Transparency, Expectations Anchoring and Inflation Target*

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Abstract

In various speeches, former Fed Chairman Ben Bernanke contrasted the proposal of setting a higher inflation target by claiming that it could unanchor inflation expectations. A standard New Keynesian framework with learning supports this claim both asymptotically, because a higher inflation target shrinks the E-stability region when a central bank follows a Taylor rule, and in the transition phase, because a higher inflation target slows down the speed of convergence of expectations. Transparency helps anchoring expectations. However, the importance of being transparent diminishes with the level of the inflation target. Finally, the higher the inflation target, the more policy should respond to inflation and the less to output to guarantee E-stability. Hence, a policy that increases both the inflation target and the monetary policy response to output would be "reckless".

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1 Introduction

> *"In this context, raising the inflation objective would likely entail much greater costs than benefits. Inflation would be higher and probably more volatile under such a policy, undermining confidence [...]. Inflation expectations would also likely become significantly less stable."* Bernanke's remarks at the 2010 Jackson Hole Symposium.

Following the Great Recession, Blanchard et al. (2010) proposed to increase the central bank inflation target in order to deal with the problem of the zero lower bound on interest rates. More recently, Ball (2014) and Krugman (2014) have forcefully supported this view. In various speeches, the former Federal Reserve Chairman Ben Bernanke contrasted this argument by claiming that a higher inflation target could unanchor inflation expectations. The debate is still ongoing. On the one hand, in April 2015 Eric Rosengren, president of the Federal Reserve Bank of Boston, returned to the topic arguing that the Fed may need to set a higher inflation target. On the other hand, in the same month, at an IMF panel, none of the panelists, both policy makers and monetary policy experts, shared the proposal to increase the inflation target. Among them, Stanley Fischer, the Federal Reserve Vice Chairman, strongly contrasted the choice of a 4% inflation target dubbing it as "a mistake".[1] Few months later, the Federal Reserve Chair Janet Yellen (2015) declared there was no point in raising the inflation target. Again, in May 2016, three Fed Presidents supported Yellen's idea.[2]

Do higher inflation targets unleash inflation expectations? This is a very topical and fundamental question about monetary policy design. A positive answer would provide a significant argument against the Blanchard et al.'s (2010) (and others') policy prescription of raising the inflation target. The New Keynesian literature has convincingly shown that price stability should be the goal of monetary policy even after taking into account the perils of hitting the zero lower bound (e.g. Coibion et al., 2012; Schmitt-Grohé and Uribe, 2010). However, these papers, assuming rational expectations, cannot address Bernanke's concern that a higher inflation target could destabilize inflation expectations. Given the importance of this debate, this paper aims at providing a thorough investigation of Bernanke's proposition.

The appropriate framework to investigate this issue should encompass various elements: a positive inflation target, the possibility of expectations unanchoring, and the communication strategy of monetary policy.

As for the former, we will adopt the New Keynesian macromodel with trend inflation proposed by Ascari and Ropele (2009). These authors show that a higher inflation target could destabilize the economy by increasing the likelihood of a self-fulfilling rational expectations equilibrium (REE).

In addition, the concept of expectations unanchoring requires us to drop the assumption of rational expectations and assume an alternative mechanism for expectation formation. The learning literature provides a natural alternative environment where agents create forecasts

[1] See Fischer et al. (2015).

[2] The three Fed President were San Francisco's John Williams, Atlanta's Dennis Lockhart and Dallas' Robert Kaplan who were panelists at Hoover Institution's International Monetary Stability Conference on May 5, 2016.

according to a linear model updated recursively.[3] In this context, expectations are unanchored when the learning rule fails to converge to the rational expectations solution of the model - technically, the REE is not expectationally stable or E-stable.

Moreover, the paper explores further the notion of expectation anchoring tackling two points recently brought into the debate by Ball (2014). Proposing to raise the target from 2 to 4 percent, Ball claims that: (i) expectations should remain anchored as long as the central bank is able to explain the change to private agents; (ii) the transitional period of learning should not necessarily harm the economy significantly.[4] Contrary to (i) above, Yellen (2015) notably argued that expectations anchoring after a change of the inflation target may prove difficult, despite transparency, because this result could only be achieved if a given policy is in place long enough for agents to learn the new average level of inflation.

Regarding the first aspect, our analysis acknowledges that the communication strategy is particularly relevant for a policymaker that wants to keep private sector's expectations under control and that ponders to modify the inflation target.[5] To capture this distinctive feature of monetary policy, we follow Eusepi (2005) and Preston (2006) and consider two opposite communication strategies characterised by the amount of information that the monetary authority provides to the public: transparency, where central bank fully discloses its policy function so that the agents can use it to forecast interest rates, and opacity, where agents need to resort to their adaptive forecasting rule. We specifically address this point and examine how the degree of monetary policy transparency affects the stability of expectations for different levels of trend inflation.

With respect to the second aspect, we study both the length of the transition to a new equilibrium and its potential adverse effects on the economy. To this end we investigate the condition for asymptotic convergence (E-stability) but also the speed at which convergence occurs. From a policy perspective, the speed of convergence is an important aspect, often neglected in the literature that focuses mainly on E-stability. While a fast convergence means that the economy will always be very close to the REE, a slow convergence implies that the behaviour of macro variables will be dominated by the transitional dynamics implied by the learning algorithm.

Characterising how the inflation target changes the set of policy rules that guarantees sta-

[3] Interestingly, Bernanke himself suggested to use the adaptive learning framework to study this topic: *"What is the right conceptual framework for thinking about inflation expectations in the current context? [...] Although variations in the extent to which inflation expectations are anchored are not easily handled in a traditional rational expectations framework [...] In a learning context, the concept of anchored expectations is easily formalized."* Bernanke's speech at the NBER Monetary Economics Workshop, July 10, 2007. For a thoughtful survey on how learning affects the science of monetary policy, see Eusepi and Preston (2016).

[4] *"We have learned from recent experience that 4% inflation is better than 2%, because of the zero bound problem. Why can't policymakers explain this, raise inflation to 4%, and keep it there? [...] An increase in the central bank's inflation target might involve a transitional period of learning, during which inflation uncertainty is greater than usual. But nobody has demonstrated that this transition would harm the economy significantly."* (Ball, 2014, p. 14).

[5] *"The second major element of best-practice inflation targeting (in my view) is the communications strategy [...] To the extent that it can explain its general approach, clarify its plans and objectives, and provide its assessment of the likely evolution of the economy, the central bank should be able to reduce uncertainty, focus and stabilize private-sector expectations."* Bernanke's speech at the Annual Washington Policy Conference of the National Association of Business Economists, March 25, 2003.

bility of the REE under learning allows us to study how monetary policy design should change with the inflation target to guarantee expectations anchoring, that is, whether a central bank that targets a higher inflation level needs to respond more or less aggressively to inflation in order to stabilize expectations.

The paper yields a number of results. First and foremost, our main result provides support to the Bernanke's (2010) statement: a higher inflation target tends to destabilize expectations *both asymptotically*, because it shrinks the E-stability region for a given Taylor rule, and *in the transition phase*, because it slows down the speed of convergence of expectations to the REE. Second, a transparent communication strategy can only marginally offset the destabilizing effect of a high inflation target. While for low inflation targets our results support the claim that transparency is an essential component of the inflation targeting approach to monetary policy, the advantage of being transparent rapidly fades if the inflation target is raised, both in terms of E-stability and speed of convergence. These findings support the view by Yellen (2015). Third, in terms of monetary policy design under a higher inflation target, expectations stabilization calls for a hawkish reaction to inflation and only a mild response to output. This result questions the arguments that urged the Fed to increase the inflation target and, contemporaneously, ease monetary policy to respond to the surge in unemployment.[6] Our findings suggest that such a policy would indeed be "reckless" and "unwise", as Bernanke (2012) put it.[7] Overall, these findings suggest that the proposals to lift up the inflation target should be viewed with some scepticism, because expectations would be more difficult to stabilize, even after considering the central banks communication strategy.

Related literature. The effects of trend inflation on expectational stability are studied even by Kobayashi and Muto (2013) and Kurozumi (2014). Following a similar approach to ours, they find that the REE is likely to become unstable once the inflation target is raised. With respect to these works, we (i) study the effects of central bank's communication strategy on the anchoring of expectations; (ii) analyse the effects of the inflation target on the speed of convergence of learning.

Three other works employ Ascari and Ropele's (2009) model under learning. Florio and Gobbi (2015) augment it with fiscal policy to study the effects of trend inflation and transparency on expectations anchoring under different monetary-fiscal mixes. Branch and Evans (2011) study the dynamics of the model after a change in the long-run inflation target. They show that imperfect knowledge of the inflation target could generate near-random walk beliefs and unstable dynamics due to self-fulfilling paths hence instability in inflation rates. A related work by Cogley et al. (2011) studies optimal disinflation under learning. When agents have to learn about the new policy rule, then the optimal disinflation policy is more gradual, and the sacrifice ratio much larger, than under the case of transparency. However, they find that imperfect information about the policy feedback parameters, rather than about the long-run inflation target, is the crucial source of the explosiveness of the dynamics.

[6] For example, see Krugman's article on The New York Times of April 24, 2012.

[7] *"I guess the question is, does it make sense to actively seek a higher inflation rate in order to achieve a slightly increased pace of reduction in the unemployment rate? The view of the committee is that that would be very reckless."* Bernanke, FOMC Press Conference transcript, April 25, 2012.

The paper is structured as follows. Section 2 presents the model and the methodology. Section 3 illustrates the main results. Some robustness checks are reported in Section 4. Section 5 concludes.

2 Model and methodology

The model we use is based on Ascari and Ropele (2009), that extends the basic New Keynesian model (e.g., Galí, 2008; Woodford, 2003) to allow for positive trend inflation. Log-linearizing the model around a generic level of steady state inflation yields the following equations (see the appendix):

$$\hat{y}_t = E^*_{t-1}\hat{y}_{t+1} - E^*_{t-1}\left(\hat{\imath}_t - \hat{\pi}_{t+1}\right) + u_{d,t}, \tag{1}$$

$$\hat{\imath}_t = \phi_\pi E^*_{t-1}\hat{\pi}_t + \phi_y E^*_{t-1}\hat{y}_t + u_{m,t}, \tag{2}$$

$$\hat{\pi}_t = \beta_{\bar{\pi}} E^*_{t-1}\hat{\pi}_{t+1} + \kappa_{\bar{\pi}} E^*_{t-1}\hat{y}_t + \kappa_{\bar{\pi}}\frac{\sigma_n}{1+\sigma_n}E^*_{t-1}\hat{s}_t + \eta_{\bar{\pi}} E^*_{t-1}\hat{\phi}_{t+1} + \kappa_{\bar{\pi}} u_{s,t}, \tag{3}$$

$$\hat{\phi}_t = \alpha\beta\bar{\pi}^{(\theta-1)}E^*_{t-1}\left[\left(\theta-1\right)\hat{\pi}_{t+1} + \hat{\phi}_{t+1}\right], \tag{4}$$

$$\hat{s}_t = \xi_{\bar{\pi}}\hat{\pi}_t + \alpha\bar{\pi}^\theta\hat{s}_{t-1}, \tag{5}$$

where hatted variables denote percentage deviations from the deterministic steady state. The structural parameters and their convolutions ($\beta_{\bar{\pi}}$, $\kappa_{\bar{\pi}}$, $\eta_{\bar{\pi}}$ and $\xi_{\bar{\pi}}$) are described in Table 1. $u_{d,t}$, $u_{m,t}$, and $u_{s,t}$ are exogenous AR(1) processes with stationary autoregressive coefficients $\rho_i \in (0,1)$, $i = \{d, m, s\}$.

The first equation is the standard Euler equation derived from the households' utility maximization problem. The second equation is a simple Taylor rule characterizing the behaviour of the central bank that reacts to expected inflation and output. The last three equations represent the supply side of the economy in presence of trend inflation, so they are the counterpart of the standard New Keynesian Phillips Curve (NKPC) for the zero inflation steady state case. $\hat{\phi}_t$ is just an auxiliary variable (equal to the present discounted value of future expected marginal revenues) that allows the model to be written recursively. Equation (5) describes the evolution of relative price dispersion, $\hat{s}_t$. In contrast to the zero inflation steady state case, for positive levels of trend inflation price dispersion affects inflation dynamics even at first-order approximation and thus has to be taken into account.[8]

Of course, Ascari and Ropele's (2009) generalized model encompasses the standard NKPC. When trend inflation is equal to zero, one has that $\bar{\pi} = 1$ and $\eta_{\bar{\pi}} = \xi_{\bar{\pi}} = 0$ so that both the auxiliary variable and the measure of price dispersion become irrelevant for the dynamics of inflation. Thus, equation (3) collapses into the standard specification of the New Keynesian model:

$$\hat{\pi}_t = \beta E^*_{t-1}\hat{\pi}_{t+1} + \kappa E^*_{t-1}\hat{y}_t + \kappa u_{s,t}. \tag{6}$$

[8] Kobayashi and Muto's (2013) analysis disregards price dispersion, because they assume a simple proportional relationship between the marginal cost and the output gap. However, as shown in Ascari and Ropele (2009), this is not general and it requires the additional assumption of indivisible labour (i.e., $\sigma_n = 0$).

The dynamics of the model with positive trend inflation turns out to be substantially different from the baseline New Keynesian framework around zero inflation. First, the inflation target directly affects the coefficients of the log-linearized equations. In particular, the higher the inflation target, the more price-setting becomes "forward-looking", because higher trend inflation leads to a smaller coefficient on output ($\kappa_{\bar{\pi}}$) and a larger coefficient on expected future inflation ($\beta_{\bar{\pi}}$). With higher trend inflation the price-resetting firm sets a higher price since it anticipates that trend inflation will erode its relative price in the future. Keeping up with the trending price level becomes a priority for the firm, that will be thus less affected by current marginal costs. Consequently, if the central bank increases the inflation target, the short-run NKPC flattens: the inflation rate becomes less sensitive to variations in current output and more forward-looking. Second, a positive inflation target adds two new endogenous variables: $\hat{\phi}_t$, which is a forward-looking variable, and $\hat{s}_t$, which is a predetermined variable. The dimension of the dynamics of the system is of fourth order, so analytical results are not possible and we proceed with numerical simulations. The benchmark calibration follows Ascari and Ropele (2009): $\sigma_n = 1$, $\alpha = 0.75$, $\theta = 11$, $\beta = 0.99$. The shocks processes are assumed to be very persistent: $\rho_d = \rho_m = \rho_s = 0.9$ (Woodford, 2003).

Learning. We follow Bullard and Mitra (2002) approach, which builds on Evans and Honkapohja (2001) and much of the related literature on learning, by assuming that agents have non-rational expectations, that we denote with E^*. When agents do not possess rational expectations, the existence of a determinate equilibrium does not ensure that agents coordinate upon it. As from the seminal contribution of Evans and Honkapohja (2001), we assume agents do not know the value of the structural parameters and, as such, they cannot form expectations using the true law of motion of the economy. Rather, they behave as econometricians and compute expectations according to a reduced-form model whose parameters are estimated through recursive least squares using the data produced by the economy. Agents are assumed to share identical beliefs and to form forecasts using a perceived law of motion (PLM) which has the same structure of the minimal state variable (MSV) solution of the model obtainable under rational expectations.[9] Each period, as additional data become available, they estimate the coefficients of their PLM and compute expectations that, once inserted into the equations of the model, give rise to the actual law of motion (ALM). We then investigate whether the PLM converges to the MSV solution, the speed at which convergence occurs, and the dynamics of the economy under learning.[10] In other terms, we want to characterise the design of monetary policy that makes agents able to readily learn the REE of the model.

Communication strategy. We borrow from Eusepi (2005) and Preston (2006) the two communication strategies by the central bank: transparency (henceforth, TR) and opacity (OP). Eusepi and Preston (2010) further analyse what happens to E-stability when the Taylor principle holds and the central bank employs a variety of communication strategies, assuming

[9]As our model is written in deviations from the steady state, the MSV and the PLM do not contain a constant term. Adding a constant to the PLM leaves our main conclusions unaffected (results are available from the authors upon request). Moreover, with zero trend inflation the PLM does not contain lagged endogenous variables, which are present in both the PLM and MSV in the case of positive trend inflation.

[10] See the appendix for the details of the beliefs structure (PLM) and the characterisation of E-stability.

decisions are made based on period $t-1$ information, as we also do.[11] We assume that the central bank is perfectly credible: the public believes and fully incorporates the central bank's announcements. Agents are uncertain about the economy ($\hat{\pi}$ and $\hat{y}$) and about the path of nominal interest rates ($\hat{\imath}$). Communication by the central bank simplifies the agents' problem in that it gives them information on how the monetary authority sets interest rates, that is, agents know the monetary policy rule (2). Therefore: (i) under OP, the private sector has to form forecast about the economy ($\hat{\pi}$ and $\hat{y}$) and about monetary policy ($\hat{\imath}$); (ii) under TR, agents do not need to forecast the path of nominal interest rates, because the central bank announces its reaction function. In case of TR, therefore, we substitute the monetary policy rule (2) directly in the aggregate demand equation (1), and the agents' problem boils down to forecasting inflation and output. In principle, this could help anchoring expectations by aligning agents' beliefs with the central bank's monetary policy strategy. We want to investigate this claim.[12]

Speed of convergence. As discussed by Ferrero (2007), the speed at which adaptive learning expectations converge to their rational counterparts is important to characterise the dynamics of models with learning. Rapid convergence implies that agents will readily learn their way back to the REE after the economy is hit by an exogenous shock. It follows that variables can be safely studied by focusing on the asymptotic behaviour, i.e. the dynamics under rational expectations. Conversely, persistent departures from the REE may be frequent if the rate of convergence is slow, and the model will be dominated by its transitional dynamics.

We study the speed of convergence where a single REE exists and is E-stable, that is, conditional on determinacy and E-stability. For expectations to converge, E-stability requires that the Jacobian matrix of the T-map evaluated at the REE has all eigenvalues smaller than 1 in real part - i.e., the *slope* of the T-map is less than one. In addition, the slope of the T-map directly determines the speed of convergence. Applying results from Benveniste et al. (1990), Marcet and Sargent (1995) provide a sufficient condition to ensure that parameters estimated with recursive least squares converge at root-t rate to a normal distribution centered on the REE.[13] Namely, the slope of the T-map must be less than 0.5. Hence, root-t convergence is granted only in a subset of the parametrizations that ensure E-stability. When the slope is between 0.5 and 1, the estimates still converge to the REE but no formal results about the speed of convergence are available. According to Marcet and Sargent (1995), as the effect of initial conditions fails to die out at an exponential rate, the estimates are intuitively expected to converge at a rate slower than root-t. They suggest a numerical procedure based on Monte Carlo simulations for investigating the speed of convergence when the results by Benveniste et al. (1990) do not apply. The procedure has been applied to monetary policy analysis by Ferrero

[11]Moreover, Preston (2006) and Eusepi and Preston (2010) employ what Evans et al. (2011) call the infinite horizon approach due to Preston (2005), while we use the more common Euler equation approach of Evans and Honkapohja (2001), as in Bullard and Mitra (2002) and Eusepi (2005). See Evans et al. (2011) and Evans and Honkapohja (2013) for a thorough discussion of the two approaches.

[12]Alternatively, TR can be defined as in Berardi and Duffy (2007). Under their specification, in the presence of TR the private sector adopts the correct forecast model: the structure of the PLM that coincides with the MSV solution, hence without the constant. Under OP, instead, they use an overspecified (with a constant) PLM. Incorporating even this specification in our model does not change significantly the results (available from the authors upon request).

[13]In classical econometrics, root-t is the speed at which the mean of the distribution of the least square estimates converges to the true value of the parameters.

(2007) and Ferrero and Secchi (2010). To study the effects of policy and trend inflation on the speed of convergence, we will consider both the analytical conditions for root-t convergence and the results from the Monte Carlo procedure.

3 Main Results

This section presents the main results of the paper, which are based on numerical computations, given the enlarged dynamics of the New Keynesian model with positive trend inflation.[14] In turn, we illustrate how the central bank's choice of both the inflation target and the communication strategy affects: (i) the asymptotic convergence of the expectations under learning (E-stability); (ii) the transitional convergence of expectations. Finally, we draw some conclusions on learning dynamics and monetary policy design.

3.1 E-stability

Figure 1 displays the first main result of the paper: it is more difficult to anchor inflation expectations when the central bank fixes a higher inflation target, even if monetary policy is transparent. The figure plots the determinacy and E-stability regions both under TR and under OP, for four different values of trend inflation: 0, 2%, 4% and 6%. The grey area represents the indeterminacy region, while the blue and the red lines delimit the E-stability regions for the cases of TR and OP, respectively.

[FIGURE 1 ABOUT HERE]

As known in literature, higher levels of trend inflation curtail the determinacy region. Similarly, the E-stability regions shrink substantially as the inflation target increases.[15] This effect is evident even for moderate levels of the target and occurs under both TR and OP. Under the range (ϕ_π, ϕ_y) we consider, when the inflation target is as high as 8%, the E-stability regions disappear altogether and there is no possibility to anchor inflation expectations. Henceforth, if the central bank were to raise the inflation target, expectation anchoring could be jeopardized. This result gives support to Bernanke's (2010) claim that the recent proposal by Blanchard et al. (2010) could hide the important peril of unanchoring inflation expectations.

To gain the intuition for this result, consider the determinacy conditions for the zero trend inflation case:

$$\phi_\pi + \frac{1-\beta}{\kappa}\phi_y > 1, \tag{7}$$

$$\phi_y + \kappa\phi_\pi > \beta - 1. \tag{8}$$

[14]The appendix shows analytical results under zero trend inflation. These results provide revealing insights for the case of positive inflation target.

[15] According to Van Zandweghe and Kurozumi (2014), the introduction of an auxiliary variable (as we do) in models with multiperiod expectations would shrink the region of the model parameters that return E-stability. However, the case we study, with elasticity of labour supply equal to one, returns almost identical E-stability areas up to 4% trend inflation, whether employing or not the auxiliary variable. Moreover, the regions of E-stability that show up only without the auxiliary variable are anyway indeterminate, thus not desirable from a policy perspective.

As known (see Woodford, 2003, p. 256), (7) is the "long-run" Taylor principle since $(1-\beta)/\kappa$ is the long-run multiplier of inflation on output in equation (6). So it can be interpreted as requiring that the long-run reaction of the nominal interest rate to a permanent change in inflation should be bigger than one. By the same token, according to the the second condition, the short-run reaction of the nominal interest rate should be bigger than the opposite of the long-run multiplier of inflation on output.[16] The white area in the upper-left panel thus corresponds to the parametrizations that satisfy both (7) and (8). Given our assumptions, the determinacy and the E-stability regions do not exactly coincide.[17]

How do these regions change when the inflation target increases? Recall from Section 2 that, as trend inflation increases, price setting firms become more forward-looking and two effects are at play on the NKPC: (i) a larger coefficient on future expected inflation ($\beta_{\bar{\pi}}$); (ii) a smaller coefficient on current output ($\kappa_{\bar{\pi}}$). These effects flatten the slope of the long-run Phillips curve, which under trend inflation is given by $(1-\beta_{\bar{\pi}})/\kappa_{\bar{\pi}}$, with $\beta_{\bar{\pi}}$ and $\kappa_{\bar{\pi}}$ being respectively an increasing and a decreasing function of $\bar{\pi}$. Hence, as the target increases, the long-run multiplier of inflation on output switches sign, affecting (7). The long-run Taylor principle relation rotates clockwise and eventually positively slopes in the (ϕ_π, ϕ_y) plane. The same effect is at work for the E-stability regions, as the two concepts are related.

First, note that a larger coefficient on future expected inflation in the NKPC makes learning more difficult and the model more prone to instability. A shock to expected inflation leads to larger movements in current inflation validating the initial belief and spurring self-fulfilling expectations and E-instability. Second, a smaller $\kappa_{\bar{\pi}}$ makes current inflation less sensitive to output changes. Thus, monetary policy becomes less effective in stabilizing inflation, because interest rate changes affect inflation only indirectly, through output, via the Euler equation. Both these effects restrict the options available for policy makers and call for a tougher response of monetary policy in order to control expectations when trend inflation increases. We will thoroughly discuss these effects in Section 3.3 and the implications of our analysis for monetary policy design in Section 3.4.

Figure 1 reveals also another result: transparent communications helps anchoring expectations, as the E-stability region under TR is larger than the one under OP.[18] However, the benefit of being transparent diminishes as the central bank sets a higher inflation target.

To understand why this happens, it is important to get first the intuition of what drives the difference between TR and OP when the inflation target is zero. In this case, the slope of the line that defines the E-stability region under OP and cuts through the determinacy region is

[16]Note that this second condition is not relevant if $\phi_\pi, \phi_y \geq 0$ so it is usually overlooked in studies that just consider the zero trend inflation case. However, it becomes relevant when the inflation target turns positive.

[17]In the appendix we show the analytical relationship between the determinacy and the E-stability conditions in the case of zero trend inflation. Ellison and Pearlman (2011) and Bullard and Eusepi (2014) investigate the relationship between determinacy and E-stability in a general class of models. They conclude that in general determinacy may or may not (as in our simulations) imply E-stability, depending on the specific approach used to study learning dynamics, on the assumption about the form of the PLM and on the information set available to the agents of the model.

[18]This finding echoes similar results in Preston (2006), Bullard and Mitra (2007), and Eusepi and Preston (2010) in the infinite horizon framework.

strongly related to the slope of the NKPC (κ in equation (6)).[19] The higher is this slope (i.e., the more flexible are prices), the steeper is that line, and the higher the difference between TR and OP. Under OP agents do not know the policy rule. Thus, after an increase in inflation expectations, they fail to anticipate the reaction of monetary policy and wrongly expect lower real rates, even if the opaque central bank follows the Taylor principle. As a result, output rises causing an increase in actual inflation that validates the initial surge in expectations. In this sense, expected output becomes a leading indicator of inflation (see Eusepi and Preston, 2010) and the central bank ought to respond to it to stabilize expectations. When prices are more flexible (i.e., κ is higher) the feedback mechanism between expected output and expected inflation becomes stronger thus requiring an even greater central bank's reaction to expected output in order to preserve E-stability under OP. On the contrary, when prices are very rigid (i.e., a low value of κ) the feedback between expected output and expected inflation breaks down and there is no much advantage in correctly anticipating the policy response and the behaviour of real rates and output. As a consequence, the difference between TR and OP shrinks.

The same effect also explains why the difference between TR and OP decreases with trend inflation since, as seen above (see (i) and (ii)), the higher the inflation target, the flatter the Phillips curve.

Moreover, note that looking at this result from a reverse perspective implies that TR is an important component of the inflation targeting approach. Central banks in developed countries moved in the last decades to an inflation targeting framework and greater transparency with the aim of reducing average inflation by coordinating and anchoring inflation expectations. Our result supports this view, because the lower the inflation target, the more TR is important for expectations stabilization.

To conclude, the level of the inflation target has substantial effects on the E-stability regions and hence on the ability of a central bank to control inflation expectations. The higher the target inflation rate: (i) the more difficult is to anchor expectations, (ii) the more negligible is the benefit of transparency.

3.2 Speed of convergence

Under E-stability, the learning dynamics converges to the REE if expectational errors are relatively small. However, the transition period in which agents learn their way back to the equilibrium may greatly vary depending on the inflation target. The faster a shock to inflation expectations is reabsorbed, the more easily inflation expectations will remain anchored. It is therefore important to study the effect of a positive inflation target on the speed of convergence. Figure 2 shows how the slope of the T-map varies across different inflation targets under TR (panel a) and OP (panel b).[20] The dark blue region features root-t convergence.

[FIGURE 2 ABOUT HERE]

[19] The appendix shows that, after assuming $\beta = \rho = 1$, the line that defines the E-stability condition cutting through the determinacy region under OP reduces to $\phi_y > \kappa\phi_\pi$, so that the slope is simply given by κ.

[20] More precisely, we report the contour plots of the largest eigenvalue (in real part) of the derivative of the T-map for different levels of trend inflation, under TR and OP.

It is evident from the graphs that a higher trend inflation tends to increase the derivative of the T-map, slowing down the speed of convergence. This happens exactly for the same reason why the determinacy and E-stability regions shrink. A higher inflation target increases the slope of the T-map, so that the frontiers rotate and come closer, fewer equilibria are E-stable and, when they are, the convergence of the learning dynamics is slower. Under TR, even a very modest increase in the inflation target (from 0 to 2%) has large effects on the convergence of expectations under learning. In particular, in our considered range of values for (ϕ_π, ϕ_y), the region of root-t convergence disappears. In the OP case, the effects of trend inflation are qualitatively similar to the case of TR, but because the speed is already quite low at zero inflation, they are less pronounced. Furthermore, the communication strategy of the central bank is able to influence the speed of convergence, as the contour plots under OP generally exhibit higher values than under TR. Even for the speed of convergence, however, the advantage of being transparent vanishes when trend inflation increases, as the slope of the T-map under TR and OP becomes more similar.

The results outlined so far are based on the idea that convergence is faster in the regions where the slope of the T-map is lower. However, to assess the speed of convergence we also directly simulate the model and check the empirical rate at which estimates of the recursive least squares algorithm are attracted by their limit point, i.e., the parameters of the MSV solution. This procedure has been proposed by Marcet and Sargent (1995) and first applied to the study of monetary policy in New Keynesian models by Ferrero (2007).

Table 2 presents the empirical rate of convergence δ estimated across different values for the trend inflation and the policy parameters.[21] A higher δ indicates that convergence is faster. Notice that δ is bounded from above by 0.5 (which corresponds to root-t speed), which is the fastest rate of convergence achievable by recursive least squares.

Table 2 confirms the outcome of the previous analysis based on the slope of the T-map, suggesting that the largest eigenvalue of the Jacobian matrix is indeed the main determinant of the speed of convergence. In particular: (i) raising the inflation target strongly reduces the speed of convergence; (ii) the benefits on the speed of convergence of being transparent decrease with a higher inflation target.

3.3 Learning dynamics and expectations anchoring

In the previous sections we have shown how a higher level of trend inflation can destabilize expectations both asymptotically - because the E-stability region shrinks - and in the transition phase - because the speed of convergence slows down. According to Ball (2014), however, the central bank could avoid the de-anchoring of expectations by clearly explaining to the public the increase in the inflation target. We want to check if this is true.[22]

[21] We leave a detailed discussion of the procedure in the appendix. To construct Table 2 we ran 20000 simulations starting from the unique REE and computing the approximate rate of convergence between $t = 9000$ and $t = 10000$ (as in Ferrero, 2007). For the sake of exposition, we report only few choices of the policy parameters. The appendix contains extended tables reporting a higher number of cases.

[22] Our model does not include a constant term, so there is no uncertainty on the inflation target, as implied by Ball's (2014) argument.

Figure 3 plots the responses of actual and expected inflation, interest rates and output gap to a 1% shock to inflation expectations for different levels of trend inflation under TR. The impulse responses are computed fixing ϕ_π=2.5 and ϕ_y=0.125 to guarantee determinacy and E-stability under TR for all the considered trend inflation levels.[23]

[FIGURE 3 ABOUT HERE]

The jump in inflation expectations leads agents to revise upwards their forecasts of present and future interest rates: under TR agents immediately anticipate that the central bank will raise nominal and real rates to counteract the upsurge in expected inflation. Therefore, a contraction in output is observed. As time goes by, agents update the parameters of the PLM and the expectational shock is reabsorbed. Inflation and output eventually return to zero. This behaviour is common to every level of trend inflation. However, as the inflation target increases the adjustment process slows down and the drift in inflation expectations tends to become more persistent. In particular, with higher trend inflation agents are more forward looking and put a larger weight on future expected inflation. This implies that actual inflation is more influenced by expected inflation and, as such, reverts sluggishly towards the equilibrium.[24] Even the interest rate decreases more slowly because the central bank has to react to a more persistent expected inflation. The consequent higher and more persistent interest rate exacerbates the contraction in output. Note that, absent trend inflation, low output would decrease actual inflation. This, in turn, would allow interest rates to decrease faster, raising output and bringing back the economy to the equilibrium. On the other hand, with high trend inflation, the output coefficient in the NKPC is smaller, this hinders inflation reduction slowing down the restoring mechanism towards the equilibrium. In this case, the central bank needs to induce a larger recession in order to restrain inflation expectations. The fall in output is exacerbated for high values of trend inflation as 4% or 6%.

To sum up, following a shock to expected inflation, a rise in the inflation target would increasingly unmoor expectations, slow down the speed of convergence and seriously affect the economy. This evidence goes against the proposal by Rogoff (2008) to increase the inflation target, albeit temporarily, to 6%, as expectations may become unmoored for a long time.[25] Even the more common proposal to increase the inflation target to 4% would be dangerous since, compared to the 0-2% case, it would take longer to reabsorb misperceived inflation forecasts and keep inflation anchored even under transparency. This confirms Yellen's (2015) view who declared to be skeptical about the actual effectiveness of transparency in anchoring expectations

[23] To obtain the impulse response functions, we simulate the model twice starting from the target-specific REE. In both simulations we use the same sequence of random innovations. However, in the second simulation we tilt the coefficients of the perceived law of motion (specifically, the element that loads the exogenous monetary shock into the inflation equation) in order to generate an inflation forecast that exceeds by 1% the corresponding forecast of the first simulation. The impulse response is then given by the difference between the two simulated time series. We repeat this procedure 20000 times and report median responses. The corresponding results for opacity are available from the authors upon request.

[24] In other words, the dynamics under learning becomes more self-referential when the inflation target is higher.

[25] Rogoff (2008) admitted that *"once the inflation genie is let out of the bottle, it could take several years to put it back in"*. Nonetheless, contrary to what we find, he thinks that *"with good communication policy, inflation expectations can be contained, and inflation can be brought down as quickly as necessary"*. See Rogoff (2014) for an afterthought on this point.

since this result could be achieved only if a given policy is in place long enough for agents to coordinate on a new norm and shift their expectations accordingly. Finally, contrary to Ball (2014), we find that the transitional period of learning associated to a higher inflation target might harm the economy significantly increasing inflation and causing a severe recession.

As stated in the quote at the start of the paper, with a higher inflation target, inflation expectations would become less stable and more volatile. Note that relatively small changes in the target are sufficient to bring about nontrivial effects on the dynamics of expectations. What is more, these effects are non-linear: raising the target from 0 to 2% has negligible effects if compared to the substantial slowdown in the adjustment process of inflation expectations towards the equilibrium that arises following an increase in the inflation target from 2% to 4%; the effects become even larger going from a 4% to a 6% inflation target.

3.4 Implications for monetary policy design

Figures 1 and 2 have notable implications on how monetary policy design should change with the inflation target, in order to anchor expectations and to increase the speed of convergence towards the new equilibrium.

When inflation target is zero, quite surprisingly, an aggressive response to inflation can destabilize expectations under OP, unless it is coupled by an increase in the response to output (see the upper left panel in Figure 1). Intuitively, following an increase in inflation expectations, agents fail to anticipate higher real rates under OP and output rises. As a result, actual inflation increases feeding further inflation expectations, as explained in Section 3.1 at page 8. A hawkish response to expected inflation then tends to destabilize the economy, as inflation expectations can build up progressively even after actual output falls below its steady state level. This mechanism is similar to the one in Eusepi and Preston (2010, pp. 243-244) in an infinite horizon framework. In Eusepi and Preston's words, the central bank is responding *"too much and too late"*. Hence, if the central bank wants to stabilize expectations under OP, it should react more strongly to expected output. For the same argument, a pure inflation targeting central bank (i.e., one that responds to inflation but not to output) needs to be transparent to induce E-stability, whatever the level of the inflation target.

Higher inflation targets change monetary policy design: under both TR and OP, the central bank should respond more strongly to inflation. The minimum ϕ_π required to stabilize expectations increases with the inflation target. As Figure 1 shows, the intersection of the E-stability (as well as the determinacy) conditions under both TR and OP moves to the right. A higher inflation target, however, generates an upper bound for ϕ_y for both cases of TR and OP because of the clockwise rotation of the upper frontier of the E-stability region, following what happens to (7) as the long-run relationship between output and inflation becomes negative. Hence, a too strong reaction to expected output may destabilize expectations by increasing inflation in the future. It follows that if the Fed had to adopt a higher inflation target, it would need to be more aggressive on inflation and respond less to output deviations. This finding provides support to Bernanke's view that it appears unwise to suggest a policy that would increase the inflation target and contemporaneously respond more to output.

As for the speed of convergence, in order to increase it, policy has to move towards the centre of the determinacy/E-stability regions in Figures 2a and 2b: both ϕ_π and ϕ_y have to increase, under both TR and OP.[26] A central bank that responds only to inflation exhibits a very low speed of convergence. A stronger reaction both to inflation and output gives more information to the agents, speeding up the learning process. This is a robust result in our setting: expected output is a leading indicator of inflation, so the central bank can coordinate expectations and determine faster convergence by responding to it. Nevertheless, fine tuning is important, because responding too much to output will have a negative effect on the speed of convergence and could destabilize expectations, especially for high values of the inflation target.

4 Robustness

In this section we investigate the robustness of our results along different dimensions.

Policy Rule. We investigate if and how results change when we modify the policy rule. The determinacy properties are basically the same as in Ascari and Ropele (2009). Regarding E-stability, while a forward looking policy rule does not alter the E-stability region with respect to the benchmark case, a backward looking policy rule always returns E-stability under both TR and OP. These results are not in line with Kobayashi and Muto (2013) because of the different assumptions regarding the learning process (see below).

When one considers the more realistic case of a Taylor rule that includes a lagged interest rate to account for interest rate smoothing by the central bank, then, as the degree of interest rate smoothing increases, the determinacy and the E-stability regions widen for every value of the inflation target.[27] This is in line with previous results that show that interest rate inertia enlarges the determinacy region both under zero (e.g., Woodford, 2003) and positive trend inflation (e.g., Ascari and Ropele, 2009), and promotes learnability (Bullard and Mitra, 2007). Moreover, we find that, as trend inflation increases, the E-stable region shrinks more slowly (if compared to the baseline case). Given our usual calibration, interest rate smoothing allows the central bank to anchor expectations even for values of inflation target as high as 8%. So we can confirm that inertia does promote learnability of the REE even for fairly high levels of trend inflation. Moreover, as the inertia parameter approaches unity, the difference between TR and OP disappears, at least in the positive quadrant of (ϕ_π, ϕ_y). In fact, high inertia makes interest rates more persistent and agents find easier to learn their path: this lowers the benefit of TR. In any case, the main message of the paper goes through: higher trend inflation tends to unanchor inflation expectations in the sense that it makes learnability more difficult and it lowers the speed of convergence.

Learning assumptions. We investigate the robustness of our results to our assumptions regarding the specification of the learning algorithm. If we introduce in the PLM a constant term, as in the seminal paper by Bullard and Mitra (2002), the main results are largely unaffected.

[26] More precisely, in the appendix we show that, for the zero trend inflation case, this implies staying on the locus of points such that the discriminant of the characteristic equation associated with the Jacobian matrix of the T-map is equal to zero, that is to be on the $\Delta(\phi_\pi, \phi_y) = 0$ locus that runs across that region.

[27] The effect is larger for the E-stability region.

The only change is that the long-run Taylor principle frontier - delimiting the determinacy area - and the E-stability frontier now coincide.

The hypothesis that alters more significantly our results is the one about expectation formation. Under contemporaneous expectations, the determinacy and E-stability regions in the positive quadrant of (ϕ_π, ϕ_y) do not change if compared to the baseline case. However, any difference between TR and OP vanishes. In this case there is no central bank's information fruitfully exploitable by the public. This result is in line with Eusepi and Preston (2010).

Model structure. We examine the effects of including price indexation. It is well-known that indexation counteracts the effects of trend inflation. We find that this is true both for determinacy, as in Ascari and Ropele (2009), and for E-stability. We consider the two most familiar cases in the literature: trend inflation indexation and backward-looking indexation (e.g., Christiano et al., 2005). As for E-stability, there is no substantial difference between these two cases. The effects of trend inflation are partially offset by indexation, so that as trend inflation increases the E-stability frontiers shift less with respect to the benchmark case. Partial indexation makes the slope of the Phillips curve less sensitive to trend inflation, because price setters need to a less extent to set very high prices in order to take into account the presence of trend inflation. They are then more sensitive to current marginal costs and economic conditions. This re-establishes the importance of TR.

Finally, we discuss some implications for the degree of price rigidity. More flexibility (lower α) makes both the determinacy and the E-stability frontier come closer less rapidly compared to the baseline case, because trend inflation matters less the more flexible the prices are. Moreover, recall that a lower degree of price rigidity implies a larger difference between TR and OP, because the OP line is quite sensitive to the degree of price rigidity. However, α may not be considered a truly structural parameter, and it could decrease with trend inflation (see Levin and Yun, 2007). In other words, firms would change their price more often (i.e., increase price flexibility) as trend inflation increases. As a result, there could be two possible forces acting as trend inflation changes. On the one hand, higher trend inflation flattens the OP line; on the other hand, if trend inflation causes a lower α, higher price flexibility shifts that line upwards shrinking the E-stability region under OP. Which of the two forces will prevail depends on calibration and on the eventual elasticity of α with respect to trend inflation. If the latter effect prevails, then, as trend inflation increases there would be a greater need for TR, contrary to our baseline case.

Robustness on the other calibration parameters does not qualitatively alter our main results. Decreasing the value of the elasticity of substitution (θ) or increasing the intertemporal elasticity of labour supply (σ_n) makes the difference between TR and OP shrink slower as trend inflation rises. All the above results are available upon request.

5 Conclusions

This paper supports the claim that a higher inflation target unanchors expectations, as often suggested by Bernanke and, more recently, by Yellen. We investigate a New Keynesian model that allows for trend inflation under adaptive learning, in the spirit of Evans and Honkapohja

(2001). We show that the higher the inflation target, the smaller the E-stability region and the slower the speed of convergence to the rational expectation equilibrium. Were the economy hit by a shock to inflation expectations, as the inflation target rises, expectations of the main economic variables move away from their starting equilibrium values with increasing persistence, becoming more and more unmoored, while the adjustment process slows down. Moreover, the higher the inflation target, the more policy should be hawkish with respect to inflation in order to stabilize expectations, while it should not respond too much to output. This result questions the argument that the Fed should increase the inflation target and, contemporaneously, ease monetary policy to respond to the surge in unemployment. Our results suggest that this policy would indeed be "reckless" and "unwise", to put in Bernanke's words.

In addition, our results confirm the claim that central bank communication is an essential component of the inflation targeting framework. When the monetary authority is transparent, agents know its policy rule and use it to form expectations (see Preston, 2006). When a central bank is opaque, instead, agents need to learn also the policy rule. We find that transparency helps anchoring expectations, that is, the E-stability region is wider under transparency than under opacity, but this difference shrinks as inflation targets rise. Nonetheless, a pure inflation targeting central bank needs to be transparent to anchor inflation expectations.

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Tables and Figures

Table 1. Parameters and basic symbols

Structural parameters	
β	Intertemporal discount factor
σ_n	Intertemporal elasticity of labour supply
θ	Dixit-Stiglitz elasticity of substitution
α	Calvo probability not to reoptimize prices
$\bar{\pi}$	Central bank inflation target (or trend inflation)
ϕ_π	Inflation coefficient in the Taylor rule
ϕ_y	Output coefficient in the Taylor rule
NKPC coefficients	
$\beta_{\bar{\pi}}$	$\beta\bar{\pi} + \eta_{\bar{\pi}}(\theta - 1)$
$\kappa_{\bar{\pi}}$	$\frac{\left[1-\alpha\bar{\pi}^{(\theta-1)}\right]\left(1-\alpha\beta\bar{\pi}^{\theta}\right)(1+\sigma_n)}{\alpha\bar{\pi}^{(\theta-1)}}$
$\eta_{\bar{\pi}}$	$\left[1-\alpha\bar{\pi}^{(\theta-1)}\right]\beta(\bar{\pi}-1)$
$\xi_{\bar{\pi}}$	$\frac{\alpha\theta\bar{\pi}^{(\theta-1)}(\bar{\pi}-1)}{1-\alpha\bar{\pi}^{(\theta-1)}}$
κ	$\frac{(1-\alpha)(1-\alpha\beta)(1+\sigma_n)}{\alpha}$

Table 2. Simulated speed of convergence.

Trend inflation = 0%

		Transparency ϕ_π 1.50	2.00	2.50			Opacity ϕ_π 1.50	2.00	2.50
	1.00	0.22	0.34	0.43		1.00	0.35	0.45	0.32
	0.75	0.27	0.41	0.48		0.75	0.42	0.33	0.22
ϕ_y	0.50	0.32	0.42	0.34	ϕ_y	0.50	0.24	0.18	0.11
	0.25	0.29	0.26	0.18		0.25	0.08	0.06	0.04
	0.00	0.17	0.07	0.06		0.00	-	-	-

Trend inflation = 2%

		Transparency ϕ_π 1.50	2.00	2.50			Opacity ϕ_π 1.50	2.00	2.50
	1.00	0.01	0.19	0.28		1.00	$\simeq 0$	0.21	0.29
	0.75	0.04	0.25	0.31		0.75	0.06	0.27	0.32
ϕ_y	0.50	0.10	0.29	0.36	ϕ_y	0.50	0.12	0.30	0.31
	0.25	0.18	0.32	0.34		0.25	0.13	0.23	0.21
	0.00	0.11	0.21	0.22		0.00	-	-	-

Trend inflation = 4%

		Transparency ϕ_π 1.50	2.00	2.50			Opacity ϕ_π 1.50	2.00	2.50
	1.00	-	-	-		1.00	-	-	-
	0.75	-	-	-		0.75	-	-	-
ϕ_y	0.50	-	-	$\simeq 0$	ϕ_y	0.50	-	-	$\simeq 0$
	0.25	-	$\simeq 0$	0.13		0.25	-	$\simeq 0$	0.07
	0.00	$\simeq 0$	$\simeq 0$	$\simeq 0$		0.00	$\simeq 0$	-	-

Trend inflation = 6%

		Transparency ϕ_π 1.50	2.00	2.50			Opacity ϕ_π 1.50	2.00	2.50
	1.00	-	-	-		1.00	-	-	-
	0.75	-	-	-		0.75	-	-	-
ϕ_y	0.50	-	-	-	ϕ_y	0.50	-	-	-
	0.25	-	-	-		0.25	-	-	-
	0.00	-	-	$\simeq 0$		0.00	-	-	$\simeq 0$

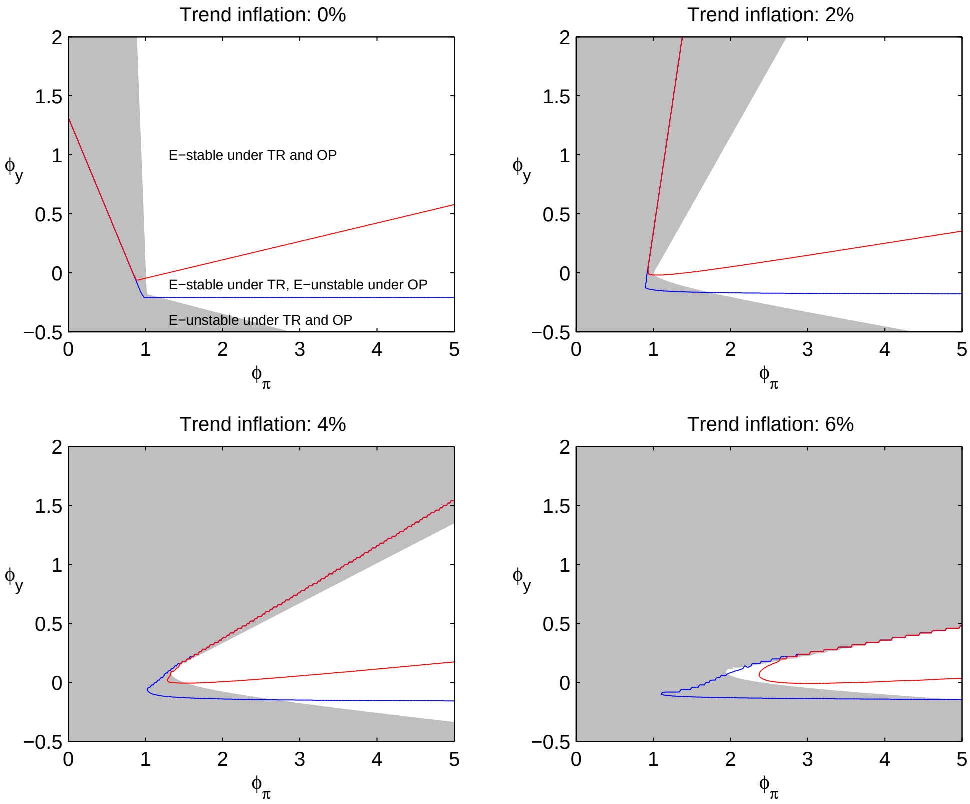
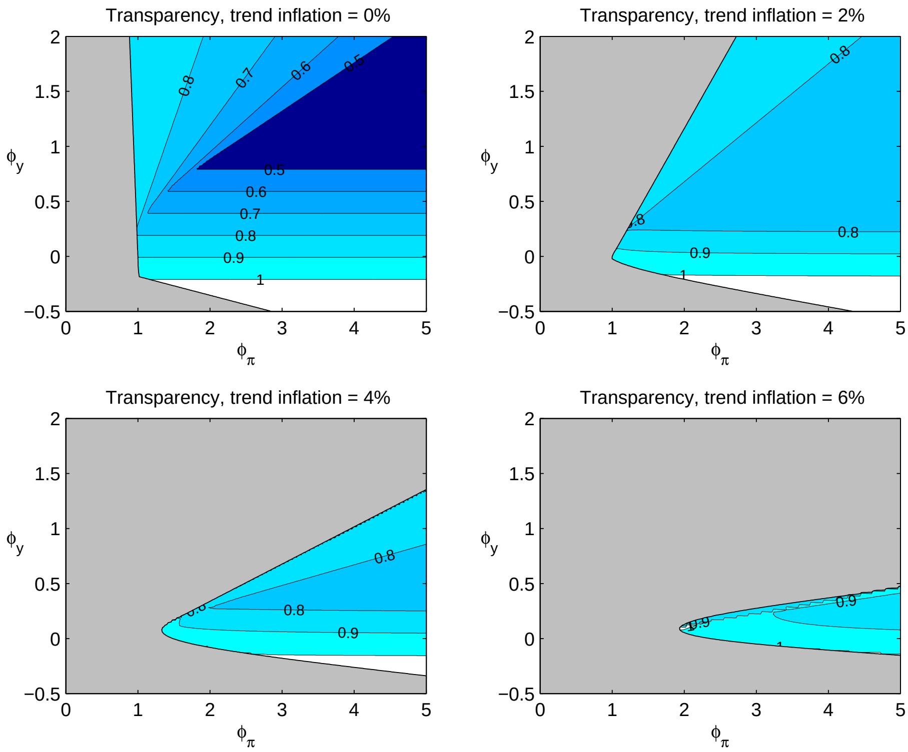
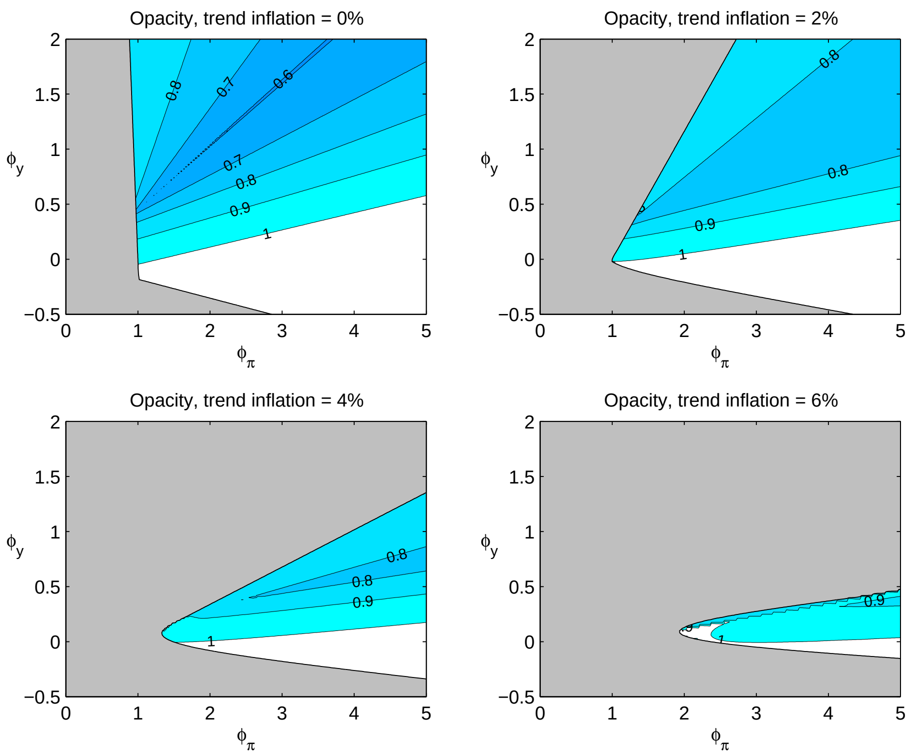


Figure 1: E-stability regions and trend inflation.

Notes: The indeterminacy regions are in grey; the E-stability regions are delimited by the blue line under transparency and by the red line under opacity.



(a) Transparency



(b) Opacity

Figure 2: Iso-eigenvalue curves for different values of trend inflation under transparency and opacity.

Notes: The indeterminacy regions are in grey.

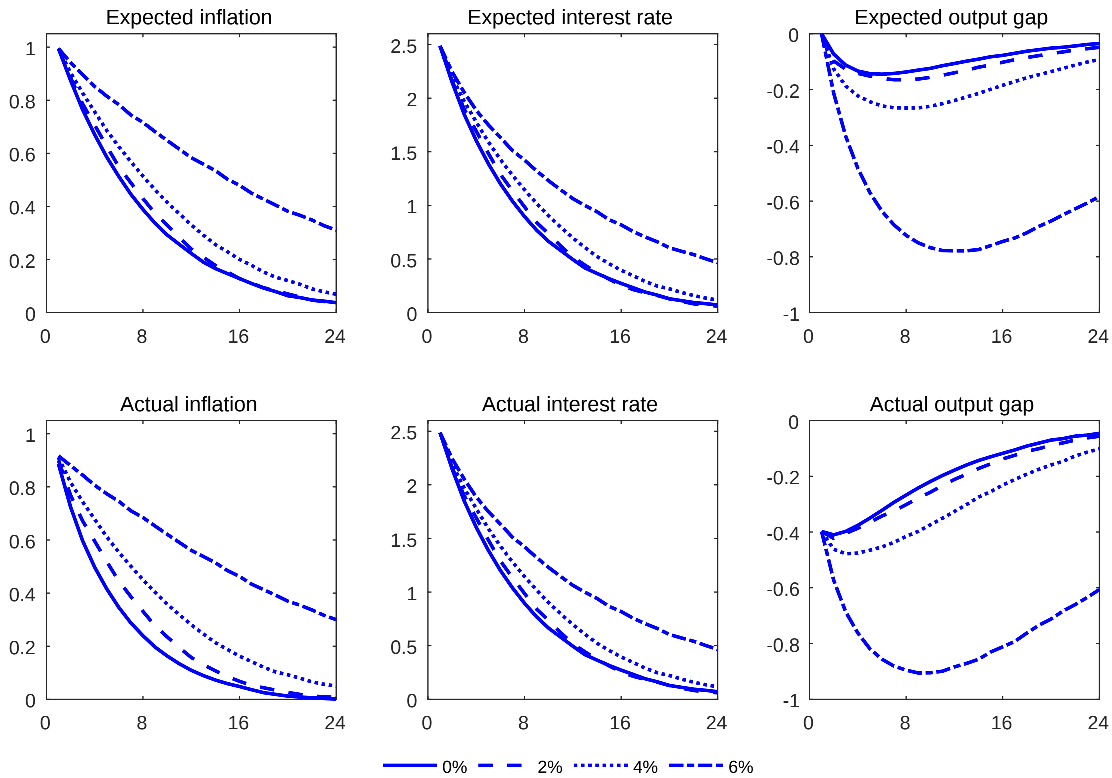


Figure 3: Impulse responses to a 1% shock to inflation expectations for different levels of trend inflation under transparency.