–2022 inflation surge, resulting in substantial output losses with very limited initial impact on inflation. As policy becomes more persistent and slack builds up, disinflationary effects start to appear by 2023. In contrast, the benchmark model views inflation shocks as shorter-lived and inflation less persistent. As a result, it calls for a tightening, that it is slightly above, but aligns closely with actual observed policy. The steeper Phillips curve in this model improves the effectiveness of monetary policy, resulting in significantly lower inflation and a smaller loss in output compared to the fixed-updating frequency model.

6. Conclusion

The findings of this paper highlight the crucial role of state-dependent price and wage-setting frequencies in shaping inflation dynamics and monetary policy trade-offs during the high inflation period. Unlike standard New Keynesian models with quasi-linear Phillips curves, our framework captures non-linear inflation responses when the economy is hit by large shocks. Endogenous price and wage-setting adjustment leads to steeper Phillips curves during periods of high inflation, and it has strong policy implications. state-dependency alters the stabilization trade-off, making monetary policy more effective in curbing inflation when inflation is already elevated, but less so in low-inflation environments.

Our empirical analysis, based on euro area data from 1999 to 2024, reveals that standard models relying primarily on exogenous supply shocks fail to fully explain inflation dynamics. Instead, we show that the interaction between demand and supply shocks is strongly state-dependent, with inflationary supply shocks triggering more frequent price and wage adjustments than disinflationary ones. This asymmetry, driven by firms' and unions' incentives to avoid being locked into unfavorable price or wage levels, plays a critical role in shaping inflation persistence and the transmission of shocks to the broader economy.

Beyond its direct implications for monetary policy, our methodology offers a flexible and scalable framework that can be embedded in larger DSGE models. By capturing the endogenous interaction between price- and wage-setting frequencies in a reduced-form, state-dependent setup, our approach provides a computationally efficient alternative to a fully

from other potentially relevant sources of nonlinearity — such as financial frictions — which could influence the inflation-output trade-off and alter the effects of alternative policy stances, possibly in the opposite direction. More broadly, the analysis does not account for the elevated real-time uncertainty that characterized the period, including the economic effects of the COVID-19 pandemic and Russia's invasion of Ukraine.

microfounded menu cost model. This enables the integration of state-dependent inflation dynamics into more complex macroeconomic environments without significantly increasing model complexity.

Overall, our results suggest that monetary policy in the euro area could have responded more aggressively to the recent surge in inflation without incurring excessive output losses. This is due to the increased flexibility in price and wage setting during high inflation periods. Future research should further investigate how state-dependent inflation dynamics influence broader DSGE used for policy evaluation, where additional nonlinearities might hinder or improve stabilization trade-offs.

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Appendix

A. Macroeconomic evidence

This appendix describes the local projection framework used to estimate the impulse responses of inflation to oil supply shocks. We work with monthly data and measure inflation as year-on-year CPI inflation. Let P_t denote the consumer price index at month t. Inflation is defined as $\pi_t = 100 \times (\log P_t - \log P_{t-12})$, so that π_t corresponds to the annual inflation rate expressed in percentage points. Using year-on-year inflation mitigates seasonality and ensures comparability across horizons in the local projection setting.

Impulse response functions are estimated using the local projection methodology. For each horizon $h = 0, 1, \ldots, H$, we estimate

$$\pi_{t+h} = \alpha_h + \sum_{\ell=0}^{11} g_h(z_{t-\ell}) + \mathbf{X}'_{t-1}\gamma_h + \varepsilon_{t+h},$$

where z_t denotes the monthly oil supply shock constructed by Känzig (2021), standardized to unit variance. The vector $\mathbf{X}_{t-1}$ includes lagged controls; in the baseline specification, it consists of 11 lags of year-on-year inflation. Standard errors are computed using Newey–West corrections. The function $g_h(\cdot)$ governs the transmission of the shock and allows for different forms of non-linearity.

Following Caravello and Martínez-Bruera (2024), we consider three specifications.

Linear specification.

$$g_h(z) = \beta_{1,h} z, \qquad \text{IRF}_h(s) = \beta_{1,h} s,$$

which implies responses that are linear and symmetric in both sign and size.

Sign-dependent specification.

$$g_h(z) = \beta_{1,h} z + \beta_{2,h} z|z|, \qquad \text{IRF}_h(s) = \beta_{1,h} s + \beta_{2,h} s|s|,$$

which allows responses to differ between positive and negative shocks of equal magnitude.

Size-dependent specification.

$$g_h(z) = \beta_{1,h} z + \beta_{2,h} z^2, \qquad \text{IRF}_h(s) = \beta_{1,h} s + \beta_{2,h} s^2,$$

which allows responses to vary with the magnitude of the shock independently of its sign.

B. The model

Time t is discrete. We borrow the notation from Sims and Wu (2021) and develop a New Keynesian model with consumption habits, indexation to lagged inflation, and state-dependent sticky prices and wages following Gasteiger and Grimaud (2023). The state-dependency allows for intensive *and* extensive margin adjustments in prices and wages.

Households. The lifetime utility of household $k \in [0,1]$ is given by

$$\mathbb{E}_t \sum_{j=0}^{\infty} \beta^j \left\{ \frac{1}{1-\sigma} \left(\frac{C_{t+j}(k)}{C^h_{t-1+j}} \right)^{1-\sigma} C^h_{t-1+j} - \frac{\psi}{1+\chi} L_{t+j}(k)^{1+\chi} \right\},$$

with relative risk aversion $\sigma > 1$, discount factor $0 < \beta < 1$, $\psi > 0$ is a scaling parameter for labor disutility, and, χ is the inverse Frisch elasticity. We incorporate multiplicative external consumption habits into the utility function via parameter $0 \leq h < 1$. This creates complementarities between individual agent consumption at time t and aggregate consumption at $t-1$. The utility function is increasing and concave in both individual and aggregate consumption. When the habit parameter $h = 0$, the utility function collapses to standard CRRA preferences. This formulation allows for the introduction of consumption smoothing in Section 4 while avoiding negative marginal utility, which could destabilize the model under nonlinear simulations in response to large shocks.

Household k, faces the nominal budget constraint

$$P_t C_t(k) + B_t(k) \leq (1-\varepsilon_{w,t}) MRS_t L_t(k) + (1-\varepsilon_{d,t}) R_{t-1} B_{t-1}(k) + DIV_t + T_t,$$

where P_t represents the price level of goods, and B_t denotes a one-period bond that pays the short-term gross interest rate R_t. The term MRS_t corresponds to the nominal remuneration households earn by supplying labor to the union. DIV_t captures the dividends households receive as owners of the private sector, while T_t represents lump-sum taxes net of subsidies, ensuring the government budget constraint is balanced.

Two exogenous AR(1) processes, $\varepsilon_{w,t}$ and $\varepsilon_{d,t}$, are introduced to generate variations in distortionary taxes or subsidies on wages and on bond income. These processes are introduced for estimation purposes. They effectively represent a labor supply shock ($\varepsilon_{w,t}$) and a shock ($\varepsilon_{d,t}$) creating a wedge between the central bank's policy rate and the return on assets held by households, similar to Smets and Wouters's (2007) risk premium shock.

Aggregating over homogeneous households and dropping the k index, the first-order conditions for a representative agent in real terms are

$$\psi L_t^{\chi} (C_t C_{t-1}^{-h})^{\sigma} = (1-\varepsilon_{w,t}) mrs_t$$

$$1 = (1 - \varepsilon_{d,t}) R_t \mathbb{E}_t \Lambda_{t,t+1} \pi_{t+1}^{-1}$$

$$\Lambda_{t,t+1} = \beta \left(\frac{C_{t+1} C_t^{-h}}{C_t C_{t-1}^{-h}} \right)^{-\sigma}$$

with $\pi_t = P_t / P_{t-1}$ the gross inflation rate, $mrs_t = MRS_t / P_t$ the real remuneration for labor supply and $\Lambda_{t,t+1}$ the the real stochastic discount factor. Clearly, multiplicative consumption habits affect both the labor supply and the inter-temporal consumption decision.

Production. Production is divided into several layers. A representative wholesale firm hires labor from the labor packer and produces output. The latter is sold to a continuum of retail firms at price $P_{w,t}$. Each retail firms $i \in [0,1]$ repackages wholesale output, and sells it to a competitive final goods firm at $P_t(f)$.

A final goods firm transforms retail output into a final output good according to $Y_t = \left[\int_0^1 Y_t(f)^{\frac{\epsilon_p - 1}{\epsilon_p}} df \right]^{\frac{\epsilon_p}{\epsilon_p - 1}}$. Profit maximization by the final goods firm gives a demand for each retail output as $Y_t(f) = \left(\frac{P_t(f)}{P_t} \right)^{-\epsilon_p} Y_t$, and, the aggregate price index as $P_t^{1-\epsilon_p} = \int_0^1 P_t(f)^{1-\epsilon_p} df$.

Retailers are price-setters. Following Gasteiger and Grimaud (2023), the retailers discount future real dividends with the stochastic discount factor of the household, as well as the time-varying price-setting frequency. The price-setting problem is therefore:

$$\max_{P_t(f)} \mathbb{E}_t \sum_{j=0}^{\infty} \left(\prod_{k=0}^{j} \phi_{p,t+k} \right) \phi_{p,t}^{-1} \Lambda_{t,t+j} \times$$
$$\times \left\{ P_t(f)^{1-\epsilon_p} (P_{t+j} / \Pi_{t,t+j}^{\varrho_p})^{\epsilon_p - 1} Y_{t+j} - P_{w,t+j} P_t(f)^{-\epsilon_p} (P_{t+j} / \Pi_{t,t+j}^{\varrho_p})^{-\epsilon_p} Y_{t+j} \right\},$$

where $0 \leq \varrho_p < 1$ is a parameter governing indexation to past inflation. We define the optimal reset price as $P_t^{\#}$, it does not depend on the index f. The first-order condition is recursively given by

$$P_t^{\#} = \frac{\epsilon_p}{\epsilon_p - 1} \frac{X_{1,t}}{X_{2,t}}$$

$$X_{1,t} = p_{w,t} (P_t / \Pi_{t,t}^{\varrho_p})^{\epsilon_p} Y_t + \mathbb{E}_t \phi_{p,t+1} \Lambda_{t,t+1} X_{1,t+1}$$

$$X_{2,t} = (P_t / \Pi_{t,t}^{\varrho_p})^{\epsilon_p - 1} Y_t + \mathbb{E}_t \phi_{p,t+1} \Lambda_{t,t+1} X_{2,t+1}$$

With $p_{w,t} = P_{w,t} / P_t$ interpreted as real marginal costs. We define $x_{1,t} = X_{1,t} / P_t^{\epsilon_p}$ and $x_{2,t} = X_{2,t} / P_t^{\epsilon_p - 1}$ so as to have

$$x_{1,t} = p_{w,t} Y_t + \mathbb{E}_t \phi_{p,t+1} \Lambda_{t,t+1} \left(\frac{\pi_{t+1}}{\pi_t^{\varrho_p}} \right)^{\epsilon_p} x_{1,t+1}$$

$$x_{2,t} = Y_t + \mathbb{E}_t \phi_{p,t+1} \Lambda_{t,t+1} \left(\frac{\pi_{t+1}}{\pi_t^{\varrho_p}} \right)^{\epsilon_p - 1} x_{2,t+1}$$

$$p_t^{\#} = \frac{\epsilon_p}{\epsilon_p - 1} \frac{x_{1,t}}{x_{2,t}}$$

with $p^{\#}_t = P^{\#}_t / P_t$. The wholesale firm produces output following

$$Y_{W,t} = L_{d,t}$$

Such that the optimality condition in real terms is given by

$$(1 - \varepsilon_{p,t}) w_t = p_{w,t},$$

in which $\varepsilon_{p,t}$ represents an exogenous tax or subsidy on marginal costs, introduced to generate supply-side inflationary shocks. Unlike labor supply shocks, these shocks move real wage and inflation in opposite directions.

Price-resetting agency. We microfound the endogenous non-resetting share $\phi_{p,t}$ through a centralized price-setting agency. The agency is owned by the representative household and owns the continuum of intermediate-goods firms, so it internalizes firm profits; any net payoff is rebated lump-sum to households. Its role is limited to the timing of re-optimization: when adjustment is authorized, firms reset to the common optimal price $P^{\#}_t$. In each period t, the agency chooses $d_{p,t} \in \{0, 1\}$, where $d_{p,t} = 1$ authorizes a reset to $P^{\#}_t$ and $d_{p,t} = 0$ implies continuation at legacy prices. Let $\mathcal{V}_{p,i,t,d}$ denote firm i's continuation value conditional on action d. Absent informational frictions, the agency would choose $d_{p,t}$ to maximize $\int_0^1 \mathcal{V}_{p,i,t,d}\, di$. We assume that for the agency, conditioning sharply on the state is costly in terms of information, therefore it chooses adjustment probabilities $\mathscr{P}_{p,0,t}$ and $\mathscr{P}_{p,1,t}$. Under symmetric implementation,these probabilities coincide with equilibrium shares,[17]

$$\phi_{p,t} \equiv \mathscr{P}_{p,0,t}, \qquad 1 - \phi_{p,t} \equiv \mathscr{P}_{p,1,t}.$$

Accordingly, aggregate continuation value takes the Calvo-style mixture form

$$\int_0^1 \mathcal{V}_{p,i,t}\, di \;=\; \mathscr{P}_{p,1,t} \int_0^1 \mathcal{V}_{p,i,t,1}\, di \;+\; \mathscr{P}_{p,0,t} \int_0^1 \mathcal{V}_{p,i,t,0}\, di.$$

Derivations of the present values of the firms. We assume that each firm i in every period either updates the price optimally, $P^{\#}_{i,t}$, or believe to update the price to the average legacy price, $P^{f}_{i,t}$. By symmetry, we have $P^{x}_{i,t} = P^{x}_t$ for $x \in \{\#, f\}$. From the FOC conditions, the value

[17] As in Blanco et al. (2024), our setup abstracts from the selection effect that arises when adjustment decisions depend on firm-level states: the agency's symmetric implementation and the insured non-adjustment payoff imply that adjustment shares can be treated as probabilities without tracking the cross-sectional composition of adjusters.

of a firm of type x is

$$\begin{aligned} V^x_{p,t|t} &= \mathbb{E}_t\left\{\sum_{j=0}^{\infty}\left(\prod_{k=0}^{j}\phi_{p,t+k}\right)\phi_{p,t}^{-1}\Lambda_{t,t+j}\left[\left(\frac{P^x_t}{P_{t+j}\Pi_{t,t+j}^{-\varrho_p}}\right)^{1-\epsilon_p} - p_{w,t+j}\left(\frac{P^x_t}{P_{t+j}\Pi_{t,t+j}^{-\varrho_p}}\right)^{-\epsilon_p}\right]Y_{t+j}\right\} \\ &= \mathbb{E}_t\left\{\sum_{j=0}^{\infty}\left(\prod_{k=0}^{j}\phi_{p,t+k}\right)\phi_{p,t}^{-1}\Lambda_{t,t+j}\left[\left(\frac{P^x_t}{P_t}\frac{P_t}{P_{t+j}\Pi_{t,t+j}^{-\varrho_p}}\right)^{1-\epsilon_p} - p_{w,t+j}\left(\frac{P^x_t}{P_t}\frac{P_t}{P_{t+j}\Pi_{t,t+j}^{-\varrho_p}}\right)^{-\epsilon_p}\right]Y_{t+j}\right\} \\ &= \mathbb{E}_t\left\{\sum_{j=0}^{\infty}\left(\prod_{k=0}^{j}\phi_{p,t+k}\right)\phi_{p,t}^{-1}\Lambda_{t,t+j}\left[\left(\frac{p^x_t}{\Pi_{t,t+j}\Pi_{t,t+j}^{-\varrho_p}}\right)^{1-\epsilon_p} - p_{w,t+j}\left(\frac{p^x_t}{\Pi_{t,t+j}\Pi_{t,t+j}^{-\varrho_p}}\right)^{-\epsilon_p}\right]Y_{t+j}\right\}, \end{aligned}$$

where we define the relative price $p^x_t \equiv P^x_t/P_t$. Next, we split $V^x_{p,t|t}$ into

$$V^x_{p,t|t} = V^x_{p,x_2,t|t} - V^x_{p,x_1,t|t},$$

where

$$\begin{aligned} V^x_{p,x_1,t|t} &\equiv \mathbb{E}_t\left\{\sum_{j=0}^{\infty}\left(\prod_{k=0}^{j}\phi_{p,t+k}\right)\phi_{p,t}^{-1}\Lambda_{t,t+j}\left(\frac{p^x_t}{\Pi_{t,t+j}\Pi_{t,t+j}^{-\varrho_p}}\right)^{1-\epsilon_p} Y_{t+j}\right\} \qquad \text{and} \\ V^x_{p,x_2,t|t} &\equiv \mathbb{E}_t\left\{\sum_{j=0}^{\infty}\left(\prod_{k=0}^{j}\phi_{p,t+k}\right)\phi_{p,t}^{-1}\Lambda_{t,t+j}p_{w,t+j}\left(\frac{p^x_t}{\Pi_{t,t+j}\Pi_{t,t+j}^{-\varrho_p}}\right)^{-\epsilon_p} Y_{t+j}\right\} \end{aligned}$$

Next, recall the definitions of the auxiliary variables $x_{1,t}$ and $x_{2,t}$. Thus, we obtain

$$V^x_{p,t|t} = p_t^{x,1-\epsilon_p}x_{2,t} - p_t^{x,-\epsilon_p}x_{1,t}.$$

The problem of the agency. Resetting entails a fixed non-pecuniary burden $\tau_p > 0$. Let $V^\#_{p,t}$ denote the continuation value associated with resetting to $P^\#_t$. Then, with symmetric firms,

$$\mathcal{V}_{p,i,t,1} \equiv V^\#_{p,t} - \tau_p, \qquad V^\#_{p,t} \equiv V_p(p^\#_{p,t}).$$

When prices are not reset ($d_{p,t} = 0$), firms operate with heterogeneous legacy prices and continuation values $V^f_{p,i,t,0}$. We assume the payoff relevant for the agency's decision is

$$V^f_{p,t} \equiv V_p(p^f_{p,t}), \qquad p^f_{p,t} \equiv \frac{P_{t-1}}{P_t} = \frac{1}{\pi_t}.$$

Hence, the agency compares

$$\mathcal{V}_{p,0,t} \equiv V^f_{p,t}, \qquad \mathcal{V}_{p,1,t} \equiv V^\#_{p,t} - \tau_p,$$

and chooses $(\mathscr{P}_{p,0,t}, \mathscr{P}_{p,1,t})$ to maximize the continuation value against an information-processing cost $\Omega(\mathscr{P}_{p,0,t}, \mathscr{P}_{p,1,t})$

$$\max_{\mathscr{P}_{p,0,t}, \mathscr{P}_{p,1,t}} \left\{ \mathscr{P}_{p,0,t} V^f_{p,t} + \mathscr{P}_{p,1,t}(V^\#_{p,t} - \tau_p) - \frac{1}{\gamma_p} \Omega(\mathscr{P}_{p,0,t}, \mathscr{P}_{p,1,t}) \right\},$$
$$1 = \mathscr{P}_{p,0,t} + \mathscr{P}_{p,1,t}.$$

where $\gamma_p > 0$ is the inverse marginal cost of information processing. Under an entropy-based information cost and a symmetric prior, Matějka and McKay (2015, Theorem 1) shows that the FOC condition boils down to the logit policy

$$\mathscr{P}_{p,0,t} \equiv \phi_{p,t} = \frac{\exp\left(\gamma_p V^f_{p,t}\right)}{\exp\left(\gamma_p V^f_{p,t}\right) + \exp\left(\gamma_p (V^\#_{p,t} - \tau_p)\right)}. \tag{B.1}$$

Equation (B.1) implies that the non-resetting share $\phi_{p,t}$ is a smooth, state-dependent function of the difference between the continuation values of non-adjustment and adjustment. The fixed burden $\tau_p > 0$ shifts the adjustment value $V^\#_{p,t} - \tau_p$ downward and therefore raises $\phi_{p,t}$, all else equal. The intensity of choice parameter $\gamma_p > 0$ governs the strength of state contingency. When γ_p is small, information is expensive and the agency responds weakly to movements in $V^f_{p,t}$ and $V^\#_{p,t}$; adjustment becomes nearly random and $\phi_{p,t}$ is close to a constant, delivering the Calvo benchmark as $\gamma_p \to 0$. As γ_p increases, information becomes cheaper, the agency conditions more sharply on the state, and $\phi_{p,t}$ varies more with the underlying present values. In the limit $\gamma_p \to \infty$, choices become nearly deterministic: the agency puts almost all probability on the higher-value action, so price adjustment becomes effectively state-dependent. For any finite γ_p, adjustment remains probabilistic and prices are therefore rigid in the sense that a positive mass of firms does not re-optimize each period.

Labor market. The labor market consists of three layers. There is a continuum of labor unions index by $l \in [0,1]$. They purchase labor from households at MRS_t and repackage it for sale to a representative labor packer $W_t(l)$. The labor packer combines differentiated labor inputs into final labor, $L_{d,t}$, via a CES technology with elasticity of substitution $\epsilon_w > 1$. Therefore, the labor demand curve faced by each union l is

$$L_t(l) = \left(\frac{W_t(l)}{W_t}\right)^{-\epsilon_w} L_{d,t},$$

and, the aggregate wage index is

$$W_t^{1-\epsilon_w} = \int_0^1 W_t(l)^{1-\epsilon_w} dl.$$

Labor unions are wage setters. Following Gasteiger and Grimaud (2023), the problem for union l that updates optimally is to choose a wage that maximizes the discounted value of future real profits. Unions apply the household's stochastic discount factor to get the net present value of profits, and take the time-varying wage-setting frequency as given, i.e.,

$$\max_{W_t(l)} \mathbb{E}_t \sum_{j=0}^{\infty} \left(\prod_{k=0}^{j} \phi_{w,t+k} \right) \phi_{w,t}^{-1} \Lambda_{t,t+j}$$
$$\times \left\{ (W_t(l)\Pi_{t,t+j}^{\varrho_w})^{1-\epsilon_w} W_{t+j}^{\epsilon_w} P_{t+j}^{-1} L_{d,t+j} - mrs_{t+j} (W_t(l)\Pi_{t,t+j}^{\varrho_w})^{-\epsilon_w} W_{t+j}^{\epsilon_w} L_{d,t+j} \right\}$$

with

$$\Pi_{t,t+j} \equiv \begin{cases} \frac{P_{t+1}}{P_t} \times \frac{P_{t+2}}{P_{t+1}} \times \ldots \times \frac{P_{t+j}}{P_{t+j-1}} & \text{for } j = 1,2,\ldots \\ 1 & \text{for } j = 0. \end{cases}$$

$0 \leq \varrho_w < 1$ captures partial indexation of wages to past inflation. Assuming that the reset wage is the same across all labor unions, the index l can be dropped. The first-order condition defining optimal reset wage $W_t^{\#}$ can be written in real terms as

$$w_t^{\#} = \frac{\epsilon_w}{\epsilon_w - 1} \frac{F_{1,t}}{F_{2,t}},$$

where

$$F_{1,t} = mrs_t w_t^{\epsilon_w} (P_t/\Pi_{t,t+j}^{\varrho_w})^{\epsilon_w} L_{d,t} + \mathbb{E}_t \phi_{w,t+1} \Lambda_{t,t+1} F_{1,t+1}$$
$$F_{2,t} = w_t^{\epsilon_w} (P_t/\Pi_{t,t+j}^{\varrho_w})^{\epsilon_w - 1} L_{d,t} + \mathbb{E}_t \phi_{w,t+1} \Lambda_{t,t+1} F_{2,t+1}$$

Defining $f_{1,t} = F_{1,t}/P_t^{\epsilon_w}$ and $f_{2,t} = F_{2,t}/P_t^{\epsilon_w - 1}$ we get

$$w_t^{\#} = \frac{\epsilon_w}{\epsilon_w - 1} \frac{f_{1,t}}{f_{2,t}},$$

where

$$f_{1,t} = mrs_t w_t^{\epsilon_w} L_{d,t} + \mathbb{E}_t \phi_{w,t+1} \Lambda_{t,t+1} \left(\frac{\pi_{t+1}}{\pi_t^{\varrho_w}} \right)^{\epsilon_w} f_{1,t+1}$$
$$f_{2,t} = w_t^{\epsilon_w} L_{d,t} + \mathbb{E}_t \phi_{w,t+1} \Lambda_{t,t+1} \left(\frac{\pi_{t+1}}{\pi_t^{\varrho_w}} \right)^{\epsilon_w - 1} f_{2,t+1}.$$

Wage-resetting agency. Wage re-optimization is microfounded using the same delegated-agency setup as for prices. A wage-setting agency chooses whether unions re-optimize their wage in period t. If a reset is authorized, unions set the common optimal real wage $w_t^{\#} \equiv W_t^{\#}/P_t$, delivering continuation value $V_{w,t}^{\#}$. If no reset is authorized, unions continue at heterogeneous legacy wages. As in the price block, we impose the restriction that the relevant non-adjustment payoff depends only on the average legacy real wage $w_t^f \equiv W_{t-1}/P_t =$

w_{t-1}/π_t, implying a common continuation value $V^f_{w,t}$ for the agency's decision. Resetting entails a fixed non-pecuniary burden $\tau_w > 0$.

Derivations of the present values of the unions. We assume that each union l in every period either updates the wage optimally, $W^{\#}_{i,t}$, or, assume to update the wage to the average old wage $W^f_{i,t}$. By symmetry, we have $W^x_{i,t} = W^x_t$ for $x \in \{\#, f\}$. Thus the value of a of type x is

$$V^x_{w,t|t} = \mathbb{E}_t \left\{ \sum_{j=0}^{\infty} \left(\prod_{k=0}^{j} \phi_{w,t+k} \right) \phi^{-1}_{w,t} \Lambda_{t,t+j} \left(W^x_t - MRS_{t+j} \right) L_{x,t+j|t} P^{-1}_{t+j} \Pi^{\varrho_w}_{t,t+j} \right\}.$$

with demand for the firm's good given by

$$l_{x,t+j|t} = \left(\frac{W^x_t}{W_{t+j}} \right)^{-\epsilon_w} L_{d,t+j}.$$

Eliminating $L_{x,t+j|t}$ yields

$$\begin{aligned} V^x_{w,t|t} &= \mathbb{E}_t \left\{ \sum_{j=0}^{\infty} \left(\prod_{k=0}^{j} \phi_{w,t+k} \right) \phi^{-1}_{w,t} \Lambda_{t,t+j} \left[W^x_t - MRS_{t+j} \right] \left(\frac{W^x_t}{W_{t+j}} \right)^{-\epsilon_w} L_{d,t+j} P^{-1}_{t+j} \Pi^{\varrho_w}_{t,t+j} \right\} \\ &= \mathbb{E}_t \left\{ \sum_{j=0}^{\infty} \left(\prod_{k=0}^{j} \phi_{w,t+k} \right) \phi^{-1}_{w,t} \Lambda_{t,t+j} \left[W^{x,1-\epsilon_w}_t W^{\epsilon_w}_{t+j} P^{-1}_{t+j} L_{d,t+j} \Pi^{\varrho_w}_{t,t+j} - mrs_{t+j} W^{x,-\epsilon_w}_t W^{\epsilon_w}_{t+j} L_{d,t+j} \Pi^{\varrho_w}_{t,t+j} \right] \right\} \end{aligned}$$

Next, we split $V^x_{w,t|t}$ into

$$V^x_{w,t|t} = V^x_{w,f_2,t|t} - V^x_{w,f_1,t|t},$$

where

$$\begin{aligned} V^x_{w,f_1,t|t} &\equiv \mathbb{E}_t \left\{ \sum_{j=0}^{\infty} \left(\prod_{k=0}^{j} \phi_{w,t+k} \right) \phi^{-1}_{w,t} \Lambda_{t,t+j} mrs_{t+j} W^{x,-\epsilon_w}_t W^{\epsilon_w}_t L_{d,t+j} \Pi^{\varrho_w}_{t,t+j} \right\} \qquad \text{and} \\ V^x_{w,f_2,t|t} &\equiv \mathbb{E}_t \left\{ \sum_{j=0}^{\infty} \left(\prod_{k=0}^{j} \phi_{w,t+k} \right) \phi^{-1}_{w,t} \Lambda_{t,t+j} W^{x,1-\epsilon_w}_t W^{\epsilon_w}_t P^{-1}_{t+j} L_{d,t+j} \Pi^{\varrho_w}_{t,t+j} \right\} \end{aligned}$$

recursively we have

$$\begin{aligned} V^x_{w,f_1,t|t} &\equiv W^{x,-\epsilon_w}_t \times F_{1,t} \qquad \text{and} \\ V^x_{w,f_2,t|t} &\equiv W^{x,1-\epsilon_w}_t \times F_{2,t} \end{aligned}$$

multiplying by $\frac{P_t^{\epsilon_p}}{P_t^{\epsilon_p}}$ and $\frac{P_t^{1-\epsilon_p}}{P_t^{1-\epsilon_p}}$ we can express all parts in real terms

$$V^x_{w,f_1,t|t} \equiv w_t^{x,-\epsilon_w} \times f_{1,t} \qquad \text{and}$$
$$V^x_{w,f_2,t|t} \equiv w_t^{x,1-\epsilon_w} \times f_{2,t}$$

so we obtain

$$V^x_{w,t|t} = w_t^{x,1-\epsilon_w} f_{2,t} - w_t^{x,-\epsilon_w} f_{1,t}.$$

In a same way as for prices, the wage-resetting agency faces an information-processing constraint and chooses a probabilistic authorization rule. Under an entropy-based information cost, the implied non-resetting share follows the multinomial-logit form (Matějka and McKay, 2015):

$$\phi_{w,t} = \frac{\exp\left(\gamma_w V^f_{w,t}\right)}{\exp\left(\gamma_w V^f_{w,t}\right) + \exp\left(\gamma_w \left(V^\#_{w,t} - \tau_w\right)\right)},$$

where $\gamma_w > 0$ is the intensity of choice (inverse marginal cost of information), $\phi_{w,t} \in [0,1]$ is the share of unions not re-optimising, and $1-\phi_{w,t}$ is the reset share.

Monetary Policy. The gross nominal rate R_t is set according to a linear Taylor rule

$$R_t = \rho R_{t-1} + (1-\rho)\left(\overline{R} + \theta_\pi\left(\pi_t - \overline{\pi}\right) + \theta_y\left(\frac{Y_t}{\overline{Y}} - 1\right)\right) + \varepsilon_{r,t}$$

with θ_π the reaction to inflation deviation, θ_y the reaction to ouput gap, ρ the smoothing parameter, and $\varepsilon_{r,t}$ an AR(1) monetary policy shock.

Aggregation. Using the properties of Gasteiger and Grimaud (2023) derived from the Calvo (1983) model, we obtain that the aggregate inflation rate and aggregate real wages laws of motion

$$1 = \left(1-\phi_{p,t}\right)\left(\pi_t^\#\right)^{1-\epsilon_p} + \phi_{p,t}\left(\frac{\pi_t}{\pi_{t-1}^{\varrho_p}}\right)^{\epsilon_p-1}$$
$$w_t^{1-\epsilon_w} = \left(1-\phi_{w,t}\right)\left(w_t^\#\right)^{1-\epsilon_w} + \phi_{w,t}\left(\frac{\pi_t}{\pi_{t-1}^{\varrho_w}}\right)^{\epsilon_w-1} w_{t-1}^{1-\epsilon_w}$$

Aggregate production function across the continuum of retailers is

$$Y_{W,t} = Y_t v_t^p$$

with $v_t^p = \int_0^1 \left(\frac{P_t(f)}{P_t}\right)^{-\epsilon_p} df$ being a measure of price dispersion, that we can write recursively, i.e.,

$$v_t^p = \left(1-\phi_{p,t}\right)\left(\pi_t^\#\right)^{-\epsilon_p} + \phi_{p,t}\left(\frac{\pi_t}{\pi_{t-1}^{\varrho_p}}\right)^{\epsilon_p} v_{t-1}^p.$$

For labor market clearing, we integrate the demand for union labors across unions and obtain

$$L_t = L_{d,t} v_t^w$$

with $v_t^w = \int_0^1 \left(\frac{w_t(h)}{P_t}\right)^{-\epsilon_p} dh$ being a measure of wage dispersion, which can also be written recursively, i.e.,

$$v_t^w = (1-\phi_{w,t})\left(\frac{w_t^\#}{w_t}\right)^{-\epsilon_w} + \phi_{w,t}\left(\frac{\pi_t}{\pi_{t-1}^{\varrho_w}}\right)^{\epsilon_w}\left(\frac{w_t}{w_{t-1}}\right)^{\epsilon_w} v_{t-1}^w.$$

Bonds are in zero net supply. Therefore the aggregate resource constraint is

$$Y_t = C_t.$$

Exogenous process. We have 4 exogenous variables, two supply shocks – a cost-push shock ε_t^p and a labor supply shock ε_t^w – and two demand shocks – a risk premium shock ε_t^d and a monetary policy shock ε_t^r. We assume that they follow a stationary AR(1) processes.

$$\varepsilon_t^z = \rho_z \varepsilon_{t-1}^z + \eta_{z,t},$$

with $\eta_{z,t} \sim$ i.i.d. $\mathcal{N}(0, \sigma_z^2)$, and $0 \leq \rho_z < 1$ for $z = \{d, p, w, r\}$.

C. Effect of trend inflation

From the steady-states $\overline{\phi}_p$, and wages, $\overline{\phi}_w$, we can derive the associated resetting costs, τ_p and τ_w. Assuming a constant steady-state labor supply of $\overline{L} = 1$ and setting τ_p and τ_w to their posterior mode, we compute the model's deterministic steady state as a function of the trend inflation rate ($\overline{\pi}$). Figure C.1 presents the impact of change in trend inflation on selected values of the deterministic steady state.

The model predicts that higher steady-state inflation increases the frequency of both wage and price adjustment – reducing $\phi_{p,t}$ and $\phi_{w,t}$, see Panel (a) – leading to a more flexible economy. The mechanism is intuitive: the higher the trend inflation, the quicker inflation erodes the relative price of non-resetting firms. As a result, a price-resetting firm in the standard Calvo model would fix a higher price (see the discussion in Ascari and Sbordone, 2014) to take into account the trend in the average price level. However, if firms had the option, they would instead choose to adjust prices more frequently, as happens in our model. The same holds for wages and unions. Higher trend inflation widens the gap between firms and unions that reset their prices or wages and those that do not (see Panel (e)). As a result, the opportunity cost of non-resetting prices and wages increases, leading to a higher fraction of firms and unions choosing to reset their wages and prices. While the present values of

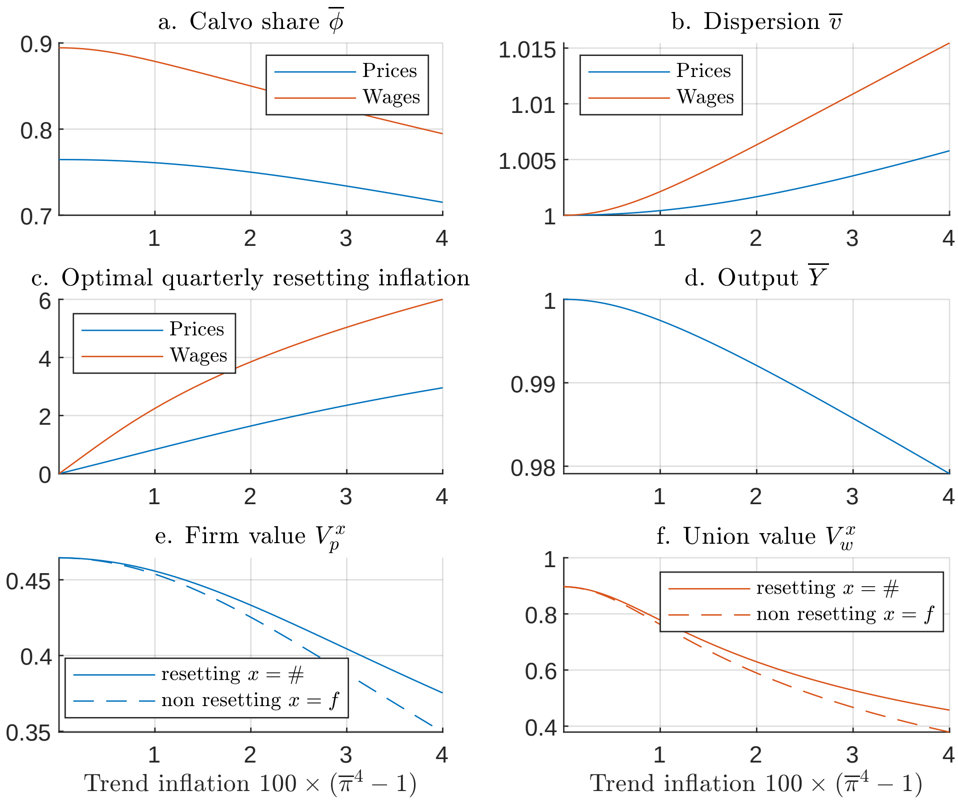
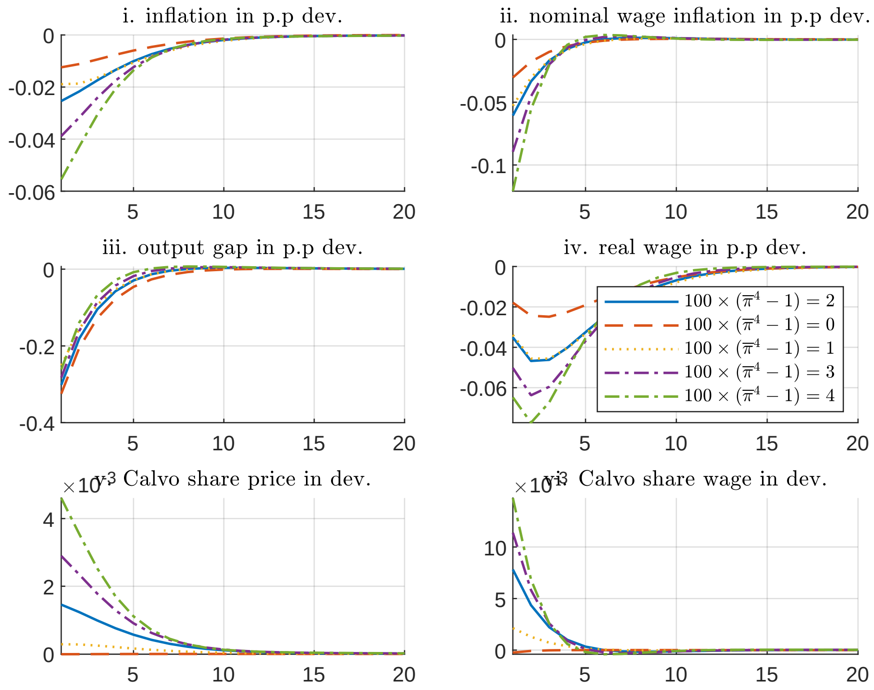


Figure C.1: **Trend inflation and steady state.** The Panels show the effect of trend inflation on the steady-state values of variables related to price (blue lines) and wage (red lines) setting, price and wage dispersion, and output. Dashed lines in Panels (e) and (f) refer to the present value of a non-resetting firm (union) that keeps the price at the average price (wage) level.

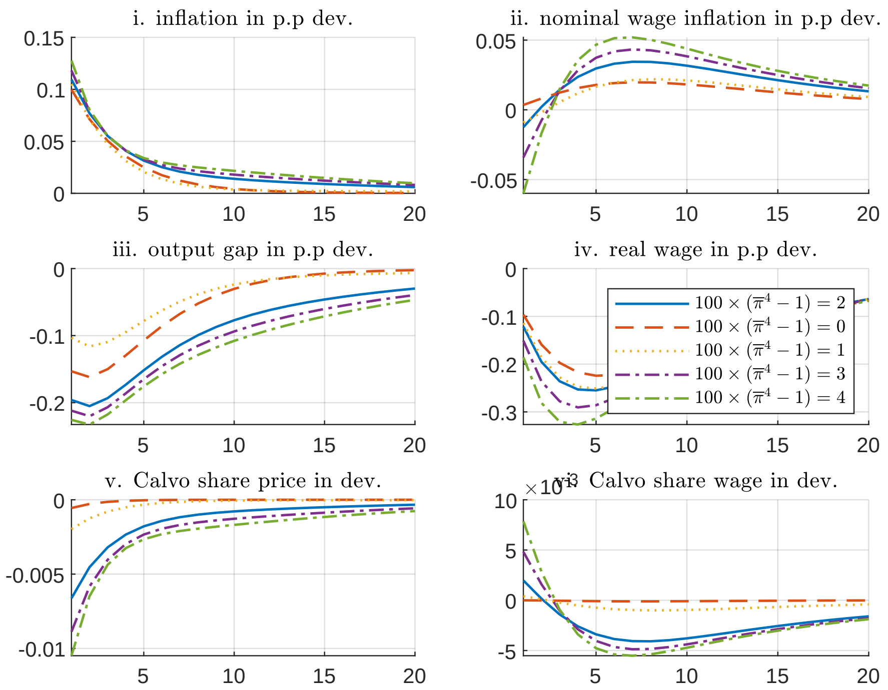
firms and unions decrease with higher trend inflation, it is the increasing difference between the values of resetting versus holding prices and wages constant that drives the higher frequency of price and wage adjustments. Appendix F, Figure C.2, shows how these changes in first moments extend to second moments in the IRFs.

This main feature of our model is both quantitatively and qualitatively consistent with results from the literature. Indeed, following L'Huillier and Schoenle (2024), we can calculate the best fitting linear steady-state relationship $f_t = \beta_0 + \beta_1 \overline{\pi} + \varepsilon_t$, where f_t is the steady-state average monthly frequency of price changes in percent[18], and $\overline{\pi}$ the net annualized trend inflation, also in percent, implied by Panel (a) in Figure C.1. Using the parameter set calibrated at the posterior mode from the estimation of the quantitative model in Section 4, we obtain $\beta_0 = 3.36$ and $\beta_1 = 0.97599$. These figures are close to the L'Huillier and Schoenle's (2024) finding – i.e. $\beta_0 \in [4.61 : 7.42]$ and $\beta_1 \in [0.98 : 2.26]$ – where they regress Nakamura et al. (2018) price setting frequency data against various trend inflation measures for the US.

[18]It is important to emphasize that, when making this comparison, we disregard model-specific features such as price indexation, which implies that all prices mechanically reset each period. As a result, the model-generated f_t does not correspond to the overall frequency of price changes, but rather reflects the frequency of optimally re-optimized prices.



(a) Responses to a + 0.25% monetary policy shock



(b) Responses to -0.5% cost-push shock

Notes: The parameter used are the posterior mode of the baseline model (see Table 1).

Figure C.2: IRFs as a function of the steady state trend inflation level

Figure C.2 relates to the effect of trend inflation on the dynamics of the model, by showing how the IRFs to monetary and cost-push shocks change with the level of trend inflation. The higher the level of trend inflation, the more flexible are wages and prices. Hence, consistent with results in the literature, the more monetary policy shocks affect inflation and the more cost-push shocks affect output.

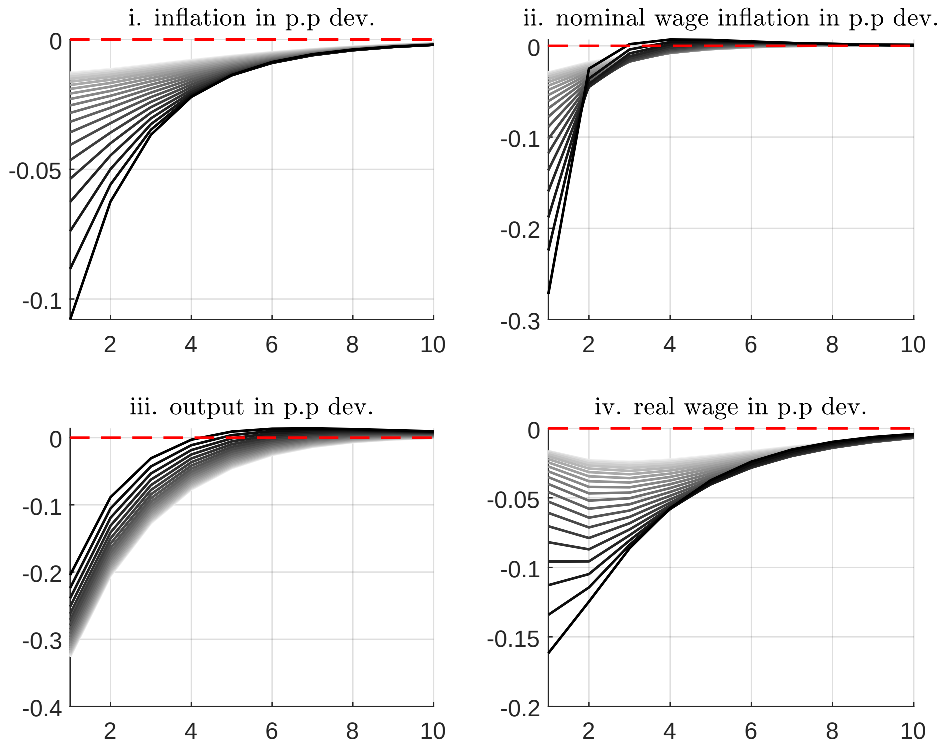
D. State-Dependent IRFs

Figure D.1 displays state-dependent impulse response functions (IRFs), computed by simulating a vector of labor supply shocks that generate inflation paths ranging from an initial annualized inflation rate of 0.5% to 5.5%. On top of each initial labor supply shock, we add either an additional $\varepsilon_{r,1} = 0.25\%$ monetary policy shock, as shown in Figure D.1a, or a $\varepsilon_{p,1} = -0.5\%$ cost-push shock, as shown in Figure D.1b. We report all the variables in deviation from the baseline underlying IRFs (i.e. minus the response to the initial labor supply shock).[19] Darker lines indicate higher initial inflation levels, corresponding to more negative underlying cost-push shocks. In a quasi-linear model, such as the standard Calvo model, all shocks would generate quasi-identical dynamics regardless of the initial inflation level, and all lines would overlap. Consequently, there would be no state-dependency in the responses.[20] In this model, instead, we observe clear state-dependency. For monetary policy, the inflation response is stronger when initial inflation is high. The underlying mechanism can be explained as follows: at higher levels of inflation, the shares of firms and unions not optimally updating the price and wage are lower, meaning that prices and wages are more flexible. This increased flexibility steepens the Phillips curves, amplifying the effects of monetary policy shocks. Thus, the higher the initial level of inflation, the larger the variations in inflation and the smaller the ones in output induced by a given contractionary monetary policy shock.

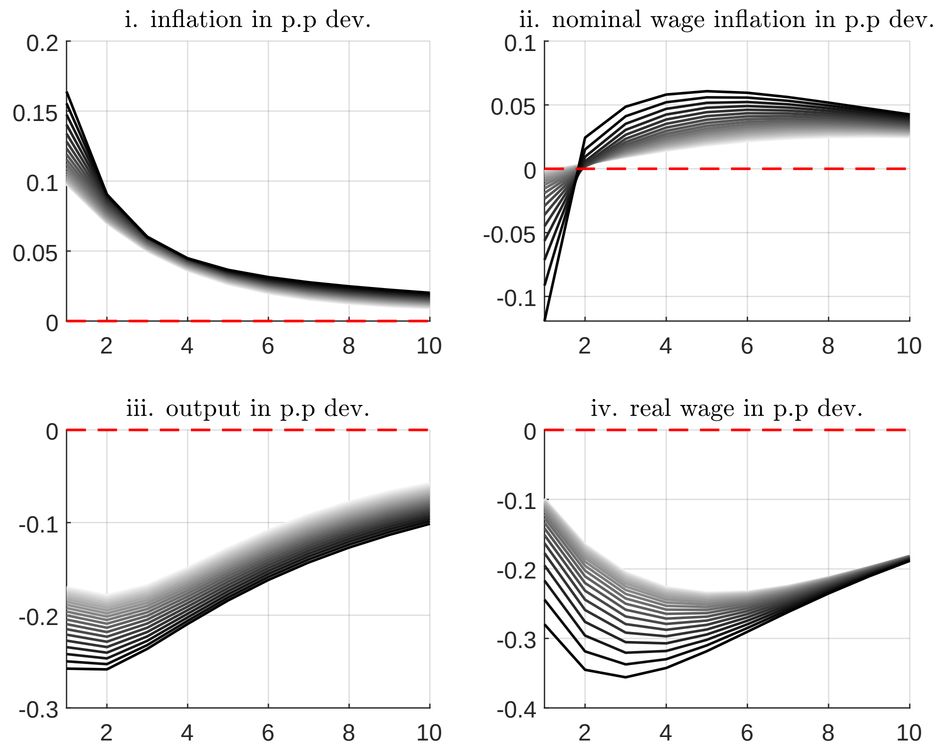
Moreover, a second-order effect due to the forward-lookingness of firms and unions further affects this state-dependency. Firms and unions would anticipate the change in the frequency of price and wage resetting. In other words, they will anticipate if in the future the economy will be on a flatter or a steeper part of the Phillips curves. These effects tend to dampen the inflation response to contractionary monetary policy shocks, because the decline in inflation makes price and wage adjustments less appealing in expectation, and nominal adjustment more rigid downward. However, the opposite occurs for expansionary monetary policy shocks. Since firms (union) anticipate future increases in price (wage) resetting frequencies effectively, they would choose a higher reset price, amplifying the response

[19] We use labor supply and not a cost-push shock because on impact the former moves wage and price inflation in the same direction.

[20] In the Calvo model, most of the difference will be generated by the non-linearity in labor supply FOC and the effect of wages and prices dispersion on marginal cost.



(a) Responses to a + 0.25% monetary policy shock



(b) Responses to -0.5% cost-push shock

Figure D.1: **IRFs are state-dependent.** The lines represent IRFs to a monetary policy (Panel (a)) and a cost-push (Panel (b) shock, for different level of starting inflation. The darker the line, the higher the initial inflation level.

Notes: The initial inflation level are generated by a vector of labor supply shocks of different sizes.

of inflation. Hence, expansionary monetary policy when initial inflation is high can ignite a strong inflationary dynamics.

Finally, the relative changes in the steepness of the NKPCs lead to pronounced differences in real wage dynamics. Under conditions of high inflation, both the wage and price NKPCs become substantially steeper. This steepening amplifies the responsiveness of real wages to demand shocks, resulting in stronger and more immediate adjustments. For example, when inflation rises, firms and unions adjust nominal wages and prices more frequently and by larger magnitudes, facilitating rapid realignment of real wages to changing economic conditions. However, despite the magnitude of these adjustments, the increased flexibility in the economy – driven by the endogeneity of price and wage setting – ensures that these real wage deviations are less persistent. In other words, while the immediate response of real wages to shocks is stronger in a high-inflation environment, the economy's enhanced adaptability allows it to absorb and dissipate these deviations more quickly.

The mechanism underlying the cost-push shock is similar to that of monetary policy shocks: the economy becomes more flexible when inflation is high, causing supply shocks to have a larger impact both on inflation and on output. A subtle yet important observation is that while these shocks propagate more strongly, they do not exhibit greater persistence. This is because, in a high-inflation environment, shocks travel faster through the economy due to its increased flexibility.

Moreover, a cost-push shock induces an opposite response of price and wage inflation. While firms increase prices, triggering a contraction in demand, which reduces both nominal wage inflation and the desired real wage. This reduction in wage inflation dampens the incentives for unions to reset wages, leading to fewer adjustments on the extensive margin of wage setting. Over time, however, this initial effect gives way to a standard price-to-wage feedback loop, where wages, as inflation remains elevated, become more flexible to catch up with the higher price levels. This adjustment reflects the endogenous response of wage-setting mechanisms to prolonged inflationary pressures, highlighting the interaction between the extensive and intensive margins of price and wage adjustments. It is worth noting that this dynamic interplay in our model makes the required adjustment to a negative supply shock, through lower both real wages and output, very persistent, no matter what the starting inflation level.

E. Real time optimal inflation targeting

In Figure E.1, we extend our analysis by considering real-time discretionary inflation targeting. Unlike the exercise described in Section 5, where we looked at the implications of varying the parameters of the Taylor rule, we now consider an optimal targeting exercise. We assume that, in each period t, the central bank's forecast about the economy's future is

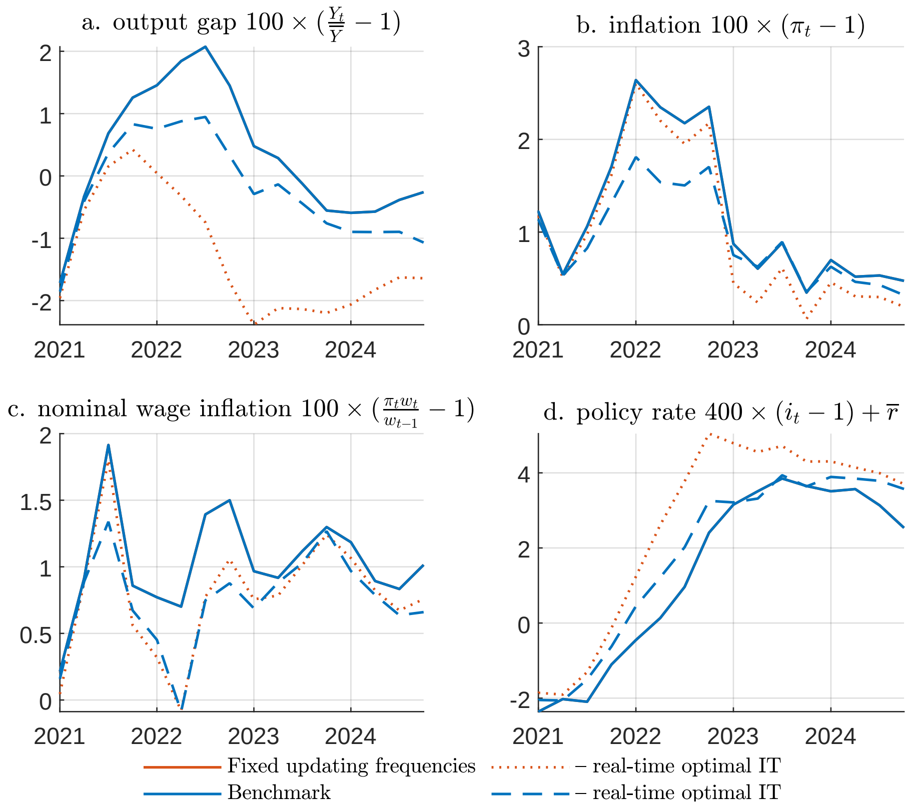


Figure E.1: **Recursive real time inflation targeting under discretion have different prescription and effect.** Counterfactual exercise finding recursively the MP shocks that minimize the CB's loss function in the benchmark and fixed updating frequencies models. Red lines: fixed updating frequencies, blue lines: benchmark model. Dotted and Dashed lines: optimal policies.

Notes: Counterfactual simulations in the benchmark model (blue lines) and the model with fixed adjustment frequencies (red lines) during the 2021q1-2023q4 period. The real time inflation targeting is constructed such that starting in 2021Q1, at each period the Central Bank – through monetary policy shocks – set the policy rate that minimize its expected loss function conditional on the information set available. The loss function reads as $\mathscr{L}_t = \left(100 \times (\pi_t - \overline{\pi})\right)^2 + \left(100 \times (R^4_t - R^4_{t-1})\right)^2 + \beta \mathbb{E}_t \mathscr{L}_{t+1}$.

given by the model's unconditional forecast. Importantly, to circumvent the forward guidance puzzle, we assume that the central bank does not communicate future interest rate paths explicitly so agents form expectations based on the model's estimated Taylor rule. The central bank thus controls the short-term rate through contemporaneous monetary policy shocks - i.e., in deviation from the rule - and, in each period t, selects the shock that minimizes the present value of the expected future loss function.

Since the central bank cannot anticipate future shocks, we implement this approach recursively. That is, at each period, the central bank updates its policy decision based on the prevailing conditions without incorporating knowledge of future exogenous shocks. This ensures that policy is dynamically consistent and remains based on real-time information, rather than relying on perfect foresight.

A key question is why we rely on an add-hoc loss function instead of microfounded conditional welfare measures. Given the current parameterization at the posteriors' modes, households exhibit an extreme aversion to inflation, which leads to counterintuitive results – agents would prefer a unrealistic output contraction rather than tolerate a small overshoot in inflation. This strong aversion likely stems from the nonlinearities in price and wage dispersion, combined with the quasi-linear disutility of labor in both models alongside very concave utility gain from consumption. Additionally, conditional welfare measures vary significantly across the two different parameterizations of the models, leading to preference structures that are highly model-dependent. Finally, in absence of financial friction, the central bank does take into consideration the policy rate volatility. Therefore, using a consistent add-hoc inflation targeting loss function approach allows for greater comparability across exercises and mitigates model-specific biases in welfare measurement.

Therefore, we set up the Central Bank loss function in such way

$$\mathscr{L}_t = \left(100 \times (\pi_t - \overline{\pi})\right)^2 + \left(100 \times (R_t^4 - R_{t-1}^4)\right)^2 + \beta \mathbb{E}_t \mathscr{L}_{t+1}$$

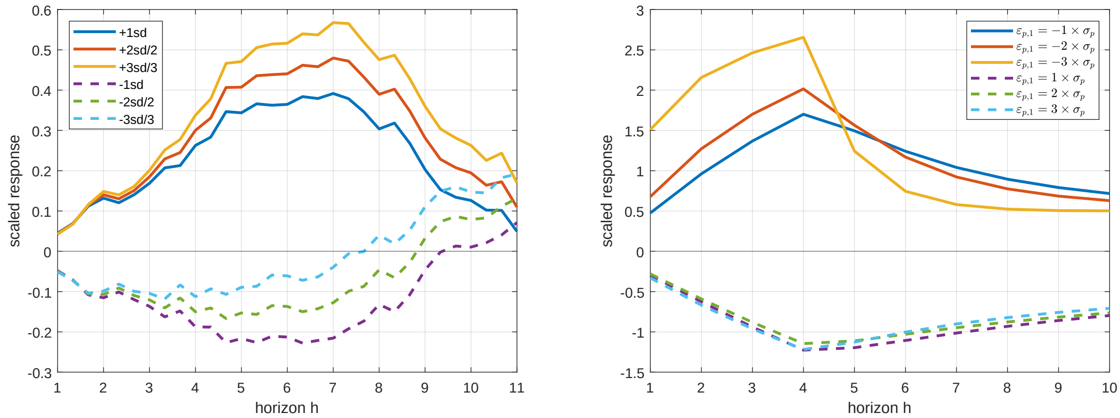
where the central bank minimize the inflation deviation from the target and policy rate volatility as a proxy for financial friction. To be clear, the purpose of this section is not to be a fully-fledged optimal policy exercise, which would be also strongly depend on the implied output gap but to assess the monetary policy stance and maximal output loss given strict inflation targeting objective.

A final caution is warranted when comparing the outcomes of the real-time optimal policy exercises. While both the benchmark and the fixed updating frequency models align with the data in their respective baseline cases, they rely on different structural parameters and shock dynamics. Therefore, the objective of this section is to examine robust optimal policies given model uncertainty. Accordingly, we focus on highlighting the differences in optimal inflation targeting prescriptions across the two models, rather than evaluating the intrinsic performance of these policy recommendations.

Our results highlight key differences in policy responses under alternative price and wage-setting mechanisms. In the fixed-updating frequency model, inflation is initially perceived as slightly above the target and highly persistent (see Figure 6b), primarily driven by near-unit-root cost-push shocks. The stabilization trade-off is significant due to the flat Phillips curve, which limits the sensitivity of inflation to economic slack. As a result, in real-time, the optimal inflation targeting initially implies hard tightening (here depicted by the alternative evolution of the shadow rate in the bottom right panel). This leads to a sharp increase in the real interest rate, generating a substantial decrease in the output gap. Given the muted pass-through from economic activity to inflation even this harsh tightening lead to strong trade-off in economic stabilization and initially little effect on inflation. However, as level and persistence of the policy strange increase, the increase in slack lead to strong disinflationary dynamics starting in 2023.

By contrast, in our benchmark model, inflation surprises are perceived as shorter-lived but occur repeatedly. This results in a less aggressive tightening path than in the fixed-updating Calvo model, and slightly more aggressive than, but fairly close to, the realized one. Moreover, the steeper Phillips curve enhances the transmission of monetary policy, leading to far lower inflation and a less pronounced output loss than in the fixed-updating frequency model.

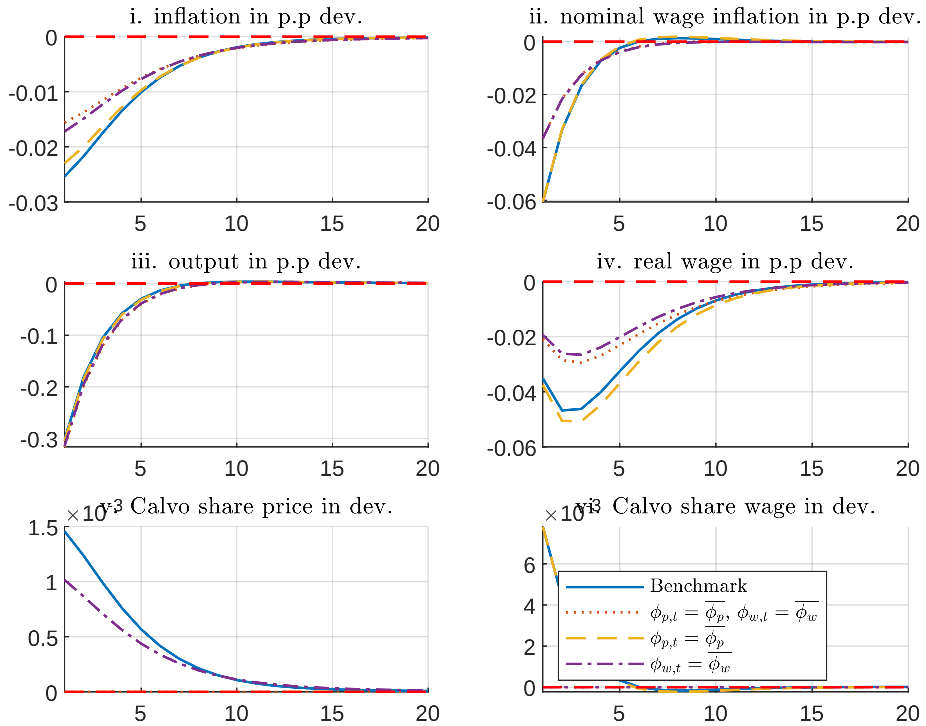
F. Additional figures



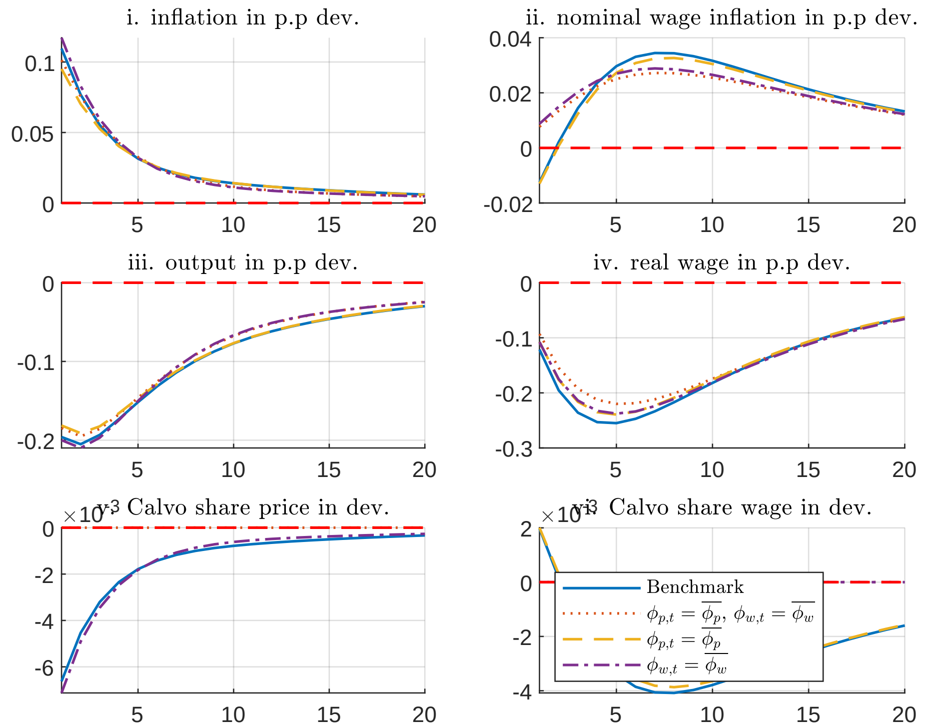
(a) Local projection responses (b) Benchmark model responses

Figure F.1: **Year-over-year inflation responses to a cost-push shock.** Panel (a): Local projection responses to oil shocks. Panel (b): Benchmark model responses to cost-push shocks. Horizon is quarterly.

Notes: Local projection is monthly frequency for year-on-year HICP inflation spanning 1997M1-2024M9. For each horizon $h = 0, 1, \ldots, H$, we estimate $\pi_{t+h} = \alpha_h + \sum_{\ell=0}^{11}(g_h(z_{t-\ell}) + \delta_{\ell,h}\pi_{t-1-\ell}) + \varepsilon_{t+h}$, where π_t denotes year-on-year inflation and z_t is the monthly oil supply shock constructed by Känzig (2021). The function $g_h(\cdot)$ captures horizon-specific nonlinearities. In this specification, $g_h(z) = \beta_{1,h}z + \beta_{2,h}z|z|$.



(a) Responses to a + 0.25% monetary policy shock



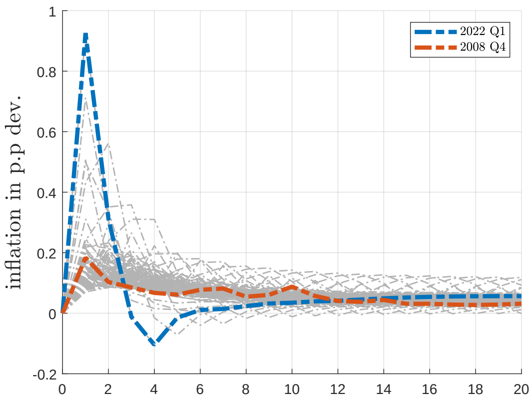
(b) Responses to -0.5% cost-push shock

Notes: The parameter used are the posterior mode of the baseline model (see Table 1).

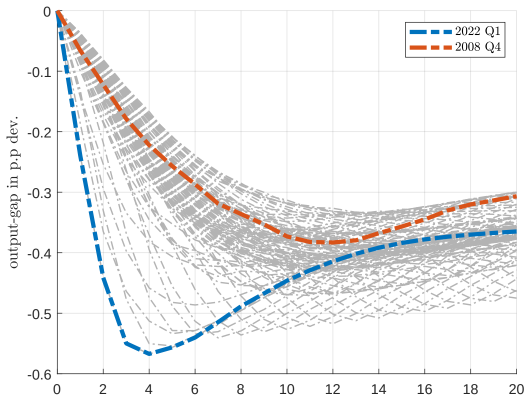
Figure F.2: IRFs with and without state-dependency in price and wage setting

Notes: This chart compares the share of re-optimized prices in the quantitative model with the share of price changes reported in Gautier et al. (2026) over their common sample (2012–2024). The correlation between the two series is 0.6146, with a 90% confidence interval of [0.4609, 0.7325]. The two objects are not perfectly comparable: in the model, non-reoptimized prices are indexed each period, so the model-based series moves even when firms do not re-optimize. Moreover, Gautier et al. (2026) cover only part of the HICP basket and, in particular, excludes energy items.

Figure F.3: Share of re-optimized prices in the quantitative model versus the share of changed prices in (Gautier et al., 2026).

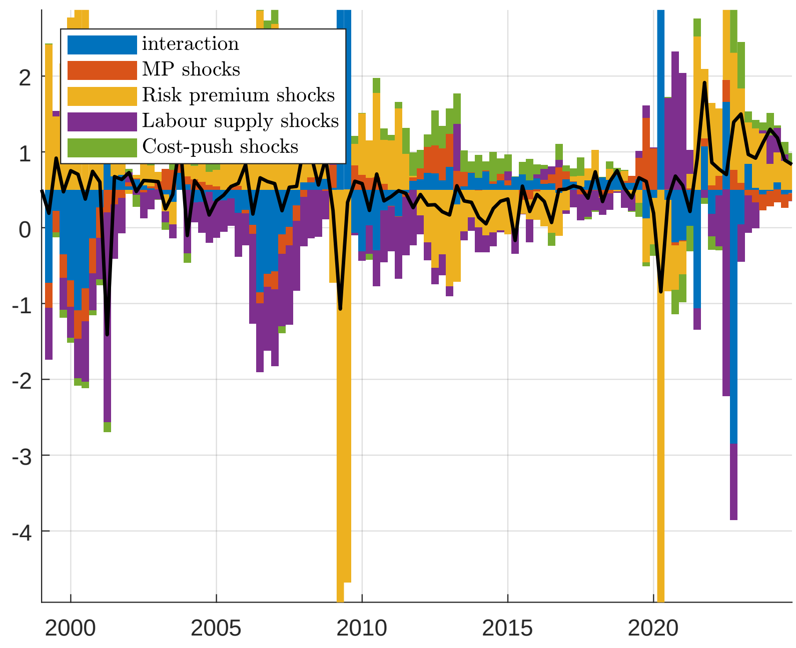


(a) IRFs of inflation

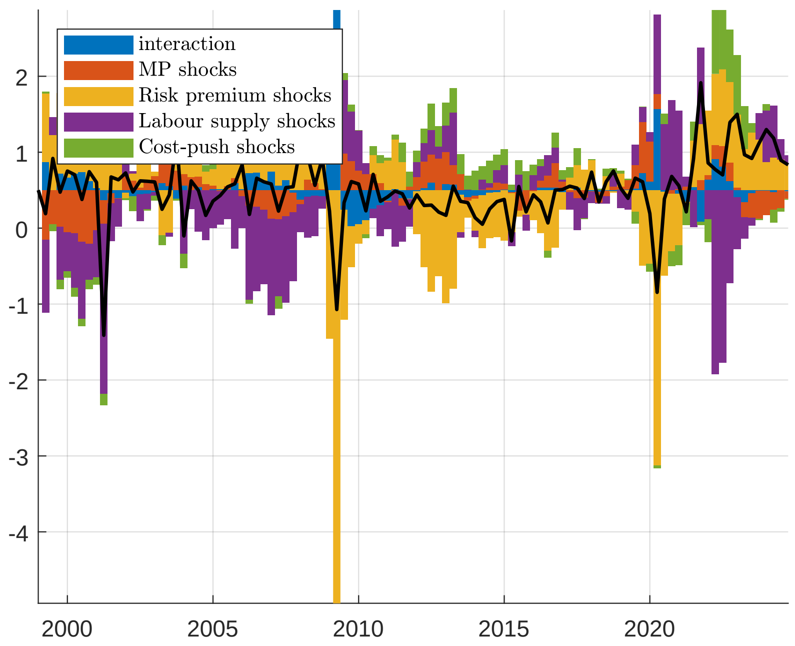


(b) IRFs of output

Figure F.4: **IRFs to an +** 0.5% **cost push shock as function of the state** Panel (a): Inflation. Panel (b): Output. State-dependent IRFs are calculated by comparing the IRFs from all filtered shocks, including an additional contemporaneous cost-push shock, with the IRFs from the same set of shocks without the cost-push shock. This isolates the effect of the cost-push shock conditional on the initial state.



(a) Benchmark



(b) Fixed updating frequency

Notes: See Figure 7.

Figure F.5: Historical decomposition of nominal wage inflation

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