The Inflation Uncertainty Amplifier *

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November 2025

Abstract

We study how uncertainty shocks affect the macroeconomy across the inflation cycle using a nonlinear stochastic volatility-in-mean VAR. When inflation is high, uncertainty shocks raise inflation and depress real activity more sharply. A nonlinear New Keynesian model with second-moment shocks and trend inflation explains this via an "inflation-uncertainty amplifier": the interaction between high trend inflation and firms' upward price bias magnifies the effects of uncertainty by increasing price dispersion. An aggressive policy response can replicate the allocation achieved under standard policy when trend inflation is low.

Keywords: Uncertainty, trend inflation, nonlinear VAR model, new Keynesian model, monetary policy.

JEL codes: C32, E32, E44, G01.

*We thank Martin Andreasen, Guido Ascari, Marco Bassetto, Francesco Bianchi, Paolo Bonomolo, Fabio Canova, Cristiano Cantore, Marco Del Negro, Stefano Fasani, Francesco Furlanetto, Domenico Giannone, Mikhail Golosov, Nicolas Groshenny, James Hansen, Qazi Haque, Diego Känzig, Michele Lenza, Jean-Paul L'Huillier, Gernot Mueller, Salvatore Nisticò, Joonseok Oh, Guillermo L. Ordoñez, Adrian Pagan, Giorgio Primiceri, Walker Ray, Tiziano Ropele, Barbara Rossi, Lorenza Rossi, Tatevik Sekhposyan, Paolo Surico, Mark Weder, and participants to various seminars and conferences for useful comments. Financial support from the Italian Ministry of Education, Universities and Research (PRIN 2022, grant 2022A9PAT3) is gratefully acknowledged. Authors' accounts: efrem.castelnuovo@unipd.it, giovanni.pellegrino@unipd.it, lsaerkjaer@econ.au.dk.

1 Introduction

The recent election of Donald Trump as the 47th President of the United States has prompted academics and commentators to anticipate, among other outcomes, a surge in economic uncertainty and a resurgence of high inflation (see, e.g., Coibion and Pandalai-Nayar (2024)). This combination is not unprecedented. In the wake of the COVID-19 pandemic, the U.S. economy - like those of many other countries - faced historically high levels of uncertainty and a sharp, persistent surge in inflation, with lasting effects on inflation expectations (Gorodnichenko and Coibion (2025)). These developments led policy institutions to adopt a "two-regime" perspective on inflation (see, e.g., Borio, Lombardi, Yetman, and Zakrajšek (2023)).[1] A comparable scenario - marked by simultaneous spikes in inflation and uncertainty - dates back to the 1970s, a decade defined by rising price pressures and repeated bouts of economic uncertainty. While a substantial body of empirical research has examined the business cycle implications of uncertainty shocks,[2] less is known about how uncertainty interacts with periods of elevated inflation. This gap is concerning, as high and persistent inflation may fundamentally alter the transmission of macroeconomic shocks (Coibion and Gorodnichenko (2011), Ascari and Sbordone (2014)).

Figure 1 documents evidence consistent with this possibility. It plots correlations involving macroeconomic uncertainty (as recently estimated by Ludvigson, Ma, and Ng (2021)), inflation, and industrial production growth in the United States conditional on realizations of inflation above/below 6%, a reference for high inflation used by Coibion and Gorodnichenko (2011) and supported by the empirical analysis by Schorfheide (2005), Canova and Forero (2024), Gargiulo, Matthes, and Petrova (2024), and our own VAR investigation (documented in Section 2). Two striking facts emerge. First, uncertainty and inflation are strongly positively correlated when inflation is high while they display basically no correlation when inflation is low. Second, the well-known countercyclicality of uncertainty (Bloom (2014)) is confirmed in both states, but it is stronger when inflation is high. These state-dependent correlations, which are robust to dropping COVID-19 observations, motivate our analysis of the possibly nonlinear effects of uncertainty

[1] For an account of how uncertainty played out during the pandemic, see Meyer, Mihaylov, Barrero, Davis, Altig, and Bloom (2022). For recent surveys on uncertainty, see Fernández-Villaverde and Guerrón-Quintana (2020), Cascaldi-Garcia, Sarisoy, Londono, Rogers, Datta, Ferreira, Grishchenko, Jahan-Parvar, Loria, Ma, Rodriguez, and Zer (2021), and Castelnuovo (2022). For analysis and discussions on the build-up of inflation during and after the pandemic, see Reis (2021, 2022), Coibion, Gorodnichenko, and Weber (2023)) Bernanke and Blanchard (2023), Giannone and Primiceri (2024), and Ascari, Bonam, Mori, and Smadu (2024).

[2] Examples focusing on macroeconomic uncertainty shocks are Carriero, Clark, and Marcellino (2019), Angelini and Fanelli (2019), Angelini, Bacchiocchi, Caggiano, and Fanelli (2019), Forni, Gambetti, and Sala (2021b), and Fasani, Mumtaz, and Rossi (2022)). A different, although connected strand of the literature has investigated the effects of financial uncertainty shocks (see, e.g., Bloom (2009), Basu and Bundick (2017), Ludvigson, Ma, and Ng (2021)) and economic policy uncertainty shocks (Baker, Bloom, and Davis (2016)).

shocks.

Contributions to the literature. This paper offers two contributions to the literature. First, it employs the state-of-the-art nonlinear stochastic-volatility-in-mean VAR framework proposed by Alessandri and Mumtaz (2019) to investigate the effects of macroeconomic uncertainty shocks on inflation and the business cycle along the inflation cycle. We find that such effects are asymmetric and stronger when inflation is over 6%.[3] In the high inflation state, a macroeconomic uncertainty shock is followed by a strong and positive response of inflation, a deep recession, and an upward shift in interest rates. When inflation is below the threshold, a macroeconomic uncertainty shock is followed by a moderate increase in inflation and a mild-to-muted response of real activity and the policy rate.[4]

Second, we interpret our empirical findings with a version of the micro-founded nonlinear new-Keynesian model of the business cycle proposed by Coibion and Gorodnichenko (2011), Coibion, Gorodnichenko, and Wieland (2012), and Ascari and Sbordone (2014) and approximated around a positive trend inflation rate. We modify such a model by allowing for a time-varying second moment for the technology process, i.e., future technology is uncertain, and this uncertainty changes over time as in e.g. Bianchi, Kung, and Tirskikh (2023). Working with our framework, we show that trend inflation crucially affects the transmission mechanism of uncertainty shocks. In particular, trend inflation amplifies the magnitude and persistence of the responses of inflation and output to an uncertainty shock, which is exactly what we document with our VAR exercise. Hence, the inflation and output responses to an equal-size uncertainty shock are larger when trend inflation is high (6%) than low (2%).

Economic intuition. Our empirical evidence, matched by our theoretical predictions, points to the existence of an "inflation-uncertainty amplifier", i.e., the business cycle effects of uncertainty shocks are amplified when trend inflation is high. According to our nonlinear VAR, the peak response of inflation - 0.37% , which materializes one year after the uncertainty shock - more than doubles compared with the peak inflation reaction in normal times, i.e., $0.37/0.16 \approx 2.3$. What is the reason behind this amplification? The new-Keynesian model we employ to interpret our empirical findings enables us to spell out the following economic intuition. Assume that trend (net) inflation is zero. In models with sticky prices, an uncertainty shock implies an upward pricing bias, i.e., firms subject to price re-optimization constraints set prices higher than they would do if the uncertainty surrounding future profits were absent (Fernández-Villaverde,

[3] Our VAR estimate the threshold value to be close to 7%. However, our results are materially the same when forcing the threshold to be 6%.

[4] A variety of papers have found uncertainty shocks to be inflationary, e.g., Alessandri and Mumtaz (2019) (in a state of normal times), De Santis and Van der Veken (2021), and Basu, Candian, Chahrour, and Valchev (2023). For contrasting evidence, see Leduc and Liu (2016).

Guerrón-Quintana, Kuester, and Rubio-Ramírez (2015), Born, Müller, and Pfeifer (2020), Born and Pfeifer (2021)).[5] This precautionary pricing behavior is optimal because under sticky prices firms face a convex marginal revenue product i.e., if they set low prices, they will have to accommodate demand by sticking to such prices and lose profits, while if they set high prices, such high prices will compensate for the fewer units they will sell. Hence, firms prefer setting high prices. What happens when trend inflation enters the picture? Our analysis unveils that re-optimizing firms set prices even higher in response to an uncertainty shock, because not only they do have to deal with the uncertainty surrounding future demand, but also because they care more about the future due to the fact that the relative prices they set today erode more quickly in expected terms (because of price stickiness) given the upward trend followed by the aggregate price index. Hence, the combination of optimal upward pricing bias and trend inflation implies a larger inflation response to an uncertainty shock.

What about the larger response of output? As said, the combination of firms' upward pricing bias and trend inflation makes re-optimizing firms more willing to set high(er) prices. This implies that price dispersion is larger than in the absence of trend inflation because firms that cannot re-optimize fall even further to the left tail of the distribution of firms' relative prices than under zero trend inflation. Consequently, price dispersion increases. But price dispersion is akin to a negative aggregate productivity shock because it increases the amount of labor required to produce a given level of output (for recent evidence on inflation dispersion and misallocation of resources, see Ropele, Coibion, and Gorodnichenko (2024)).[6] Hence, the drop in real activity after an uncertainty shock is larger when trend inflation is high due to the higher price dispersion. Notably, for any given level of output, a higher price dispersion leads to an increase in real wages and, therefore, marginal costs, reinforcing the precautionary behavior discussed above.

Policy exercise. Our VAR facts, interpreted with our nonlinear DSGE framework, point to

[5] Consistently with the implications of prices stickiness for price setting decisions in the New Keynesian framework, Kara and Pirzada (2023) work on UK micro-data and find that goods produced in sectors with relatively flexible prices experience a decline in prices after an increase in uncertainty, while those produced in sectors with sticky prices experience an increase in prices.

[6] Price dispersion implies that some firms, which have relatively low prices set very far in the past, face a high demand and produce a lot, while other firms (with relatively high prices set recently) face a low demand and produce little. If goods are imperfect substitutes and the economy-wide level of output is the result of the non-linear Dixit–Stiglitz aggregator across firms' production, the extra output produced by firms with relatively low prices does not compensate for the production foregone by firms with relatively high prices. Hence, the economy as a whole needs a higher level of employment to produce one unit of the Dixit-Stiglitz basket. When trend inflation is high, the degree of front-loading by firms able to re-optimize is higher because of the quicker erosion of relative prices. Hence, price dispersion is a positive function of trend inflation, and the negative impact of the former on output, in the long run, is larger the higher the latter is. For in-depth discussions of the relationship between trend inflation and price dispersion in New Keynesian models, see Ascari (2004), Ambler (2007), and Ascari and Sbordone (2014). Sheremirov (2020) and Alvarez-Blaser (2024) find a positive correlation between price dispersion and inflation in US micro data when excluding temporary sales and focusing on regular prices.

bigger macroeconomic fluctuations in response to an uncertainty shock when trend inflation is high. Is there any policy that can imply an economy's response similar to the one in the low-trend inflation state even if the economy is actually experiencing high-trend inflation? Our answer is positive. Working with our DGSE framework, we show that moving to a more aggressive systematic monetary policy reaction to inflation (Taylor parameter equal to 3) is enough to restore the equilibrium observed when trend inflation is low and the policy is relatively less hawkish (Taylor parameter equal to 1.75). In particular, our results suggest that even when uncertainty shocks are inflationary via the upward price bias channel, they do not imply an inflation-output trade-off. The intuition is simple: A more hawkish monetary policy is associated with inflation expectations closer to the target, which reduces firms' incentives to raise prices to self-insure against uncertain future demand – thereby significantly mitigating the upward price bias – and lowers the degree of price dispersion. This implies an economy closer to its natural rate and, therefore, a milder output loss after an uncertainty shock.

Implications. In summary, our paper documents a stronger reaction of inflation and real activity to a macroeconomic uncertainty shock in the presence of high inflation. We interpret this empirical fact with a nonlinear New Keynesian model that, as we uncover, features an endogenous interaction between firms' optimal upward price bias and trend inflation triggered by uncertainty shocks. We also find that a more hawkish systematic monetary policy in the presence of high-trend inflation can replicate the allocation of resources predicted by our theoretical model when trend inflation is low and monetary policy is more dovish. Hence, from a modeling standpoint, our paper points to the need of working with frameworks designed to deal with nonlinearities as for the uncertainty-inflation relationship. From a policy standpoint, our paper hints at state-dependent policies as a possibly optimal way to deal with the business cycle consequences of uncertainty shocks in environments characterized by high inflation.

Connection with the literature. Our paper mainly connects with two strands of the literature. The first one deals with the nonlinear effects of uncertainty shocks.[7] Our empirical analysis offers novel stylized facts that are associated with states of high vs. low inflation, and complements contributions that have investigated the effects of (first-moment) monetary policy shocks in the presence of high vs. low inflation (Ascari and Haber (2021), Canova and Forero (2024), and Gargiulo, Matthes, and Petrova (2024)). Methodologically, we work with the empirical model proposed by Alessandri and Mumtaz (2019), who focus on the nonlinear response of real activity to an uncertainty shock in the presence of financial stress. Our focus on the inflation cycle

[7]See e.g., Caggiano, Castelnuovo, and Groshenny (2014), Rossi and Sekhposyan (2015), Cacciatore and Ravenna (2021),Caggiano, Castelnuovo, and Nodari (2022), Pellegrino, Castelnuovo, and Caggiano (2023), Forni, Gambetti, and Sala (2021a), Andreasen, Caggiano, Castelnuovo, and Pellegrino (2024), Alfaro, Bloom, and Lin (2024).

provides novel and complementary information on the uncertainty-inflation nonlinear relationship with respect to the one they put forth.[8] Our contribution and the one by Alessandri and Mumtaz (2019) make clear that the discussion on the effects of uncertainty shocks on inflation (see e.g. Leduc and Liu (2016) and Fasani and Rossi (2018)) has to be entertained by appealing to a nonlinear model.

Turning to theoretical frameworks, our analysis is the first to unveil the inflation-uncertainty amplifier due to the effect of trend inflation on price dispersion in response to uncertainty shocks. Hence, we add a novel dimension to the discussion on the breaks in the transmission mechanism to first-moment macroeconomic shocks due to the shift from low to high trend inflation and surveyed by Ascari and Sbordone (2014).[9] More in general, we connect to the literature investigating the macroeconomic impact of uncertainty shocks. Working with real models that feature no nominal rigidities, Bloom (2009), Bloom, Floetotto, Jaimovich, Saporta-Eksten, and Terry (2018), and Baker, Bloom, and Terry (2024) document powerful business cycle effects of uncertainty shocks due to nonconvex adjustment costs that imply optimally pausing investment and labor demand ("waiting-and-seeing") when uncertainty is high. Alfaro, Bloom, and Lin (2024) show that these recessionary effects are deeper if uncertainty interacts with financial frictions, i.e., financially constrained firms cut investment more than unconstrained firms following an uncertainty shock. While these models deal with closed-economy settings, Fernández-Villaverde, Guerrón-Quintana, Rubio-Ramírez, and Uribe (2011) show that uncertainty surrounding the world real interest rate can have material effects on the business cycle of a variety of small open economies. Bianchi, Ilut, and Schneider (2018) work with ambiguity-averse investors and show that uncertainty surrounding future profits leads to a drop in stock prices, with firms' shareholders that substitute away from debt and reduce shareholder payouts. Working with models with nominal rigidities in models that do not focus on price dispersion, Fernández-Villaverde, Guerrón-Quintana, Kuester, and Rubio-Ramírez (2015), Basu and Bundick (2017), and Born and Pfeifer (2021) show that uncertainty shocks generate comovements among output, consumption, investment, and hours. With respect to these contributions, we: (i) focus - both empirically and theoretically - on the effects of uncertainty shocks in the presence of high vs. low trend inflation; (ii) empirically

[8] The correlation between inflation and NFCI - the financial stress indeed used in Alessandri and Mumtaz (2019) - is -0.21 (sample: January 1971 - August 2024 due to the availability of NFCI), while the correlation between inflation and the growth rate of industrial production is -0.10 in our sample (January 1962 - August 2024). While being non-zero, these relatively low correlations suggest that our results are specific to the inflation cycle as opposed to the financial or real ones.

[9] See e.g., Ascari (2004), Ascari and Ropele (2007), Ascari and Ropele (2009), Coibion and Gorodnichenko (2011), Coibion, Gorodnichenko, and Wieland (2012), Andreasen, Fernández-Villaverde, and Rubio-Ramírez (2018), Hirose, Kurozumi, and Zandweghe (2019), Ascari, Bonomolo, and Haque (2022), and L'Hullier and Schoenle (2022).

document the largest response of inflation and real activity to an uncertainty shock when trend inflation is high; (iii) unveil a novel mechanism that generates an inflation-uncertainty amplifier due to the higher price dispersion in response to an uncertainty shock when trend inflation is high; (iv) support aggressive monetary policy interventions in high-inflation environments that, in our model, can effectively dampen the negative output and inflation effects of firms' price dispersion.

The paper is structured as follows. Section 2 presents the empirical model. Section 3 documents the main stylized facts. Section 4 deals with the interpretation of our stylized facts via a DSGE framework. Section 5 concludes.

2 Nonlinear VAR

We employ the two-regime stochastic-volatility-in-mean threshold VAR model proposed by Alessandri and Mumtaz (2019), which extends the linear stochastic-volatility-in-mean framework originally proposed by Mumtaz and Zanetti (2013). In this framework, endogenous variables depend on their own lags - as in a standard VAR - but are also directly affected by the common stochastic volatility of the shocks, which is our proxy for macroeconomic uncertainty. The formal description of the model is the following:

$$\begin{aligned} Z_t = & \left(c_1 + \sum_{j=1}^{P} \beta_{1j} Z_{t-j} + \sum_{j=0}^{J} \gamma_{1j} \ln \lambda_{t-j} + \Omega_{1j}^{1/2} e_t \right) S_t \\ & + \left(c_2 + \sum_{j=1}^{P} \beta_{2j} Z_{t-j} + \sum_{j=0}^{J} \gamma_{2j} \ln \lambda_{t-j} + \Omega_{2j}^{1/2} e_t \right) (1 - S_t) \end{aligned} \tag{1}$$

where Z_t is the $N \times 1$ vector of endogenous variables, c_i are two $N \times 1$ vectors of constants, β_{ij} are two $N \times N$ matrices of coefficients, γ_{ij} are two $N \times 1$ that capture the volatility-in-mean coefficients, and Ω_{ij} are two $N \times N$ covariance matrices (with $i = 1, 2$ denoting the two regimes) that pre-multiply the vector of structural shocks e_t. S_t is a dummy determining the regime in place according to the lagged level of one of the endogenous variables, i.e., which is CPI inflation in our case:

$$S_t = 1 \iff Z_{Infl.,t-1} \leq Z^* \tag{2}$$

where Z^* is a threshold value.

The endogenous variables share a common stochastic volatility factor λ_t which follows a AR(1) process:

$$\ln \lambda_t = \alpha + F \ln \lambda_{t-1} + \eta_t \tag{3}$$

Our uncertainty shock is the stochastic element η_t, which is a mean-zero i.i.d. innovation with variance Q. The covariance matrices are given by:

$$\Omega_{1,t} = A_1^{-1} H_t A_1^{-1'} \quad (4)$$
$$\Omega_{2,t} = A_2^{-1} H_t A_2^{-1'}$$
$$H_t = \lambda_t M$$
$$M = diag\,(m_1, m_2, ..., m_N)$$

As in Alessandri and Mumtaz (2019), the scalar factor λ_t is responsible for the common time-variation of the standard deviations of the structural shocks (for the paper introducing the idea of working with a scalar volatility process in a multivariate model, see Carriero, Clark, and Marcellino (2016)). This process captures macroeconomic uncertainty. Intuitively, a sudden increase in λ_t driven by a positive realization of η_t increases the volatility of the forecast errors, i.e., agents prediction over future economic realizations become less accurate. Agents' adjustments to such higher macroeconomic uncertainty are modeled by allowing λ_t to have a direct effect on the endogenous variables we model. In this framework, an uncertainty shock η_t is identified under the following two assumptions: (i) λ_t is not affected by past realizations of Z_t; (ii) first and second-moment shocks are orthogonal, i.e., $E(e_t, \eta_t) = 0$. This implies that uncertainty is exogenous to the level dynamics of the economy, an assumption corroborated by recent empirical findings proposed by Carriero, Clark, and Marcellino (2019), Angelini and Fanelli (2019), and Angelini, Bacchiocchi, Caggiano, and Fanelli (2019).[10] Notice that, as pointed out by Alessandri and Mumtaz (2019), identification of uncertainty shocks does not require the identification of the structural level shocks. Moreover, the recursive factorization of the covariance matrices of the VAR could play a role only if it affected the estimated average volatility process λ_t, which we verified not to be the case in our empirical application.

The vector of endogenous variables $Z_t = [CPI\ \ Infl., IP, 3mTB, 10yTB]'$ contains the following monthly variables: the yearly growth rate of inflation, the monthly growth rate of industrial production, the annualized three-month Treasury Bill rate, and the annualized 10-Year Treasury Bill rate.[11] The choice of modeling yearly (as opposed to monthly) inflation aims to avoid

[10] Our Appendix shows that our estimated uncertainty shocks are uncorrelated with well-known proxies for oil supply shocks and monetary policy shocks, which some papers suggest may be behind the volatility of inflation in the '70s (see, e.g., Sims and Zha (2006), Boivin and Giannoni (2006)). In addition, our Appendix documents the unpredictability of the estimated λ_t process. These exercises speak in favor of a correct identification of uncertainty shocks.

[11] All the series were downloaded from the FRED dataset by the St. Louis Fed. The mnemonics of the series are: CPALTT01USM661S, INDPRO, TB3MS, and DGS10.

excessively volatile high/low inflation regimes. The presence of the 10-Year Treasury Bill rate in our VAR is justified by our desire of accounting for an interest rate that was unconstrained during the zero lower bound period (Swanson and Williams (2014)). Our data spans the period January 1962-August 2024, where the beginning of the sample is dictated by data availability.[12] Our baseline model sets $P = 3, J = 3$ and uses CPI inflation as the threshold variable.[13] The model is estimated using Bayesian methods. A Metropolis-Hastings algorithm is used to estimate the threshold Z^*.[14]

3 Empirical results

This Section presents our estimated measure of macroeconomic uncertainty and documents the impulse responses produced via our nonlinear VAR.

Estimated macroeconomic uncertainty. Figure 2 (top panel) plots the stochastic volatility estimated by our VAR framework against the macroeconomic uncertainty measure put forth by Jurado, Ludvigson, and Ng (2015) and Ludvigson, Ma, and Ng (2021). A few considerations are in order. First, the two series clearly co-move and their correlation is high ($\rho = 0.75$). Second, our measure of uncertainty displays comparable peaks during the first phase of the pandemic and the recession that occurred in the early 1980s, as well as a distinct peak during the great recession. This evidence further corroborates our measure of uncertainty, given that these three have been identified as associated with elevated uncertainty (see e.g. Jurado, Ludvigson, and Ng (2015) and the evidence on uncertainty during the pandemic available at Sydney Ludvigson's website).[15] Third, our measure of uncertainty does not feature a distinct peak in October 1987, i.e., the Black Monday episode. This separates our proxy from financial market-based measures of uncertainty such as e.g. the VIX or the proxy for financial uncertainty recently proposed by Ludvigson, Ma, and Ng (2021) (the comparison with the latter is plotted in the bottom panel of Figure 2) - the correlation between our estimated uncertainty measure and Ludvigson et al.'s (2021) measure of financial uncertainty is 0.36. Overall, our estimated volatility can be interpreted as a proxy for macroeconomic (as opposed to financial) uncertainty.[16]

[12] Our stochastic-volatility VAR enables us to capture the outliers related to COVID-19 observations. For a different approach, see Carriero, Clark, Marcellino, and Mertens (2020).

[13] We focus on the causal link going from movements in uncertainty to the business cycle. For quantitative approaches allowing uncertainty to be influenced by business cycle fluctuations, see Mumtaz and Theodoridis (2020), Mumtaz (2018), and Ascari, Fasani, Grazzini, and Rossi (2023).

[14] Details on the algorithm employed to estimate this framework are provided in Alessandri and Mumtaz (2019) and in our Appendix.

[15] See https://www.sydneyludvigson.com/ .

[16] As we document in the Appendix, augmenting the VAR with the NFCI measure of financial stress does not

Inflation cycle. Figure 3 plots the CPI inflation rate we model with our VAR against the high/low inflation regimes identified with our framework. The identification of the two regimes is based on an estimated threshold value of 7%. As expected, the high inflation regime is mainly characterized by inflation observations in the mid and late '70s/early '80s as well as in 2022. The high inflation regime covers 12% of our observations. According to Hansen (1999), each identified regime in a nonlinear analysis should contain at least 10% of the realizations of an investigated sample, which is the case here.

Nonlinear impulse responses to an uncertainty shock. Figure 4 documents our regime-dependent generalized impulse response functions for the regimes of high vs. low inflation after a one standard deviation uncertainty shock.[17] The dynamics of the economy after the uncertainty shock are very different depending on whether the shock occurs in a phase of high vs. low inflation. In normal times, our VAR estimates the response of inflation and the 10-year interest rate to be moderately positive (with a peak response close to 0.2% and 0.1%, respectively), while the reaction of the policy rate is basically muted and no real activity reaction is detected. A strikingly different response of the economy materializes in the high inflation regime: the response of inflation is much stronger, with a peak response three times as large as the one in normal times. Industrial production significantly drops and takes about 18 months to go back to its pre-shock trend.[18] The response of the 10-year interest rate more than doubles with respect to the one in normal times. The response of the policy rate is also substantial, with a peak reaction of almost 60 basis points (possibly associated with the larger reaction of inflation) after the shock. Notably, while the dynamic responses are clearly different between the two regimes (as documented in the third column of Figure 4), the path followed by uncertainty after the shock is the same in the two regimes. Hence, our impulse responses must reflect differences in the underlying economic structure that are related to the level of inflation present in the economic system.

Robustness to different VAR specifications. We check the robustness of our results to different modifications of the baseline empirical model. We consider: (i) a version of the model with

imply any substantial change in our estimated measure of macroeconomic uncertainty.

[17] Generalized impulse responses (GIRFs) are obtained using Montecarlo integration as described in Koop, Pesaran, and Potter (1996). More details are available in the Appendix. Importantly, the switch between regimes is treated as endogenous in the GIRFs calculation: the economy can freely transition from low inflation to high inflation dynamics and back over the simulation horizon, depending on the sign and size of the shock. In other words, the simulation takes into account the dynamics of both the endogenous variables Z_t and the parameters Ψ_t. We focus throughout on the average responses in each regime. The low-inflation response (respectively, high-inflation response) is thus calculated as the average response to the shock of interest across all histories that belong to regime $S = 1$ (respectively, $S = 0$). By averaging over histories, we aim to obtain the most representative picture of the dynamics associated with each regime.

[18] In the high inflation regime, a one standard deviation uncertainty shock leads to a peak response in industrial production growth of around 1/8 of its unconditional standard deviation.

financial stress as captured by the National Financial Conditions Index estimated by the Federal Reserve Bank of Chicago;[19] (ii) one that accounts for potentially omitted factors by modeling a latent factor obtained via a principal component approach applied to the monthly database for macroeconomic research created by McCracken and Ng (2016); (iii) a version of the model with core CPI instead of headline CPI; (iv) a different sample ending in 2019 to exclude COVID-19 observations; (v) a version of the model with an imposed (non-estimated) threshold of 6%; (vi) a version of the model where the dating of the inflation cycle is done conditional on a proxy for trend inflation (external to the model) as opposed to inflation *per se* (which is what we do in our baseline case); (vii) a version of the model where we do not consider regime switches after a shock occurs (hence computing conditionally-linear IRFs for each regime). All these exercises confirm the solidity of our baseline results. We also find similar results using UK data and euro area aggregated data, suggesting that our results do not reflect US-specific historical circumstances. Our Appendix offers further details on these checks.

Forecast error variance decomposition. Table 1 documents the contribution of uncertainty shocks to the volatility of the variables modeled with our VAR. The contribution of macroeconomic uncertainty shocks is clearly larger in the presence of high inflation. In such a state, uncertainty shocks explain about one-fifth of the forecast error volatility of inflation, one-fourth of that of the long-term interest rate, and three-fifths of that of the (short-term) policy rate. The contribution to the volatility of industrial production is about 10% (1-year horizon) and 11.5% (two-year horizon). For all these variables, the contribution of uncertainty shocks is substantially milder in the presence of low inflation, in particular as far as industrial production and the policy rate are concerned. Hence, uncertainty shocks' impact on the business cycle is clearly nonlinear and connected with the inflation cycle.

4 DSGE model

This Section presents the dynamic stochastic general equilibrium (DSGE) model we work with and offers intuitions on the role played by trend inflation in amplifying the macroeconomic effects of uncertainty shocks.

[19] Details on such index can be found here: https://www.chicagofed.org/research/data/nfci/current-data .

4.1 A small-scale New Keynesian framework

We work with a nonlinear small-scale New Keynesian DSGE model with Calvo-type price setting (Galí (2008)) approximated around a positive trend inflation rate (Coibion and Gorodnichenko (2011), Coibion, Gorodnichenko, and Wieland (2012), Ascari and Sbordone (2014)). With respect to previous contribution, the novelty here is that of allowing for the presence of an exogenous uncertainty process.[20] Models that feature price stickiness and uncertainty shocks are chacterized by an "upward-pricing bias" transmission channel: given nominal rigidities and convex marginal revenues, after an increase in volatility firms optimally prefer to set higher prices than the ones they would set in the absence of uncertainty due to the fear of being "stuck" with too low prices (see Fernández-Villaverde, Guerrón-Quintana, Kuester, and Rubio-Ramírez (2015), Born and Pfeifer (2021), and Andreasen, Caggiano, Castelnuovo, and Pellegrino (2024)). Crucially, we show that this channel becomes stronger when trend inflation is positive, i.e., an "inflation-uncertainty amplifier" endogenously arises in this framework. This happens because the interaction of the upward pricing bias and trend inflation generates state-dependent responses (conditional on the level of trend inflation) that can help us interpret our VAR findings.[21]

Model structure. Our framework is the nonlinear version of the Ascari and Sbordone (2014) one enriched with a process that models the evolution of exogenous uncertainty surrounding future TFP realizations.[22] The model features a representative household that maximizes an intertemporal separable utility function in consumption, C_t, and labor, N_t:

$$\mathbb{E}_t \sum_{j=0}^{\infty} \beta^j \left(\frac{C_{t+j}^{1-\sigma}}{1-\sigma} - d_n e^{\zeta_t} \frac{N_{1+j}^{1+\varphi}}{1+\varphi} \right), \tag{5}$$

[20] Ascari, Castelnuovo, and Rossi (2011) formally compare models with trend inflation featuring Calvo and Rotemberg adjustment costs. They point to the former way of modeling nominal frictions as the one implying an empirically superior reduced-form representation as far as time-series macroeconomic data of the US economy are concerned. Oh (2020) compares the effects of uncertainty shocks in economies with Calvo vs. Rotemberg pricing frictions. He finds that the former tends to return a positive response of inflation, while the latter a deflationary one. Interestingly, the negative response of inflation in the Rotemberg case depends on the way adjustment costs are modeled. For instance, Fernández-Villaverde, Guerrón-Quintana, Kuester, and Rubio-Ramírez (2015) show that a positive response of inflation under such a pricing scheme can be obtained by assuming price adjustment costs that directly affect firms' marginal costs. In addition, working with the Leduc and Liu (2016) model with standard Rotemberg adjustment costs, Fasani and Rossi (2018) find that uncertainty shocks are inflationary once a reasonably calibrated degree of interest rate smoothing is modeled.

[21] Our model does not feature a cost channel, i.e., a direct link between a short-term interest rate and firms' marginal costs that could reduce price dispersion via the systematic policy response of the central bank to movements in inflation (Ravenna and Walsh (2006)). However, Rabanal (2007) finds the relevance of the cost channel for the dynamic response of inflation to a variety of macroeconomic shocks to be moderate at best.

[22] We thank Johannes Pfeifer for providing the codes to replicate the results in Ascari and Sbordone (2014) via his website: https://sites.google.com/site/pfeiferecon/ .

subject to the budget constraint:

$$P_t C_t + (1 + i_t)^{-1} B_t = W_t N_t + D_t + B_{t-1}, \tag{6}$$

where i_t is nominal interest rate, B_t is one-period bond holdings, W_t is the nominal wage, D_t is firms' profits, and ζ_t is a labor supply shock. σ and φ are the intertemporal elasticity of substitution in consumption and the Frisch elasticity of labor supply, respectively, while d_n is a parameter regulating labor disutility. The first-order conditions give the Euler equation:

$$\frac{1}{C_t^\sigma} = \beta \mathbb{E}_t \left[\frac{P_t}{P_{t+1}} (1 + i_t) \frac{1}{C_{t+1}^\sigma} \right], \tag{7}$$

and the labor supply equation:

$$w_t \equiv \frac{W_t}{P_t} = d_n e^{\zeta_t} N_t^\varphi C_t^\sigma \tag{8}$$

The final good, Y_t, is produced by perfectly competitive firms by combining a continuum of intermediate inputs $Y_{i,t}$, $i \in [0, 1]$, with the CES aggregator:

$$Y_t = \left(\int_0^1 Y_{i,t}^{\frac{\varepsilon-1}{\varepsilon}} \, di \right)^{\frac{\varepsilon}{\varepsilon-1}}, \tag{9}$$

where $\varepsilon > 1$ is the elasticity of substitution among intermediate inputs. Profit maximization and the zero profit condition for final goods firms yield a CES aggregate price index:

$$P_t = \left(\int_0^1 P_{i,t}^{1-\varepsilon} \, di \right)^{\frac{1}{1-\varepsilon}} \tag{10}$$

and the demand for intermediate inputs:

$$Y_{i,t} = \left(\frac{P_{i,t}}{P_t} \right)^{-\varepsilon} Y_t. \tag{11}$$

Intermediate inputs are produced by a continuum of firms with a simple production function that only uses labor as input of production:

$$Y_{i,t} = A_t N_{i,t}, \tag{12}$$

where A_t is a stationary process for technology and $N_{i,t}$ is labor employed by firm i. Nominal wages are assumed to be set in perfectly competitive markets and the real marginal costs across firms depend only on aggregate variables:

$$MC_{i,t} = MC_t = \frac{W_t}{A_t P_t}. \tag{13}$$

Imperfect substitutability generates market power for intermediate input producers, which are therefore price setters. We assume intermediate input producers are subject to a price-setting problem characterized by the Calvo-Yun model, Calvo (1983), Yun (1996). In each period firms can re-optimize their nominal prices with a fixed probability $1-\theta$, while with probability θ they cannot change their price and hence charge the same price as in the previous period.[23] When possible, firms re-optimize their price to the price $P^*_{i,t}$ that maximizes their expected profits:

$$\mathbb{E}_t \sum_{j=1}^{\infty} \theta^j \mathcal{M}_{t,t+j} \left[\frac{P^*_{i,t}}{P_{t+j}} Y_{i,t+j} - TC_{t+j}\left(Y_{i,t+j}\right)\right], \tag{14}$$

subject to the demand function in (11). $\mathcal{M}_{t,t+j}$ is the stochastic discount factor, while $TC_{t+j} = \frac{W_{t+j}}{P_{t+j}} \frac{Y_{i,t+j}}{A_{t+j}} = MC_{t+j} Y_{i,t+j}$ represents total costs. The first-order condition for this problem can be written as:[24]

$$p^*_{i,t} \equiv \frac{P^*_{i,t}}{P_t} = \frac{\varepsilon}{\varepsilon-1} \frac{\mathbb{E}_t \sum_{j=0}^{\infty} \theta^j \mathcal{M}_{t,t+j} Y_{t+j} \Pi^{\varepsilon}_{t,t+j} MC_{t+j}}{\mathbb{E}_t \sum_{j=0}^{\infty} \theta^j \mathcal{M}_{t,t+j} Y_{t+j} \Pi^{\varepsilon-1}_{t,t+j}}, \tag{15}$$

where $\Pi_{t,t+j}$ is the cumulative gross inflation rate:

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

Using a recursive formulation (15) can be written as:

$$p^*_{i,t} = \frac{\varepsilon}{\varepsilon-1} \frac{\psi_t}{\phi_t}, \tag{16}$$

where:

$$\psi_t \equiv MC_t Y_t^{1-\sigma} + \theta\beta \mathbb{E}_t \left(\pi^{\varepsilon}_{t+1} \psi_{t+1} \right) \tag{17}$$

$$\phi_t \equiv Y_t^{1-\sigma} + \theta\beta \mathbb{E}_t \left(\pi^{\varepsilon-1}_{t+1} \phi_{t+1} \right). \tag{18}$$

The aggregate price level evolves according to:

$$P_t = \left(\theta P_{t-1}^{1-\varepsilon} + (1-\theta) P_{i,t}^{*1-\varepsilon} \right)^{\frac{1}{1-\varepsilon}}. \tag{19}$$

[23] Full indexation of prices to past inflation and/or trend inflation would mute the impact of trend inflation on the dynamic responses to macroeconomic shocks in this framework. However, Cogley and Sbordone (2008) estimate the degree of price indexation to be zero when allowing for time-varying trend inflation. Even in a model without trend inflation, Smets and Wouters (2007) document an increase in the fit (as measured by the marginal likelihood) of their estimated DSGE framework when price indexation is set to zero. Benati (2008) offers a data-driven warning against interpreting price indexation as a structural parameter. For a discussion on indexation, see Ascari and Sbordone (2014).

[24] The steady state of this equation implies upper bounds for the steady state (trend) inflation rate: $\bar{\pi} < (1/\theta\beta)^{1/\varepsilon-1}$ and $\bar{\pi} < (1/\theta\beta)^{1/\varepsilon}$. For the standard values we borrow from Ascari and Sbordone (2014) ($\theta = 0.75$, $\beta = 0.99$, $\varepsilon = 10$), these bounds are 14.1 percent and 12.6 percent annual rates, respectively.

From the latter equation, we can also get the firm's optimal relative price:

$$p_{i,t}^{*}=\left(\frac{1-\theta\pi_{t}^{\varepsilon-1}}{1-\theta}\right)^{\frac{1}{1-\varepsilon}} \tag{20}$$

Aggregate labor demand is given by:

$$N_t=\int_0^1 N_{i,t}\,di=\int_0^1 \frac{Y_{i,t}}{A_t}\,di=\frac{Y_t}{A_t}\int_0^1\left(\frac{P_{i,t}}{P_t}\right)^{-\varepsilon}di. \tag{21}$$

Defining a measure of price dispersion s_t as:

$$s_t\equiv\int_0^1\left(\frac{P_{i,t}}{P_t}\right)^{-\varepsilon}di\geq 1, \tag{22}$$

we can express output as:

$$Y_t=\frac{A_t}{s_t}N_t, \tag{23}$$

from which we can see that an increase in price dispersion s_t acts as a negative technology shock, as it increases the amount of labor required to produce a given level of output. The evolution of price dispersion can be shown to be:

$$s_t=(1-\theta)\left(\frac{P_{i,t}^{*}}{P_t}\right)^{-\varepsilon}+\theta\left(\frac{P_t}{P_{t-1}}\right)^{\varepsilon}s_{t-1} \tag{24}$$

A simple Taylor rule is assumed for monetary policy:

$$\frac{1+i_t}{1+\bar{i}}=\left(\frac{1+i_{t-1}}{1+\bar{i}}\right)^{\rho_i}\left(\left(\frac{\pi_t}{\bar{\pi}}\right)^{\phi_\pi}\left(\frac{Y_t}{\bar{Y}}\right)^{\phi_Y}\right)^{1-\rho_i}e^{\nu_t} \tag{25}$$

where bars denote steady-state values, ν_t is a monetary policy shock, $\pi_t=\frac{P_t}{P_{t-1}}$ is the gross inflation rate, and ϕ_π,ϕ_Y are non-negative parameters. Further details on the model can be found in Ascari and Sbordone (2014).

The complete non-linear model is given by the aggregate resource constraint $Y_t=C_t$ and equations (7), (8), (13), (16), (17), (18), (20), (23), (24), and (25), which determine the evolution of Y_t, w_t, MC_t, $p_{i,t}^{*}$, ψ_t, ϕ_t, π_t, N_t, s_t, and i_t.

Calibration and solution. Given that our aim is to handle uncertainty shocks, we modify the framework by Ascari and Sbordone (2014) and allow their TFP stochastic process to feature a time-varying volatility that we model as an AR(1).[25] The white noise disturbance to the

[25] Bianchi, Kung, and Tirskikh (2023) deal with a medium-scale model of the business cycle that features several sources of uncertainty. They find TFP-related uncertainty shocks to be a powerful driver of inflation.

AR(1) process is our uncertainty shock. Formally, we use the following specification for the TFP process:

$$A_t = \rho_A A_{t-1} + e^{\sigma_{t-1}} u_{A,t} \tag{26}$$

$$\sigma_t = (1 - \rho_\sigma)\sigma_{ss} + \rho_\sigma \sigma_{t-1} + \sigma_\sigma u_{\sigma,t}, \tag{27}$$

where $u_{\sigma,t}$ is an ex-ante uncertainty shock as in Basu and Bundick (2017). In the absence of uncertainty shocks, our nonlinear framework nests the log-linearized Ascari and Sbordone (2014) model. To simulate the effects of uncertainty shocks, we work with a third-order pruned perturbations approximation as proposed in Andreasen, Fernández-Villaverde, and Rubio-Ramírez (2018), and we compute generalized impulse responses (GIRFs) by using the authors' Dynare package (available on Martin Andreasen's personal webpage).[26]

We calibrate the model following Ascari and Sbordone (2014) as far as the parameters in common are concerned (see Table A2 in our Appendix for details.) As for our stochastic process for TFP first and second-moment shocks, we calibrate $\rho_A = 0.95$, $\sigma_{ss} = ln(0.007)$, $\rho_\sigma = 0.75$, and $\sigma_\sigma = 0.693$ such that a one-standard-deviation uncertainty shock doubles the level of steady-state volatility similarly to Fernández-Villaverde and Guerrón-Quintana (2020). We set the systematic policy response to inflation to 1.75, that to output to 0.125, and we also assume an interest rate smoothing parameter of 0.65. These values are fairly in line with standard estimates of the Taylor rule (see e.g., Clarida, Galí, and Gertler (2000), Coibion and Gorodnichenko (2012)).

4.2 Theoretical predictions and intuition from a stylized model

Theoretical predictions. Figure 5 shows the macroeconomic effects of a TFP uncertainty shock in our model for real GDP, the yearly inflation rate, and the annualized interest rate at different levels of trend inflation.[27] The three levels of trend inflation, i.e., 0%, 2%, and 6% correspond - respectively - to the case of zero trend inflation often assumed in analysis conducted with new Keynesian frameworks and the low/high inflation regimes documented by Schorfheide (2005). A

[26] Ascari and Sbordone (2014) analyze the role played by the Frisch elasticity $\varphi > 0$ as a possible "magnifier" - via the response of price dispersion, which increases the persistence of output and inflation by enabling mutual feedback between inflation and price dispersion itself. When the Frisch elasticity is positive, price dispersion enters the New Keynesian Phillips curve and becomes a determinant of inflation. Our baseline simulations are deliberately conducted with $\varphi = 0$ to prevent assigning additional leverage to the inflation-uncertainty amplifier. Simulations conducted with $\varphi = 3$ confirm Ascari and Sbordone's (2014) result also for the case of uncertainty shocks. The full calibration of the DSGE model is provided in our Appendix.

[27] Our Appendix shows that our impulse responses are robust to adjusting price stickiness in response to changes in the trend inflation level as in L'Hullier and Schoenle (2022). For a similar approach, see Coibion, Gorodnichenko, and Wieland (2012). For a model featuring an endogenous frequency of price changes that is a function of trend inflation, see Blanco, Boar, Jones, and Midrigan (2024).

few messages emerge. First, an uncertainty shock is recessionary and inflationary. As anticipated, firms' upward pricing bias play a crucial role here. Firms set prices higher than they would in the absence of uncertainty to maximize expected future profits. Given the asymmetric shape of the profit function (due to the low elasticity of demand), when setting their prices, firms prefer to err toward higher prices and risk attracting low demand rather than sell at lower prices and face high demand. According to our calibrated model, this upward pricing bias: (i) leads to a positive response of inflation in equilibrium; (ii) amplifies the negative effects of uncertainty shocks on consumption and output that work via price dispersion and resource misallocation. Notice that in our model, very much as in our VAR, the policy rate reacts positively to dampen inflation fluctuations, i.e., the calibration of the Taylor rule implies a policy preference toward inflation stabilization.

The second message that arises from Figure 5 is that the above-described effects are state-dependent and quantitatively larger (to an equally-sized uncertainty shock) when trend inflation is high. Higher trend inflation implies a larger drop in GDP, a bigger increase in inflation, and a much stronger response to the nominal interest rate. Under the assumption that phases of persistently high inflation can be interpreted as phases of high trend inflation, these theoretical predictions qualitatively match the empirical findings on the nonlinear effects of uncertainty shocks documented via our nonlinear VAR model.[28]

Why is trend inflation relevant for the dynamic responses to an uncertainty shock? In the presence of trend inflation, re-optimizing firms face an upward-trending aggregate price index. As a consequence, they use future expected inflation rates to discount future marginal costs, which makes them more forward-looking.[29] Having more forward-looking price-setting firms amplifies the macroeconomic effects of the previously explained upward price bias channel of uncertainty shocks.

Economic intuition in a two-period partial equilibrium model. To see more clearly why trend inflation affects the impact of uncertainty shocks, consider the following stylized two-period partial equilibrium setup for the ith firm, where we can study in isolation the upward price bias channel. The firm is monopolistically-competitive and has the objective to set a price P_i^* that

[28]The connection between high and persistent inflation and high trend inflation has been identified by, among others, Stock and Watson (2007), Ireland (2007), Cogley and Sbordone (2008), and Cogley, Primiceri, and Sargent (2010). In the Appendix we show that our VAR findings are robust to using a measure of time-varying trend inflation as opposed to constant trend inflation as a (time-dependent) threshold.

[29] In the words of Ascari and Sbordone (2014), p. 693: "*Forward-looking firms know that they may be stuck with the price set at t and that inflation will therefore erode their markup over time; hence they use future expected inflation rates to discount future marginal costs. The higher the future expected inflation rates, the higher the relative weight on expected future marginal costs; firms become effectively more forward-looking, giving more weight to the future than to present economic conditions.* This reasoning follows from equation 15.

holds for two periods, t and $t+1$, similarly to Taylor-type price frictions. The firm is initially at the steady steady where either $\bar{\pi} = 1$ (zero trend inflation) or $\bar{\pi} = 1.06$ (trend inflation equal to 6%). No shocks affect real quantities meaning that $MC_{i,t} = (\varepsilon - 1)/\varepsilon$ and $Y_t = 1$. The aggregate price level in the next period P_{t+1} is unknown at time t, i.e., when the firm sets its price. On the other hand, the current aggregate price level P_t is assumed to be known. The expression for real profits is similar to the one provided in the full model, except that future profits are discounted by β and that, with probability one, the firm cannot reset its price in the next period. Hence the firm solves the problem:

$$\max_{P_i^*} \quad \mathbb{E}_t \sum_{j=0}^{1} \beta^j \left[\frac{P_i^*}{P_{t+j}} Y_{i,t+j} - MC_{t+j} Y_{i,t+j} \right], \tag{28}$$

where $Y_{i,t+j} = \left(\frac{P_i^*}{P_{t+j}} \right)^{-\varepsilon} Y_t$, for $j = \{0, 1\}$. Suppose that the firm expects an aggregate price level in period $t+1$ of either $P_{t+1} = \bar{\pi} P_{t+1} + \sigma$ or $P_{t+1} = \bar{\pi} P_{t+1} - \sigma$ with equal probability, where $\bar{\pi}$ is (gross) trend inflation and $\sigma = \sqrt{\mathbb{V}ar_t\left(P_{t+1}\right)} > 0$ represents future price uncertainty.[30] This setting allows us to study how the presence of positive trend inflation under sticky prices affects the firm's optimal upward price bias due to uncertainty about P_{t+1}, hence extending the results in Fernández-Villaverde, Guerrón-Quintana, Kuester, and Rubio-Ramírez (2015) and Born and Pfeifer (2021).

To illustrate the effects of accounting for trend inflation, let $\beta = 0.99$, $\varepsilon = 6$ (implying a 20% markup), and $P_t = 1$ (without loss of generality, so that to read our results in terms of the optimal *relative* price, P_i^*/P_t). Figure 6 shows the firm's expected profit function and the optimal price P_i^* - i.e., the function maximand - for the cases of certainty ($\sigma = 0$) and uncertainty ($\sigma = 0.2$) and for the case of either no trend inflation (left panel) or 6% trend inflation (right panel). We can present results distinguishing between three possibilities: certainty, uncertainty without trend inflation, and uncertainty with 6% trend inflation. First, under certainty, the firm picks a relative price equal to one in the absence of trend inflation, whereas, as formally shown in the Appendix, it chooses to have a higher relative price under positive trend inflation as the firm is more forward-looking under price stickiness and hence anticipates future inflation with higher prices today.[31] Second, under uncertainty and no trend inflation, future inflation risk implies that firms optimally upward-bias their prices. As explained earlier, since the profit function is asymmetric,

[30] We introduce uncertainty over the future aggregate price level P_{t+1} for simplicity (for a similar approach, see Born and Pfeifer (2021)). However, in our dynamic setting this is equivalent to having uncertainty over future inflation, $\pi_{t+1} = \frac{P_{t+1}}{P_t}$, as the current aggregate price P_t is known (and later assumed equal to one).

[31] For our parameterization the firm chooses $P_i^* = 1.034$ in presence of trend inflation $\bar{\pi} = 6$ and certainty. As we formally show in the Appendix, since the profit function is asymmetric, the firm will choose to increase today's price by more than half the trend inflation rate in this two-period model.

the firm prefers to err on the side of higher prices to avoid the lower profits associated with lower prices (see Fernández-Villaverde, Guerrón-Quintana, Kuester, and Rubio-Ramírez (2015) and Born and Pfeifer (2021)). Third, under uncertainty and trend inflation, we find that the firm's optimal upward pricing bias is larger. As shown in Figure 6, for our parameterization, we find that the firm will upward bias its price by 8.94% in a world without trend inflation and by 9.66% in a world with 6% trend inflation. The reason for this larger upward pricing bias under trend inflation in this stylized model is the following. If a firm is able to reoptimize at time t is aware it will get stuck with its price for a few periods after re-optimization, then it will fear the erosion of its relative price and markup. Given a volatile environment, the higher the level of trend inflation, the higher the likelihood of experiencing a large erosion in the markup. Therefore, under sticky prices, after a sudden increase in uncertainty about future profits, a firm's optimal reset price will be a positive function of trend inflation.

Propagation in the general equilibrium model. The intuition proposed above is also valid when moving to our general equilibrium New Keynesian framework. Given Calvo pricing—and the resulting concern among price-setting firms about being stuck with their prices for an extended period—the upward price bias channel becomes stronger as trend inflation increases. Higher prices and markups, on the one hand, exert a greater recessionary impact on output and, on the other hand, necessitate a stronger response from the central bank's policy rate via the Taylor rule, potentially amplifying the recessionary effect on output.[32] The stronger effects on output arise from greater price dispersion caused by the uncertainty shock under trend inflation[33] Hence, price dispersion acts as a negative aggregate productivity shock, as shown earlier in the model description (Ascari and Sbordone (2014)).[34]

Price dispersion: Evidence from the extant literature. Recent empirical studies lend support to the role played by price dispersion in our model. Sheremirov (2020) and Alvarez-Blaser (2024) document a significantly positive relationship between inflation and price dispersion.[35] Ropele, Coibion, and Gorodnichenko (2024) work with firm-level Italian data and document a causal

[32]In the Appendix, we use a standard medium-scale DSGE model with capital to show that, in the presence of a Calvo-type setting, also preference uncertainty shocks as in Basu and Bundick (2017) – in addition to technology ones – have an amplified effect when there is trend inflation. The crucial point is that of generating uncertainty around firms' future marginal costs, which implies an upward pricing bias by firms.

[33]Trend inflation increases price dispersion by causing a greater difference between the price set by the resetting firms and the average price level. Due to a stronger upward price bias, the increase in price dispersion after an uncertainty shock will be greater the higher the trend inflation.

[34] We verify in the Online Appendix that the stronger effect on real activity in the presence of trend inflation mainly works through a stronger upward price bias channel. If one assumes either fully flexible firms or inelastic demand, the effects of uncertainty TFP shocks in this small-scale model without Epstein-Zin preferences are negligible.

[35] A different view is proposed by Nakamura, Steinsson, Sun, and Villar (2018), who find little evidence that the Great Inflation of the late 1970s and early 1980s led to substantial increases in price dispersion.

link going from changes in the dispersion of beliefs about future inflation and misallocation of resources, which the authors quantify to induce a more severe misallocation in times of high inflation. In the survey they handle, firms "treated" with a repeated provision of information display very little disagreement about future inflation relative to untreated firms. They find that higher dispersion in inflation forecasts leads to greater misallocation (measured as the dispersion of marginal revenue products of both capital and labor as well as the dispersion in their differences). Such a misallocation is costly. Working with a calibrated small New-Keynesian framework, Ropele, Coibion, and Gorodnichenko (2024) conclude that a modest reduction in the dispersion of firms' inflation expectations could be associated with a gain in aggregate TFP of about 0.2-0.5 percent, while an increase in dispersion comparable to what was observed in the data from 2021 to 2022 could lead to a loss in aggregate TPF of 2.2 percent or more. Relatedly, Bunn, Anayi, Bloom, Mizen, Thwaites, and Yotzov (2022) and Yotzov, Anayi, Bloom, Bunn, Mizen, Öztürk, and Thwaites (2023) work with firm-level survey data and find a negative correlation between inflation uncertainty and productivity.

4.3 Policy exercise

Suppose an inflationary shock (e.g., a pandemic, a war, a breakdown in the global supply chain, an energy market-related disturbance, or tariffs) materializes and the economic system is taken to a path characterized by high and persistent inflation. We interpret this situation with our model by setting trend inflation to 6%, which is consistent with post-pandemic figures on inflation expectations (Gorodnichenko and Coibion (2025)).[36] Suppose now that an uncertainty shock (that captures the suddenly higher uncertainty about the future macroeconomic environment, for instance, because of more uncertain future macroeconomic policy interventions) hits too. Is there anything a central bank can do to dampen the otherwise large business cycle response to macroeconomic uncertainty?

Figure 7 shows the impulse responses under the baseline calibration of our model and conditional to 2% and 6% trend inflation together with the ones predicted by our model when we simulate an economy characterized by: (i) 6% trend inflation; (ii) a more aggressive systematic monetary policy response to inflation. Such a policy response is "hawkish" with respect to the baseline one because it is characterized by a policy coefficient $\phi_\pi = 3$ instead of the baseline $\phi_\pi = 1.75$ one. As shown in the Figure, the responses implied by this more aggressive policy

[36]Referring to the concept of trend inflation, Ireland (2007) writes (p. 1853): *"[...] systematic tendency for Federal Reserve policy to translate the short-run price pressures set off by adverse supply shocks into more persistent movements in the inflation rate itself - part of an effort by policymakers to avoid at least some of the contractionary impact those shocks would otherwise have had on the real economy."*

response in the presence of high-trend inflation closely align with those triggered by the very same uncertainty shock in an environment where trend inflation is low and monetary policy is conducted as in "normal times". This occurs because a more "hawkish" central bank reduces expected future inflation and hence implies a lower target relative price for the optimizing firms, $p_{i,t}^* = P_{i,t}^*/P_t$, which significantly mitigates the upward price bias channel of uncertainty shocks. Bottom line: according to our model, it may make sense to switch to a more aggressive policy response to inflation when trend inflation is high and an uncertainty shock materializes to limit the economic damage inflicted by such a shock. Importantly, the calibration $\phi_\pi = 3$ is an empirically credible one (e.g., it belongs to the 68% confidence bands of the estimates proposed by Coibion and Gorodnichenko (2011) - see their Figure 3, p. 362).

What are the implications of this more aggressive policy for output? Figure 7 shows that also the response of output conditional on a high trend inflation rate and a "hawkish" monetary policy replicates that under the low trend inflation when a relatively more moderate policy response is in place. Notably, given that output in our model is fully informative as far as the response of the output gap is concerned, and given the already commented response of inflation in the presence of a "hawkish" vs. more moderate policy, our policy exercise implies that, conditional on an uncertainty shock occurring, an aggressive reaction to inflation in the presence of a high trend inflation rate is welfare-enhancing *all else being equal*.

Our policy exercise suggests that, in spite of the supply shock-type of responses due to an uncertainty shock, a monetary policy that stabilizes inflation also automatically stabilizes the output gap.[37] Is our framework characterized by the presence of the "divine coincidence" à la Blanchard and Galí (2007)? The answer is negative. In our model, the central bank *does* face a trade-off when it comes to *first-moment* inflationary shocks. Our Appendix shows that a first-moment cost-push shock generates an increase in inflation and a real activity downturn that forces the central bank to trade-off a less volatile inflation rate with a more volatile output. Such a trade-off has nothing to do with price dispersion. Instead, it is present because, conditional on a higher inflation rate, it is the central bank's response itself that opens a recession to reduce expected marginal costs and, therefore, inflation via firms' pricing decisions. Hence, a more

[37] As far as real activity is concerned, the welfare-relevant object is the output gap, i.e., the difference between output under sticky prices and the natural level of output that materializes under flexible prices. Notice that, absent price stickiness, firms' price dispersion does not materialize in our model given that technology is common across firms and that we focus on aggregate shocks. In our small-scale framework, the natural output level does not respond to uncertainty shocks given the absence of capital that prevents households from intertemporally reallocating resources. Hence, as shown in our Appendix, the impulse response of output *per se* is fully informative on the response of the output gap. In a medium-scale model with capital, Basu and Bundick (2017) show that, under fully flexible prices, the drop in consumption due to precautionary savings leads households to increase labor supply, which in turn increases the "natural" level of output. Our Appendix documents the robustness of our policy experiment results to a version of our model with capital.

aggressive response to inflation by the central bank will naturally lead the economy to enjoy more stable inflation at the cost of a more volatile output. Differently, a *second-moment* uncertainty shock generates a large amount of price dispersion via firms' upward price bias, which can however be dampened with a switch toward a more aggressive policy response to inflation, as explained above. Such a response limits the increase in both firms' optimal reset price and price dispersion, therefore moderating *both* inflation *and* output volatility. Hence, our model points to the existence of a "volatility-related divine coincidence", which is actually explained by the impact of systematic monetary policy on firms' inflation expectations and, consequently, cross-sectional price dispersion.

5 Conclusions

This paper estimates a nonlinear VAR to document a novel stylized fact, i.e., uncertainty shocks are a more potent driver of the business cycle in the presence of high inflation. We interpret this stylized fact with a new-Keynesian model approximated around a positive inflation rate. In line with our VAR evidence, different calibrations of trend inflation lead to different macroeconomic responses, with a large reaction of inflation and output when trend inflation is high. The model's ability to replicate our stylized fact hinges upon the interaction between upward pricing bias and trend inflation, with the latter magnifying the former - an "inflation-uncertainty amplifier". Crucially, firms' price dispersion - which acts as a negative technology shock in trend inflation frameworks - is larger when this interaction occurs, and this is what enables the model to replicate our nonlinear VAR impulse responses. When using our model to conduct policy analysis, we find that even in a world with high trend inflation the business cycle effects of an uncertainty shock can be moderate if a reasonably hawkish policy is in place.

From a modeling standpoint, our paper points to the need of working with models featuring trend inflation to fully understand the consequences of uncertainty shocks, above all in environments characterized by high inflation. Policywise, our simulations point to the possible optimality of state-dependent policy rules that feature aggressive responses to inflation when trend inflation is high. Finally, we see our findings as supportive of the choice of a 2% inflation target (or less) as suggested by Coibion, Gorodnichenko, and Wieland (2012).

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Tables

Variable	Low Inflation		High Inflation	
	One Year	Two Year	One Year	Two Year
CPI	13.4	15.9	13.2	20.1
	(2.4,30.4)	(2.4,37.6)	(1.3,42.3)	(1.8,52.4)
Industrial Production	1.4	1.6	9.8	11.5
	(0.3,5.1)	(0.4,5.5)	(2.5,23.2)	(3.6,25.0)
3-month Treasury Bill	0.8	1.3	61.9	60.2
	(0.1,5.8)	(0.1,8.8)	(31.2,80.6)	(26.4,81.3)
10-year Rate	9.3	11.6	17.4	25.8
	(0.8,23.4)	(0.9,29.8)	(1.8,46.7)	(2.6,58.4)

Table 1: **Forecast Error Variance Decomposition.** The Table reports figures regarding the state-dependent contribution (posterior median) of macroeconomic uncertainty shocks to the 1-year and 2-year ahead forecast errors of the variables modeled with our nonlinear VAR. 90% credible sets are reported in brackets.

Figures

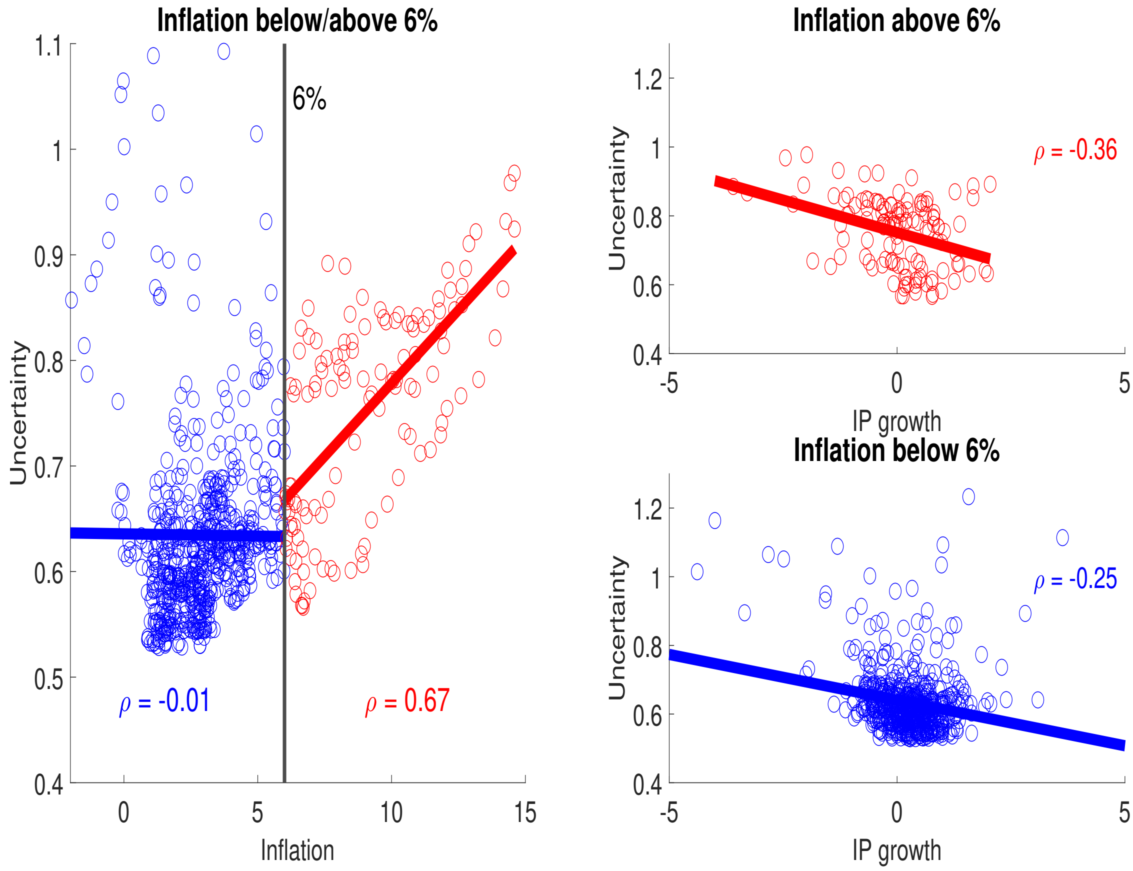

Figure 1: **Uncertainty and Business Cycle Indicators: High vs. Low Inflation.** Left panel: Correlation between uncertainty and inflation with a break in correspondence with an inflation rate equal to 6%. Right upper (lower) panel: Correlation between uncertainty and industrial production growth conditional on inflation being above (below) 6%. Sample: January 1962-August 2024.

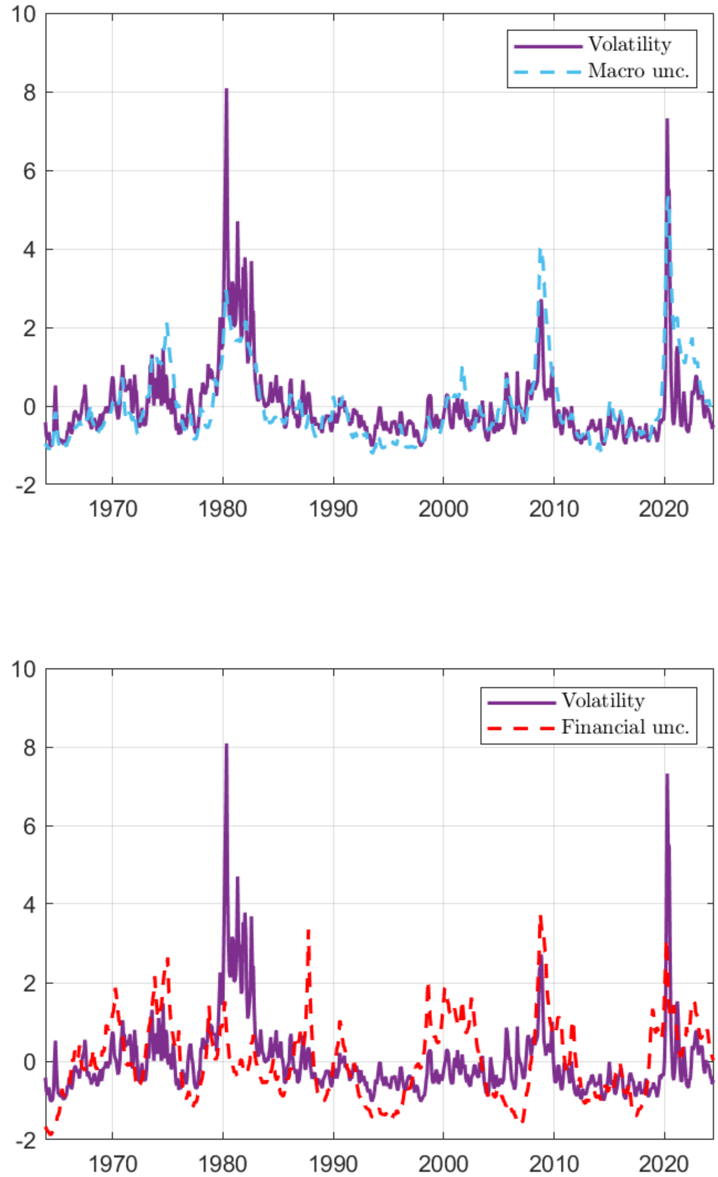

Figure 2: **Estimated Uncertainty.** Top panel: The solid purple line (dashed light blue line) represents the common stochastic volatility as estimated by our stochastic-volatility-in-mean Threshold VAR model (macro uncertainty measure at the one-month horizon estimated by Ludvigson, Ma, and Ng (2021)). Bottom panel: The solid purple line (dashed light red line) represents the common stochastic volatility as estimated by our stochastic-volatility-in-mean Threshold VAR model (financial uncertainty measure at the one-month horizon estimated by Ludvigson, Ma, and Ng (2021)). All series have been normalized.

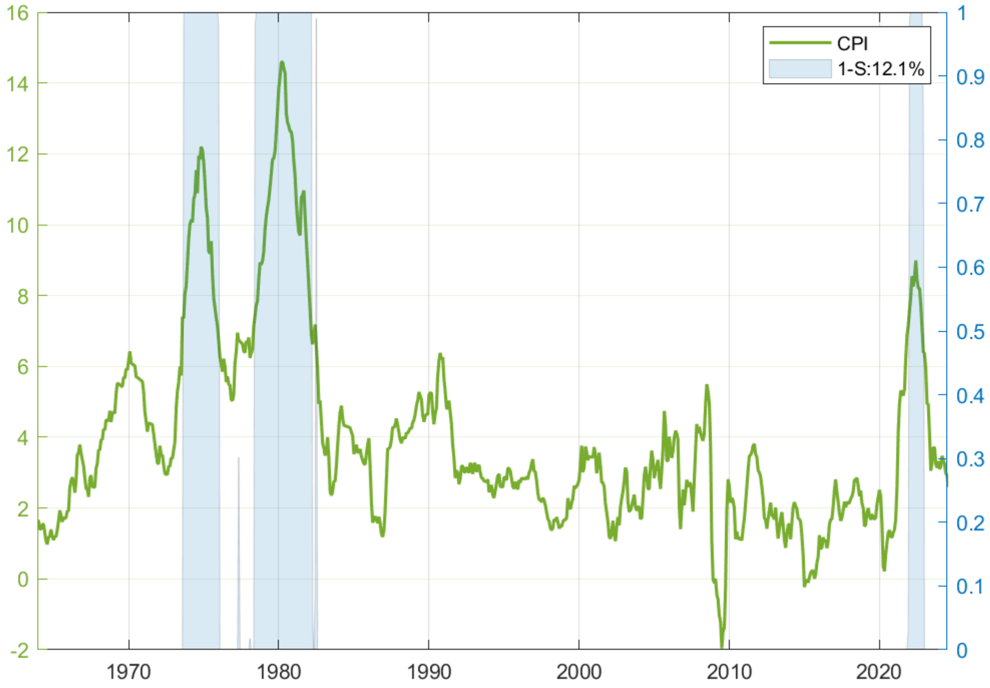

Figure 3: **High inflation regime.** Green line: year-over-year CPI inflation. Shaded area: High Inflation regime averaged over the retained Gibbs draws. The median estimated threshold is 7.005.

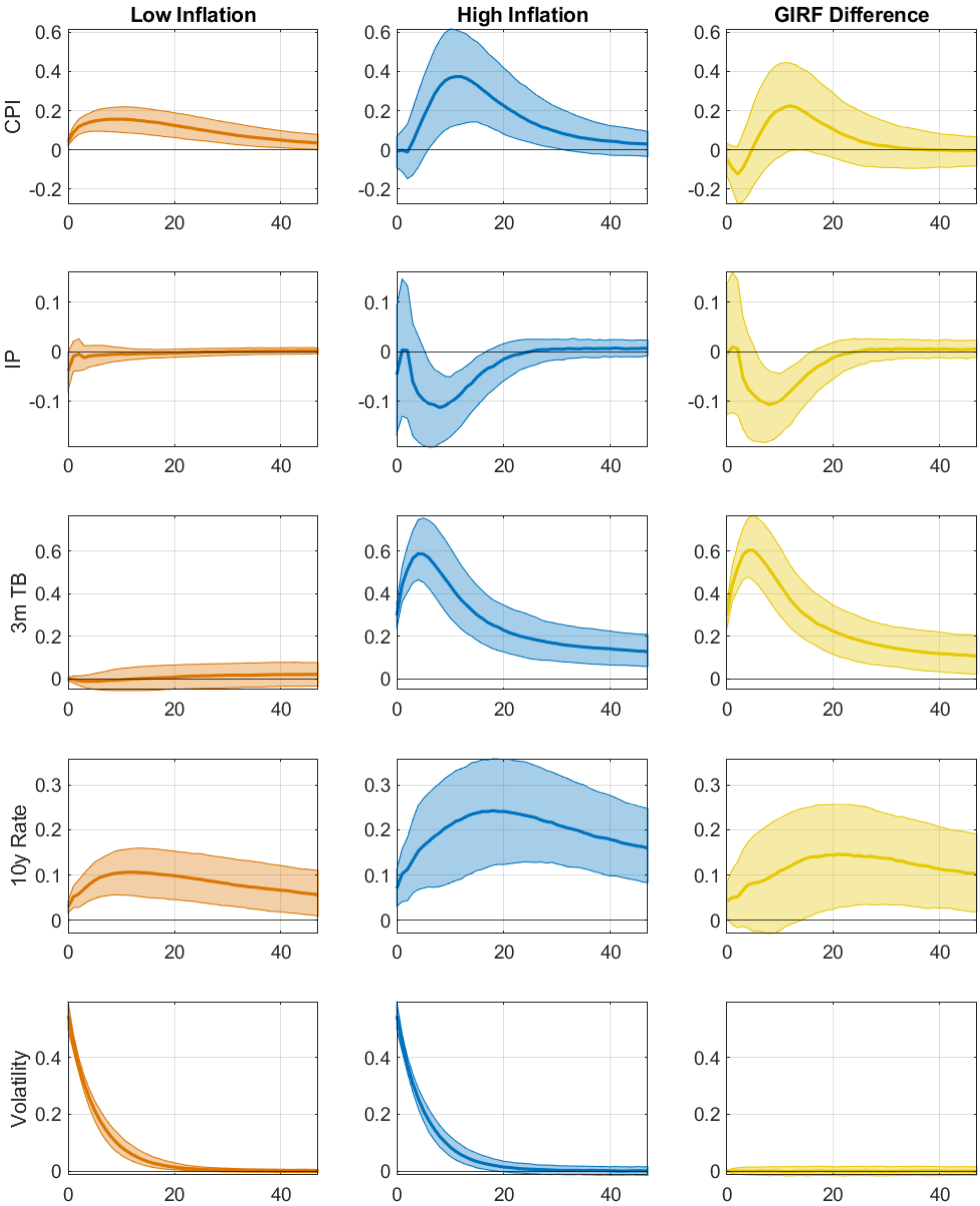

Figure 4: **Generalized impulse response functions for the high and low inflation regimes.** Response to a one standard deviation shock to uncertainty in the low (first column) and high (second column) inflation regimes. Third column: Difference between the high inflation and the low inflation GIRFs. Solid lines: Posterior medians. Shaded areas: 68% credible sets.

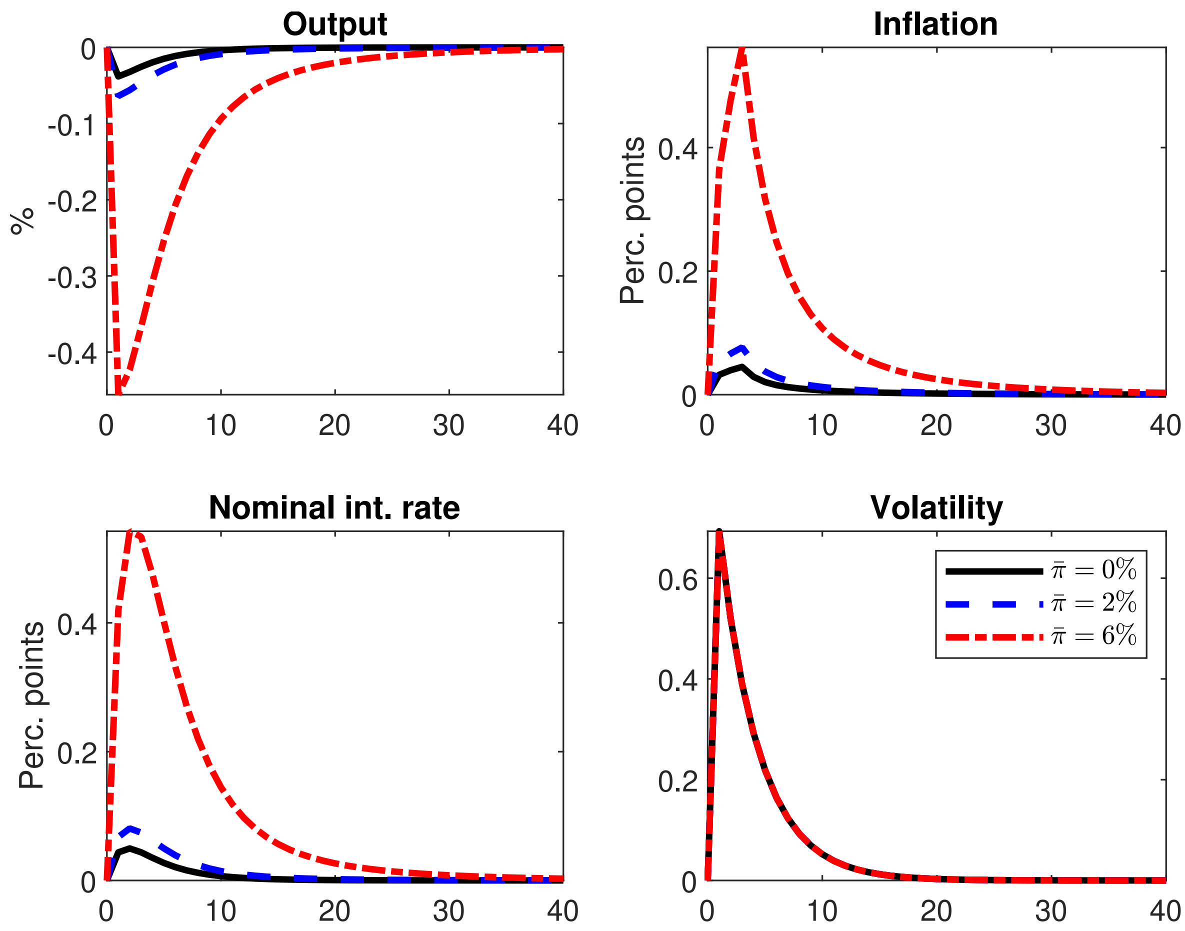

Figure 5: **Impulse response functions to a second-moment technology shock for different levels of trend inflation.** Different calibrations of trend inflation indicated in the legend, where $\bar{\pi}$ stands for trend inflation. Calvo probability of not being able to reset the price equal to 0.75, as in Ascari and Sbordone (2014).

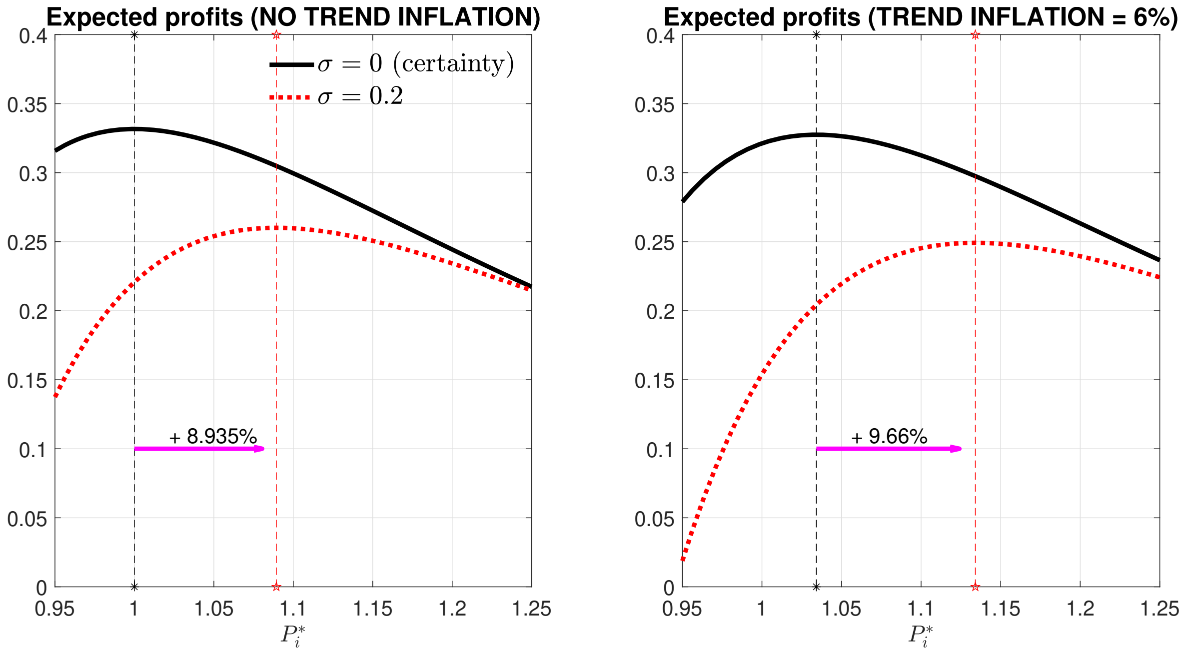

Figure 6: **Asymmetric profit function: Upward pricing bias under uncertainty, Taylor-type price stickiness, and trend inflation.** This figure shows the solution of the firm's problem outlined in Section 4.2 for the parameters' values indicated in the same Section. It has been assumed $P_t = 1$, hence the results can be read in terms of the optimal *relative* price, P_i^*/P_t. The left panel plots the firm's biperiodal expected profit function and optimal price – i.e., the function maximum – in a situation of no trend inflation given Taylor-type price rigidities for both the cases of certainty ($\sigma = 0$) and uncertainty ($\sigma = 0.2$), Vertical lines represent optimal prices. The right panel plots the same objects for the case of trend inflation at 6%.

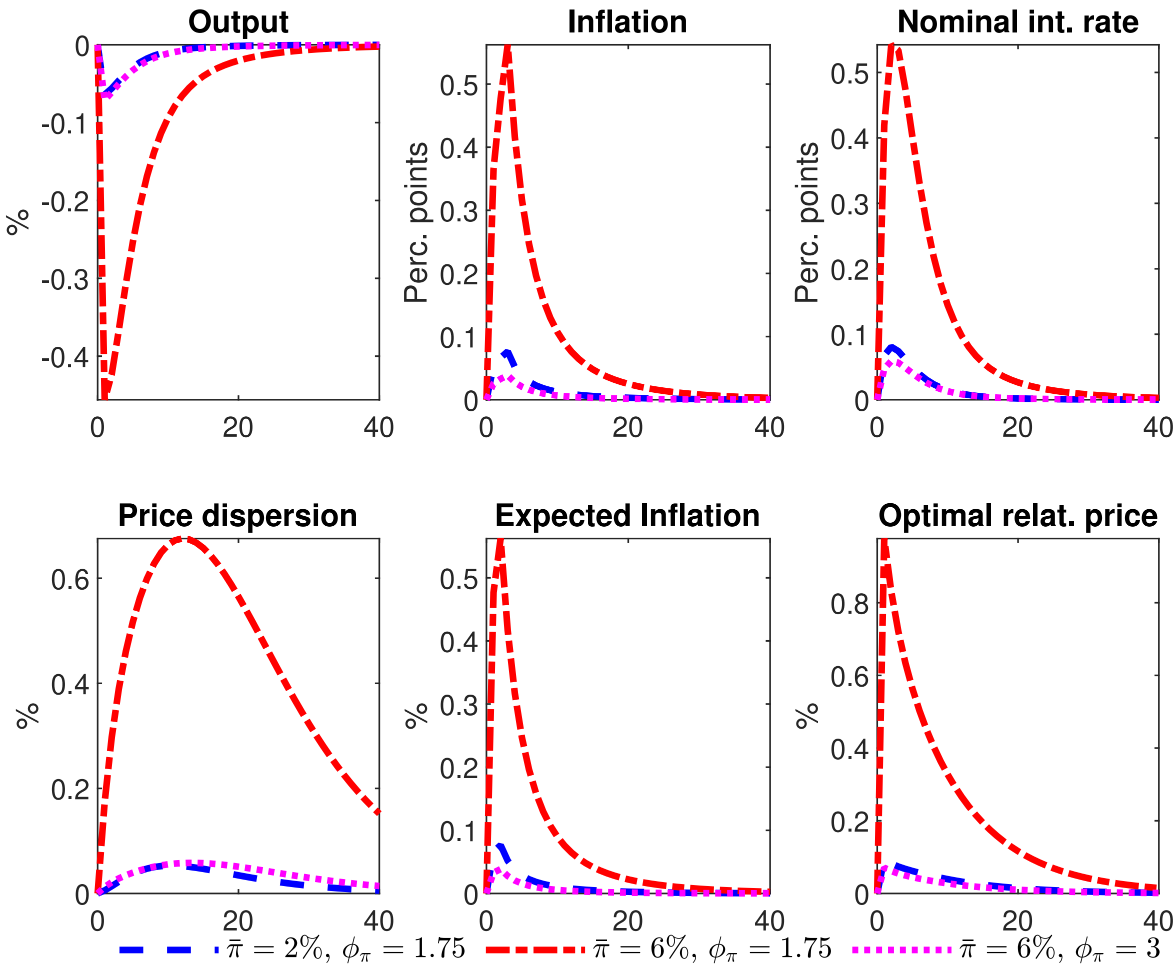

Figure 7: **Policy exercise: Role of "hawkish" monetary policy when trend inflation is high.** Different calibrations of trend inflation indicated in the legend, where $\bar{\pi}$ stands for trend inflation. Calvo probability of not being able to reset the price equal to 0.75, as in Ascari and Sbordone (2014).

Appendix of the paper "The Inflation Uncertainty Amplifier" by Efrem Castelnuovo, Giovanni Pellegrino, Laust L. Særkjær

A: Algorithm to estimate the nonlinear VAR and compute impulse responses

The Gibbs sampling algorithm used to estimate the nonlinear VAR framework we work with is extensively documented in the paper by Alessandri and Mumtaz (2019) and their Appendix, and the code to replicate the computations in Alessandri and Mumtaz (2019) is available at Haroon Mumtaz's webpage, i.e., https://sites.google.com/site/hmumtaz77/home. In short, conditional on a given draw for λ_t, the model is a threshold VAR with a known form of heteroscedasticity. At this point, it is handy to perform a GLS transformation of the model that implies that the conditional posterior distributions of the regime-dependent VAR parameters, the threshold, and delay are identical to those of a standard threshold VAR (see Alessandri and Mumtaz (2017)). In particular, the threshold value can be drawn from its non-standard posterior via a Metropolis step. Then the data can be split into regime-specific observations, and the VAR autoregressive coefficients sampled from the normal distribution. Given the residuals of the VAR and λ_t, the conditional posterior for A is standard (see, e.g., Cogley and Sargent (2005)). The variances M can be drawn from the inverse Gamma distribution. Given these parameters, the model admits a non-linear state-space representation. The state-variable λ_t is drawn using the independence Metropolis algorithm introduced in Jacquier, Polson, and Rossi (1994) for stochastic volatility models.

We employ the same set of priors as documented in Alessandri and Mumtaz (2019), but we set the prior variance of the threshold to one to ensure the smooth behavior of the sampling algorithm and a reasonable number of observations in each regime (Hansen, 1999).[38]

Once the posterior distribution of all parameters is available, "generalized" impulse responses are obtained using Montecarlo integration as described in Koop, Pesaran, and Potter (1996). In practice, the responses are calculated as differences between conditional expectations obtained by simulating the model under a shock scenario and under a baseline, no-shocks scenario. For a

[38] In Section B, we show that the results are robust to setting the threshold to 6%, a reference for high inflation used by e.g. Coibion and Gorodnichenko (2011) and supported by the empirical analysis by Schorfheide (2005), Canova and Forero (2024), Gargiulo, Matthes, and Petrova (2024).

given regime ($S = 0, 1$) and regime-specific history (Z_{t-1}^S), the responses are defined as:

$$\text{IRF}_t^S = \mathbb{E}(Z_{t+k} \mid \Psi_t, Z_{t-1}^S, \mu) - \mathbb{E}(Z_{t+k} \mid \Psi_t, Z_{t-1}^S),$$

where Ψ_t represents all the parameters and hyperparameters of the model, k is the horizon under consideration and μ denotes the shock of interest (in our case, an increase in uncertainty). We focus on the average responses in each regime. The low-inflation response (respectively, high-inflation response) is thus calculated as the average response to the shock of interest across all histories that belong to regime $S = 1$ (respectively, $S = 0$). By averaging over histories we aim to obtain the most representative picture of the dynamics associated to each regime.

B: Identification of uncertainty shocks

Identification of uncertainty shocks in the nonlinear VAR we work with relies on two assumptions: (i) uncorrelation with respect to other identified macroeconomic shocks and (ii) unpredictability of the uncertainty process at time t with respect to information available to the econometrician at time t-1.

Uncorrelation with respect to other identified shocks. Table A1 shows the correlation coefficients between the identified uncertainty shocks from our estimated nonlinear VAR with proxies of oil supply shocks and monetary policy shocks that have been proposed by the literature. This exercise accounts for a possible misspecification of our baseline nonlinear VAR, i.e., the fact that volatility is exogenous to first-moment shocks. Oil supply shocks and monetary policy shocks are often considered to be behind the high volatility of the economic system in the '70s (see, e.g., Sims and Zha (2006), Boivin and Giannoni (2006)). As proxies for monetary policy shocks we consider Jarociński and Karadi (2020) and Romer and Romer (2004) (as updated by Coibion, Gorodnichenko, Kueng, and Silvia (2017)) and as proxies for oil supply shocks we consider a battery of series, namely: the oil supply shocks OPEC-related series produced by Günther and Henßler (2021), who extend and refine the one originally proposed by Kilian (2008) that is based on exogenous production shortfalls due to geopolitical events relative to some country-specific counterfactual; the oil supply series provided by Baumeister and Hamilton (2019) based on a Bayesian SVAR model; the oil supply shocks series by Caldara, Cavallo, and Iacoviello (2019), which is based on narrative records; and the oil supply news shocks by Känzig (2021), which is constructed using OPEC announcements. As shown in Table A1, none of the shocks considered is correlated with our estimated uncertainty shocks. Hence, this exercise speaks in favor of a correct identification of the latter.

Unpredictability of the uncertainty process. We test the unpredictability of the estimated λ_t process by regressing it (median value extracted from the posterior density) against a constant, its lagged value (to reproduce the autoregressive structure of the process) and three lags of the first factor extracted from the McCracken and Ng (2016) database. This Forni and Gambetti (2014) type of test largely rejects predictability, with a p-value associated with the null hypothesis of joint zero significance of the coefficients associated to the factor equal to 0.45. Combined with the evidence on uncorrelation with other identified shocks provided above, the evidence of unpredictability reassuringly supports the idea of correct identification of the uncertainty shocks and their macroeconomic effects.

C: Nonlinear VAR analysis: Robustness checks

Figure A1 presents the outcome of a variety of robustness checks of our baseline VAR results. In particular, we consider: (i) a proxy of the financial cycle (FCI) produced by the Federal Reserve Bank of Chicago to control for the transmission of macroeconomic uncertainty shocks via financial markets; (ii) a macroeconomic factor estimated by considering the large dataset constructed by McCracken and Ng (2016); (iii) a measure of core CPI (as opposed to headline CPI); (iv) a sample that stops in 2019M12 to avoid dealing with COVID-19 observations; (v) an imposed (non-estimated) threshold of 6% for inflation. Checks (i) and (ii) are conducted by replacing the long-term interest rate in the VAR with the above mentioned potentially relevant omitted factors (to keep the highly-parametrized VAR parsimonious); check (iii) is conducted by replacing the policy rate and headline inflation in the VAR with, respectively, the shadow rate and core CPI. Our baseline results are extremely robust along all these dimensions.

In our paper, we use a two-regime stochastic-volatility-in-mean threshold VAR model as in Alessandri and Mumtaz (2019) where, following the authors, we compute generalized impulse response functions (GIRF) à la Koop, Pesaran, and Potter (1996) to account for the fact that the economy can switch regime after a shock hits. Here, we assess the role of regime switches for our impulse response estimation by comparing our baseline GIRF with the corresponding conditionally-linear impulse response functions under the assumption that the initial regime remains in place after a shock hits. Although rougher, the latter computation is more in line with the way we compute impulse responses in the DSGE model, where we assume absorbing regimes. Figure A2 shows that not allowing endogenous regime switches in the VAR does not affect quantitatively our main findings.

Appendix D: Nonlinear VAR for the UK and the euro area

Our baseline results for the US suggest that an uncertainty shock is more inflationary and more recessionary if it occurs in a phase of high inflation. The high inflation regime in the US is quite delimited and is mainly capturing mid '70s, late '70s, and early '80s. Given this delimited time period of high inflation, one may wonder whether results may reflect US specific historical circumstances in this period.

UK data. As a robustness check for our main findings, we also estimate our VAR on UK data. In particular, consistently with our baseline analysis, we model the following vector of endogenous variables: $Z_t = [CPI\ Infl., IP, 3mTB, 10yTB]'$, which contains the following monthly UK variables: the yearly growth rate of inflation, the monthly growth rate of industrial production, the annualized three-month Treasury Bill rate, and the annualized 10-Year Treasury Bill rate.[39] The monthly sample period is 1961:1-2017:1 (the end is dictated by data availability).

Figure A3 documents the results for the UK. As for the US, an uncertainty shock causes inflation, the policy rate, and the long-term rate to increase in the UK; much more if the shock occurs in the high inflation regime.[40] In addition, as for the US, industrial activity falls more after an uncertainty shock when inflation is high. This fall is comparable in terms of magnitude to the US drop.

Euro area data. As a further robustness check, we also estimate our VAR on euro area data which we constructed for the period 1965:2-2023:10 by aggregating data for the "big four" countries (Germany, France, Italy, and Spain).[41] Figure A4 documents the results, which are overall in line with our main findings.[42]

[39] All the series were downloaded from the FRED dataset by the St. Louis Fed available at https://fred.stlouisfed.org/ (mnemonics: GBRCPIALLMINMEI_PC1, IPIUKM, IRLTLT01GBM156N, and IR3TTS01GBM156N).

[40] The magnitudes of these impulse responses are bigger for the UK than for the US, something that may be explained by the fact that yearly inflation reached a higher level in the UK in the 70s-80s than in the US: 27% vs. 14.5%, respectively.

[41] In particular, we downloaded all series from the FRED dataset by the St. Louis Fed and proceeded as follows. First, we approximated the year-over-year inflation rate for the euro area by taking the average of the year-over-year inflation rates of the big four countries (mnemonics: CPALTT01DEM657N, CPALTT01FRM657N, CPALTT01ITM657N, CPALTT01ESM657N), obtaining a series very close to the official shorter one for the 19 countries (mnemonic: EA19CPALTT01GYM) in the common sample (correlation=97%). Second, we approximated the month-over-month IP growth rate series by taking the average of the corresponding series for the big four countries (mnemonics: DEUPRINTO01GYSAM, FRAPRINTO01GYSAM, ITAPRINTO01GYSAM, ESPPRINTO01GPSAM) and we spliced the obtained series with the official one (mnemonic: EA19PRINTO01GYSAM) because of minor discrepancies between the two in the common sample (correlation=95%). Third, we use the 3-month and 10-year interest rates for Germany as a proxy of the euro area ones (mnemonics: IR3TIB01DEM156N and IRLTLT01DEM156N, respectively).

[42] In order to obtain convergence of the estimated nonlinear VAR, we have imposed the same threshold value for inflation as estimated in our baseline analysis, i.e., $Z^* = 7.005$.

Appendix E: Nonlinear VAR and trend inflation

Our baseline analysis focuses on inflation *per se*. However, the literature on trend inflation has stressed the conceptual and empirical differences between inflation and trend inflation, the latter being the low-frequency component of the former (for a compelling discussion, see Ascari and Sbordone (2014) and the literature therein). It is important to understand if the classification of the two regimes we engage with in our baseline exercise is robust to consider trend inflation (as opposed to inflation), because our DSGE analysis captures the dynamic responses of the economic system to an uncertainty shock when the former (i.e., trend inflation) is high vs. low. We address this question by first extracting the low frequency component of inflation via the Hodrick-Prescott filter.[43] Then, we re-estimate our nonlinear VAR by considering this proxy for trend inflation (as opposed to inflation) to date the inflation cycle, i.e., per each month in our sample, we check if our proxy for trend inflation takes a value higher (lower) than the estimated (constant) threshold, and classify such a monthly observation as belonging to the high (low) inflation regime.[44]

Figure A5 shows trend inflation as approximated by the HP filter, which is roughly consistent with the estimates in Ascari and Sbordone (2014) based on a time-varying parameter VAR and those in Ascari, Bonomolo, and Haque (2022) based on a new Keynesian framework. Figure A5 also documents the estimates for the High Trend Inflation regime. This regime captures the ten years from early '70s to early '80, which mostly contains the High Inflation phases during these years as estimated by our baseline VAR (see Figure 3).

Figure A6 contrasts our baseline nonlinear impulse responses (produced by considering high/low inflation states determined on the basis of the inflation rate) with the alternative ones obtained by dating the inflation cycle on the basis of trend inflation realizations. The two sets of impulse responses are very similar, suggesting that our results can be interpreted as due to high vs. low trend inflation.

Appendix F: Inflation uncertainty multiplier: Drivers

It is of interest to verify how powerful the inflation uncertainty amplifier – operating through price dispersion – is in shaping the dynamic response of the system to an uncertainty shock. Figure A7 the new Keynesian model-based baseline responses (left column) along with those obtained with

[43] We set the smoothing parameter of the filter $\lambda = 129,600$ as suggested by Ravn and Uhlig (2002).

[44] We treat trend inflation as exogenous to an uncertainty shock in computing the impulse responses. The argument for doing so is that trend inflation reflects a low-frequency component in inflation that is unlikely to be importantly affected by uncertainty shocks in the short-run.

the same model by alternatively: (i) switching off price stickiness (central column); (ii) setting to zero demand elasticity (right column). Evidently, an uncertainty shock exerts modest-to-zero effects when prices are flexible or demand is inelastic in our simple model. The first case relates to the fact that an RCB version of our model would not be able to replicate the facts (in part due to households' preferences, which are not Epstein-Zin), the intuition being that firms able to reoptimize every period do not sufficiently "fear" uncertainty about future marginal costs because they can optimally adjust their prices in each given period to align their markups to the desired ones. The case of inelastic demand is associated with a symmetric profit function. In this case, firms see as equally costly to set too low/high a price relative to their competitors. Hence, uncertainty does not affect their pricing decisions. As shown by Fernández-Villaverde, Guerrón-Quintana, Kuester, and Rubio-Ramírez (2015), as demand become elastic, the profit function becomes asymmetric due to the fact that the marginal period profits are strictly convex in the relative price of firms' product. In this case, it is indeed more costly for a firm to set too low a price relative to its competitors than too high a price. Hence, firms upward bias their prices.

Overall, the findings in Figure A7 show that the amplification of the effects of uncertainty shocks when trend inflation is high passes through a stronger upward nominal price bias channel and a stronger response of price dispersion.

Appendix G: Price stickiness and trend inflation

In our paper, we assumed a fixed Calvo parameter when moving from a trend inflation regime to another. Is the assumption of a constant probability of price re-optimization across different scenarios characterized by different levels of trend inflation a safe one? A recent paper by L'Hullier and Schoenle (2022) empirically documents a negative linear relationship between the frequency of price adjustments and trend inflation in US data. Their baseline estimate indicates that a 1% increase in the inflation target is associated with an increase in the average monthly frequency of price changes in a given year by 0.98% (i.e., $\beta_{\bar{\pi}} = 0.98$, where $\beta_{\bar{\pi}}$ is the coefficient attached to trend inflation).[45] Exploiting such an estimated relationship, we re-calibrate the Calvo parameter (θ) to admit for higher price flexibility in high trend inflation environments. L'Huillier and Schoenle's (2022) estimates imply $\theta = 0.79$ when $\bar{\pi} = 0\%$, $\theta = 0.74$ when $\bar{\pi} = 2\%$, and $\theta = 0.65$ when $\bar{\pi} = 6\%$. Figure A8 documents the implied impulse responses. Notably, the overall picture is robust to the case of more flexible prices in the presence of high trend inflation.

[45] Importantly, this relationship is stronger than the one estimated by Nakamura and Steinsson (2008) corresponding to $\beta_{\bar{\pi}} = 0.5$. The latter value is used by Coibion, Gorodnichenko, and Wieland (2012) to adjust the Calvo parameter according to trend inflation, similarly to our exercise in this Section.

Appendix H: Cost-push shock vs. uncertainty shock: Role of policy

Our paper shows that a more aggressive monetary policy works in favor of stabilizing both output and inflation, i.e., the uncertainty shock does not imply an inflation-output volatility trade-off. This is true in spite of the fact that such a shock looks like a supply shock, in that it moves inflation and output in opposite directions. However, in our model, the crucial amplification mechanism of uncertainty shocks under high trend inflation is price dispersion: the higher the level of trend inflation is, the greater firms' upward price bias will be, and the larger price dispersion will also be, with negative consequences on aggregate demand. This propagation channel can be affected by a more aggressive systematic monetary policy, which dampens price dispersion by mitigating firms' upward price bias -since inflation expectations are more firmly anchored around the target - and therefore leads to more stable output and inflation.

Does this mean that this model does not feature any policy trade-off? The answer is negative. While the second-moment uncertainty shock we analyze in this paper does not imply a policy trade-off, first-moment supply-side shocks do. Figure A9 contrasts the impulse responses to the (already documented) uncertainty shock (first four rows in the left column) with those of a first-moment markup shock, i.e., a shock to the elasticity of substitution among goods as in e.g. Smets and Wouters (2007) and Ireland (2007) (right column). The size of the mark-up shock is calibrated to replicate the peak effect on output induced by the uncertainty shock. We focus on a 2% trend inflation case (the reference target for many central banks in industrialized countries) to make our point. The dashed-blue lines point to similar responses of output, inflation, and the policy rate to both shocks. However, and crucially, price dispersion responds very little to the cost-push shock. Indeed, the reason why this inflationary shock is also recessionary is not mainly related to price dispersion. Instead, it is due to the systematic policy response to inflation, which opens a recession to exert downward pressures on inflation. Hence, when shifting to a more aggressive systematic monetary policy (a more "hawkish" one designed to contain inflation fluctuations), conditional on the same cost-push shock the system will experience a milder inflation cycle at the cost of a more severe output cycle. In other words: given that the systematic policy response has to handle the trade-off, a more aggressive policy response to inflation will buy a less volatile inflation rate at the cost of a more volatile output. Differently, this trade-off is not present when dealing with an uncertainty shock, because in this case a more aggressive policy dampens price dispersion, therefore affecting the crucial mechanism that generates both inflation and output volatilities.

The last three rows of Figure A9 also show the impulse responses of the potential level of output (i.e., the "natural" output level that would prevail in a flexible price world), the output gap, and the average markup that would prevail under flexible prices. In response to an uncertainty shock, the potential output is not affected in this economy. Indeed the upward price bias channel does not affect firms' markup under flexible prices (because the firms can change their prices flexibly and hence are not subject to future inflation uncertainty).[46] Therefore, the output gap is negative because of the output drop. Instead, in response to an adverse markup shock, potential output decreases because of the increase of the firms' markup as a direct consequence of the shock, which increases the firms' desired markup. In the presence of sticky prices, there are two channels that can affect output after a markup shock: on the one hand, firms cannot adjust immediately their markups to reflect their desired markup, and, on the other hand, systematic monetary policy can affect real activity via the aggressiveness of its response to inflation. The interplay of these two channels implies that with a more dovish central bank, output decreases, but not as sharply as it would under flexible prices, resulting in a positive output gap. On the other hand, with a more hawkish central bank, output decreases more than potential output, leading to a negative output gap.

Appendix I: Upward pricing bias in a two-period firm's model in the presence of trend inflation and price stickiness

In the paper we argue that the higher trend inflation, the higher the upward price bias in today's firms' price decision due to precautionary pricing behavior. Here we consider a simple two-period partial equilibrium model to study the optimal pricing decision of a monopolistically-competive firm having to set a price for two periods. We show that, under future inflation risk, the higher the level of trend inflation the higher the optimal upward-price bias that the firm will optimally choose to adopt, i.e., the higher will be the firm's optimal price under uncertainty with respect to the one under certainty. This implies that an uncertainty shock implies a stronger impulse response of the firm's optimal price the higher the level of trend inflation. As we show later, the model we use here implies a first-order condition for the firm's optimal pricing decision that is a simplified version of the one in the paper. Hence, we use this simple model to build intution on the reasons why the upward-pricing bias channel gets amplified in the presence of trend inflation.

Consider the following problem of the representative firm, which generalizes the problem considered in Fernández-Villaverde, Guerrón-Quintana, Kuester, and Rubio-Ramírez (2015) and Born and Pfeifer (2021) to the case of two periods under Taylor-type pricing frictions (to make

[46] In our economy we do not have capital (i.e., $C_t = Y_t$), and hence, under flexible prices, since output is supply-determined, precautionary savings do not affect the "natural" level of output. Basu and Bundick (2017) show that in a medium-scale model with capital, under flexible prices, the drop in consumption due to precautionary savings increases labor supply, which in turn increases the "natural" level of output.

the mechanism as transparent as possible). Consider a firm living for two periods, today (t) and tomorrow ($t+1$), subject to the assumption that the firm sets its price today but cannot re-set its price in the next period. Suppose also, without loss of generality, that the firm is initially in steady state with steady state (net) inflation rate π when an *ex-ante* mean-preserving spread (uncertainty) shock regarding tomorrow aggregate price level realizes (today's aggregate price level P_t is assumed certain). Given the price rigidities considered, the firm sets today – i.e., before tomorrow's uncertainty is resolved – the fixed price holding for the two periods. For simplicity, assume two equally-likely states of the world in $t+1$, so that the firm expects an aggregate price of either $P_{t+1} = (1+\pi) P_t + \sigma$ or $P_{t+1} = (1+\pi) P_t - \sigma$ with 50% probability each, where σ denotes the standard deviation of the realizations of tomorrow's price level, or $\sigma = \sqrt{\mathbb{V}ar_t (P_{t+1})}$. We have that $\mathbb{E}_t(P_{t+1}) = (1+\pi) P_t$. Under the usual Dixit–Stiglitz-type demand function, real firm's profits of period t are given by $\Gamma_t = \left(\frac{P_t(i)}{P_t} - MC(i)\right)\left(\frac{P_t(i)}{P_t}\right)^{-\theta_\mu} Y$, where $MC(i)$ denotes the firm's real marginal costs, Y denotes real aggregate output, and $\theta_\mu > 1$ is the price elasticity of demand. We further assume that there is neither growth nor other shocks affecting real quantities, meaning that $MC_t(i) = MC_{t+1}(i) = MC(i)$ and $Y_t = Y_{t+1} = Y$. Hence, we only focus on uncertainty over the price level because it is the only variable with respect to which the profit function is asymmetric, and hence it is the only variable for which future uncertainty matters. For simplicity, we also assume that the firm discounts future profits with the discount rate β. Hence, to determine the optimal price for the two periods, $P^*(i) = P_t(i) = P_{t+1}(i)$, the firm solves the following intertemporal problem:

$$
\begin{aligned}
Max_{P^*(i)} \quad & \left(\frac{P^*(i)}{P_t}\right)^{1-\theta_\mu} Y - MC(i)\left(\frac{P^*(i)}{P_t}\right)^{-\theta_\mu} Y + \\
+\beta & \left\{ \begin{array}{c} 0.5\left[\left(\frac{P^*(i)}{(1+\pi)P_t+\sigma}\right)^{1-\theta_\mu} Y - MC(i)\left(\frac{P^*(i)}{(1+\pi)P_t+\sigma}\right)^{-\theta_\mu} Y\right] + \\ 0.5\left[\left(\frac{P^*(i)}{(1+\pi)P_t-\sigma}\right)^{1-\theta_\mu} Y - MC(i)\left(\frac{P^*(i)}{(1+\pi)P_t-\sigma}\right)^{-\theta_\mu} Y\right] \end{array} \right\},
\end{aligned}
$$

The firm's optimality condition for $P^*(i)$ is:

$$
\begin{aligned}
&(1-\theta_\mu)\left(P^*(i)\right)^{-\theta_\mu}\left[\frac{1}{P_t}\right]^{-\theta_\mu+1} Y + MC(i)\cdot\theta_\mu\left(P^*(i)\right)^{-\theta_\mu-1}\left[\frac{1}{P_t}\right]^{-\theta_\mu} Y + \\
&+\beta 0.5\left[\begin{array}{c}(1-\theta_\mu)\left(P^*(i)\right)^{-\theta_\mu}\left(\frac{1}{(1+\pi)P_t+\sigma}\right)^{-\theta_\mu}\frac{Y}{(1+\pi)P_t+\sigma} \\ +MC(i)\theta_\mu\left(P^*(i)\right)^{-\theta_\mu-1}\left(\frac{1}{(1+\pi)P_t+\sigma}\right)^{-\theta_\mu-1}\frac{Y}{(1+\pi)P_t+\sigma}\end{array}\right]+ \\
&+\beta 0.5\left[\begin{array}{c}(1-\theta_\mu)\left(P^*(i)\right)^{-\theta_\mu}\left(\frac{1}{(1+\pi)P_t-\sigma}\right)^{-\theta_\mu}\frac{Y}{(1+\pi)P_t-\sigma} \\ +MC(i)\theta_\mu\left(P^*(i)\right)^{-\theta_\mu-1}\left(\frac{1}{(1+\pi)P_t-\sigma}\right)^{-\theta_\mu-1}\frac{Y}{(1+\pi)P_t-\sigma}\end{array}\right] \\
= \; & 0
\end{aligned}
$$

which implies:

$$
P^*(i) = \frac{\theta_\mu}{\theta_\mu - 1}\frac{\left[Y\cdot(P_t)^{\theta_\mu}\cdot MC(i) + \beta\cdot\mathbb{E}_t\left(Y\cdot((1+\pi)P_t)^{\theta_\mu}\cdot MC(i)\right)\right]}{\left[Y\cdot(P_t)^{\theta_\mu-1} + \beta\cdot\mathbb{E}_t\left(Y\cdot((1+\pi)P_t)^{\theta_\mu-1}\right)\right]}
$$

This equation for the optimal price is nested to the one for the optimal price with Calvo-type pricing frictions obtained in Ascari and Sbordone (eqt. 14). In particular, the Ascari-Sbordone's one collapses to the one here when there are only two periods and the Calvo probability of not being able to reset price is equal to 1.[47] This confirms the fact that this stylized two-period model is a good framework where to build intuitions on the mechanism in the full model.

We now first analyze analytically the optimal firm's pricing decision in the absence of uncertainty and then solve the general problem with uncertainty numerically.

Optimal firm's pricing behavior under no uncertainty

Two cases:

[47] To obtain equation 14 in Ascari and Sbordone (2014), it is enough to divide left and right-hand sides by P_t, so that the equation refers to the optimal *relative* price. Notice that under our simplifying assumptions output and marginal costs are assumed constant (something that Ascari and Sbordone assume in their eqt. 15). Notice that the equation in the text can be re-written as:

$$
P^*(i) = \frac{\theta_\mu}{\theta_\mu-1}\frac{\mathbb{E}_t\sum_{j=0}^{1}\left(\beta(1+\pi)^{\theta_\mu}\right)^j P_t MC(i)}{\mathbb{E}_t\sum_{j=0}^{1}\left(\beta(1+\pi)^{\theta_\mu-1}\right)^j},
$$

i.e., the firm charges a constant markup over future expected marginal costs. The presence of trend inflation makes firms more forward-looking as the weight attached to future marginal costs increases.

- If no trend inflation ($\pi = 0$) and no uncertainty ($\sigma = 0$):

$$
\begin{aligned}
P^*(i) &= \frac{\theta_\mu}{\theta_\mu - 1} \frac{(P_t)^{\theta_\mu} \left(MC(i) + \beta \cdot MC(i) \right)}{(P_t)^{\theta_\mu - 1} (1+\beta)} \\
&= \frac{\theta_\mu}{\theta_\mu - 1} \frac{(P_t)^{\theta_\mu} (1+\beta) MC(i)}{(P_t)^{\theta_\mu - 1} (1+\beta)} = \frac{\theta_\mu}{\theta_\mu - 1} P_t MC(i)
\end{aligned}
$$

This is the standard result that monopolistically-competitive firms will set the price with a constant markup over nominal marginal costs. This implies that the optimal relative price is equal to one in steady state (where $MC(i) = MC = (\theta_\mu - 1)/\theta_\mu$), i.e., both the relative prices today and tomorrow will be $P^*(i)/P_t = 1$. This is equivalent to the firm's optimal price decision in a flexible price setting.

- If no uncertainty ($\sigma = 0$) and trend inflation ($\pi > 0$) :

$$
\begin{aligned}
P^*(i) &= \frac{\theta_\mu}{\theta_\mu - 1} \frac{(P_t)^{\theta_\mu} \left(MC(i) + \beta (1+\pi)^{\theta_\mu} \cdot MC(i) \right)}{\left[(P_t)^{\theta_\mu - 1} \left(1 + \beta (1+\pi)^{\theta_\mu - 1} \right) \right]} \\
&= \frac{\theta_\mu}{\theta_\mu - 1} \left(\frac{1 + \beta (1+\pi)^{\theta_\mu}}{1 + \beta (1+\pi)^{\theta_\mu - 1}} \right) P_t MC(i)
\end{aligned}
$$

which nests the previous case when $\pi = 0$. The latter equation is identical to equation 15 in Ascari and Sbordone (2014) when there are only two periods and the Calvo probability of not being able to reset price is equal to 1.[48]

  - If $\theta_\mu \to 1^+$(i.e., the profit function is not asymmetric as the demand is inelastic to the firm's price), then:

$$
P^*(i) = \frac{\theta_\mu}{\theta_\mu - 1} \left(\frac{1 + \beta (1+\pi)}{1+\beta} \right) P_t MC(i)
$$

  and if $\beta = 1$ (so that the future counts as the present)

$$
P^*(i) = \frac{\theta_\mu}{\theta_\mu - 1} \left(1 + \frac{\pi}{2} \right) P_t MC(i),
$$

  i.e., the firm will optimally choose a price that is halfway between today's and tomorrow's aggregate price level. Today's relative price in steady state will be $\frac{\pi}{2}$ percent

[48] Differently than Ascari and Sbordone (2014), for us π denotes net (and not gross) steady-state inflation.

higher than what would be with flexible prices (i.e., $P^*(i) = P_t$) and tomorrow's relative price will be $-\frac{\pi}{2}$ percent lower than the optimal price with flexible prices (i.e., $P^*(i) = (1+\pi)\,P_t$). Since the profit function is perfectly symmetric the firm shares equally the losses due to price-rigidities between the two periods. The losses are due to not being able to set the best price in both periods as prices are fixed and there is trend inflation.

– If $\theta_\mu > 1$, since the profit function is asymmetric, and the firm needs to select a price that holds for the two periods, the firm will choose to increase today's price by more than half the future inflation, i.e., $P^*(i) > \frac{\theta_\mu}{\theta_\mu - 1}\left(1+\frac{\pi}{2}\right) P_t MC(i)$, even in the absence of uncertainty. To see this we will consider the limit, i.e., the case of infinite price elasticity of demand.

– If $\theta_\mu \to \infty$ (perfectly elastic demand), then $\left(\frac{1+\beta(1+\pi)^{\theta_\mu}}{1+\beta(1+\pi)^{\theta_\mu - 1}}\right) \to (1+\pi)$, i.e., the firm will optimally choose to fully anticipate the future increase in prices, i.e., it will choose to charge a constant markup over future nominal marginal costs:

$$P^*(i) = \frac{\theta_\mu}{\theta_\mu - 1}\,(1+\pi)\,P_t MC(i),$$

i.e., today's relative price will be $P^*(i)/P_t = 1{+}\pi$, whereas the relative price tomorrow $P^*(i)/P_{t+1} = P^*(i)/\left((1+\pi)P_t\right) = 1$. This is consistent with the fact that the profit function is extremely asymmetric: it is better to set a too high price today rather than a too low tomorrow. Hence, as explained in Ascari and Sbordone (2014), trend inflation introduces more forward-lookingness in firms' decisions.

Optimal firm's pricing behavior in the presence of uncertainty

To solve the previous firm's problem we use the following parameters: $\beta = 0.99$, $\theta_\mu = 6$ (implying a 20% markup), $P_t = 1$ (without loss of generality, so that to read our results in terms of the optimal *relative* price, $P^*(i)/P_t$), and, for simplicity, $Y = 1$, and steady-state marginal costs $MC(i) = MC = (\theta_\mu - 1)/\theta_\mu$.

Figure A10 plots the firm's expected profit function and optimal price $P^*(i)$ – i.e., the function maximum – for both the cases of certainty ($\sigma = 0$) and uncertainty ($\sigma = 0.2$) over tomorrow's aggregate price, and for the cases of no trend inflation ($\pi = 0$, left panel) or high trend inflation ($\pi = 6\%$, right panel). Several conclusions can be drawn. First, and as already known from the uncertainty literature (Fernández-Villaverde, Guerrón-Quintana, Kuester, and Rubio-Ramírez (2015) and Born and Pfeifer (2021)), in the absence of trend inflation future inflation risk imply that firms optimally upward-bias their price. This occurs because the profit function is asymmetric and because firms are stuck with the price they set today, hence they prefer to err on the right-hand side of the profit function, the side associated to lower losses from suboptimal price. Indeed, given the asymmetric profit function, for the firm is more costly to be stuck with a too low price with respect to a too high price. Second, and as already known from the trend inflation literature (e.g., Ascari and Sbordone (2014, equation 15)), trend inflation makes firms more forward-looking (even) in the absence of uncertainty. In particular, as also seen analytically earlier, the firm's optimal relative price today in a certain world anticipates future inflation (as shown earlier, more than a half so, again due to the asymmetric profit function).[49] Third, as we uncover in this paper, the presence of trend inflation amplifies the upward pricing bias channel in the presence of uncertainty. As the right panel of Figure A10 shows, also in this context the firm will upward bias its optimal price with respect to the optimal price in the absence of uncertainty, but it will do it by more with respect to a world without trend inflation (or in general, with respect to a situation with smaller trend inflation). For our parameterization, we find that the firm will upward bias its price by 8.94% in a world without trend inflation and by 9.66% ((1.1341 − 1.0342)/1.0342) in a world with trend inflation at 6%, i.e., the firm will increase its markup by more under trend inflation. Hence, in this partial equilibrium setting, a sudden increase in uncertainty will imply a higher impulse response of the firm's price and markup in a world with a higher degree of trend inflation. This happens because firms are more forward-looking in a trend inflation world. As explained in the paper, the higher the level of trend inflation, the more price-setting firms will fear eroding their markups in case they remain stuck with a price in a more volatile environment, something implying that firms will optimally set an even higher price after an uncertainty shock relative to a situation with lower trend inflation.

Appendix J: Calibration of the DSGE model by Ascari and Sbordone (2004)

The small-scale New Keynesian DSGE model à la Ascari and Sbordone (2014) that we employ is calibrated as in Table A2. We calibrate all common parameters as in Ascari and Sbordone (2014) and calibrate $\rho_A = 0.95$, $\sigma_{ss} = ln(0.007)$, $\rho_\sigma = 0.75$, and $\sigma_\sigma = 0.693$ such that a one-standard-deviation uncertainty shock doubles the level of steady-state volatility similarly

[49] As it can be seen from Figure A10, for our parameterization the firm chooses $P^*(i) = 1.034$ in the presence of a trend inflation rate $\pi = 6$ and no uncertainty.

to Fernández-Villaverde and Guerrón-Quintana (2020). We set the systematic policy response to inflation to 1.75, that to output to 0.125, and we also assume an interest rate smoothing parameter of 0.65. These values are fairly in line with standard estimates of the Taylor rule (see e.g., Clarida, Galí, and Gertler (2000), Coibion and Gorodnichenko (2012)). We calibrate the rate of trend inflation to either 0%, 2%, or 6%. The first two values are also considered in Ascari and Sbordone (2014). The latter value is a reference for high inflation used by e.g. Coibion and Gorodnichenko (2011) and supported by the empirical analysis by Schorfheide (2005).

Appendix K: Medium-scale New-Keynesian DSGE model

In this Section, we show that in a medium-scale DSGE model with capital, our main results hold true and can be generalized, i.e.:

- both TFP and preference uncertainty shocks have stronger inflationary and recessionary effects under higher trend inflation in a Calvo-type setting;
- uncertainty shocks do not imply a trade-off for systematic monetary policy between stabilizing output and inflation.

We use a standard medium-scale Calvo-type New Keynesian DSGE model similar to Oh (2020), where the economy is composed by identical infinitely lived household, a continuum of identical competitive final goods firms, a continuum of monopolistically competitive intermediate good firms, and a monetary authority. We consider two uncertainty shocks, a TFP uncertainty shock as in our baseline model and a preference uncertainty shock as for example in Basu and Bundick (2017).

Model. *Households.* The representative household maximizes the lifetime utility:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t a_t \left(\frac{C_t^{1-\gamma}}{1-\gamma} - \chi \frac{N_t^{1+\eta}}{1+\eta} \right)$$

where $\mathbb{E}_0$ is the conditional expectation operator, C_t denotes consumption, and N_t labor supply. β is the household's subjective discount factor, γ is the coefficient of relative risk aversion, η measures the inverse elasticity of labor supply, and χ measures the degree of disutility from working. a_t is an exogenous preference shock that follows a stochastic volatility autoregressive process of order one:

$$\begin{aligned} \log a_t &= \rho_a \log a_{t-1} + \sigma_t^a \varepsilon_t^a \\ \log \sigma_t^a &= (1-\rho_{\sigma^a}) \log \sigma^a + \rho_{\sigma^a} \log \sigma_{t-1}^a + \sigma^{\sigma^a} \varepsilon_t^{\sigma^a} \end{aligned}$$

where $0 \leq \rho_a < 1, 0 \leq \rho_{\sigma^a} < 1$, $\varepsilon_t^a \sim N(0,1)$ is a first-moment shock, and $\varepsilon_t^{\sigma^a} \sim N(0,1)$ is a second-moment uncertainty shock that temporarily increases the volatility of future first-moment shocks over its steady state level σ^a.

The household's flow budget constraint is:

$$P_t C_t + P_t I_t + \frac{B_{t+1}}{R_t} = B_t + W_t N_t + R_t^k K_t - P_t T_t + P_t \Pi_t,$$

where P_t is the price level, I_t is investment, B_t is one-period nominal bonds holdings, R_t is the gross nominal interest rate, W_t is the nominal wage rate, R_t^k is the nominal rental rate of capital, K_t is the capital stock, T_t is a lump-sum tax, and Π_t is profit income.

The law of motion of the capital stock follows Christiano, Eichenbaum, and Evans (2005):

$$K_{t+1} = (1-\delta) K_t + \left(1 - \frac{\kappa}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2\right) I_t,$$

where δ is the depreciation rate and κ is a parameter controlling for the size of adjustment costs as the level of investment varies over time.

Final goods firms. The final good Y_t is produced by a perfectly competitive, representative firm. The firm produces the good by combining a continuum of intermediate goods, indexed by $i \in [0,1]$ using the technology:

$$Y_t = \left(\int_0^1 Y_t(i)^{\frac{\varepsilon-1}{\varepsilon}} di\right)^{\frac{\varepsilon}{\varepsilon-1}},$$

where $Y_t(i)$ is the quantity of intermediate good i used as an input and $1 \leq \varepsilon < \infty$ denotes the elasticity of substitution between intermediate goods. The profit maximization problem of the final good firm implies the following demand schedule for the intermediate good i:

$$Y_t(i) = \left(\frac{P_t(i)}{P_t}\right)^{-\varepsilon} Y_t, \tag{29}$$

where $P_t(i)$ is the price of intermediate good i. Finally, the zero profit condition implies that the price index is given by

$$P_t = \left(\int_0^1 P_t(i)^{1-\varepsilon} di\right)^{\frac{1}{1-\varepsilon}}. \tag{30}$$

Intermediate goods firms. The intermediate goods are produced by a continuum of monopolistically competitive firms, indexed by $i \in [0,1]$. Each firm produces its own differentiated good i using a Cobb-Douglas production function:

$$Y_t(i) = Z_t K_t(i)^\alpha N_t(i)^{1-\alpha} - \Phi,$$

where α denotes the capital income share and Φ denotes the fixed cost of production. Z_t is an exogenous productivity shock that follows a stationary, stochastic volatility AR(1) process:

$$\begin{aligned}\log Z_t &= \rho_Z \log Z_{t-1} + \sigma_t^Z \varepsilon_t^Z, \\ \log \sigma_t^Z &= (1-\rho_{\sigma^Z}) \log \sigma^Z + \rho_{\sigma^Z} \log \sigma_{t-1}^Z + \sigma^{\sigma^Z} \varepsilon_t^{\sigma^Z}\end{aligned}$$

where $0 \leq \rho_Z < 1$, $0 \leq \rho_{\sigma^Z} < 1$, $\varepsilon_t^Z \sim N(0,1)$ is a first-moment shock, and $\varepsilon_t^{\sigma^Z} \sim N(0,1)$ is a second-moment uncertainty shock that temporarily increases the volatility of future first-moment shocks over its steady state level σ^Z.

Profit maximization implies that all intermediate goods firms have the same capital to labor ratio and the same marginal cost:

$$\frac{K_t(i)}{N_t(i)} = \frac{\alpha}{1-\alpha} \frac{W_t}{R_t^k},$$

$$MC_t = \frac{1}{Z_t} \left(\frac{W_t}{1-\alpha} \right)^{1-\alpha} \left(\frac{R_t^k}{\alpha} \right)^{\alpha}.$$

Intermediate goods firms have market power and set prices to maximize their discounted profits. We assume that firms' prices are sticky due to nominal price rigidities à la Calvo (1983). In each period, an intermediate goods firm i keeps its previous price with probability θ and resets its price with probability $1-\theta$. The firm that gets the chance to set its price chooses its price $P_t^*(i)$ to maximize:

$$\max_{P_t^*(i)} \mathbb{E}_t \sum_{j=0}^{\infty} \theta^j \Lambda_{t,t+j} \left(\frac{P_t^*(i)}{P_{t+j}} - \frac{MC_{t+j}}{P_{t+j}} \right) Y_{t+j}(i),$$

subject to its demand in Equation 29, where $\Lambda_{t,t+j} \equiv \beta^j \frac{a_{t+j}}{a_t} \left(\frac{C_{t+j}}{C_t} \right)^{-\gamma}$ is the stochastic discount factor. The first-order condition is:

$$\mathbb{E}_t \sum_{j=0}^{\infty} \theta^j \Lambda_{t,t+j} \left((1-\varepsilon) \left(\frac{P_t^*(i)}{P_{t+j}} \right)^{1-\varepsilon} + \varepsilon \frac{MC_{t+j}}{P_{t+j}} \left(\frac{P_t^*(i)}{P_{t+j}} \right)^{-\varepsilon} \right) Y_{t+j} = 0,$$

from where it can be seen that the optimal reset price, $P_t^* = P_t^*(i)$, is the same for all firms resetting their prices in period t as all firms face the identical problem. The optimal reset price is:

$$P_t^* = \frac{\varepsilon}{\varepsilon - 1} \frac{\mathbb{E}_t \sum_{j=0}^{\infty} \theta^j \Lambda_{t,t+j} P_{t+j}^{\varepsilon} \frac{MC_{t+j}}{P_{t+j}} Y_{t+j}}{\mathbb{E}_t \sum_{j=0}^{\infty} \theta^j \Lambda_{t,t+j} P_{t+j}^{\varepsilon-1} Y_{t+j}}.$$

We can rewrite Equation 30 so that to have the dynamics of the aggregate price level:

$$P_t = \left((1-\theta) P_t^{*1-\varepsilon} + \theta P_{t-1}^{1-\varepsilon} \right)^{\frac{1}{1-\varepsilon}}.$$

Fiscal and monetary authority. The fiscal authority runs a balanced budget and raises lump-sum taxes, T_t, to finance government spending, G_t so that:

$$G_t = T_t.$$

Government spending follows a AR(1) process:

$$\log G_t = (1 - \rho_G) \log G + \rho_G \log G_{t-1} + \sigma^G \varepsilon_t^G,$$

where $0 \leq \rho_G < 1$ and $\varepsilon_t^G \sim N(0,1)$. G is the deterministic steady-state government spending.

The monetary authority sets the (gross) nominal interest rate R_t according to a conventional Taylor rule:

$$\log R_t = (1 - \rho_R) \log R + \rho_R \log R_{t-1} + (1 - \rho_R) \left(\phi_\pi \left(\log \pi_t - \log \pi\right) + \phi_Y \left(\log Y_t - \log Y\right)\right) + \sigma^R \varepsilon_t^R,$$

where $0 \leq \rho_R < 1$ and $\varepsilon_t^R \sim N(0,1)$. $\pi_t \equiv \frac{P_t}{P_{t-1}}$ is the gross inflation rate and π denotes trend inflation. Y and R denote the deterministic steady state values for output and the nominal interest rate, respectively.

Market clearing. In equilibrium aggregate output satisfies:

$$s_t Y_t = Z_t K_t^\alpha N_t^{1-\alpha} - \Phi,$$

where $K_t = \int K_t(i) di$ and $N_t = \int N_t(i) di$. $s_t \equiv \int \left(\frac{P_t^*(i)}{P_t}\right)^{-\varepsilon} di$ is the relatice price dispersion and can be written in the following recursive form:

$$s_t = (1 - \theta) \left(\frac{P_t^*(i)}{P_t}\right)^{-\varepsilon} + \theta \left(\frac{P_t}{P_{t-1}}\right)^{\varepsilon} s_{t-1}.$$

The equilibrium in the goods market is given by:

$$Y_t = C_t + I_t + G_t.$$

Parameterization and results. The model is parameterized to a quarterly frequency. Table A3 summarizes the values adopted for the model's parameters. We used the same values for the parameters shared with the small-scale DSGE model in the paper, and we used standard values for the other parameters. With respect to the paper, we used a coefficient of risk aversion $\gamma = 2$ rather than $\gamma = 1$ (log utility) to generalize our results to the use of a CARA utility function.[50]

To simulate the effects of uncertainty shocks, we work with a third-order pruned perturbations approximation around the deterministic steady state of the model as proposed in Andreasen,

[50] As in our baseline model, we parameterized a Frisch elasticity $\eta = 0$, which implies that we are conservative on the degree of amplification due to trend inflation.

Fernández-Villaverde, and Rubio-Ramírez (2018), and we compute GIRFs by using the authors' Dynare package (available on Martin Andreasen's personal webpage).[51]

Figures A11 and A12 show the macroeconomic effects of a TFP uncertainty shock and a preference uncertainty shock, respectively, for real GDP, the yearly inflation rate, and the annualized interest rate for two different levels of trend inflation, i.e., $\pi = 2$ and $\pi = 5$.[52] In line with the main results in the paper, the findings suggest that, in a standard Calvo-type New Keynesian framework, both TFP uncertainty shocks and preference uncertainty shocks are more recessionary and more inflationary under higher trend inflation.[53]

Figure A13 presents the findings from a policy counterfactual exercise similar to the one we have in the paper but conducted in the medium-scale model under consideration in this Section. The Figure compares the impulse response functions of real GDP and yearly inflation rate to either a TFP uncertainty shock (left column) or a preference uncertainty shock (right column) conditional to 2% and 5% trend inflation with the responses predicted by the same model in presence of: (i) 5% trend inflation; (ii) a more aggressive systematic monetary policy response to inflation characterized by the policy coefficient $\phi_\pi = 2.5$ (which is more "hawkish" with respect to the baseline $\phi_\pi = 1.75$ one). As shown in the Figure, and in line with the results in the paper, the real effects of an uncertainty shock implied by this more aggressive policy response in the presence of high-trend inflation are very similar to those triggered by the very same uncertainty shock in an environment where trend inflation is low and systematic monetary policy is more dovish. Hence, by being more "hawkish" the central bank can at the same time mitigate the depth of the economic contraction induced by the uncertainty shock and significantly reduce its

[51] Our computations are conducted with the Dynare software package, see https://www.dynare.org/manual/ .

[52] The model does not satisfy the Blanchard-Kahn determinacy condition for $\pi = 6$.

[53] Instead, trend inflation affects more negligibly the propagation of uncertainty shocks when modeling price rigidity with Rotemberg pricing. We verified this point by working with the equivalent version of our model with Calvo pricing replaced by Rotemberg pricing à la Ascari and Rossi (2012) and Oh (2020) with adjustment costs $\frac{\phi_P}{2}\left(\frac{P_t(i)}{P_{t-1}(i)} - 1\right)^2 Y_t$ and ϕ_P calibrated such that to have an equally sloped Phillips curve in the linearized version of the model. Under Rotemberg pricing, firms still display an upward pricing bias in response to an uncertainty shock (see Andreasen, Caggiano, Castelnuovo, and Pellegrino (2024)), but substantially milder than under Calvo pricing (see Oh (2020)). However, the degree of upward pricing bias – captured by firms' markup – is not significantly affected by trend inflation under Rotemberg because each intermediate good firm can adjust its price *every period* subject to some adjustment costs (rather than being stuck with a price for some time like under Calvo). To gain more intuition, we also verified that in the Basu and Bundick (2017) model, with Rotemberg adjustment costs $\frac{\phi_P}{2}\left(\frac{P_t(i)}{\pi P_{t-1}(i)} - 1\right)^2 Y_t$, trend inflation does not virtually affect the propagation of uncertainty shocks. Consider the latter adjustment costs and suppose there is trend inflation: intuitively, the single firm is not *more* concerned about future uncertainty in the presence of high trend inflation because she can always update her inflation rate according to trend inflation without paying extra adjustment costs. Hence, under trend inflation, firms do not fear their relative prices to get eroded quickly as under Calvo pricing because they are aware they can reoptimize with probability one when optimal. Consequently, the uncertainty-trend inflation amplification effect that is present under Calvo pricing does not materialize under Rotemberg pricing.

inflationary effects via the firms' upward pricing bias.

Shock	Source	Sample	Correlation (p-value)
OIL SUPPLY	Baumeister and Hamilton (2019)	1978m01-2019m12	-0.01 (0.88)
	Caldara, Cavallo, and Iacoviello (2019)	1987m01-2015m04	-0.07 (0.46)
	Guentner and Henssler (2021)	1973m01-2020m11	0.00 (0.91)
	Kaenzig (2021)	1975m01-2021m12	0.07 (0.10)
MONETARY	Romer and Romer (2004) updated	1969m03-2008m12	0.03 (0.48)
	Jarociński and Karadi (2020)	1990m02-2016m12	-0.02 (0.68)
	Miranda-Agrippino and Ricco (2021)	1991m01-2018m12	-0.05 (0.39)

Table A1: **Correlations between the nonlinear VAR uncertainty shocks and oil supply / monetary policy shocks in the literature.**The oil supply shocks series were retrieved from the authors websites. The shock series by Günther and Henßler (2021) extends the one by Kilian (2008). Jarocinski and Karadi's (2020) monetary policy shocks were collected from the supplementary material of their paper. The updated series for the Romer and Romer (2004) monetary policy shocks was downloaded from Olivier Coibion's website. The sample used depends on the availability of the shocks series.

Par.	Description	Value	Source
β	Discount factor	0.99	Ascari and Sbordone (2014)
φ	Frisch elasticity	0	Ascari and Sbordone (2014)
θ	Calvo parameter	0.75	Ascari and Sbordone (2014)
σ	Risk aversion	1	Ascari and Sbordone (2014)
ε	Elasticity of substitution	10	Ascari and Sbordone (2014)
$\bar{\pi}$	Gross quarterly steady state inflation	$(1 + trend\_inflation/100)^{1/4}$	This paper
ϕ_π	Taylor rule: inflation coefficient	1.75	This paper
ϕ_Y	Taylor rule: output coefficient	0.125	Ascari and Sbordone (2014)
ρ_i	Taylor rule: int. rate smoothing parameter	0.65	This paper
d_n	Labor disutility parameter	Cal. to fix labor to 1/3 in s.s.	Ascari and Sbordone (2014)
ρ_A	TFP proc.: persist. of the 1^{st}-moment shock	0.95	Ascari and Sbordone (2014)
σ_{ss}	TFP proc.: steady steady volatility	$ln(0.007)$	This paper
ρ_σ	TFP proc.: persist. of the 2^{nd}-moment shock	0.75	This paper
σ_σ	TFP proc.: std. of the 2^{nd}-moment shock	0.693	This paper

Table A2: **Calibration of Ascari and Sbordone's (2014) small-scale DSGE model.** The Table reports the calibrated values of the parameters of the small-scale New Keynesian DSGE model.

Par.	Description	Value	Source
β	Discount factor	0.99	Ascari and Sbordone (2014)
η	Frisch elasticity	0	Ascari and Sbordone (2014)
θ	Calvo parameter	0.75	Ascari and Sbordone (2014)
γ	Risk aversion	2	This paper
ε	Elasticity of substitution	10	Ascari and Sbordone (2014)
π	Gross quarterly steady state inflation	$(1 + trend\_inflation/100)^{1/4}$	This paper
ϕ_π	Taylor rule: inflation coefficient	1.75	This paper
ϕ_Y	Taylor rule: output coefficient	0.125	Ascari and Sbordone (2014)
ρ_R	Taylor rule: int. rate smoothing parameter	0.65	This paper
χ	Labor disutility parameter	Cal. to fix labor to 1/3 in s.s.	Ascari and Sbordone (2014)
α	Capital income share	0.33	This paper
δ	Capital depreciation rate	0.025	This paper
κ	Investment adjustment cost parameter	3	This paper
Φ	Production fixed cost	Insures $\Pi = 0$ in steady state	Oh (2020)
ρ_Z	TFP proc.: persist. of the 1^{st}-moment shock	0.95	Ascari and Sbordone (2014)
σ^Z	TFP proc.: steady steady volatility	0.01	This paper
ρ_{σ^z}	TFP proc.: persist. of the 2^{nd}-moment shock	0.75	This paper
σ_{σ^z}	TFP proc.: std. of the 2^{nd}-moment shock	0.75	This paper
ρ_a	Pref. proc.: persist. of the 1^{st}-moment shock	0.95	This paper
σ^a	Pref. proc.: steady steady volatility	0.01	This paper
ρ_{σ^a}	Pref. proc.: persist. of the 2^{nd}-moment shock	0.75	This paper
σ_{σ^a}	Pref. proc.: std. of the 2^{nd}-moment shock	0.75	This paper
σ^R	Mon. policy shock proc.: volatility	0.01	This paper
ρ_G	Fiscal policy shock proc.: persistence	0.95	This paper
σ^G	Fiscal policy shock proc.: volatility	0.01	This paper
G	Fiscal policy shock proc.: steady state gov. spending	so that $G/Y = 0.2$	This paper

Table A3: **Calibration of Oh's (2014) medium-scale DSGE model.** The Table reports the calibrated values of the parameters of the medium-scale New Keynesian DSGE model.

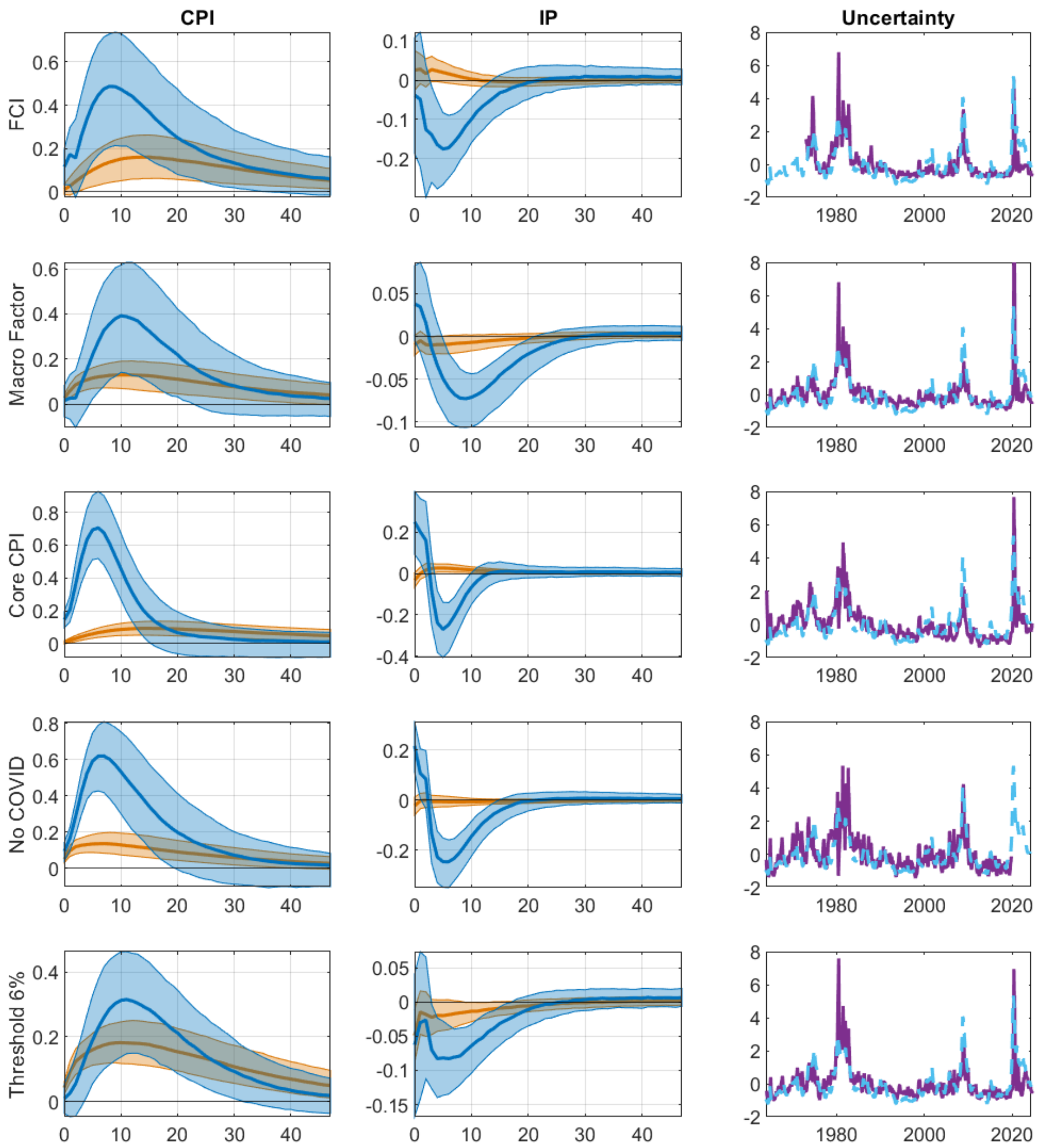

Figure A1: **Robustness Checks.** Impulse responses in the high and low inflation states for inflation (left column) and industrial production growth (central column) across differently specified VARs (described in the text and in the Appendix). Shaded areas: 68% credible sets. Estimated macroeconomic uncertainty proxies (baseline estimate – in dashed blue line – vs. alternative estimates conditional on our robustness checks – in solid purple line) plotted in the right column.

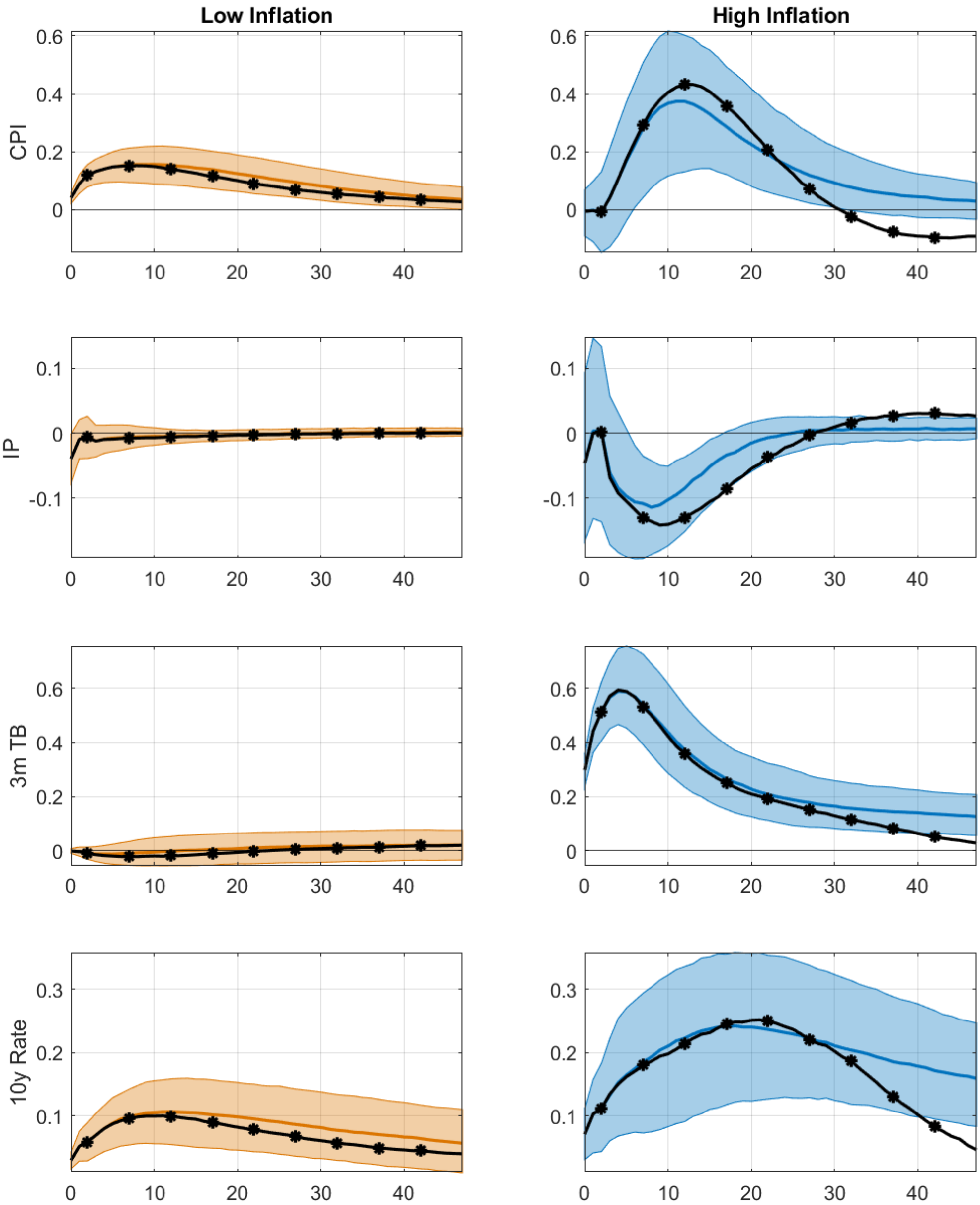

Figure A2: **No Regime Switch.** Baseline impulse responses in red and blue, median impulse response without endogenous regime switching in black stars. Shaded areas: 68% credible sets.

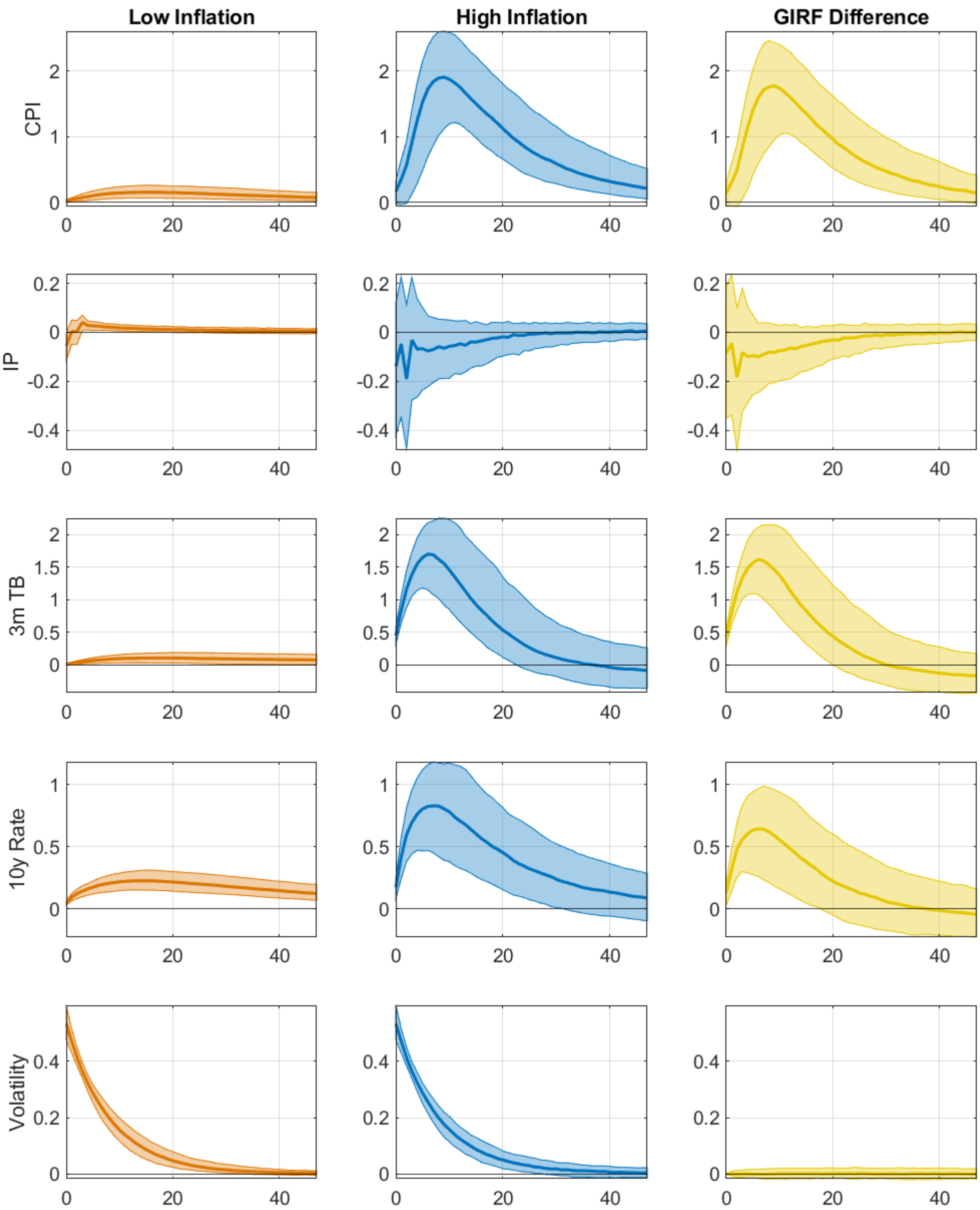

Figure A3: **UK data: GIRFs for the high and low inflation regimes.** Response to a one standard deviation shock to uncertainty in the low (first column) and high (second column) inflation regimes. Third column: Difference between the high inflation and the low inflation GIRFs. Solid lines: Posterior medians. Shaded areas: 68% credible sets.

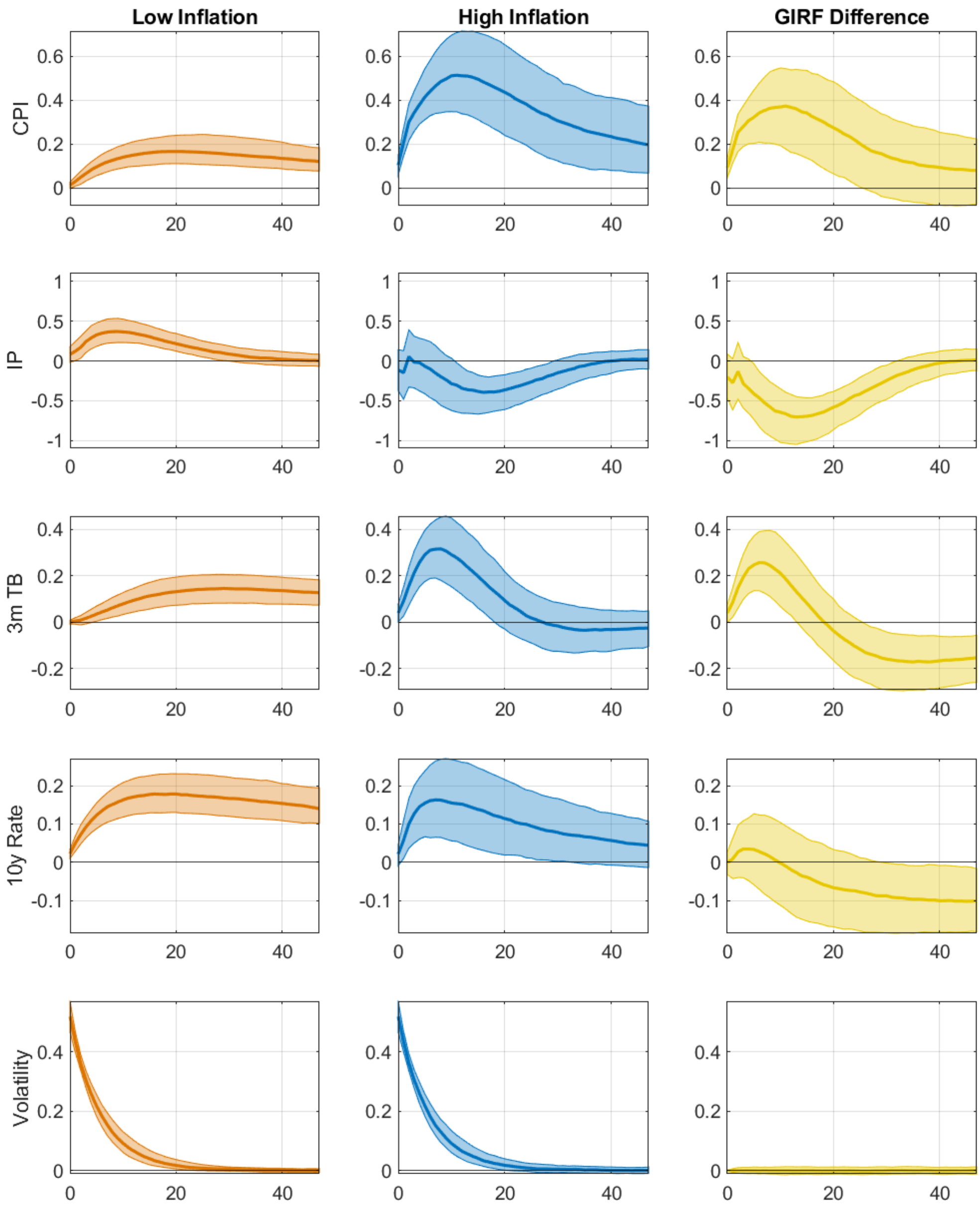

Figure A4: **Euro area data: GIRFs for the high and low inflation regimes.** Response to a one standard deviation shock to uncertainty in the low (first column) and high (second column) inflation regimes. Third column: Difference between the high inflation and the low inflation GIRFs. Solid lines: Posterior medians. Shaded areas: 68% credible sets.

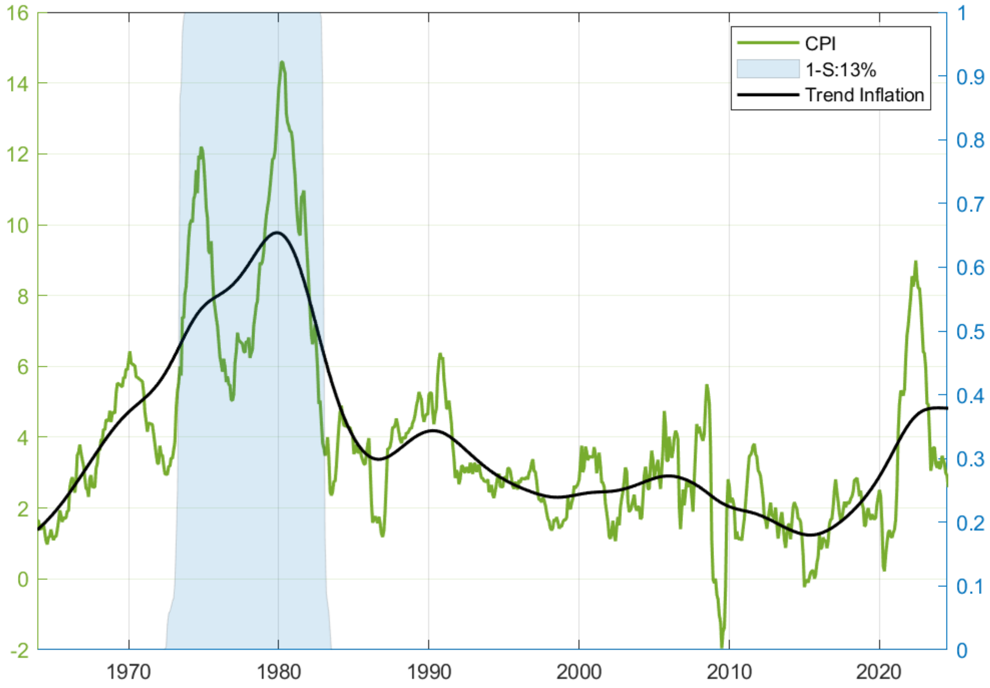

Figure A5: **High Trend Inflation regime.** Green line: year-over-year CPI inflation. Black line: trend inflation extrapolated with a HP filter ($\lambda = 129,600$). Shaded area: high inflation regime determined by trend inflation averaged over the retained Gibbs draws. The median estimated threshold is 6.49.

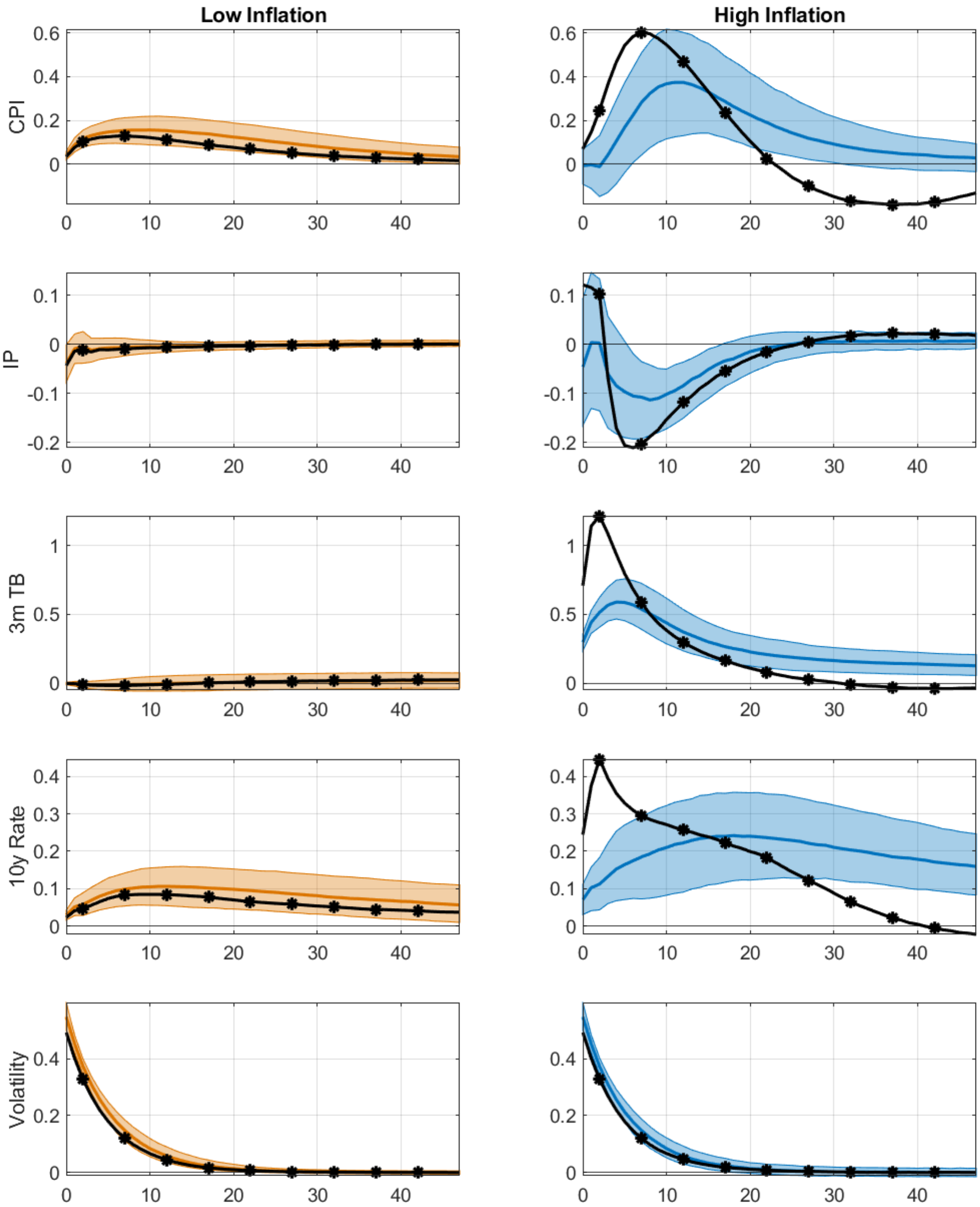

Figure A6: **GIRFs for the High vs. Low Trend inflation regimes.** Impulse responses to a one standard deviation uncertainty shock in the Low and High Inflation regimes for the baseline model (orange and blue, respectively) against the median impulse responses given by the High and Low Trend Inflation regime (black). Shaded area is the 68% baseline confidence band.

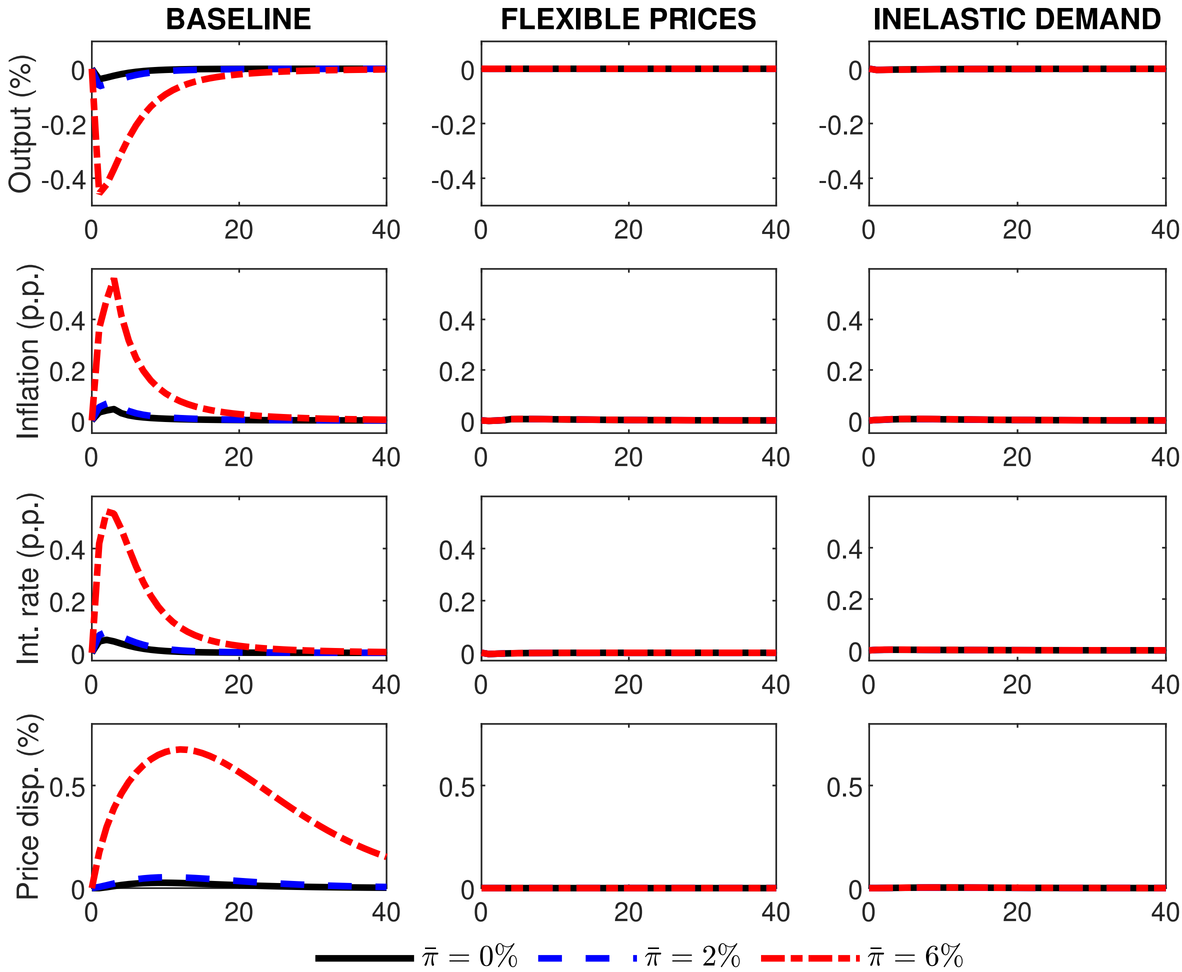

Figure A7: **IRFs to a second-moment TFP shock in the Ascari and Sbordone (2014) model for different levels of trend inflation.** Different calibrations of trend inflation indicated in the legend, where $\bar{\pi}$ stands for trend inflation. Baseline: Calvo probability of not being able to reset the price equal to 0.75 and elasticity of demand equal to 6 as in Ascari and Sbordone (2014).

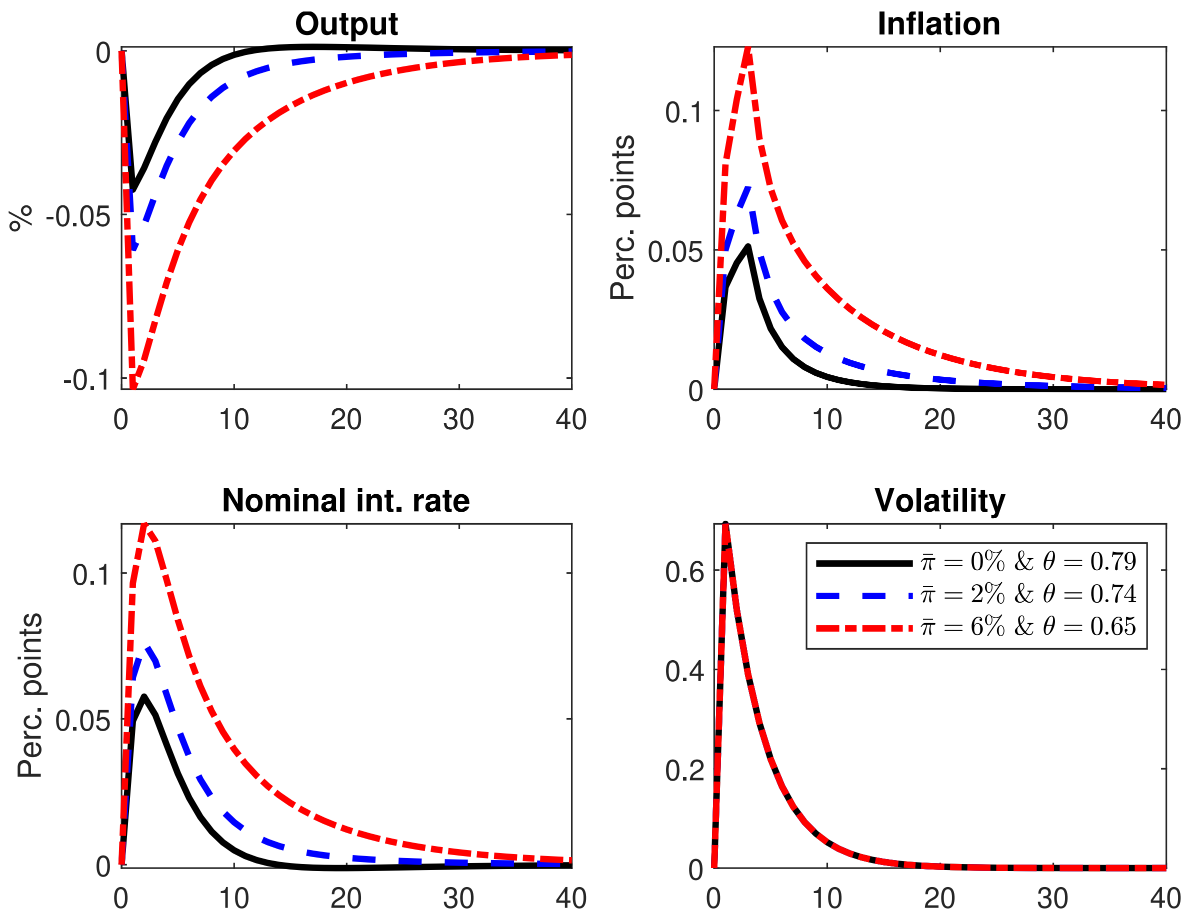

Figure A8: **IRFs to a second-moment TFP shock for different levels of trend inflation.** Different calibrations of trend inflation indicated in the legend, where $\bar{\pi}$ stands for trend inflation. The Calvo probability is a function of the level of trend inflation as in L'Hullier and Schoenle (2022).

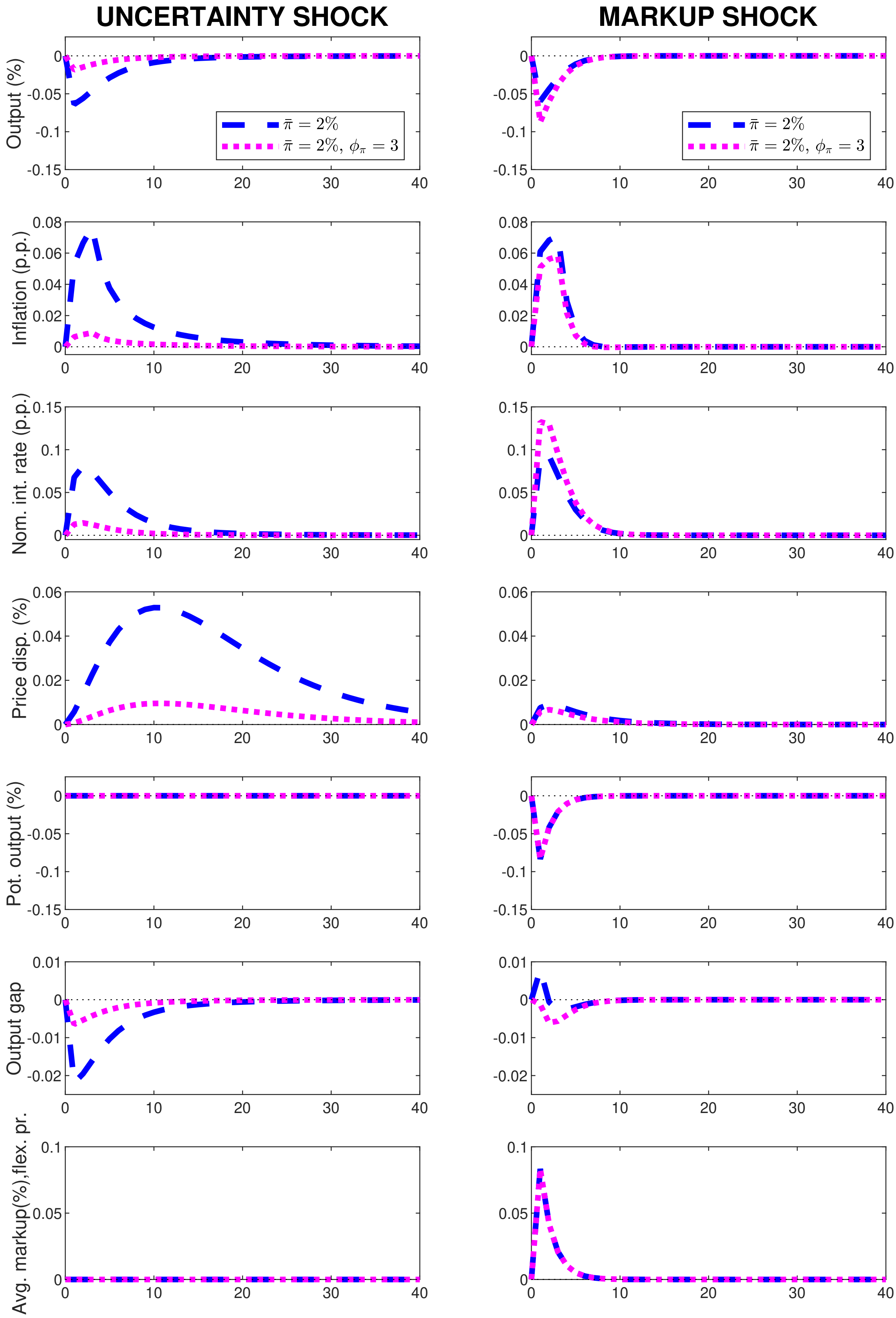

Figure A9: **IRFs to a second-moment TFP shock vs. a first-moment cost-push shock under different policy rules.** Different policy rules: Baseline one, coefficient of the systematic response to inflation: 1.75. Alternative one: 3.0.

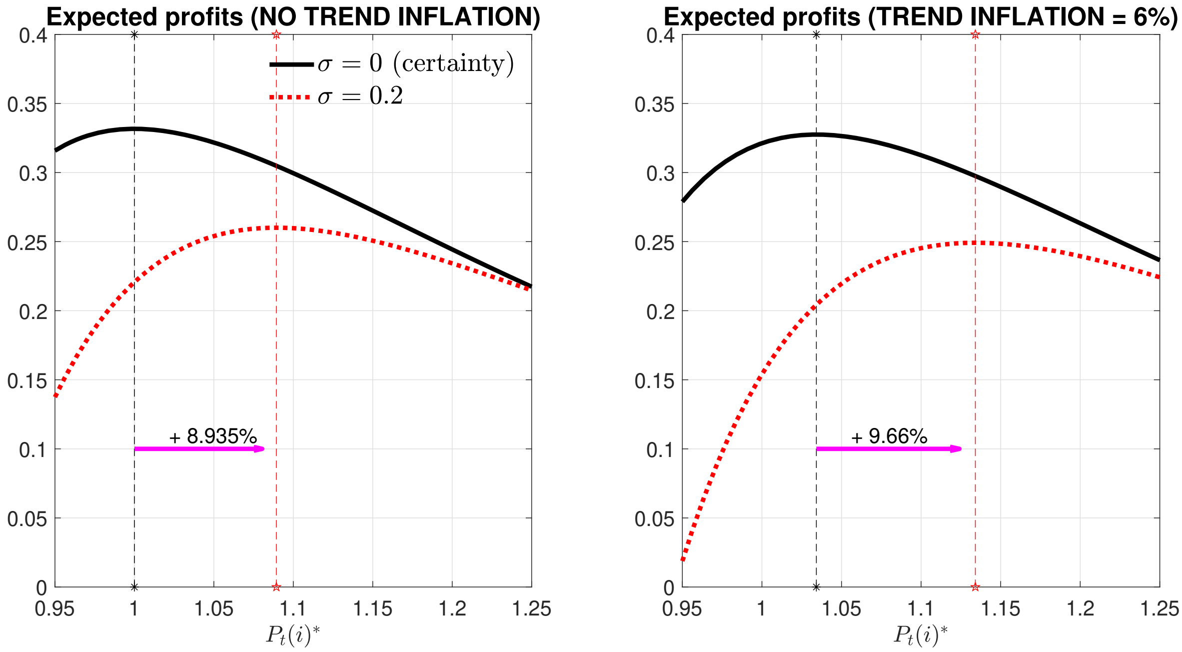

Figure A10: **Asymmetric profit function: Upward pricing bias under ex-ante uncertainty, price stickiness, and trend inflation.** This figure shows the solution of the firm's problem outlined in Section 4.2 of the paper for the parameters' values indicated in the same Section. It has been assumed $P_t = 1$, hence the results can be read in terms of the optimal *relative* price, P_i^*/P_t. The left panel plots the firm's biperiodal expected profit function and optimal price – i.e., the function maximum – in a situation of no trend inflation given Taylor-type price rigidities for both the cases of certainty ($\sigma = 0$) and uncertainty ($\sigma = 0.2$), Vertical lines represent optimal prices. The right panel plots the same objects for the case of trend inflation at 6%.

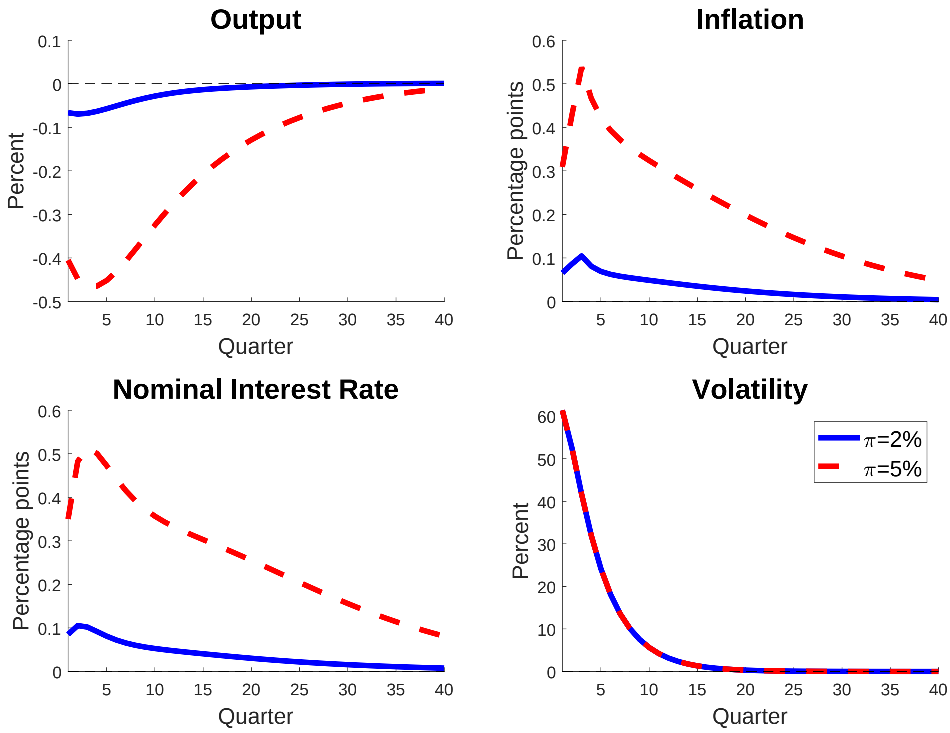

Figure A11: **IRFs to a second-moment TFP shock in the Oh's (2020) medium-scale New Keynesian DSGE model for different levels of trend inflation.** Different calibrations of trend inflation indicated in the legend, where "pi" stands for trend inflation. Calvo probability of not being able to reset the price equal to 0.75, as in Ascari and Sbordone (2014).

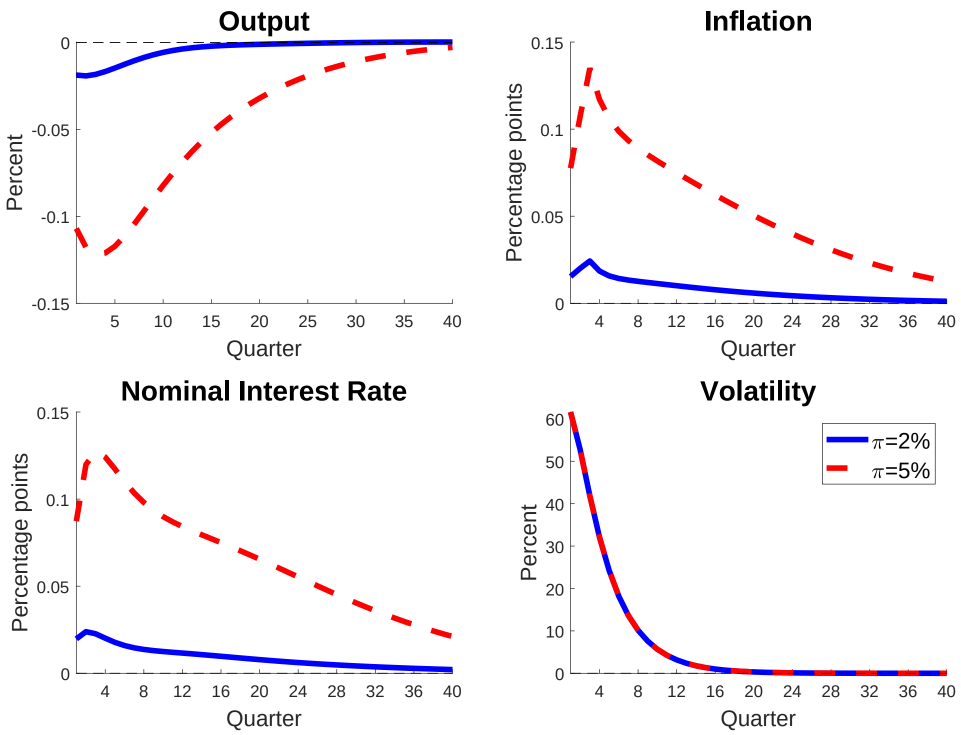

Figure A12: **IRFs to a second-moment preference shock in the Oh's (2020) medium-scale New Keynesian DSGE model for different levels of trend inflation.** Different calibrations of trend inflation indicated in the legend, where "pi" stands for trend inflation. Calvo probability of not being able to reset the price equal to 0.75, as in Ascari and Sbordone (2014).

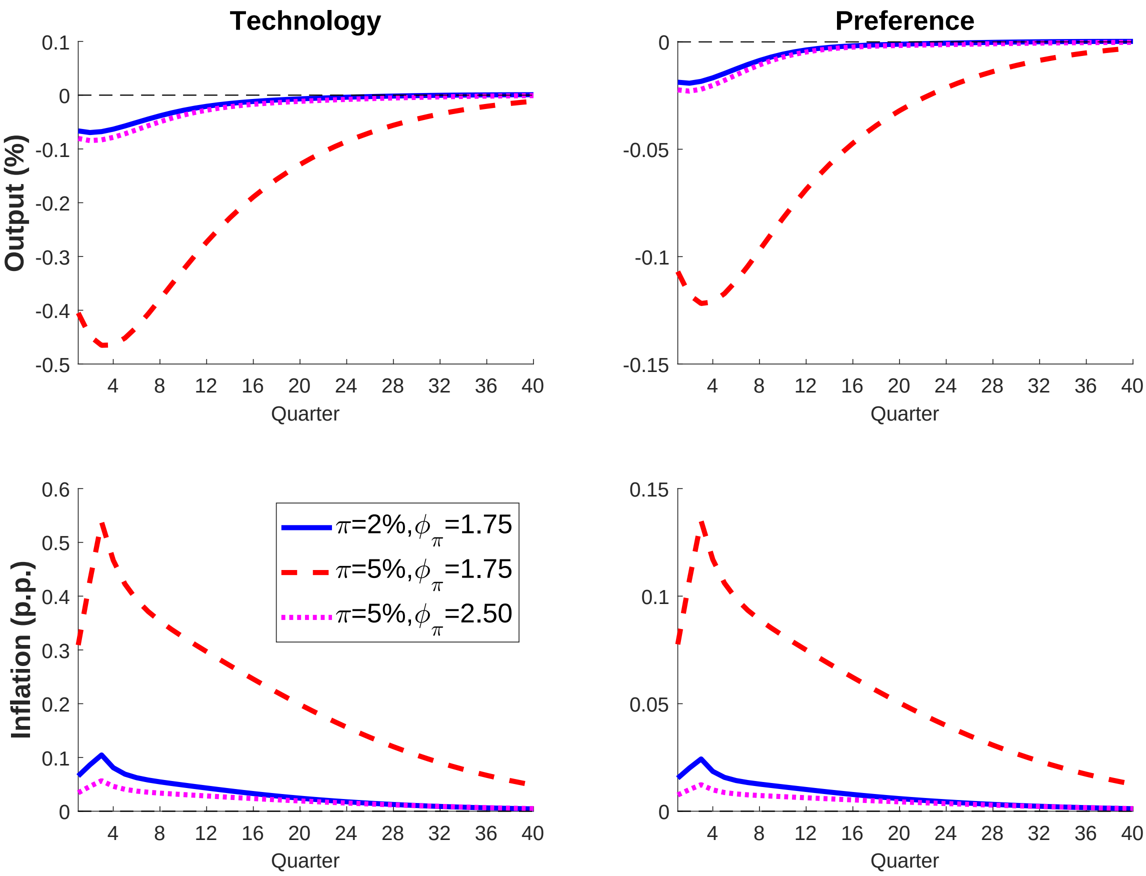

Figure A13: **Policy exercise in the medium-scale DSGE model: Role of "hawkish" monetary policy when trend inflation is high.** Left column: Technology uncertainty shock. Right column: Preference uncertainty shock. Different calibrations of trend inflation indicated in the legend, where "pi" stands for trend inflation. Calvo probability of not being able to reset the price equal to 0.75, as in Ascari and Sbordone (2014).