EUROPEAN CENTRAL BANK

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1 The views expressed herein are those of the authors and do not necessarily reflect those of the European Central Bank or the Eurosystem.

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Abstract

This paper quantifies the deterioration of achievable stabilization outcomes when monetary policy operates under imperfect credibility and weak anchoring of long-term expectations. Within a medium-scale DSGE model, we introduce through a simple signal extraction problem, an imperfect knowledge configuration where price and wage setters wrongly doubt about the determination of the central bank to leave unchanged its long-term inflation objective in the face of inflationary shocks. The magnitude of private sector learning has been calibrated to match the volatility of US inflation expectations at long horizons. Given such illustrative calibrations, we find that the costs of maintaining a given inflation volatility under weak credibility could amount to 0.25 pp of output gap standard deviation.

Keywords: Monetary policy; Imperfect credibility; Signal extraction.

JEL Classification: E4, E5, F4.

Non-Technical Summary

An abundant strand of literature has studied monetary policy stabilization under rational expectations and perfect central bank credibility. In this context, a monetary authority committed to deliver price stability can successfully steer expectations in the face of inflationary disturbances and achieve appropriate inflation volatility at reasonable output costs. However, a less extreme description of the macroeconomic landscape would have to account for imperfect credibility of the central bank: credibility is an asset which is built and preserved over time, and could for example be undermined by an adverse sequence of inflationary shocks which, taken individually, would not have required specific policy actions.

In this note, we intend to illustrate such a configuration within a medium-scale DSGE model for the US economy where price and wage setters question the determination of the monetary authority to deliver price stability in the face of cost-push shocks. More specifically, we specify an *ad hoc* filtering problem where price and wage setters do not observe the central bank's inflation target and the "true" inflationary shock separately.

This phenomenon would strongly amplify the transmission of the price shock, notably through stronger wage claims: monetary policy will face a higher sacrifice ratio in its attempt to bring down inflation volatility. The deterioration of achievable stabilization outcomes due to our imperfect credibility specification has some resemblance with the implications of backward indexation in price and wage settings.

1 Introduction

An abundant strand of literature, to which Woodford (2003) is the most representative contribution, has studied monetary policy stabilization under rational expectations and perfect central bank credibility. In this context, a monetary authority committed to deliver a given inflation rate over the medium term can successfully steer expectations in the face of inflationary disturbances and achieve appropriate inflation volatility at reasonable output costs. However, a less extreme description of the macroeconomic landscape would have to account for imperfect credibility of the central bank: credibility is an asset which is built and preserved over time, and could for example be undermined by an adverse sequence of inflationary shocks which, taken individually, would not have required specific policy actions. In this note, we intend to quantify the deterioration of achievable stabilization outcomes for monetary policy under imperfect credibility. To this aim, we use a medium-scale DSGE model, where firms and unions set price and wages according to their imperfect perception about the central bank's inflation target in the face of cost-push shocks.

2 Analytical framework

We make use of the medium-scale DSGE model presented in Smets and Wouters (2007) and rationalize some misperceptions by private agents on the inflation objective of the monetary authority through a stylized signal extraction problem when cost-push shocks hit the economy. We do not spell out here all the log-linearized equations of the model and refer to the previous paper for a full description of these relations.

2.1 Model

The core hypothesis of our analysis is that price and wage setters wrongly perceive a time varying inflation target, denoted $\bar{\pi}_t$. Here we thus present all the Smets and Wouters equations that are modified by this assumption. The linearized version of the price setting behavior is given by:

$$\pi_t = \pi_1 \pi_{t-1} + \pi_2 E_t \pi_{t+1} - \pi_3 \mu_t^p + \varepsilon_t^p + (1 - \pi_1 - \pi_2 \rho_\pi)\bar{\pi}_t \tag{1}$$

where $\pi_1 = \frac{\iota_p}{1+\beta\gamma^{(1-\sigma_c)}\iota_p}$, $\pi_2 = \frac{\beta\gamma^{(1-\sigma_c)}}{1+\beta\gamma^{(1-\sigma_c)}\iota_p}$ and $\pi_3 = \frac{1}{(1+(\phi_p-1)\varepsilon_p)} \frac{(1-\xi_p)(1-\beta\gamma^{(1-\sigma_c)}\xi_p)}{\xi_p(1+\beta\gamma^{(1-\sigma_c)}\iota_p)}$.

The real wage dynamics is governed by:

$$\begin{aligned} w_t = {} & w_1 w_{t-1} + (1 - w_1)(E_t w_{t+1} + E_t \pi_{t+1}) - w_2 \pi_t + w_3 \pi_{t-1} - w_4 \mu_t^w + \varepsilon_t^w \\ & + (w_2 - w_3 - (1 - w_1)\rho_\pi)\bar{\pi}_t \end{aligned} \tag{2}$$

where $w_1 = \frac{1}{1+\beta\gamma^{(1-\sigma_c)}}$, $w_2 = \frac{1+\beta\gamma^{(1-\sigma_c)}\iota_w}{1+\beta\gamma^{(1-\sigma_c)}}$, $w_3 = \frac{\iota_w}{1+\beta\gamma^{(1-\sigma_c)}}$ and $w_4 = \frac{1}{(1+(\phi_w-1)\varepsilon_w)} \frac{(1-\xi_w)(1-\beta\gamma^{(1-\sigma_c)}\xi_w)}{\xi_w(1+\beta\gamma^{(1-\sigma_c)})}$.

The notations are similar to equations (10) and (13) of Smets and Wouters (2007).
The monetary authority behavior is strictly similar to Smets and Wouters. It is assumed to operate according to an interest rate feedback rule specification reflecting our assumption that the central bank has a fixed inflation objective over the long-term, corresponding to the steady state inflation rate. For the sake of clarity, we recall that the rule has, in deviation from the steady state, the following form:

$$r_t = \rho r_{t-1} + (1-\rho)\left[r_\pi \pi_t + r_y y_t^{gap}\right] + r_{\Delta y}\Delta y_t^{gap} + \varepsilon_t^r \tag{3}$$

where a small case variable denotes log-deviation of that variable from its deterministic steady-state level. It incorporates terms on lagged inflation, lagged output gap and its first difference. The output gap is defined as the log-difference between actual and flexible-price output.

2.2 Private sector learning

We assume that private agents do not have a perfect knowledge of central bank's inflation target: they doubt about the commitment of the monetary authority to maintain a fixed inflation target in the face of cost-push shocks.

More specifically, we specify an *ad hoc* filtering problem where price and wage setters do not observe $\bar{\pi}_t$ and ε_t^p separately. Instead, we approximate an imperfect knowledge configuration where price and wage setters only receive a signal on the aggregate markup in the goods the market, defined as $\varepsilon_t^\pi = \varepsilon_t^p + (1 - \pi_1 - \pi_2\rho_\pi)\bar{\pi}_t$.

They face a signal extraction problem that therefore entails backing out the two components. Given their supposed knowledge of the driving process of the shocks and their perceived standard deviation of the inflation target, they form an estimate of the current inflation target shift and expectations of the future target using a simple Kalman filter characterized by the following state-space system:

$$\begin{bmatrix} \bar{\pi}_t \\ \varepsilon_t^p \end{bmatrix} = \begin{bmatrix} \rho_\pi & 0 \\ 0 & \rho_p \end{bmatrix} \begin{bmatrix} \bar{\pi}_{t-1} \\ \varepsilon_{t-1}^p \end{bmatrix} + \begin{bmatrix} \eta_t^\pi \\ \eta_t^p \end{bmatrix} \tag{4}$$

$$\varepsilon_t^\pi = \begin{bmatrix} (1 - \pi_1 - \pi_2\rho_\pi) & 1 \end{bmatrix} \begin{bmatrix} \bar{\pi}_t \\ \varepsilon_t^p \end{bmatrix} \tag{5}$$

where $\rho_p, \rho_\pi \in [0,1]$ and η_t^p, η_t^π are *iid.* exogenous shocks. Example of such kind of imperfect information mechanism can be found, although for a different set of shocks, in Erceg and Levin (2003). Note here that we specified the stochastic process for the cost-push shock as AR(1) while Smets and Wouters (2007) used an ARMA(1,1). This simplifies the filtering problem and allows more direct comparison with the imperfect credibility specification of Erceg and Levin (2003)

in particular.

Applying the Kalman filter to the state-space system described above, one obtains the optimal estimates of the two unobserved components of ε_t^{π}. These estimates of the current inflation target and cost-push shock are given respectively by:

$$E_t\bar{\pi}_t = \left(1 - \frac{\kappa_1}{\rho_\pi}(1 - \pi_1 - \pi_2\rho_\pi)\right) E_{t-1}\bar{\pi}_t - \frac{\kappa_1}{\rho_\pi}E_{t-1}\varepsilon_t^p + \frac{\kappa_1}{\rho_\pi}\varepsilon_t^{\pi} \tag{6}$$

and

$$E_t\varepsilon_t^p = -\frac{\kappa_2}{\rho_p}(1 - \pi_1 - \pi_2\rho_\pi)E_{t-1}\bar{\pi}_t + \left(1 - \frac{\kappa_2}{\rho_p}\right) E_{t-1}\varepsilon_t^p + \frac{\kappa_2}{\rho_p}\varepsilon_t^{\pi} \tag{7}$$

where κ_1 and κ_2 are the elements of the Kalman gain matrix of the filter defined as $K = \begin{bmatrix} \kappa_1 \\ \kappa_2 \end{bmatrix}$. Finally, the optimal forecasts of the expected future inflation target and cost push shocks are obtained using the system (4):

$$\begin{bmatrix} E_t\bar{\pi}_{t+1} \\ E_t\varepsilon_{t+1}^p \end{bmatrix} = \begin{bmatrix} \rho_\pi & 0 \\ 0 & \rho_p \end{bmatrix} \begin{bmatrix} E_t\bar{\pi}_t \\ E_t\varepsilon_t^p \end{bmatrix} \tag{8}$$

2.3 Calibration issues

All the parameter values, if not discussed later, are fixed to the mode of the posterior distribution of the long sample estimates of Smets and Wouters (2007). The persistence parameter of the AR(1) process for the markup shock ε_t^p, and the standard deviation of the structural shock, have been estimated, assuming that all other parameters of model were fixed at their value in Smets and Wouters. In particular, the autoregressive parameter, ρ_p, is estimated at 0.25.

We set to zero the backward indexation parameters for price and wage settings, ι_p and ι_w. Several papers have highlighted the fact that those modeling features suffer from weak structural foundations. Benati (2008) shows notably that statistical inference on *intrinsic* inflation persistence embedded in traditional hybrid New Keynesian Phillips curves depends on the monetary regime in place. Monetary policy conduct which fails to provide a credible nominal anchor or a credible commitment to low and stable inflation may increase the backward-looking features of inflation dynamics. Against this background, we preferred to pursue the imperfect credibility exercise at the core of this note in purely forward-looking price and wage settings. Thereafter, we will nonetheless compare the monetary policy implications of our learning specification to the ones of higher backward indexation, interpreted as weak central credibility.

The learning features will be designed to increase the volatility of 5-year forward 5 years ahead inflation expectations towards levels consistent with available evidence. Among the indicators of inflation expectations, the break-even inflation rates (BEIRs) derived from nominal and inflation-indexed bond yield constitute an important market-based measure. Notably, the BEIRs which measure inflation compensation for the 5-year period starting in 5 years time over a five-year horizon, is used by many central banks as a preferred measure of private sector forecast for the medium-term inflation rate. Concerning the US, some studies have documented the excess sensitivity of long-term forward break-even inflation rates to macro-economic news (see for example Beechey, Johannsen and Levin (2008)). This phenomenon may partly reflect the weak anchoring of long term expectations when economic agents do not have a perfect knowledge of the central bank inflation objective. To give an order of magnitude, the standard deviation of the 5-year forward BEIR 5 years ahead (seasonally adjusted) from January 2005 to January 2008 amounts to 0.16 pp of annual inflation[1].

By contrast, the medium-scale DSGE estimated on US data of Smets and Wouters (2007) which features rational expectations as well as a constant inflation objective for the central bank, would point to a much lower unconditional volatility of average expected inflation at such distant horizons. This results hold when setting backward indexation parameters to zero or replacing the ARMA(1,1) process for the cost-push shock by an AR(1). By comparing the BEIRs to the conditional inflation forecasts of the DSGE, we interpret those market-based indicators of inflation expectations as the best predictors of inflation outcomes at a given horizon. Beyond the obvious caveat related to time-varying risk premia embedded in asset prices, it is important to notice that in our calibration exercise, the BEIRs do not represent the perceptions of a particular set of agents about future inflation developments, and a fortiori about central bank's objective, but instead they map the most likely course of inflation rates resulting from the general equilibrium allocation. A clear distinction should therefore be drawn between the inflation forecast of the DSGE model (which could be compared to the BEIRs indicators) and the uncertainty of price and wage setters about the medium-term inflation target of the monetary authority (which is only one element of the macroeconomic determination of inflation dynamics).

Consequently, when calibrating our imperfect knowledge specification, we chose a stochastic process for the perceived inflation objective of price and wage setters so that the volatility of the inflation forecasts generated by the model comes close the observed variance of BEIRs. More precisely, we set the autoregressive coefficient on the perceived inflation target, ρ_π, to 0.99, as

[1]Of course, the BEIRs are not unbiased measures of inflation expectations since they incorporate a time-varying risk premia. But, available measures trying to correct for such risk compensations still tend to indicate that market-based inflation expectations for the US economy would feature excessive fluctuations. Thereafter, we examine the implications for monetary policy should expectation instability be due to imperfect credibility.

in Erceg and Levin (2003). Then, we choose the variance of the innovation, η_t^{π}, in order to achieve a standard deviation of average inflation expectations over a 5-year period, in 5 years time, which corresponds to the standard deviation of the 5-year forward BEIR 5 years ahead (seasonally adjusted) from January 2005 to January 2008.

Figure 1: Private sector perceptions.

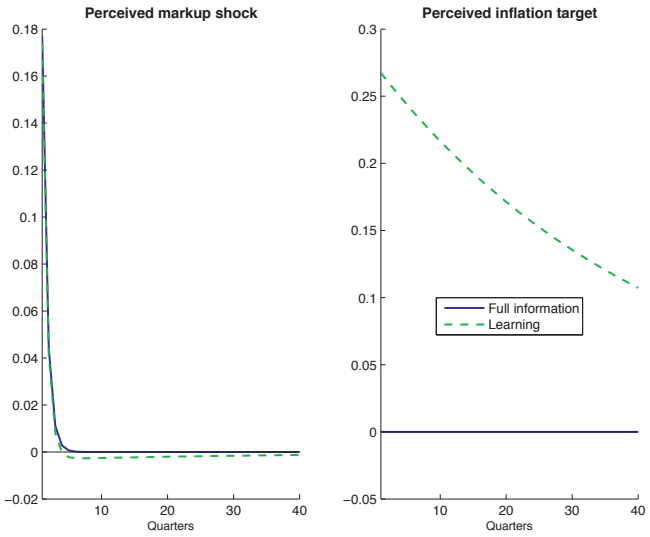


Figure 1 presents the private sector perception of the price markup disturbance and the inflation target compared with *true* developments. While the markup shock is well perceived by agents, the degree of misinterpretation about the central bank objective is sizeable in this calibration. Under rational expectations, a high volatility in the inflation target is needed to generate sufficient fluctuations in inflation expectations at long horizons. Overall, a markup shock which implies *ex ante* an inflationary impulse of 0.2 pp leads to initial shift on the perceived inflation target of the same magnitude. The imperfect credibility mechanism introduced in this note could seem rather extreme but remains illustrative of the degree of misperception required to account for higher volatility in long-term inflation forecasts. Actually, taking as example the case of oil price shocks, the learning mechanism calibrated in this paper would assume that price and wage setters extrapolate the direct effect of oil prices on headline inflation, into an upward shift of the central bank's inflation objective of a similar magnitude. While extreme, this calibration may portray a plausible situation when long-term inflation expectations become weakly anchored in a context of repeated and one-sided price shocks.

3 Monetary policy under imperfect credibility

The calibration of the imperfect credibility mechanism has been obtained using the estimated interest rate rule as the best empirical description of historical monetary policy conduct. However, in order to assess the policy implications of expectation instability, we will rely on a more precise description of central bank's decision problem.

We consider a class of monetary policy conducts which aim at minimizing an intertemporal loss function, given the structural equilibrium conditions describing the economy. The loss function considered can be written as follows:

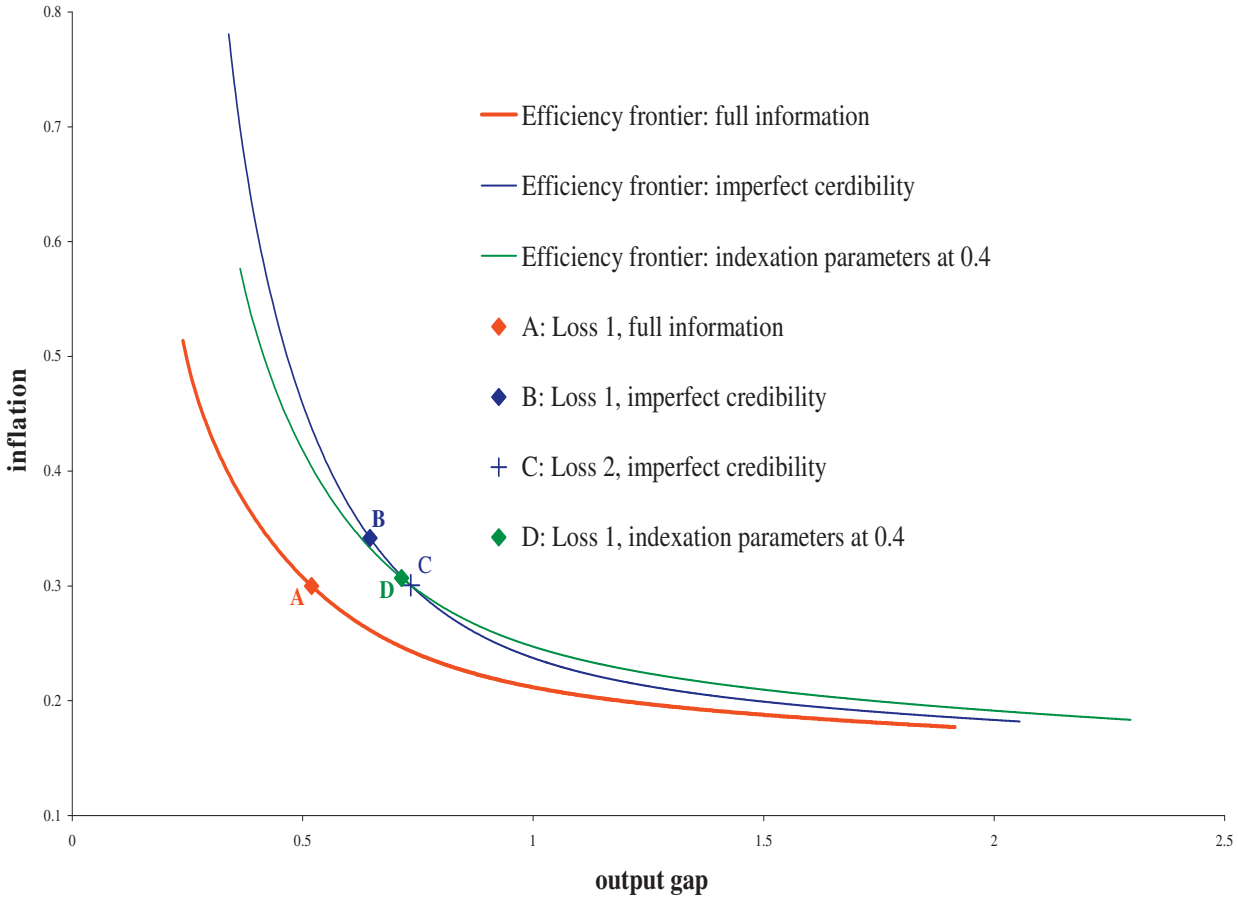
$$\mathcal{L}_t = \lambda_\pi \pi_t^2 + \lambda_y \left[y_t^{gap}\right]^2 + \lambda_r r_t^2 + \beta \mathbb{E}_t \mathcal{L}_{t+1}$$

where λ_π, λ_y and λ_r are the coefficients weighting the respective costs of inflation volatility, fluctuations in the model-based output gap and in the nominal interest rate. We set $\lambda_y = \lambda_r = 0.15$ such that, for $\lambda_\pi = 1$ and under perfect credibility, the model closely replicates the second order moments of the reference model where monetary policy follows a Taylor rule. We then vary the weight on inflation from 0 to 100. For any loss function, we derive the stochastic allocation and compare the standard deviations of inflation and output gap.

Figure 2 presents efficiency frontiers along the inflation/output gap tradeoff under three configurations: full information, imperfect credibility, and backward indexation in price and wage settings. We see that the imperfect credibility specification induces a shift in the efficiency frontier to the North East of the diagram. Our description of private agents' doubts on central bank inflation objective has made it exogenous to monetary policy conduct over the cycle: this intends to illustrate the fact that once the credibility of the monetary authority weakens, monetary policy has to operate in a less favorable environment where achievable stabilization outcomes inevitably deteriorate. Consider first the loss function which delivers in the full information case, the same inflation volatility as under the estimated rule. This loss function has a weight on inflation, λ_π, of approximately 1 (point A in Figure 2). It turns out that the imperfect credibility would worsen the stabilization tradeoff, increasing the standard deviations of quarterly inflation and output gap, by 0.05 pp and almost 0.2 pp respectively (shift from A to B in Figure 2). Should monetary policy attempt to restore the level of inflation variance close to the full information case, monetary policy would need to be less tolerant for the inflationary effects of cost-push shocks, increasing λ_π to more than 2 (shift from B to C in Figure 2). Then the output gap costs of inflation stabilization reach more than 0.25 pp of standard deviation.

For the sake of comparison, we derived the efficiency frontier under full information and backward indexation parameters set at $\iota_p = \iota_w = 0.4$. We chose illustrative values which are close

Figure 2: Comparison of efficiency frontiers. *Standard deviations of quarterly variables, in %.*



to Smets and Wouters estimates. With higher indexation, the macroeconomic stabilization deteriorates as the efficiency frontier shifts to the right of Figure 2, towards higher output gap volatility for given inflation variance. Interestingly, the efficiency frontier under higher indexation is very close to the one obtained under imperfect credibility. However, similar volatility configurations are implemented through a lower relative aversion for inflation variance in the higher indexation case. This is attested by the proximity of points D and C in Figure 2.

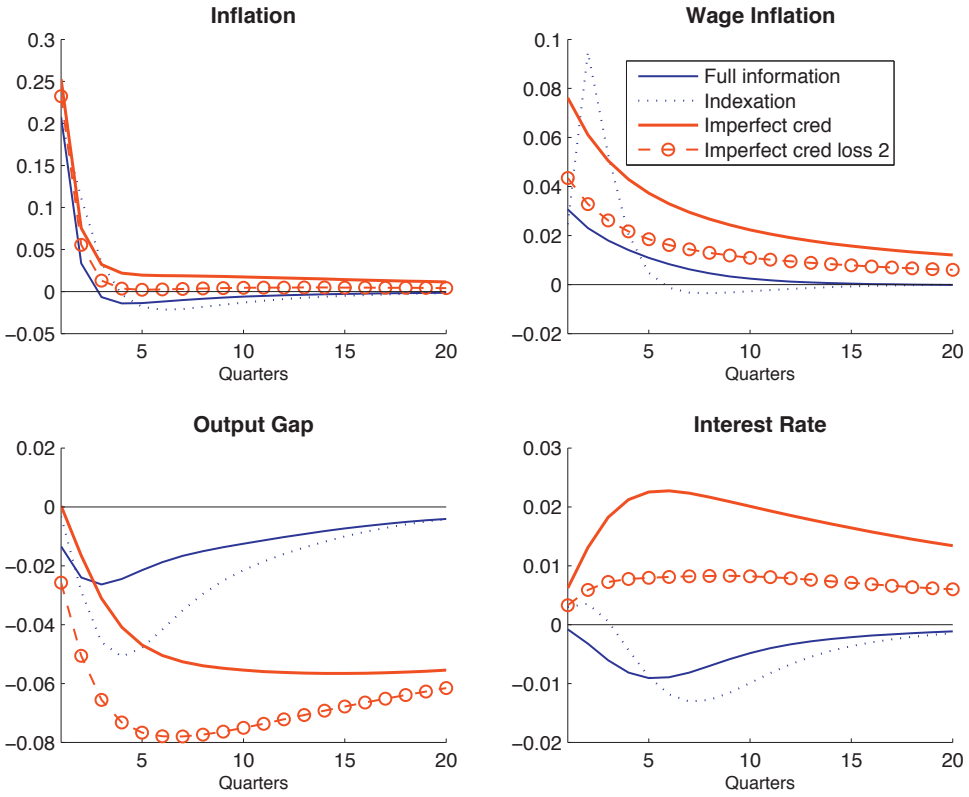
The comparison of the efficiency frontiers is illustrative of overall stabilization costs stemming from imperfect credibility, but unconditional moments may mask more pronounced modifications in the propagation mechanism.

We plot in Figure 3 impulse response functions to a cost-push shock for the 4 configurations highlighted in Figure 2 by the points *A, B, C, D*. As regards the macroeconomic transmission under imperfect credibility compared with the full information case, the shift in private perceptions about the long term inflation objective of the central bank leads to a stronger and more persistent reaction of wages which perpetuate the inflationary shocks. Inflation remains above baseline for a protracted period of time while, under full information, monetary policy aimed at compensating somewhat the initial inflation slippage over the medium term. The contraction in output is also more pronounced and persistent, with the peak effect being almost three times larger. In resisting intensified underlying inflationary pressures, the monetary authority increases slightly the nominal interest rate, contrary to the marginal interest rate cuts implemented in the full information case.

Given our imperfect credibility specification and the rational expectations hypothesis, the commitment of the central bank to amend its "rule-like" behaviour in a certain way may have powerful implications on economic propagation through expectation channels. By increasing the policy aversion for inflation volatility, the central bank can indeed mute the price pressures generated by shifts in private perceptions and bring the inflation response much closer to the full information case (see Loss 2 in Figure 3). Compared with the benchmark transmission under imperfect credibility, the commitment to a stronger anti-inflationary policy conduct affects expectations of price and wage setters in a self-equilibrating manner, thereby leading to a weaker increase in wage claims and more subdued cost pressures for firms. The weaker inflation response is also achieved through a more pronounced contraction of output. Ex post, given the effective steering of expectations and the moderate inflation dynamics, interest rates are lower than in the benchmark imperfect credibility case.

Like imperfect credibility, backward indexation amplifies the response of wages and inflation, has a contractionary effect and leads to higher interest rates. However, the dynamic properties

Figure 3: Comparison Impulse response functions. *Standard deviations of quarterly variables, in %.*



of the macroeconomic propagation are sensibly different. Through backward indexation, the inflationary shock mechanically triggers a surge in wage claims in the first quarters, beyond the magnitude of increases recorded in the imperfect credibility case, but the rise in compensation turns out to be short-lived. Price and wage inflation rates revert to below-baseline levels after approximately 5 quarters. The persistence of the inflationary shock on nominal variables is therefore much more limited in the backward indexation case. The widening of the output gap is similar to the one observed under imperfect credibility over the first 5 quarters but afterwards the reversion towards baseline is much faster. The nominal interest rate ends up below baseline after only few quarters. Overall, the IRFs highlight differences between backward indexation and our imperfect credibility specification that were masked by moments' comparison. Backward indexation leads to stronger price and wage response in the short-term but the persistence of the macroeconomic propagation is significantly weaker than under imperfect credibility.

4 Conclusion

History shows that private agents' perceptions about the objectives of the central bank can temporarily deviate from the central bank's own views and communication even in monetary regimes that have a solid institutional and social legitimacy. Inflationary shocks can occasionally get entrenched in price and wage settings if circumstances are particularly unfavourable and deviations from price stability prolonged in time.

If a central bank is weakly credible in delivering price stability, private agents may interpret cost-push shocks as a temporary change in the "comfort zone" in which the central bank could tolerate medium-term inflation dynamics. This phenomenon would strongly amplify the transmission of the price shock notably through stronger wage claims: monetary policy will face a higher sacrifice ratio in its attempt to bring down inflation volatility. We rationalized here such deterioration in achievable stabilization outcomes by a simple filtering problem where agents infer from aggregate markup dynamics a perception of the central bank's medium term objective and of the true cost-push shock.

Under more realistic descriptions of the functioning of the economy, the status of backward indexation in wage and price setting as "deep structural features" becomes relatively fragile: indexation may plausibly reflect the weak credibility of the monetary authority or the adaptive nature of private agents' learning process. Here, we illustrated some similarities in terms of achievable stabilization outcomes between our imperfect credibility specification and the presence of backward indexation.

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