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Forward Guidance and Long Term Interest Rates: Inspecting the Mechanism*

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Abstract

Forward guidance policies are often argued to stimulate economic activity by reducing nominal long term interest rates. We document why a lower nominal long rate is neither necessary nor sufficient for forward guidance to be successful. We determine the mechanisms behind widely varying long rate responses in existing empirical structural models. Imperfect information about the rationale for forward guidance can severely distort long rate effects and attenuate much of its expansive effect. These results suggest caution in interpreting event-studies of forward guidance.

Keywords: Forward guidance, long term interest rate

JEL: E43, E52, E58

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1 Introduction

Forward guidance is one of the unconventional policy instruments introduced during the recent economic crisis and is likely to become a more standard and permanent instrument of monetary policy as suggested by, e.g., John Williams (2013a). In principle, inflation targeting central banks that publish their expected interest rate path for the near future have been using forward guidance as an implicit instrument in practice for a while.

Not many studies, however, provide a detailed discussion of the transmission channel of forward guidance. For example, little is known about the impulse response function of an announced shock to future monetary policy: empirical research aiming at identifying such a shock is rare as this type of policy shock has not been part of the standard monetary policy strategy until recently. From a theoretical perspective, there have been limited efforts to understand the exact transmission mechanism of such a policy announcement. We provide a detailed analysis of the transmission of this kind of policy interventions in the context of models of varying complexity. We focus on three main issues: forward guidance's effect on the long term interest rate, the size of its macroeconomic effects and the implications of imperfectly informed agents in the face of forward guidance policies.

To illustrate the relevance of these questions, consider the impact of forward guidance on the long term interest rate. In its communication on forward guidance, the Federal Reserve insisted that forward guidance supports the economy through lowering the long term interest rate. However, if the central bank can effectively support the economy by indicating that it will keep its short rate lower for a longer time than previously expected, this will have a positive effect on inflation expectations and the expected future behavior of monetary policy. The impact on the nominal long rate is therefore not unambiguously negative. In order to motivate this point further, we refer to two well-known DSGE models that imply opposing answers. According to the New York Fed DSGE model (Del Negro, Giannoni and Patterson, 2014), a stimulating policy action through forward guidance induces a decline in the nominal long rate: a decline that can be very large unless the future short rate policy intentions are fine-tuned to yield "empirically estimated" long rate reactions. On the other hand, policy simulations with the models of Smets and Wouters (2007) and Gali, Smets and

Wouters (2011) produce positive responses in the long rate. Since it is not straightforward to determine which model features precisely cause such differences, we analyze the features of the transmission channel and the economic conditions that determine the impact of forward guidance on the long rate.

We illustrate how any announced forward guidance policy can be decomposed in terms of a series of announced future policy shocks relative to a historical or benchmark policy rule. We explain how these announced policy actions operate in a basic 3-equation NK model, and extrapolate afterwards to more sophisticated DSGE models. In a model that is purely forward-looking, the forward guidance announcement directly controls the long term interest rate response as the economic development further ahead in the future (after the policies are implemented) is left unaffected. In more complicated models, endogenous persistence in output, inflation and the policy rate are important determinants of the transmission channel. The reaction of the economy, and of the long rate in particular, will depend on what happens after the forward guidance is terminated and when the standard policy rule is re-activated: will the economy still be in a depressed state, or will the economy be booming and inflation rising during the exit period? We conclude that, depending on the alternative model features, a successful forward guidance policy can lead to an increase in the nominal long rate, and that communication about this policy should therefore concentrate on the real long rate rather than on the nominal long rate.

Empirical event studies (Moessner, 2013; Williams, 2013b; Woodford, 2013) that establish the negative response of long rates to forward guidance should therefore be interpreted with caution. Firstly, announcements of forward guidance are often combined with other non-conventional policy actions (e.g. in terms of quantitative monetary stimulus) which may have independent effects on long term interest rates. Secondly, forward guidance comes with changing beliefs about underlying economic fundamentals. It is not always clear how agents interpret announced forward guidance: is it a signal of additional monetary stimulus, or rather a sign that the central bank's economic outlook became worse? This leads to a filtering problem that is particularly difficult in the short run, the frequency upon which event studies rely entirely. We illustrate how this misperception of the announced forward policy intentions under incomplete information can both attenuate the effectiveness of the stimulus and implies an initial negative long rate response.

As regards the size of the macroeconomic effects, it is widely documented in the literature that forward guidance, and particularly extended periods of low interest rates pegs, can produce extremely large impulse responses (and even sign reversals, e.g., Carlstrom, Faust and Paustian, 2012) in model simulations. We show how DSGE models generate realistic effects of forward guidance policies when they are formulated in a credible way, i.e. when they are specified conditional on the future state of economy, extreme outcomes or unrealistic impulse responses are avoided in such policy experiments (see also Coenen and Warne, 2013).

The paper is organized as follows. Section 2 identifies the different channels at work in simple forward-looking DSGE models. The effect of backward-looking components is discussed in Section 3. The insights gained thus far help explain the very different outcomes across various policy models, documented in Section 4. Section 5 shows the effect of state-dependent rather than time-dependent forward guidance. The impact of imperfect information on the response of the long rate and the macroeconomy is taken up in Section 6.

2 Forward guidance in a standard 3-equation NK model

In this section, we first explain how forward guidance can be understood in terms of a series of announced interest rate deviations from the historical or the benchmark policy rule. The impact of (changes in) forward guidance can therefore be decomposed in a series of innovations to these announced shocks. We illustrate how we can recover these innovations and how they affect the economy using the standard three-equation NK-model. We start with a purely forward-looking version of the model in which the relation between forward guidance and the long rate is mechanical. Then, we complicate the analysis by introducing endogenous inertia in inflation, output an the policy rule. We document how the structural parameters determine the response of the long yields, inflation and output. These insights will help to understand the outcome of forward guidance simulations in larger empirical DSGE models, that we will discuss in the next section.

2.1 Conceptual issues

First, we introduce a standard three-equation model

$$
\begin{aligned}
y_t &= \frac{h}{(1+h)} y_{t-1} + \frac{1}{(1+h)} y_{t+1} - \frac{(1-h)}{\sigma(1+h)} [r_t - \pi_{t+1}] + \varepsilon_t^y \\
\pi_t &= \frac{\iota}{(1+\iota\beta)} \pi_{t-1} + \frac{\beta}{(1+\iota\beta)} \pi_{t+1} + \frac{(1-\theta)(1-\theta\beta)}{\theta(1+\iota\beta)} y_t \\
r_t &= \rho r_{t-1} + (1-\rho) \left[\phi_\pi \pi_t + \phi_y y_{t-1} + \phi_{\Delta y}(y_t - y_{t-1})\right] + \varepsilon_t^{r0} + \varepsilon_{t-1}^{r1} + \varepsilon_{t-2}^{r2} + ... + \varepsilon_{t-n}^{rn}
\end{aligned}
$$

where y is the output gap, π is inflation and r denotes the short term nominal interest rate. The model has both forward and backward-looking elements. The model simplifies to a purely forward-looking model if the three sources of inertia (habits h, inflation indexation ι, and policy smoothing ρ) are turned off ($h = \iota = \rho = 0$). In that case the only structural parameters are σ (inverse intertemporal substitution), θ (the Calvo probability) and the policy response coefficients to inflation and output. The model features a standard IS shock ε_t^y and a contemporaneous policy shock ε_t^{r0}. As in, e.g., De Graeve, Emiris and Wouters (2009), the long term (10 year) nominal interest rate is implied by the expectation hypothesis and defined as

$$
r_t^{10y} = \frac{1}{40} \sum_{i=0}^{39} E_t r_{t+i}.
$$

Forward guidance is often related to the zero lower bound; in this case the forward guidance states how long the short rate will remain at the lower bound. More generally, the guidance can feature any interest rate path that the policy maker announces for the future, e.g. the published interest rate intentions of inflation targeting central banks. In model simulations forward guidance will matter only if the implied interest rate path deviates from the interest rate dictated by the policy rule. In this case, the message from the forward guidance will appear as announced deviations from this policy rule. Thus, the sole non-standard feature in the above model is the presence of announced innovations to the policy rule, ε_{t-i}^{ri}. These announced innovations from the policy rule effectively enable incorporating zero lower bound-constraints (with innovations imposed on policy by the constraints) and forward guidance (with innovations decided by policy), as shown in Laséen and Svensson (2011). We consider a maximum horizon of n periods in the forward guidance communication.

Defining the series $\{r_0^{FG}, r_1^{FG}, ..., r_n^{FG}\}$ as the announced interest rate path (e.g. the zero interest rate that will be retained for n periods), the policy rule can be written as

$$r_t = \begin{cases} \rho r_{t-1} + (1-\rho)\left[\phi_\pi \pi_t + \phi_y y_{t-1} + \phi_{\Delta y}(y_t - y_{t-1})\right] & \text{if } t > n \\ r_t^{FG} & \text{otherwise.} \end{cases}$$

The policy innovations ε_{t-i}^{ri} that implement such policies can be solved for recursively. For a purely forward-looking model, this is simple as the economy will be in steady state at period $n+1$. The solution for period n directly determines ε_{t-n}^{rn} as the unique innovation that will put the interest rate at the announced level r_n^{FG}. In period $n-1$, the outcomes for n are given and one can solve for the $\varepsilon_{t-(n-1)}^{r(n-1)}$ that will give the announced interest rate rate for $n-1$, r_{n-1}^{FG}. Rolling backward until $t = 0$ thus gives the entire path of innovations consistent with the announced path.

For a model with inertia, the calculations are more complicated as one has to start at a horizon further in the future, and the required shock in period n will change if the announced shock for $n-1$ is changed too, requiring more iterations to converge on the corresponding path of shocks.[1]

We investigate properties of forward guidance in this model for various parameter constellations. For certain experiments, however, it is useful to have a benchmark calibration which produces realistic outcomes. Particularly, since forward guidance is a type of monetary policy intervention, we choose our benchmark calibration such that it produces a more or less standard impulse response to instantaneous monetary policy shocks.[2]

The parameters of that calibration are given in Table 1. Note that the calibration features a high degree of nominal stickiness and interest rate sensitivity of demand, together with a high degree of persistence in all three dimensions: real (habit), nominal (indexation) and policy (smoothing). The response to unanticipated shocks in the benchmark model are contained in Figure 1. Observe that the latter closely matches the generally accepted

[1] A simple procedure implementing such paths uses the deterministic simulator in Dynare. Particularly, using the *simul* function the announced interest rate path can be imposed and the corresponding interest rate shock can be solved as part of the iterative solution method. Hebden, Lindé and Svensson (2010) and Blake (2012) discuss the uniqueness of such shock combinations.

[2] Recent efforts to estimate DSGE models accounting for anticipated monetary policy shocks include Milani and Treadwell (2012) and Gomes, Iskrev and Mendicino (2014).

empirical monetary policy impulse response functions (e.g. in a DSGE context Christiano, Eichenbaum and Evans, 2005; Smets and Wouters, 2003 and 2007; and in a VAR context Christiano, Eichenbaum and Evans, 1999).

Table 1: Baseline calibration

β	0.99	θ	0.95
ϕ_y	0.125	h	0.85
$\phi_{\Delta y}$	0	ι	1
ϕ_π	1.5	π^{ss}	2%
σ	1	r^{ss}	4%
ρ	0.85		

Given the baseline calibration we now provide an example of a zero lower bound scenario for the interest rate following a Great Recession style experiment. In Figure 2 the solid blue line depicts the effect of a severe negative demand shock, ε_t^y. The shock pushes output 4% below steady state while inflation bottoms out at 2% below steady state. The zero lower bound on the interest rate for this calibration is located at -4%. The model's policy rule would dictate the central bank allows the interest rate to go negative, as the impulse response goes below -4%. Since that cannot occur, the red dashed line shows the central bank's response when its behaviour is constrained by the zero lower bound. This happens from $t+6$ until $t+14$. As the actual policy rate is above that implied by the policy rate, this is absorbed by a series of anticipated restrictive policy shocks. Due to this series of additional positive policy shocks, the actual output and inflation responses are -conform the impulse response to monetary policy shocks- even worse than when the lower bound would not bind.

Of course, this path may not be considered as optimal by monetary policy makers as it is exogenously imposed on them by the zero lower bound. As a result, they may well choose to resort to unconventional policies, e.g. some form of quantitative easing or forward guidance. We here are concerned with the latter. Figure 2 (blue dashed line) shows what happens if the central bank were to announce a policy that implements a zero short term interest rate for two additional periods: one quarter before ($t+5$) and one quarter after (*t+15*) the ZLB binds in the red scenario. Thus, the central bank announces to keep the interest rate low for a longer period than the lower bound binds. Observe how the implied anticipated shocks change: the additional stimulus of longer zero interest rates boosts the economy, so the restrictive shocks from $t+6$ to $t+14$ become smaller. Additionally, the extra shocks when the bound would normally not be binding (i.e. periods $t+5$ and $t+15$) are expansionary. This combination of less restrictive shocks and additional expansionary shocks can produce a quantitatively large stimulus. This rationalizes why this forward guidance policy instrument (e.g. additional quarters at the zero lower bound) can be very powerful.[3] In the present case, the announcement of forward guidance manages to fully offset the negative effects of the binding constraint: output and inflation dynamics are virtually the same as in the absence of the constraint.

The policy experiment in Figure 2 already indicates that, contrary to the language often used in policy statements, long term nominal interest rates need not fall as a result of expansive forward guidance. In view of fully appreciating the mechanisms at work, we now turn to analyzing similar announced policy shocks in some very basic models.

2.2 Forward guidance in a purely forward-looking model

We start by discussing the impact of an isolated announced policy shock n quarters ahead in the future. This impulse response is the building block to understand the full impact of forward guidance about the whole interest path. Subsequently we consider the impact of such a shock in combination with a constant interest rate path from the date of the announcement until the period of the policy implementation.

2.2.1 Announced shock in isolation

Figure 3 contains the impulse responses to an announced reduction in the policy rate of 100 basis point 8 quarters ahead.[4]

[3]Eggertson and Woodford (2003) show how a commitment by the central bank to stay longer at the zero lower bound after recovery sets in can help boost the economy.

[4]Thus, across parameterizations the reduction in the short rate r_{t+8} is the same, but the amount of the shock ε^{r8}_{t-8} may differ. In Appendix we show very similar results when keeping shock size constant across

We here only consider one particular horizon at which the expansion is announced, *viz.* $t+8$. The effects of announcements at shorter horizons can be read from the same graphs by simply shifting periods. For instance, the impulse response from $t+8$ onward looks exactly the same as an impulse response to a standard unannounced shock ε_t^{r0} from $t=0$ onward. Similarly, to know the effect of an announcement today of an expansion in $t+4$ it suffices to relabel period 4 in Figure 3 as period 0 (and subsequent periods accordingly). This is true because the model is purely forward-looking.[5]

In the simple forward-looking model there are only four parameters that matter: the intertemporal elasticity of substitution which determines the elasticity of demand to the interest rate; the elasticity of inflation to the output gap and the monetary policy reaction coefficients to inflation and output.[6] Each of these has a direct and clear effect on the transmission of a monetary policy shock. Particularly, the impact of an announced interest rate decline in the future affects the economy via the interest rate elasticity of demand $\frac{1}{\sigma}$. The closer σ is to 1, the larger is the impact of policy shocks on demand, and therefore the higher the resulting boom is. Higher aggregate demand stimulates economic activity which increases the marginal production cost for the firms and thus implies inflation. The extent to which this happens is controlled by the degree of price stickiness θ, which determines the elasticity of inflation to output, or the slope of the Phillips curve.

The forward-looking nature of the model implies that these output and inflation effects start materializing before the actual shock takes place. Thus, if the announcement is credible and agents believe that the future short rate will be different from what they expected before, their decisions will be affected immediately. With aggregate demand and inflation responding to the announced shock starting today, there will also be an endogenous policy response of

different model parameter values.

[5]Depending on the calibration, this also holds true for longer announcement horizons. However, for longer horizon announcements, output may start to react in a cyclical way especially if the policy reaction to inflation is very strong and the real short rate switches sign over the announcement period. All the effects described in the present paper occur at horizons shorter than those that generate "unusual equilibria" of the sort discussed and in Laséen and Svensson (2011) and Carlstrom et al. (2012).

[6]In the calibrations considered here we set $\phi_y = \phi_{\Delta y}$. Hence, in the purely forward-looking model monetary policy responds to contemporaneous output, while the response to growth is absent.

the central bank via the standard reaction function. This policy rule will induce a stabilizing endogenous policy response in short term interest rates that tries to offset the impact of the announced future exogenous disturbance.[7] In other words, the central bank endogenously and immediately leans against the boom it causes by its announced future expansion. This explains the behaviour of the short rate prior to $t+8$.

One important question for our objective in this paper is understanding the response of the nominal long term interest rate. The behaviour of the short rate exhibited in Figure 3 has important implications for the response of long rates. Specifically, the long rate combines the announced exogenous shock in the short rate (which exerts a downward effect on long rates) and the endogenous response of the short rate to the induced inflation and output effects. Importantly, it turns out that under various parameterizations the endogenous reaction in the short rate dominates the exogenous shock effect. This is a first -perhaps surprising- result: long rates today can increase in response to the announcement of a future expansion.

What determines the long rate response then? The relative strength of the endogenous channel is crucial. It is driven by two components. On the one hand, the strength of the monetary transmission mechanism, through σ and θ, determines the extent to which output and inflation react to a given change in policy. On the other hand, how strong the central bank responds to a given change in those variables is determined by ϕ_π and ϕ_y.

Thus, the long rate is more likely to increase when the output and inflation effects of the shock are maximized. This occurs in cases with high elasticity of intertemporal substitution/low risk aversion ($\sigma \downarrow$) and low price stickiness ($\theta \downarrow$). In Figure 3 (panel: long rate), these cases correspond to the subplots toward the northwest. Conversely, in the bottom right corner calibration with low elasticities of both output and inflation, monetary policy shocks have very small effects. As a result, the central bank need not respond much today, thereby reducing the strength of the endogenous channel.

Turning to the policy response, different lines within a given subplot correspond to different policy rules. The first three rules solely respond to inflation, $\phi_y = 0$. Consider, for instance, the upper left corner calibration ($\theta = 0.5, \sigma = 1$). A dovish central bank ($\phi_\pi = 1.1$)

[7] Under a fully optimal monetary policy, the central bank would exactly offset the announcement and there is no room for policy induced surprises.

allows inflation to increase substantially in response to the announcement-induced boom. The huge increase in inflation implies -despite a low response coefficient- a large and long-lasting increase in the short term interest rate prior to the horizon of the announced shock. This implies a strong endogenous channel: short rates prior to the expansion horizon increase. Their upward effect on long rates will counter (and even overturn) the downward effect of the announcement itself. Now compare this to a hawkish central bank ($\phi_\pi = 3$) that keeps inflation in the early periods in check. Here the response of short rates remains small, implying a much smaller endogenous upward effect on long rates (though in this calibration still large enough to overturn the exogenous channel).

When monetary policy also responds to output the relative response as well as the relative timing of output and inflation effects matter. In Figure 3, more flexible prices and higher inflation effects imply that the output effect is smaller. Depending on the reaction coefficient to both indicators, the outcome for the long rate can depend positively or negatively on the price stickiness. For our calibration, it seems that more flexible inflation dominates the output channel, since endowing the policy rule with a non-zero output response does not seem to switch the sign of the long rate response. That said, for the more relevant parameter constellations in Figure 3 ($\theta \uparrow, \sigma \downarrow$) the effect of responding to output is quantitatively substantial. Note particularly how the nominal long rate response is high compared to the other policy rules (stronger endogenous response), which implies less of a fall in the real long rate and thus contributes to a milder boom in output.

The equilibrium outcome of the shock for output -taking into account the inflation and policy response- is summarized by the long *real* rate reaction. As implied by the Euler equation, the output response mirrors the outcome for the long real rate. Both the real long rate and output can increase or decrease following an announced shock: a higher interest elasticity of demand ($\sigma \downarrow$), and more price stickiness ($\theta \uparrow$) increase the real demand effect.

2.2.2 Announced interest path plus additional shock

We now turn to the impact of an announced shock in combination with a constant interest rate path from the date of the announcement until the period policy implementation. This can be thought of as a projection under a fixed interest rate path but with a change in the interest rate path only in the future. This sheds light on mechanisms also present in case of an announced prolongation of the forward guidance horizon, a policy that many central banks have recently adopted by announcing to stay longer than initially announced at the zero lower bound.

Suppose that the central bank announces the same drop in the short rate in $t+8$, but promises to keep interest rates unchanged prior to that date. In other words, the following policy is announced: $\left\{r_0^{FG}, r_1^{FG}, ..., r_n^{FG}\right\} = \{0,0,0,0,0,0,0,-1\}$.

Essentially, the constant path implies that the endogenous reaction is neutralized by further expansionary shocks. Particularly, the central bank now chooses shocks $\left\{\varepsilon_{t-0}^{r0}, \varepsilon_{t-1}^{r1}, ..., \varepsilon_{t-8}^{r8}\right\}$ that implement the announced path. Figure 4 shows, for one particular calibration, how such a policy changes the impulse responses relative to an announced impulse in $t+8$ without the promise to keep the path fixed. We saw earlier that an announced shock will endogenously entice the central bank to increase its short rate before the actual policy implementation. Eliminating that increase implies a series of intermediate announced expansive policy shocks, as seen in the bottom right subplot. This has two important effects. First, the expansive nature of these shocks implies that output and inflation effects will be reinforced. Second, the nominal long rate response now only depends on the exogenous shock.

2.2.3 Discussion

Summing up, the forward-looking model exemplifies how 1) the announcement of a future policy expansion generates an immediate endogenous response, which may well overturn standard negative long term interest rate responses, 2) when combined with a fixed interest rate path, this endogenous channel is effectively turned off.

An important implication is that an extension of the forward guidance horizon beyond what is thus far announced need not lead to a decrease in long term interest rates. To see that, let us return to Figure 2. Consider a situation where we are at present below the ZLB. Effectively, this means the economy is hit by a series of restrictive monetary policy shocks (shown by the red dashed line in the bottom right subplot of the figure). At this point, lift-off from the ZLB is expected at $t+14$.[8] Now suppose the central bank announces it intends to

[8] Though not by a large amount, the short term nominal interest rate in $t+15$ is in fact positive. Hence

keep interest rates at zero for longer (presumably in view of providing additional stimulus). The effect of this policy will work through the mechanisms described earlier. First, the exogenous effect of an announced shock will tend to reduce nominal long rates. Second, however, that additional stimulus also implies, through the endogenous channel, that the short rate in the intermediate periods will rise, as seen in Figure 3. This means that the restrictive policy shocks that implemented the ZLB initially now become less restrictive (i.e. the switch from the red to the blue line in the bottom right subplot of Figure 2). Figure 4 (top left and bottom right subplots) exemplifies how future expansions under a constrained intermediate path will induce such effects. Another way of stating the same thing is that the shadow rate (i.e. the short rate that would apply if nominal rates were allowed to go below zero) becomes less negative due to the prolongation of forward guidance. Through this endogenous channel, prolongation of the time spent at the ZLB may thus imply an increase in nominal long term interest rates.

This does not necessarily mean that if nominal long rates increase the forward guidance prolongation will have detrimental effects on the real economy. But it does show that the channel through which policy is often argued to work is not necessarily operative.

In the experiment of Figure 4 we saw how the nominal long rate reaction to a future announcement with a fixed intermediate path depends exclusively on what is going to happen after the intermediate period is terminated. But since the present model is purely forward-looking, nothing happens after the announced shock (i.e. from $t + 9$ onwards, all IRFs are back to baseline). Therefore, the long rate response is entirely driven by the announced exogenous shock in $t + 8$.

Such an extreme form of front-loading is, however, particular to purely forward-looking models. In more general models backward-looking model features do imply post-implementation effects. These will exert additional effects on nominal long rates. Thus additional questions become relevant: Will the short rate increase faster or more slowly once the standard policy reaction function kicks in again? Is the economy (and inflation) boosting during that period? Or will the economy cool down as soon as the stimulus from the central bank is terminated? We now study such effects by activating the backward-looking components of

the ZLB only binds until $t + 14$.

the model described in Section 2.1.

2.3 Forward guidance with persistence

Persistence can come from different blocks of the model. We here consider the effects of output persistence (through habits h), inflation persistence (through indexation ι) and monetary policy inertia (through smoothing in the policy rule, ρ). We present results conditional on one particular calibration of the parameters in the forward-looking model: that underlying Figure 2. Of course, there exist potential interactions between parameters that scale inertia and parameters that characterize the forward-looking model. We indicate such interactions where relevant.

A general feature of models with backward-looking components is that real transmission will extend beyond the announcement date. As a result, an endogenous channel similar to the one found in the forward-looking model arises. The central bank policy rule responds to fluctuations after the announcement. That response will trigger movements in the short rate, which will transmit to long rates. As a result, to the extent that the economy is booming when the forward guidance period ceases, this may exert an additional positive impact on long term nominal interest rates.

2.3.1 Announced shock in isolation

Figure 5 contains the impulse responses to an announced shock in $t + 8$ in the backward-looking model. Two particular calibrations in these figures are noteworthy. First, the ($\rho = 0$)-response in the upper left corresponds to the exact same policy rule as in the forward-looking model (which in Figure 3 can be found in the bottom right corner). Second, the ($\rho = 0.75$)-response in the bottom right corresponds to the more realistic calibration that underlies Figure 2.

The response of the long rate clearly exhibits post announcement-period dynamics. These were absent in the forward-looking model, where all the effects of the announced shock are front-loaded.

For very high degrees of indexation the sign of the long rate response can change. The quantitative impact, however, remains somewhat limited. Recall that high price stickiness (θ) is one crucial parameter to generate a negative response in the long rate in the forward-looking model. This is a retained feature in the backward-looking model. The long rate reaction is much more positive in case of lower stickiness. The reason is intuitive: lower stickiness implies a stronger inflation response. In the forward-looking model this implies an endogenous leaning against the wind policy by the central bank in the periods prior to the announced shock. Once inertia are incorporated in inflation dynamics (higher indexation ι), this also translates in significant inflation post-announcement. As a result, the endogenous channel will push short and long term rates upward also after the forward guidance period ends.

Habits (h) and a positive policy response to output growth ($\phi_{\Delta y}$) generate similar effects to the above, though in this case through the persistence in output dynamics. The persistence parameter ρ determines the size of the shock to some extent: with more persistence in the policy rule, the policy shock is perceived as more persistent and therefore the effects are reinforced (more positive or more negative overall).

As before, the long rate response summarizes the short rate response. The endogenous response in the short rate is uniformly positive prior to the shock. In the post forward guidance period, the endogenous response can be initially negative (mostly in cases with high persistence in the policy rule ρ), but often turns positive afterward.

In the present calibration the endogenous reaction remains quantitatively limited because both output and especially inflation is very insensitive to the exogenous shock.

The long *real* rates are almost uniformly negative and very similar across parameterizations. Again, they mirror the real output effects, which are notably smoother in case of higher habit.

Importantly, observe that the announced shock induces a boom in all these calibrations. This happens despite the fact that nominal long rates occasionally increase. This showcases how the success of forward guidance does not hinge on reduced long term nominal rates.

As a final note, in the backward-looking model it is not necessarily the case that different horizons for the shock can be read from the same graphs. In fact, there is a small difference. For instance, in case of high indexation coupled with high habits the long rate response to a shock in $t + 8$ is uniformly positive, as is apparent from the lower right subplot in Figure 5. When the timing of the shock is $t + 4$, however, the long rate initially responds negatively. The reason is that the boom in output is now smaller and takes place earlier. This implies that the entire endogenous channel is quantitatively smaller, and that the pre-implementation endogenous response does not build up as long. Both contribute to a lower nominal long rate response.

2.3.2 Announced interest path plus additional shock

We now consider the case of keeping the policy rate fixed in the intermediate period, prior to the implementation of the shock. The short rate impulse response in Figure 6 illustrates what happens in this scenario. Particularly, the short rate is kept constant during two years at its previously announced path and is followed by a negative shock. These scenarios are particularly informative as to what happens, for instance, when policy is constrained by the zero lower bound and then announces to keep the rate low for one extra period.

As in the forward-looking model, such a policy effectively shuts down the intermediate period endogenous channel. However, the post forward guidance endogenous channel is still operative and crucial for the outcomes here. In fact, it is obvious that now the dynamics that follow after the forward guidance period become crucial to determine the long rate response. With no persistence in the policy rule, the short rate turns positive immediately after the shock as it reacts more to the expansionary effects. These effects will be stronger with more persistence in the economy both on the real side (habit) and the nominal side (indexation). If there is more persistence in the policy rule the short rate response will be lower for the subsequent periods as well. It will, however, exceed the outcome with no inertia later on as the endogenous reaction to the expansionary effects dominate. Here too, this response will be stronger the more persistence there is in the economy.

It naturally follows that long rate response will be higher in calibrations characterized by more persistence (through habit, indexation and policy). As before, these responses would shift upward if price stickiness was lower, or if the intertemporal elasticity of substitution was higher (σ lower).

From the impulse responses for output and inflation, it is clear that more persistence

$(h, \iota, \rho, \phi_{\Delta y})$ generates much stronger post-forward guidance output and inflation effects. Thus, the higher output, output growth or inflation during that period, the stronger the endogenous reaction will be. If the economy exits the forward guidance period with a booming economy and high inflation, the expected policy reaction will be much more restrictive which can induce a positive long rate response. If, on the other hand, the economy displays a strong front-loading of the effects (similar to the purely forward-looking model), the economy risks to be already on a declining growth and inflation trend when exiting the guidance period, thus contributing to lower interest rates. Note that persistence in the inflation process, more than the habit process for the real economy, plays a very important role.

3 The long rate reaction to forward guidance in fully-specified DSGE models

We now consider three estimated medium-scale DSGE models. These are the models of Del Negro et al. (2014, henceforth DGP), Smets and Wouters (2007, SW) and Gali et al. (2012, GSW). The policy studied is one where the central bank announces to keep interest rates fixed for five quarters, followed by an expansive shock in $t+6$: $\{0, 0, 0, 0, 0, -0.5\}$.

The response of the long term nominal interest rate across these models is shown in the upper right subplot of Figure 7. The DGP model implies a negative nominal long rate response. Although the scenarios they consider are somewhat different, DGP argue that the fall is implausibly large from a quantitative perspective (relative to observed long rate changes on policy dates).

This negative long rate response contrasts with the response in the other two models, where it is positive. Apparently, the fall in long rates found in DGP is model-dependent. This has two immediate implications. First, perhaps there is not as much a puzzle, as there is a need to dig into understanding how various structural features matter for transmission of forward guidance to long term rates. The previous section did as much in the canonical NK model. The remainder of this section further documents which frictions matter mostly for long rate outcomes between these medium-scale models.

A second implication concerns empirics. Most of the empirical evidence we have thus far on forward guidance comes from event studies around policy dates where forward guidance was not necessarily the sole policy change. For instance, ample changes in QE were communicated alongside forward guidance statements. As a result, the measured change in long term interest rates is affected by all policies. Since long rates may well increase following forward guidance (as shown earlier), and other policies could arguably cause a decrease in long rates (e.g. QE), measured changes only capture a net effect of multiple, and possibly opposing forces. This is further complicated by the potentially unclear informational content of the policy intervention: is the announcement signaling additional bad news about the state of the economy, or is it really additional stimulus given a particular state of the economy (i.e. announcing exogenous expansive policy shocks). This suggests caution when interpreting results of event studies. Importantly, as also apparent from the earlier analysis, the success of forward guidance does not hinge on a particular nominal long rate response. Instead, in the models studied here the real long term interest rate response is what matters for output dynamics.

So what explains the substantial difference between the DGP model on the one hand, and the SW and GSW models on the other? The remaining panels of Figure 7 contain the responses for variables other than the nominal long rate. Note that the short rate response in DGP remains negative throughout, whereas it becomes positive in (G)SW shortly after the guidance period ends. This suggests that the endogenous channel is relatively unimportant in DGP. This could be because the economy responds fairly little to the monetary expansion, or because monetary policy responds little to the demand effects.

To shed light on this, Table 2 contains differences across these models in terms of structural parameters. It shows how, compared to (G)SW, the DGP model is characterized by a high degree of nominal stickiness (low price and wage elasticities), absence of indexation, and a policy rule with a strong inflation but low output (growth) response. In view of assessing which frictions are key, numbers in bold typeface in Table 2 document counterfactual long rate responses: those that occur if we impose the DGP values of certain structural parameters in SW and GSW.

Consider what happens to the long rate response when plugging DGP's degree of nominal (wage and price) stickiness in SW and GSW. The long rate response in SW jumps into negative territory: from +0.030 to -0.035. Similarly, in GSW the long rate falls by -0.053 following the announcement with DGP stickiness, compared to an initial increase of +0.104 in GSW. No other friction generates as large a negative effect on the long rate response as nominal stickiness. It accounts for more than half (!) of the difference between (G)SW and DGP. The reason nominal stickiness is essential is easily understood. DGP have a very high nominal price and wage stickiness. Therefore, the inflation response to an expansive forward guidance shock in SW+DGP stickiness will be lower than in the original SW, as is apparent from Figure 8. This implies that the endogenous short rate response after the exit from forward guidance will have to increase by less. As a result, the long rate will increase by less, or even decrease. In sum, by preventing the strong rise in inflation observed in SW, a strong contributor to the endogenous channel is shut down in DGP.

While the counterfactuals go in the same direction for indexation, it has a quantitatively smaller impact: the long rate response is now only about 0.035 lower for both SW (-0.003) and GSW (+0.063). The reason for the absence of indexation contributing to a lower long rate response comes from increased front-loading. In DGP, the effects on inflation and output peak earlier in time, while the fixed-rate path is still in effect. This implies that both output and inflation will be on a downward trend when the forward guidance period ends (see Figure 8). As a result, during the exit phase, the endogenous policy contribution will demand lower short term interest rates compared to the SW model, where inflation is still higher and output growth is still positive.

Of all the remaining differences in parameters across models, the only block of the model that can also generate a substantially negative nominal long rate response is the policy rule. The main difference between rules in the different models is that DGP is characterized by a very small response to output and output growth. The policy response to output was quantitatively important in the purely forward-looking model already, although it did not alter the sign of the long rate response. Here, changes in the response to real dynamics do turn a positive response in (G)SW into a negative one.

Compared to SW, DGP also contains a financial accelerator, while GSW incorporates a labor market block. None of these turn out to drive the long rate differences in a quantitatively important sense. Other parameter differences, such as habits and investment adjustment costs, also do not seem to be able explain why long rates fall in DGP, while they rise in the alternative models.

As argued in Carlstrom et al. (2012), prolonged fixed rate paths in NK models can give rise to substantial sensitivity. This is particularly true for models with ample backward-looking components, such as the above medium-scale DSGE models. Figure 9 shows that sensitivity, by extending the horizon an additional period further. One can observe a rather strong quantitative sensitivity of the outcomes, particularly for GSW. One way of preventing such extremes is by means of conditional, or state-dependent, forward guidance. We now turn to such policies.

4 Conditional forward guidance scenarios in GSW

In this section, we consider the macroeconomic effects of forward guidance when the duration of the announced policy rate is conditioned on the future state of the economy. In light of its enhanced communication strategy regarding the future short-term interest rate to improve transparency and to support economic recovery, the FOMC switched from date-based to state dependent forward guidance in December 2012 by announcing that no increase in the federal funds rate should be expected "*at least as long as the unemployment rate remains above* $6-1/2$ *percent, inflation between one and two years ahead is projected to be no more than a half percentage point above the Committee's* 2 *percent longer-run goal*"[9].

As stated by Coenen and Warne (2013), this explicit linking of the policy rate to the Fed's dual mandate objectives can help to prevent extreme and unrealistic outcomes. We illustrate this idea by performing an experiment along the lines of the one conducted in Section 2.1, within the GSW framework. Among the DSGE models considered previously, GSW is the most suitable for this exercise given that it allows us to explicitly consider unemployment as a treshold variable on which the policy rate can be conditioned. In order to make the scenario more realistic, we set the initial state of the economy to be consistent with the one prevailing at the end of 2012, i.e., the time around which conditional forward guidance

[9]Quote taken from the Federal Reserve Issues FOMC Statement (2012).

was first announced. Figure 10 shows the results of the experiment where the short term rate is fixed at zero for as long as unemployment remains above $6-1/2$ percent. A baseline scenario where the short term policy rate is unconstrained is represented by the solid bold line, while the solid thin line prevents the rate to go below zero. As is clear from the figure and in line with the discussion of Figure 2 in Section 2.1, the economic outlook worsens when the policy rate is not allowed to decline below the zero bound. Compared to the baseline scenario where the policy rate remains negative for four quarters, the constrained scenario implies restrictive anticipated policy shocks for the four consecutive quarters. As a result, responses of output, inflation and unemployment worsen.

When the central bank announces to keep the policy rate at zero for longer and as long as unemployment remains above $6-1/2$ percent, the condition is achieved when the interest rate is kept at zero for six quarters[10]: the broken bold line in the figure plots the responses of all the variables in this case. From the third panel on the right of the figure, we can observe that unemployment reaches its treshold value around the sixth quarter, which is when the response of unemployment crosses the horizontal dotted line.

As discussed in the previous section, the GSW model features a relatively low degree of price and wage stickiness. This makes the inflation response particularly sensitive and one period of additional forward guidance can lead to a large increase in the magnitude of the responses. Indeed, when we keep the policy rate at zero for one additional period after the condition for unemployment has been reached, inflation responds more strongly than before, as shown by the thin broken line. While the response in the nominal long rate is rather contained, the real long rate response is strong and as a result we observe similar excessive responses in output and unemployment. By conditioning forward guidance on the state of the economy, however, macroeconomic stability can be imposed to the extent that the occurrence of extreme scenario's can be avoided. In this way, conditional forward guidance guarantees that the implied policy behavior and the corresponding macroeconomic

[10] Because of the higher sensitivity of GSW compared to SW and DGP, the unemployment treshold is reached somewhat sooner than what one might consider as a realistic horizon for forward guidance. When we perform a similar exercise in SW, for example, by defining a treshold for employment that is equivalent to the unemployment treshold in GSW, the forward guidance scenario lasts for eight quarters. Hence, compared to GSW two additional periods are needed to reach convergence in the SW model.

prospects are consistent with the central bank's mandate which is a necessary condition for the credibility of the announced policy intentions as well.

5 Forward guidance under imperfect information

Forward guidance is the announcement of future planned actions, not actual decisions. This implies that the credibility of the announced plans and the correct interpretation by the private sector are crucial questions. The message about more expansionary future plans is a difficult message: the benchmark against which this more expansionary plan has to be evaluated is not directly observable or even well-defined. Therefore, it is very difficult for the private sector to distinguish the underlying motivation for the lower than previously expected rates. On the one hand, it may signal additional (exogenous) monetary stimulus for a given state of the economy. On the other hand, it could equally signal additional (endogenous) stimulus in response to a worsened assessment of the state of the economy.

This interpretation problem is even more important for forward guidance at the ZLB: the response of the short term interest rate does not help discriminating between such interpretations. Clearly, which interpretation holds potentially has important effects on the long rate response to forward guidance and its macroeconomic impact. Additionally, because the reaction of the long rate is not unambiguous (see Sections 2 and 3) and therefore not very informative, it may itself even be a potential source of confusion.

Campbell et al. (2012) and Filardo and Hofmann (2014) go some way in empirically discerning the role played by different interpretations. Seok Lee (2014) analyzes the reduced informational content of the short rate at the ZLB. We here conduct a number of model experiments that shed light on how such confusion might play out, and in particular on how it would affect the response of the long rate. We study the effect of partial information following the solution methods proposed in Pearlman et al. (1986), who solve the intricate filtering problem agents are faced with when deviating from a full information setup. Our analysis is related to earlier applications of that approach, such as Erceg and Levin (2003), Lippi and Neri (2007) and Collard and Dellas (2010). The presence of anticipated shocks and long term interest rates introduces additional effects over and above those described therein.

The setting we consider is as follows. We conduct all experiments in the SW model *cum* long rates. This model contains 7 shocks and was estimated under the assumption that agents have full information, with the econometrician having 7 observable variables (r, p, w, y, i, c, l). Departing from full information, with agents observing only those 7 observables (rather than all the shocks and variables as in SW) has no impact: the impulse responses to all shocks are identical.

5.1 (Un)anticipated shocks

Introducing anticipated shocks in that imperfect information environment does have substantial consequences.[11] For a given set of observables there are now more shocks, which generally burdens identification on behalf of the agents. But anticipated shocks are particularly hard to disentangle. To see that, consider first the response to unanticipated monetary policy shocks in Figure 11. They have very similar effects under partial information compared to the full information case. Similar results obtain for alternative unanticipated shocks. This contrasts with the impulse responses to an announced monetary policy shock one quarter ahead, shown in the upper panel of Figure 12. Here, quantitatively substantial and long lasting differences in transmission occur as a result of the partial information assumption. Apparently, the filtering problem that agents face with anticipated shocks is particularly difficult.

The bottom panel of Figure 12 provides additional detail on the mechanism behind those differences. An essential feature of imperfect information is that expectations adapt through time: with more information, agents update their beliefs. The right-hand subplots show such updates: the blue line shows the expectation agents have in period 1 (the announcement period) about the periods to come. The green line contains the expectation made at time 2 for periods 3 and beyond. Two features are particularly noteworthy. First, under full information expectations overlap. Since all the relevant information about shocks and states is immediately available to the agents, their expectations are immediately correct and do

[11] Because the long rate and future short rates are part of the model, agents understand the announcement in the sense that they know the short rate (an observable) will fall, but not necessarily why.

not require updating. Second, under partial information the biggest revision in expectations occurs at the time the anticipated shock actually takes place. As shown in Figure 12, agents' uncertainty about which shock they face is (largely, but not fully) resolved only once the shock actually takes place.

This effect of partial information is particularly relevant for long term interest rates. At least initially, expectations of future short term interest rates can be very different from their eventual outcome. Since long rates cumulate expectations over a long horizon, partial information may imply very different long rate effects compared to a full information environment. At a general level, this evidence adds to the sensitivity of long rate responses documented earlier. More specifically, these results show how the scope for confusion is maximal immediately after the announcement is made. As a result, the long rate response in a short time window following the announcement need not be the best measure of the success of forward guidance.

5.2 Fixed rate path

Solving for the path of anticipated shocks that implements a fixed rate path is particularly intricate in a partial information environment and beyond the scope of the paper. Instead, as a simple way to see what happens when the central bank cannot move the interest rate, we consider the effect of an alternative policy rule:[12]

$$r_t = \rho r_{t-1} + (1-\rho)\left[\phi_\pi E_{t-6}\pi_t + \phi_y E_{t-6}\hat{y}_t + \phi_{\Delta y} E_{t-6}\Delta\hat{y}_t\right] + \varepsilon_t^{r0} + \varepsilon_{t-1}^{r1} + \varepsilon_{t-2}^{r2} + ... + \varepsilon_{t-n}^{rn}$$

where $\hat{y}_t = y_t - y_t^f$. Rather than responding to current economic conditions, the short rate now responds to earlier expectations of current inflation and output. As evident from Figure 13 (solid line), this policy rule implements a fixed short rate path by construction. The full information response here is identical to that obtained when implementing a fixed rate path using anticipated shocks with a conventional policy rule - i.e. the approach explained in Section 2.1 and adopted thus far. Note from the figure that the real rate falls on impact, causing an immediate boom, while the nominal long rate increases.

[12] We have experimented with alternative approaches to approximate the ZLB, with overall similar conclusions.

Under partial information, the policy announement has the following effect. If agents do not observe the long rate, or if the long rate is measured with error (i.e. $R^L = EH + ME$, where EH denotes the expectations hypothesis component and ME measurement error), the dashed IRF occurs (Figure 13). In this setting, forward guidance loses a fair bit of its potence. That is, essentially nothing happens on impact: the real rate slightly rises, output and inflation remain unchanged. Any positive effects of additional forward guidance are pushed out into the future, and only occur once the policy is effectively implemented and the agents' confusion is largely resolved. Importantly, throughout this time, the nominal long rate falls. But this is hardly a sign of success. It only occurs because agents are pessimistic about inflation and output prospects relative to a full information setting, and these lower expectations act as a drag on the intended economic expansion.

There are various potential reasons to think that long rates are less than fully informative about the announced policy. First, movements in term premia may obscure the expectations-driven part. Second, alternative policies such as QE, often announced simultaneously, may distort long rates in unknown ways. Third, alternative (real and nominal) anticipated shocks, though here unmodeled, will equally confound movements in long rates.

One way to view central bank communication is that it can shed light on those components. Particularly, the clearer the expectations part of long term interest rates is conveyed, the less scope there is for agents to be confused. To see this effect, consider the dotted IRF in Figure 13, which obtains when ME is entirely absent (or the long rate perfectly observed). This will result in forward guidance being more effective: the real rate falls on impact, causing the economy to boom simultaneously. This goes some way toward restoring the potential of forward guidance, as observed under full information.

Ultimately, provided all possible information is clearly communicated, forward guidance achieves its full potential. This is the case in the circled IRF in Figure 13, where agents actually observe the full path of forward rates, without error. These IRF overlap entirely with those under full information.

In sum, in the presence of imperfect information, agents may confuse the exogenous expansive nature of the policy announcement with (an endogenous policy response to) a worse outlook for the economy. As a consequence, the nominal long rate falls. In evaluating policy across the world, the extent of the fall in the long rate is often taken as a measure of success of forward guidance. The experiments above show that need not be very informative: while the nominal long rate falls by more compared to the full information case, the real long rate falls by less, or even increases. This limits the ability of the announcement to generate a boom. It is in this sense that clear communication of the central bank can help. By explicitly stating expectations, not just of short rates, but also of inflation and output, agents can form expectations subject to less confusion and thus more closely mimic the full information response.

On a final note, remark that uncertainty lies behind these alternative effects of forward guidance. Uncertainty about the source of fluctuations causes potential confusion on behalf of the agents. The channel is, however, different from alternative uncertainty effects of forward guidance, which act through volatility. Such effects are described in Akkaya, Gürkaynak and Wright (2014) and Altavilla, Carboni and Lenza (2014).

6 Conclusion

A fall in the nominal long rate is neither necessary nor sufficient for forward guidance to be successful. As regards necessity, many DSGE models can imply an increase in the long rate in response to an announced future expansion. The underlying reason is an immediate endogenous policy response to the foreseen boom in output and inflation. Concerning sufficiency, a fall in the nominal long rate in response to forward guidance need not be testimony to its success. We show how imperfect information about the rationale behind the guidance can imply both a fall in the long rate and a much attenuated boom.

Our results have three main implications. First, empirical evidence on the effects of forward guidance policies based on event studies measuring the fall in the nominal long rate should be interpreted with caution. Second, by conditioning the duration of the announced policy rate on the future state of the economy, extreme and unrealistic outcomes can be avoided, and a more stable macroeconomic environment can be achieved in implementing forward guidance. Third and finally, policy communication and evaluation could benefit from focusing more on the real long term interest rate.

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Figure 1: Standard monetary policy shock in realistically calibrated model

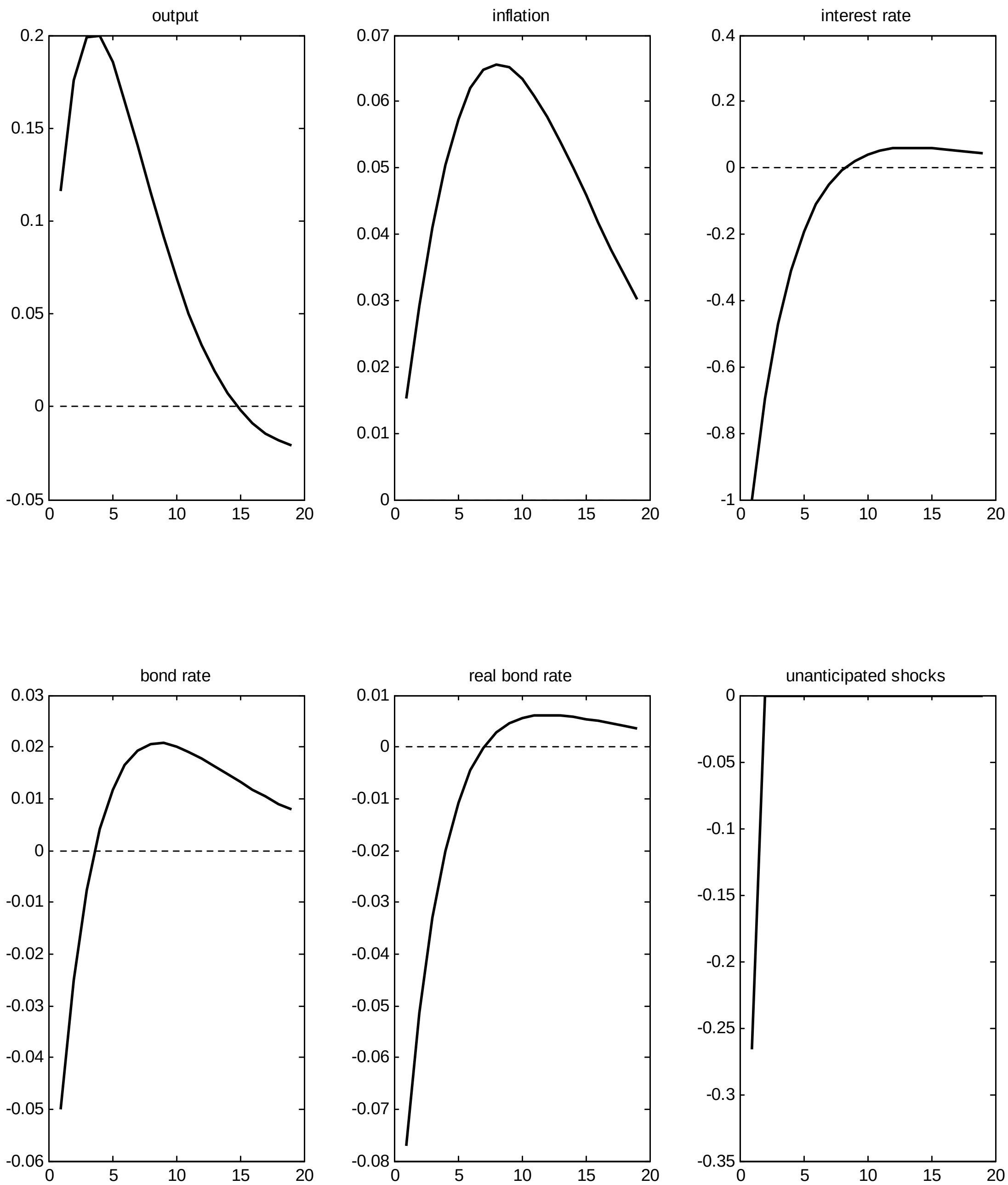


Figure 2: Crisis scenario with impact of ZLB and forward guidance

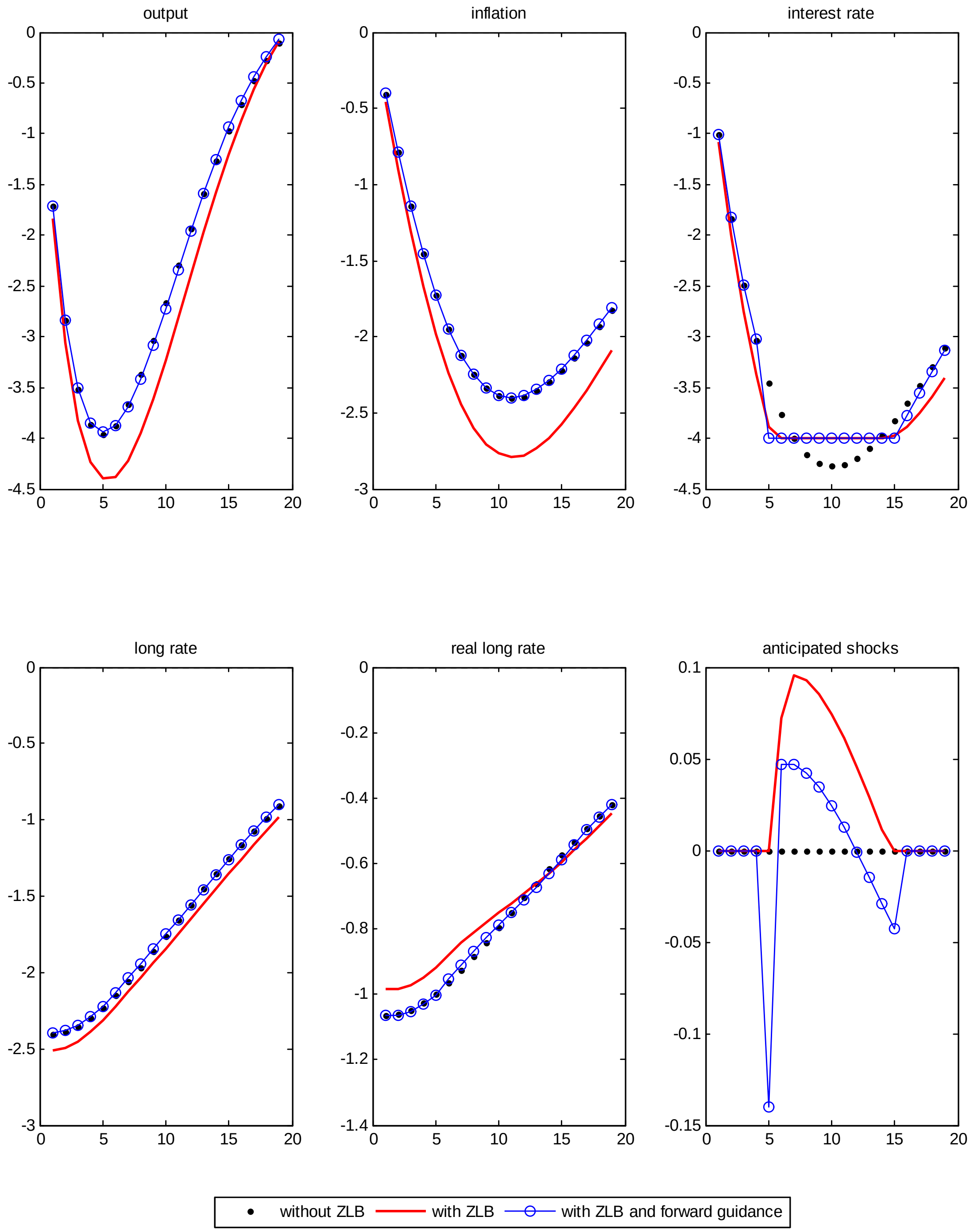


Figure 3: Announced expansion in $t+8$: Forward-looking model

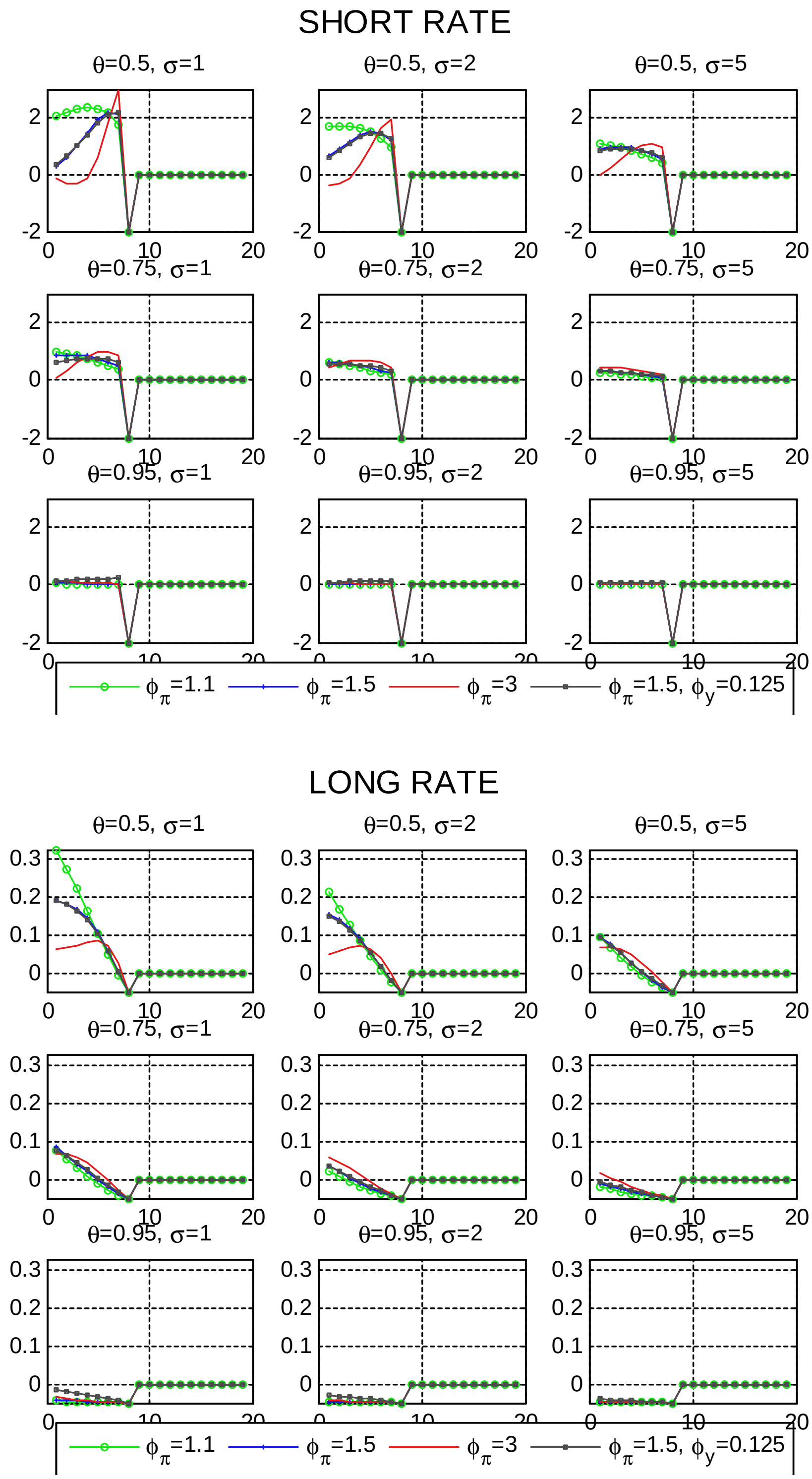
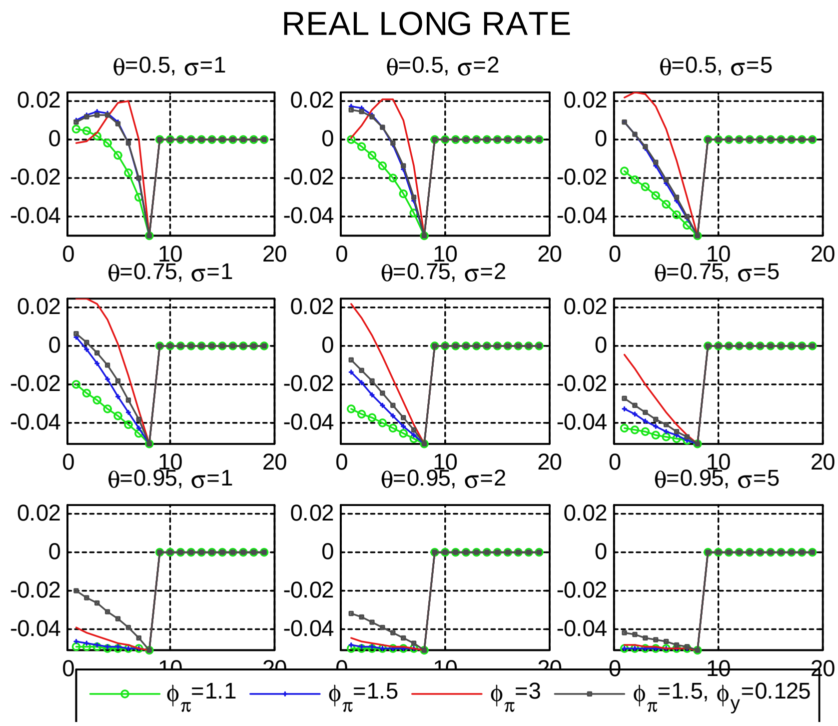


Figure 3 (cont'd): Announced expansion in $t+8$: Forward-looking model



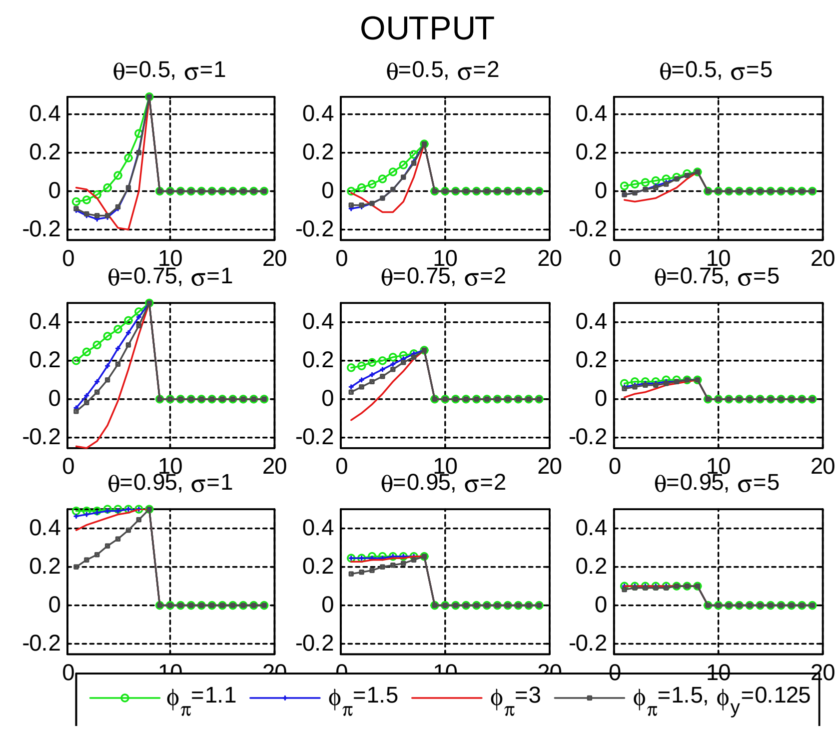
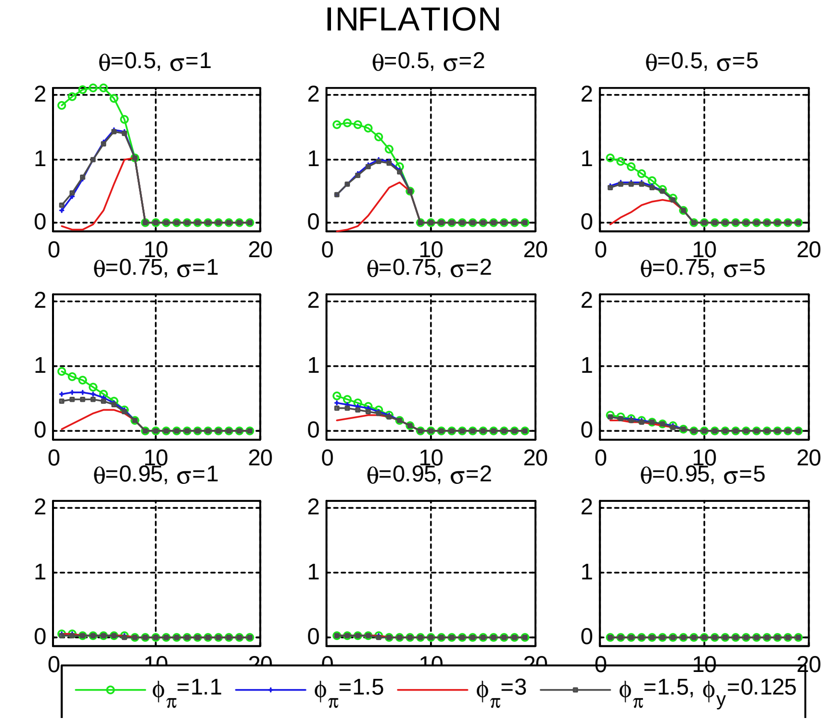


Figure 3 (cont'd): Announced expansion in $t+8$: Forward-looking model



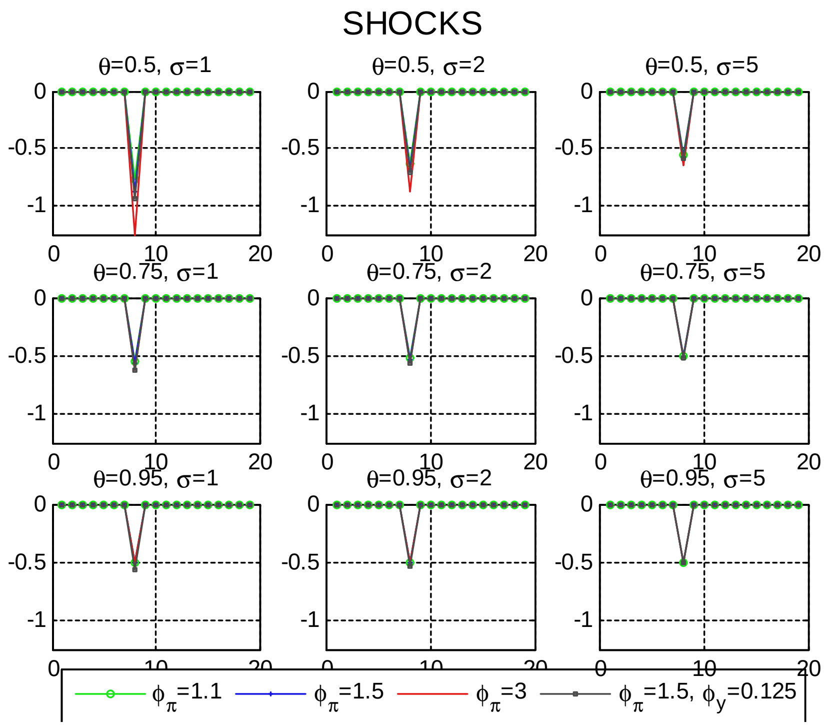
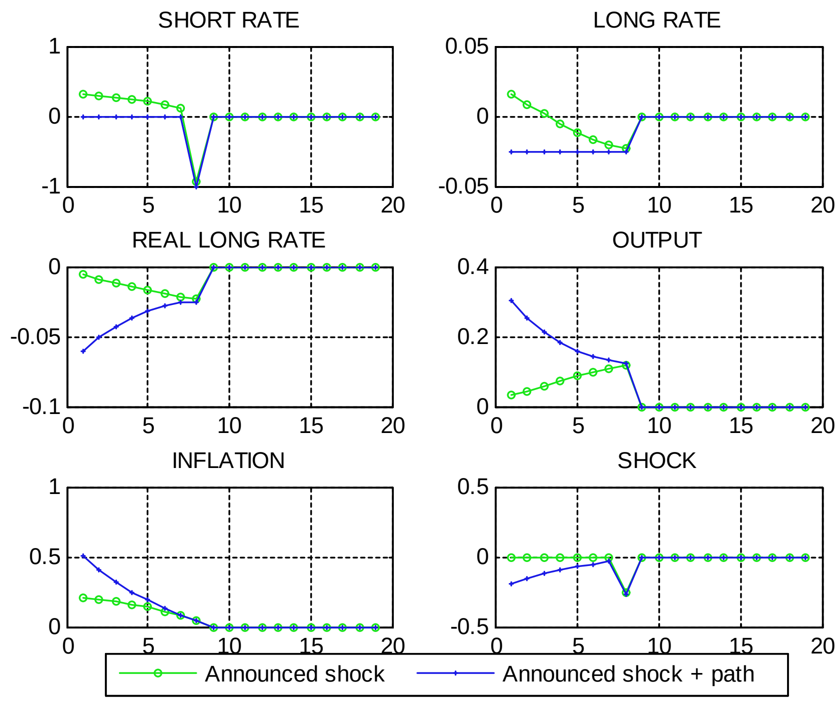


Figure 4: No-change path up to $t + 7$ and announced expansion in $t + 8$: Forward-looking model



Note: Calibration corresponds to the centre subplot of Figure 3, second policy rule.

Figure 5: Announced expansion in $t+8$: Backward-looking model

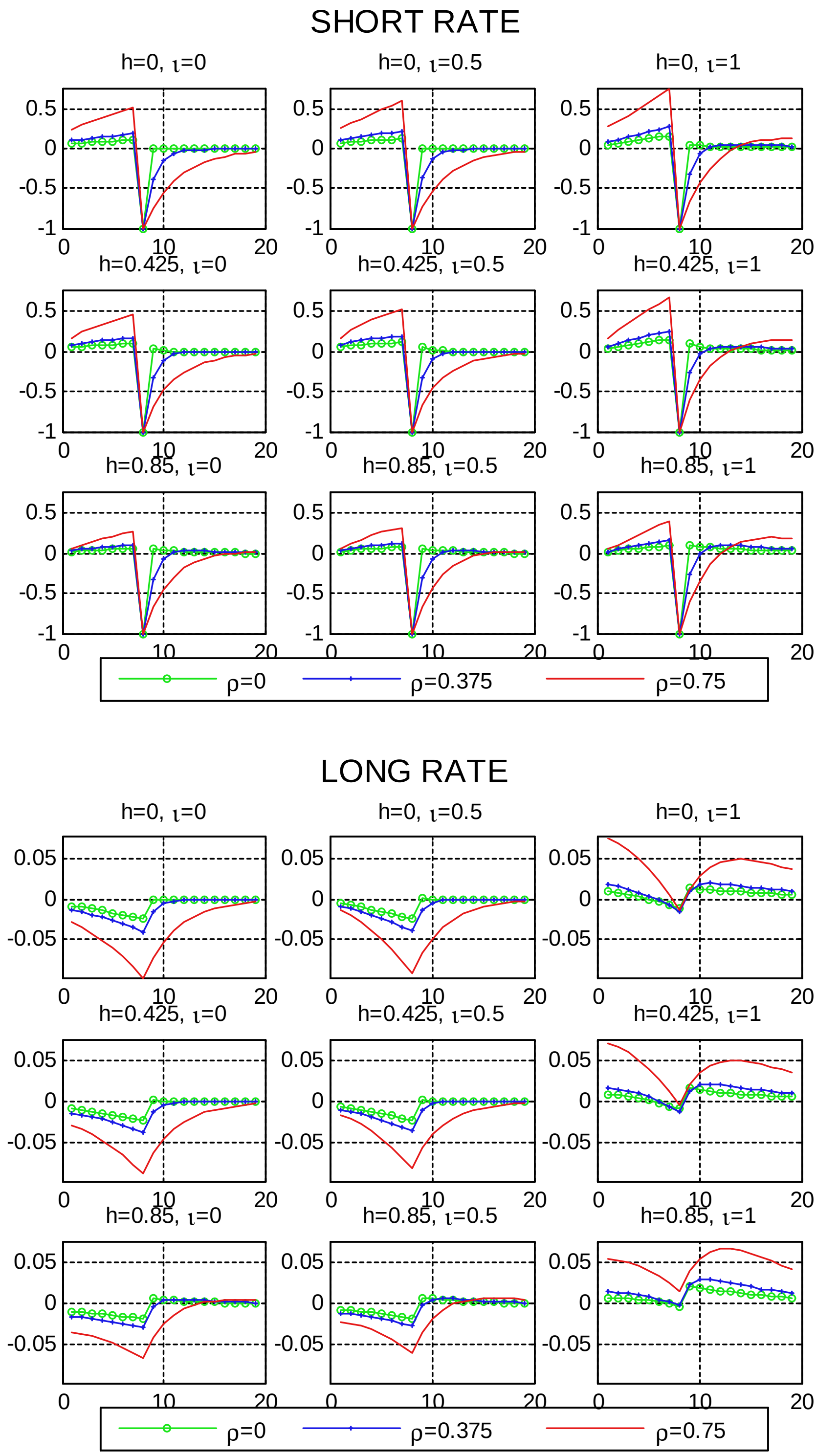
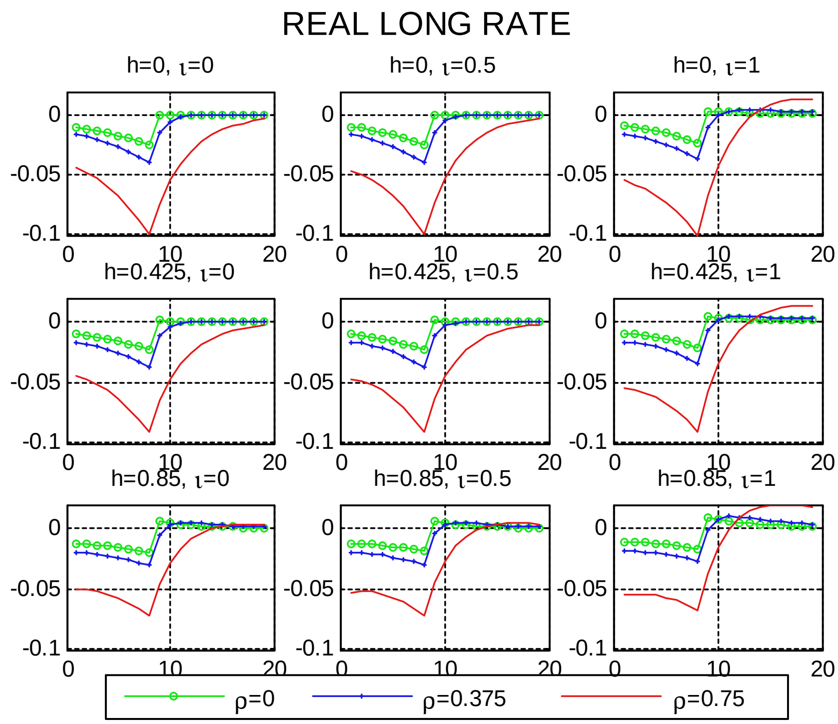


Figure 5 (cont'd): Announced expansion in $t + 8$: Backward-looking model



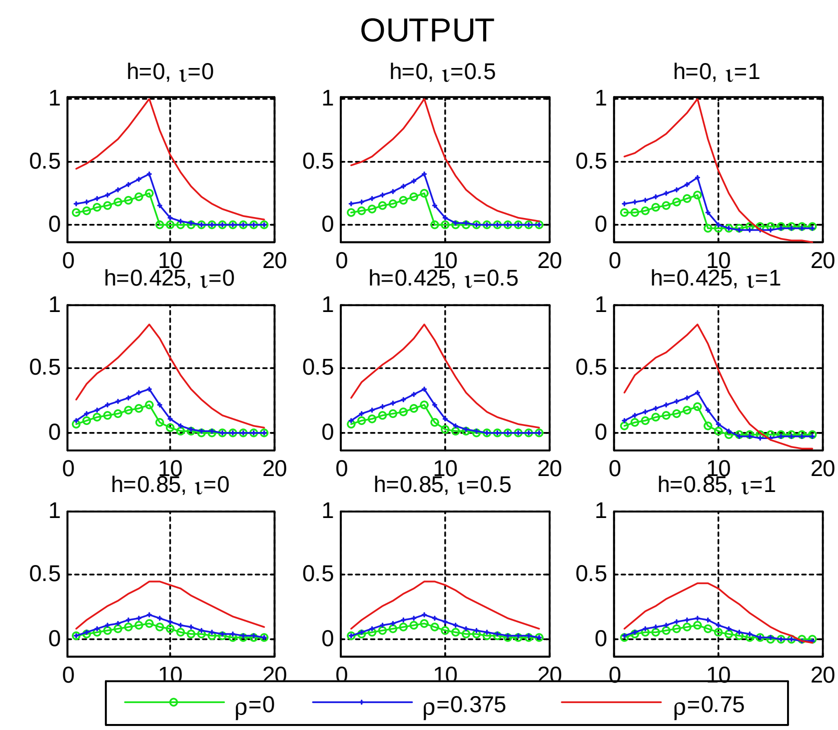


Figure 5 (cont'd): Announced expansion in $t + 8$: Backward-looking model

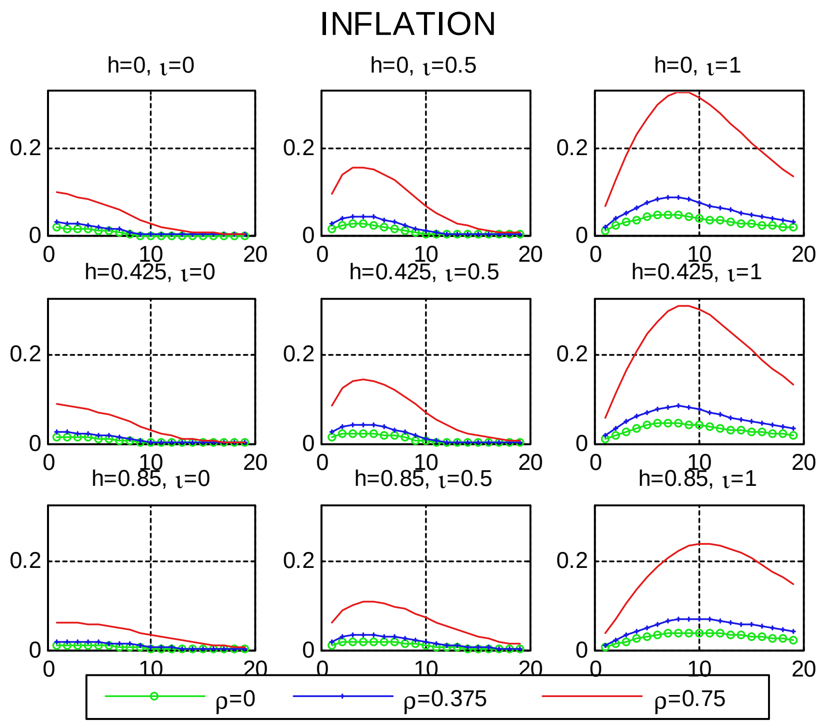


Figure 6: No-change path up to $t+7$ and announced expansion in $t+8$: Backward-looking model

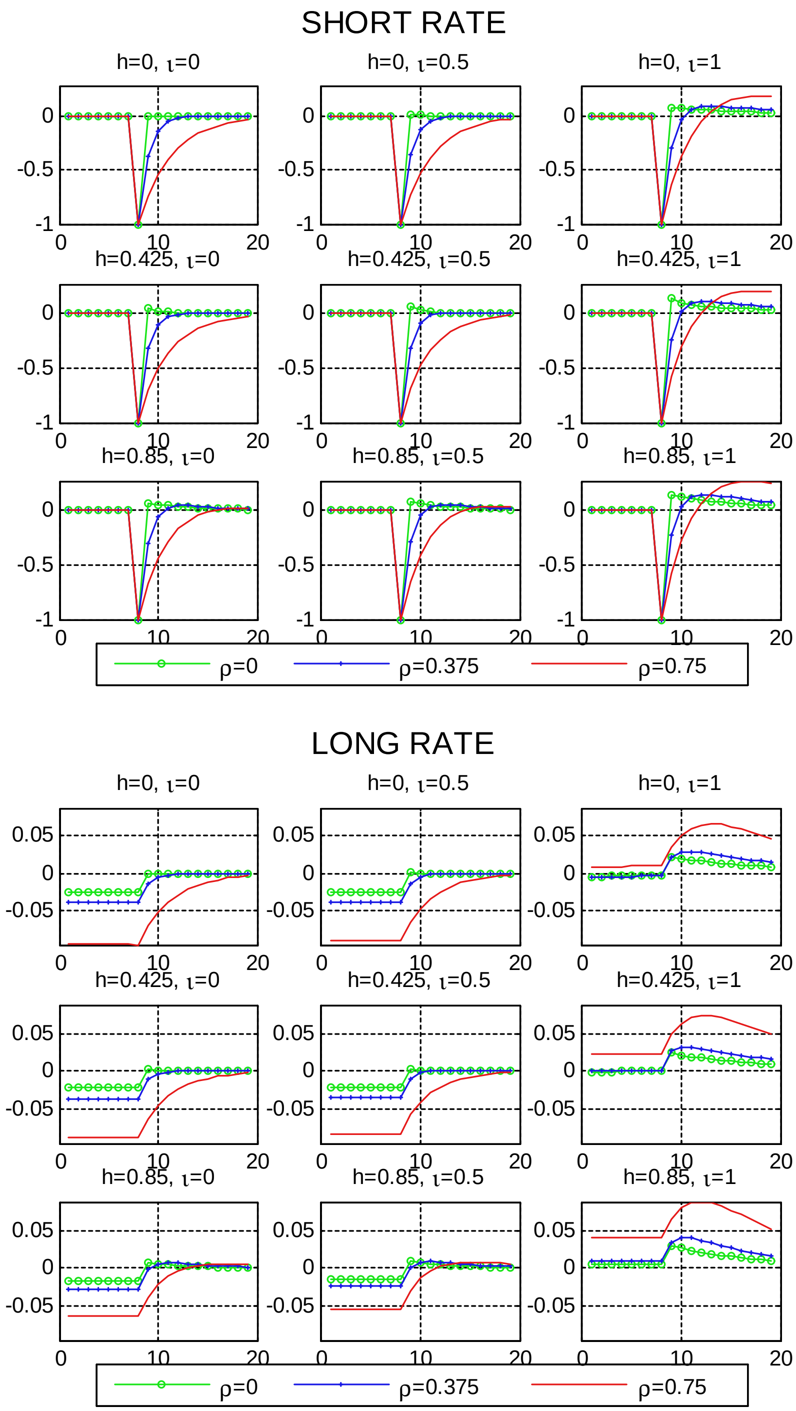
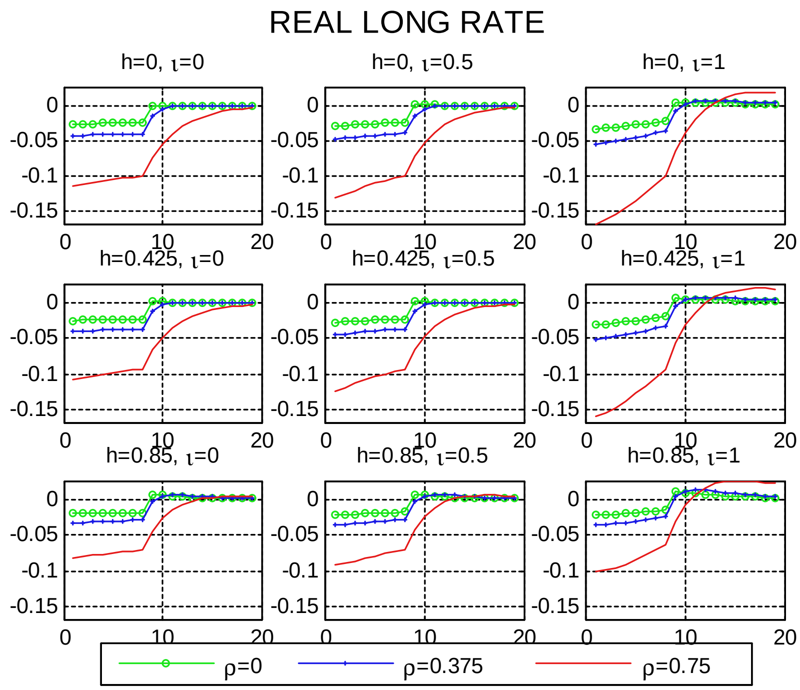


Figure 6 (cont'd): No-change path up to $t+7$ and announced expansion in $t+8$: Backward-looking model



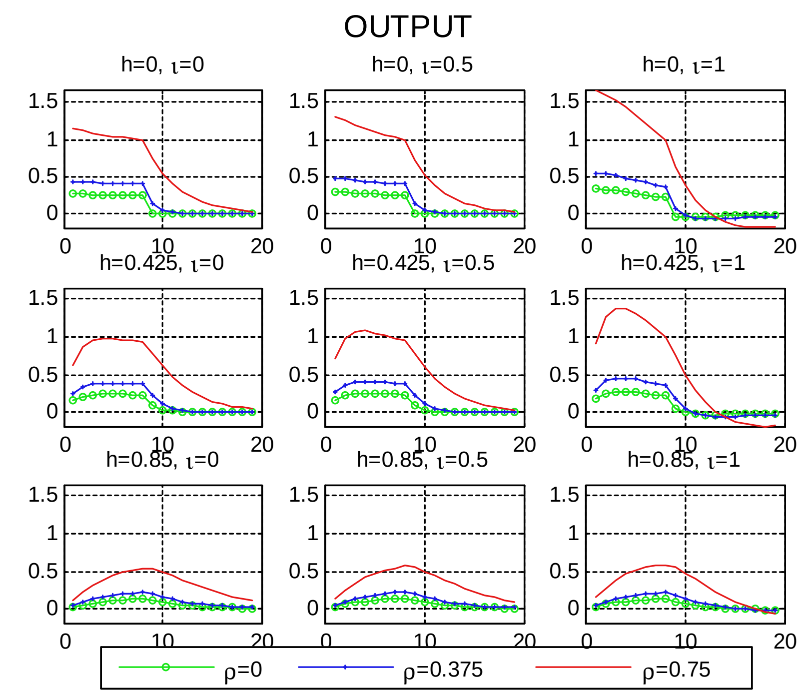


Figure 6 (cont'd): No-change path up to t+7 and announced expansion in t+8: Backward-looking model

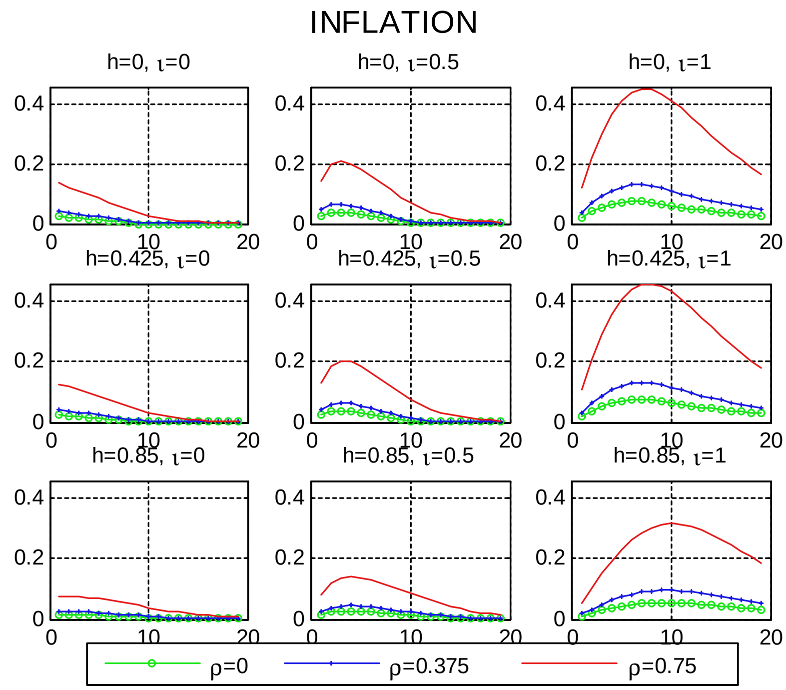


Figure 7: Forward guidance in medium scale models: fixed path + innovation in $t + 6$

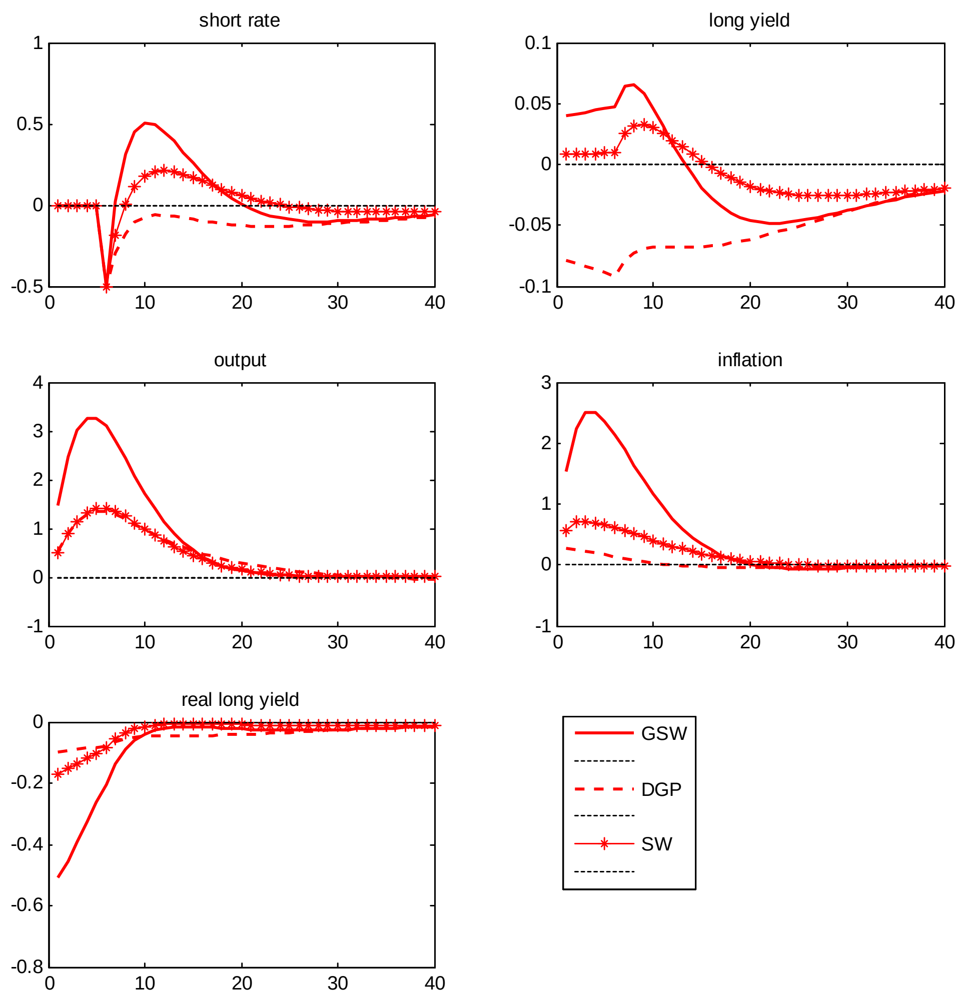


Figure 8: Counterfactuals: DGP stickiness and indexation paremeters in SW

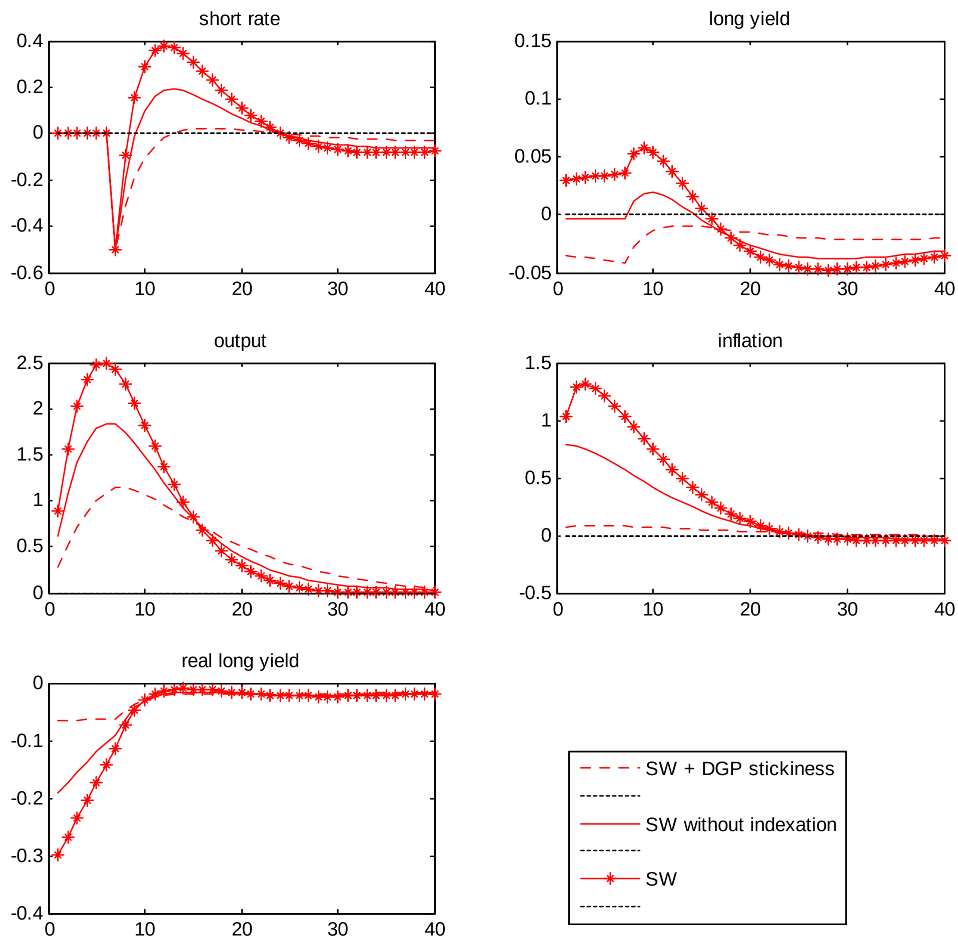


Figure 9: Forward guidance in medium scale models: fixed path + innovation in $t+7$

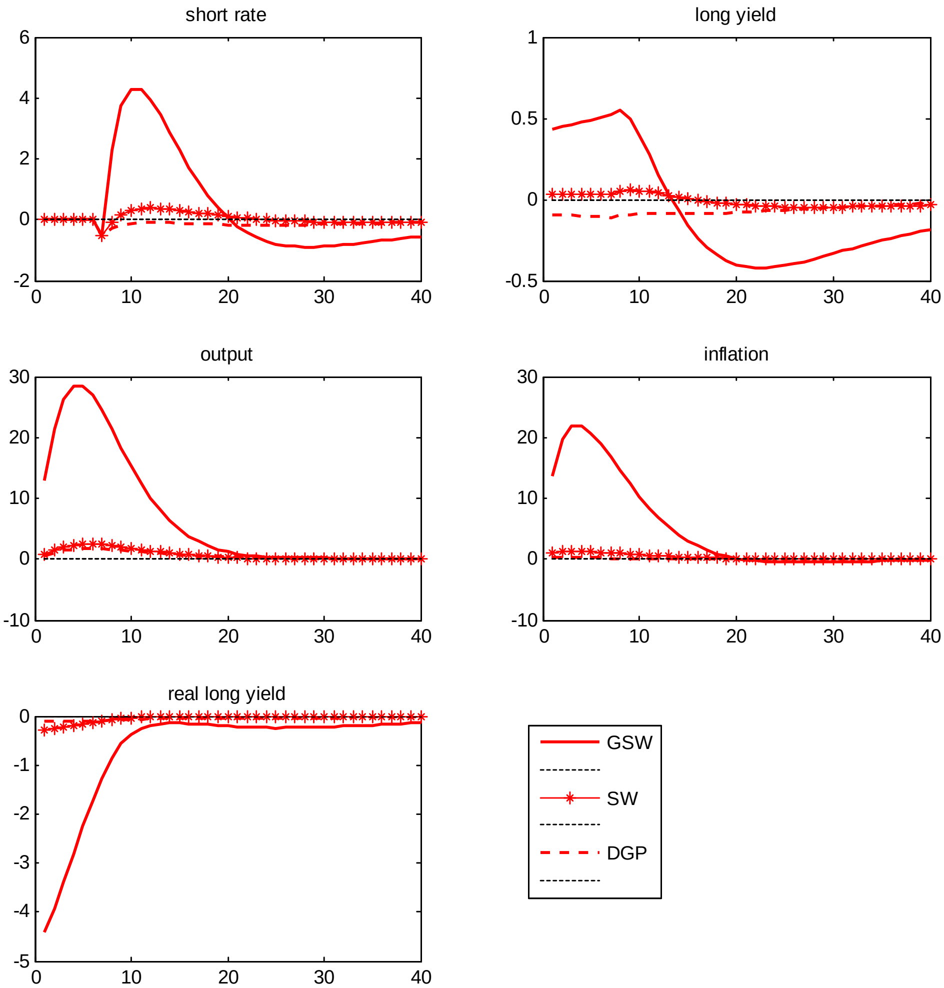
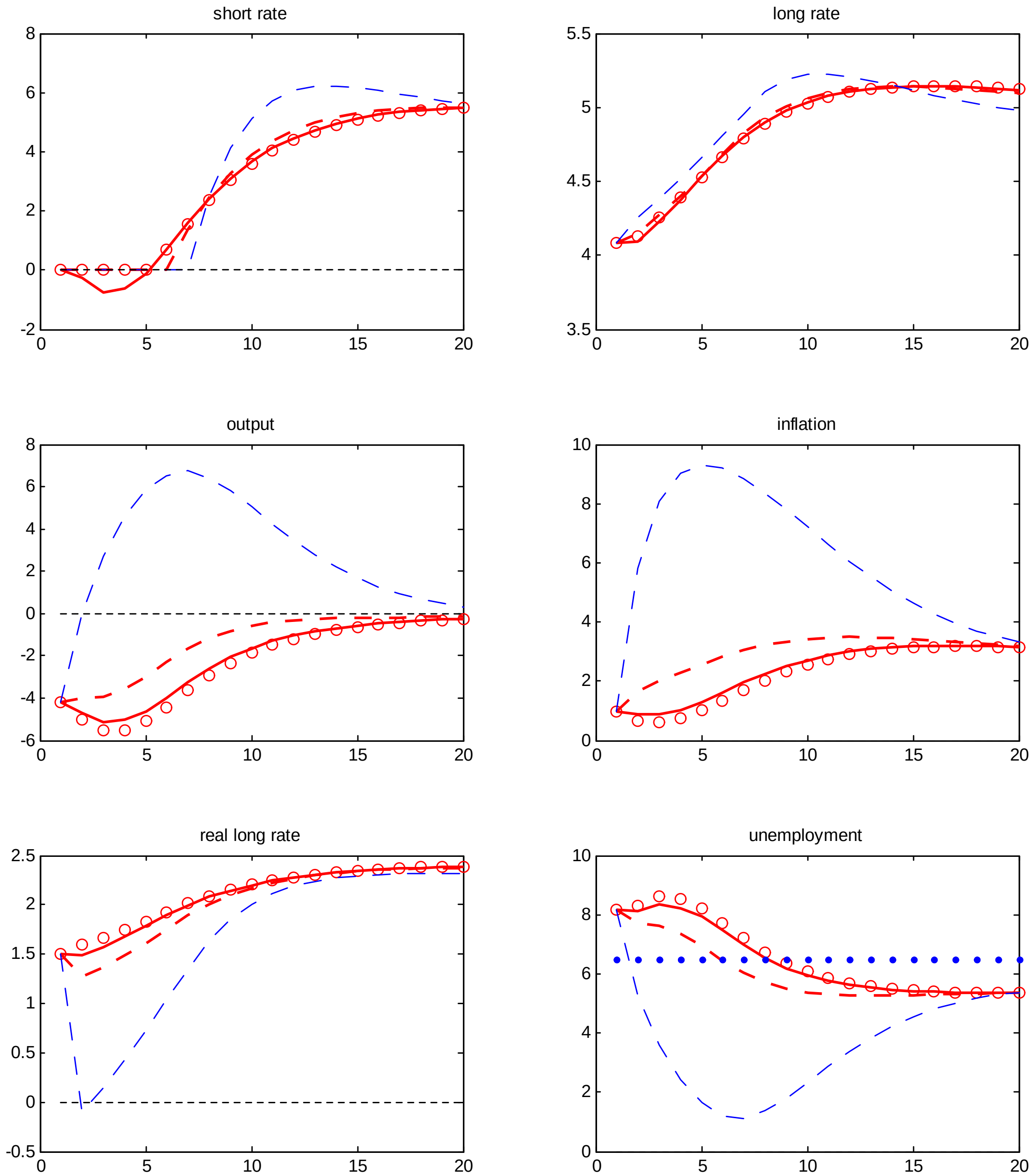


Figure 10: Conditional forward guidance in GSW



Note: Solid: Forecast. Circle: ZLB. Thick dashed: Conditional forward guidance. Thin dashed: Conditional forward guidance + 1 extra period at ZLB.

Figure 11: Imperfect information - unanticipated policy shock

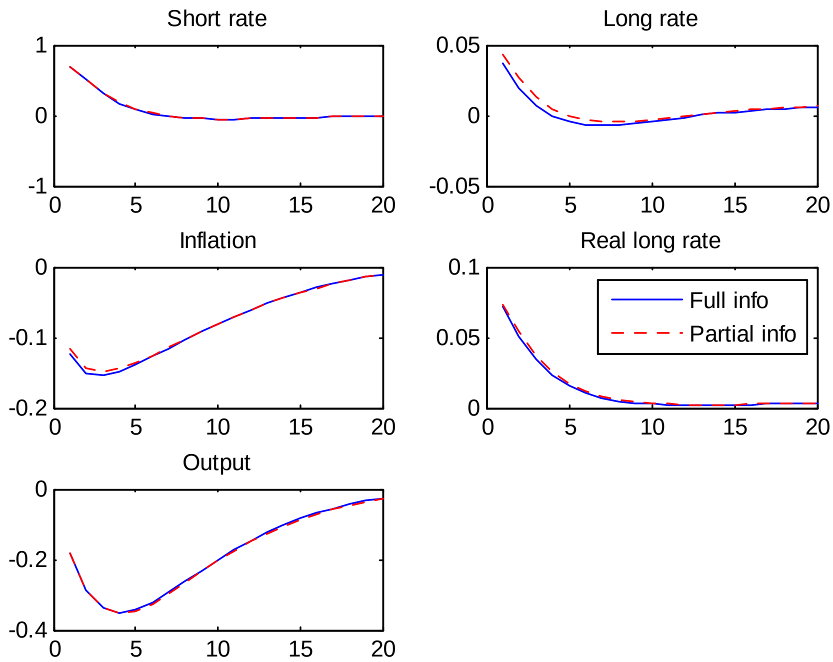


Figure 12: Imperfect information - anticipated policy shock

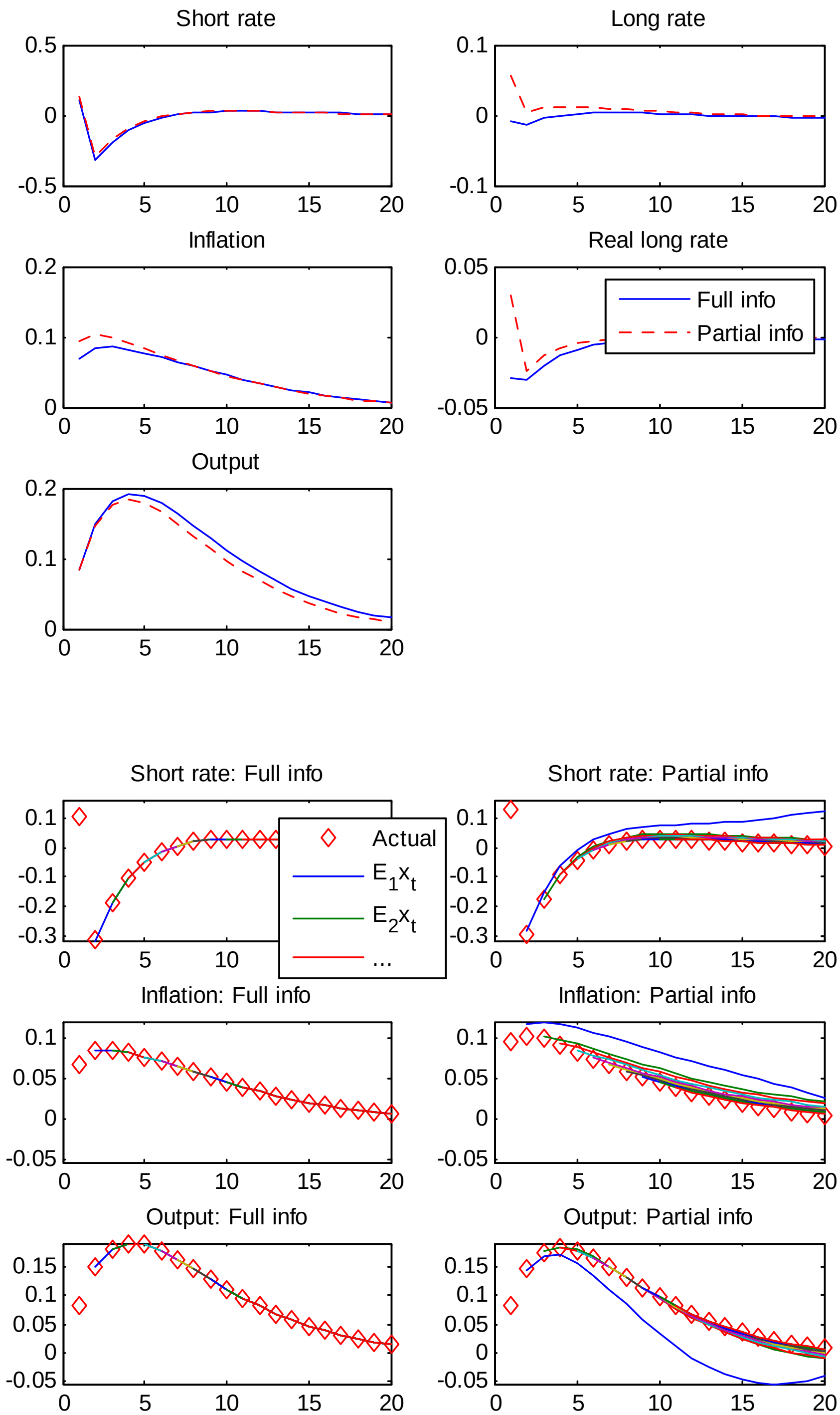


Figure 13: Imperfect information - fixed short rate

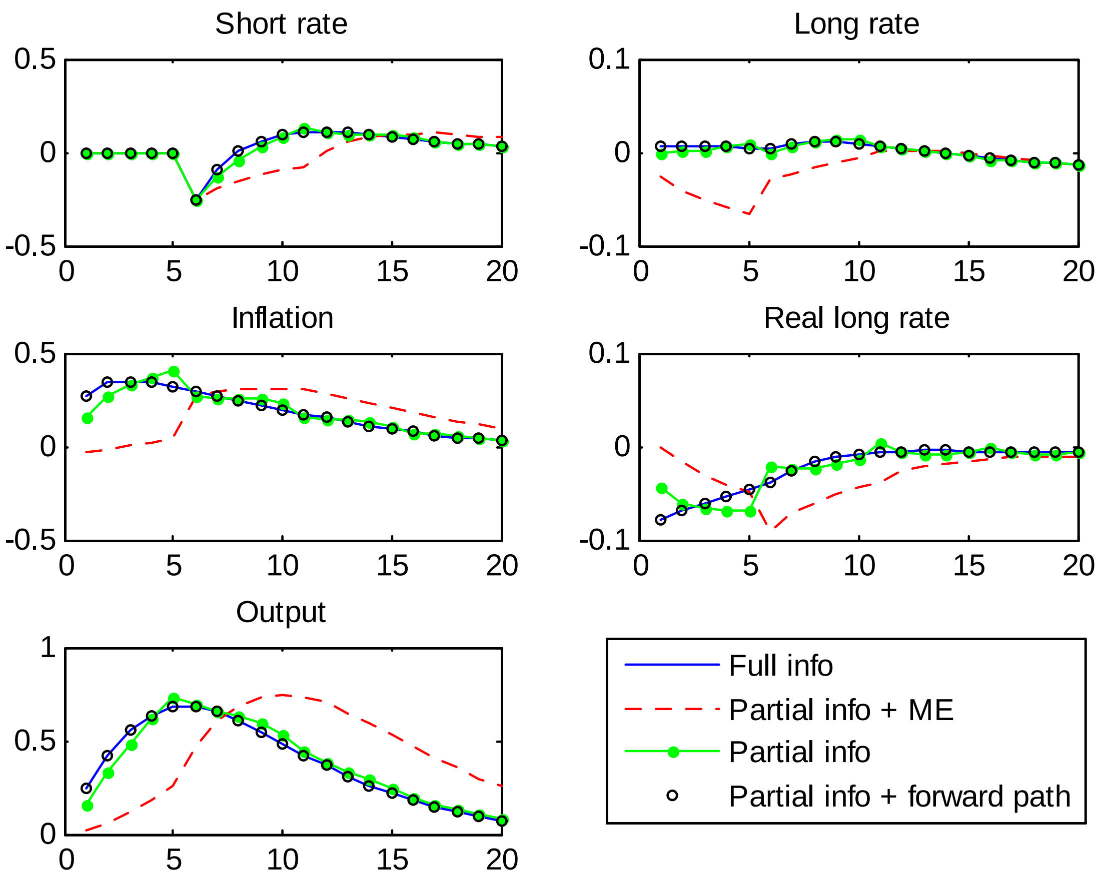


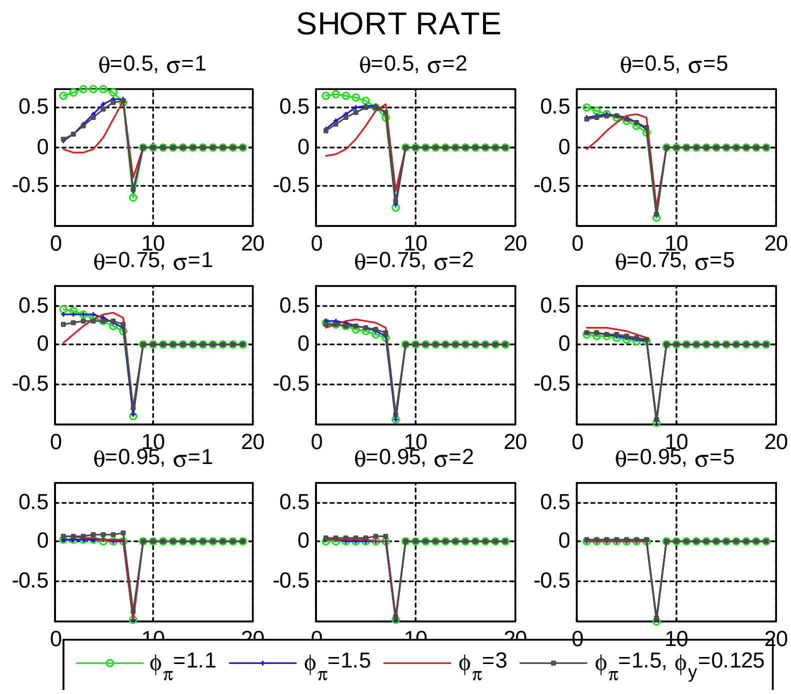
Table 2: Structural parameters and counterfactual long rate responses

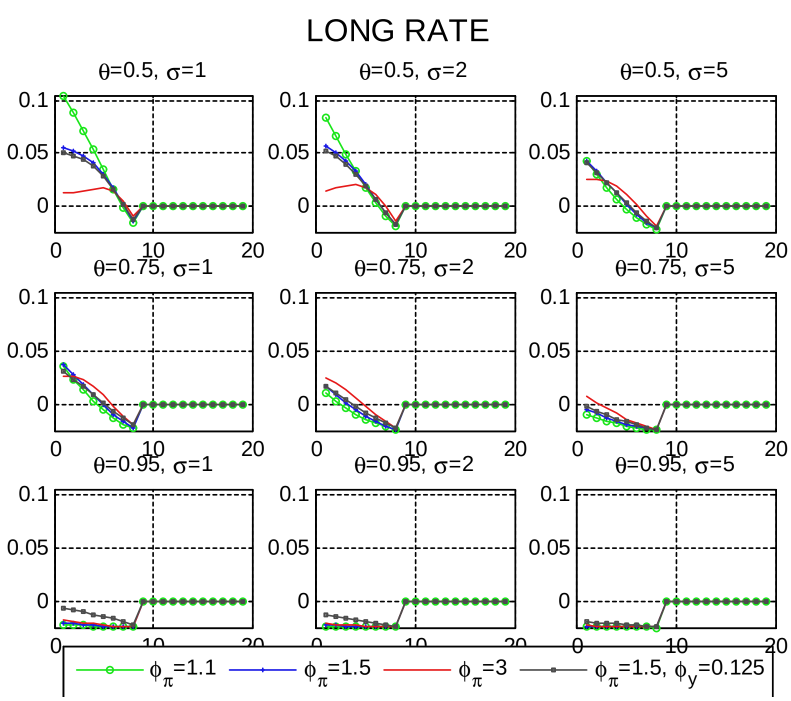
Extra period of forward guidance	DGP	SW	GSW
Impact effect on nominal long rate	**-0.078**	**+0.008**	**+0.040**
Contribution from:			
nominal stickiness		**-0.035**	**-0.055**
prices ε_{mc}^{p}	0.017	0.019	0.0278
wages ε_{mrs}^{w}	0.001	0.005	0.0136
indexation in price and wage setting		**-0.003**	**+0.0002**
price setting	0.00	0.25	0.49
wage setting	0.00	0.60	0.18
monetary policy reaction coefficients		**-0.020**	**-0.020**
inflation ϕ_π	2.02	2.00	1.91
output ϕ_y	0.00	0.09	0.15
inertia ρ	0.76	0.82	0.85
output growth $\phi_{\Delta y}$	0.07	0.23	0.24

Note: Normal typeface: value of structural parameters. Bold typeface: counterfactual long rate response when parameter values of DGP are plugged in (G)SW.

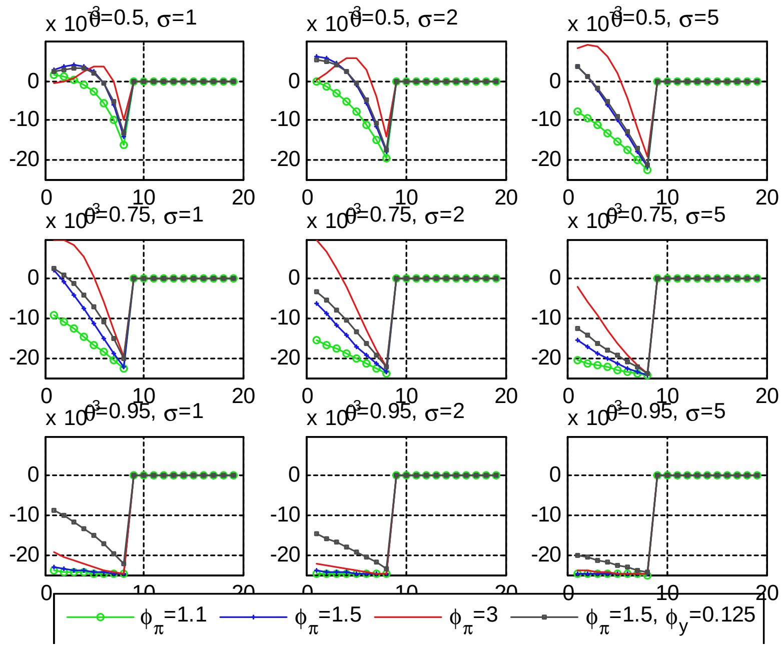
APPENDIX

Forward model with shock size equal across parametrizations (whereas in Figure 3 the normalization is based on the short rate response)

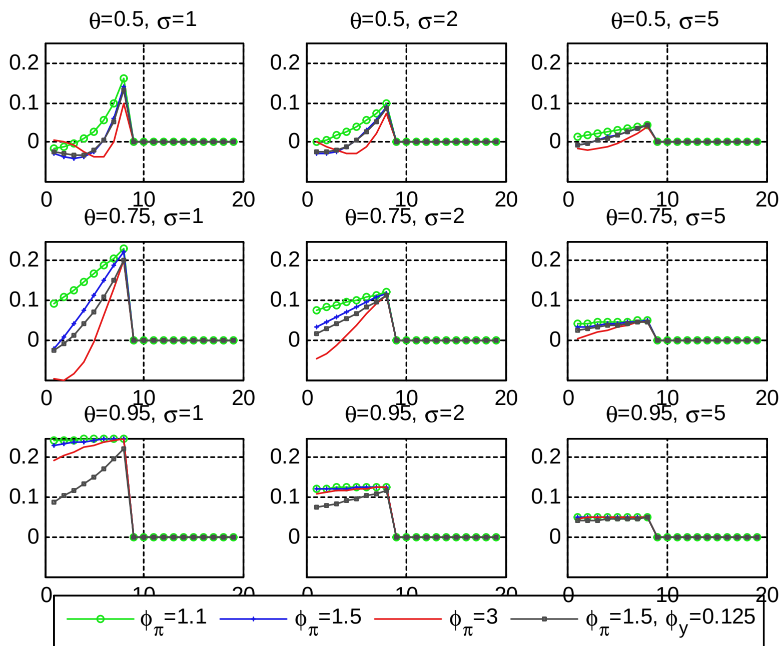


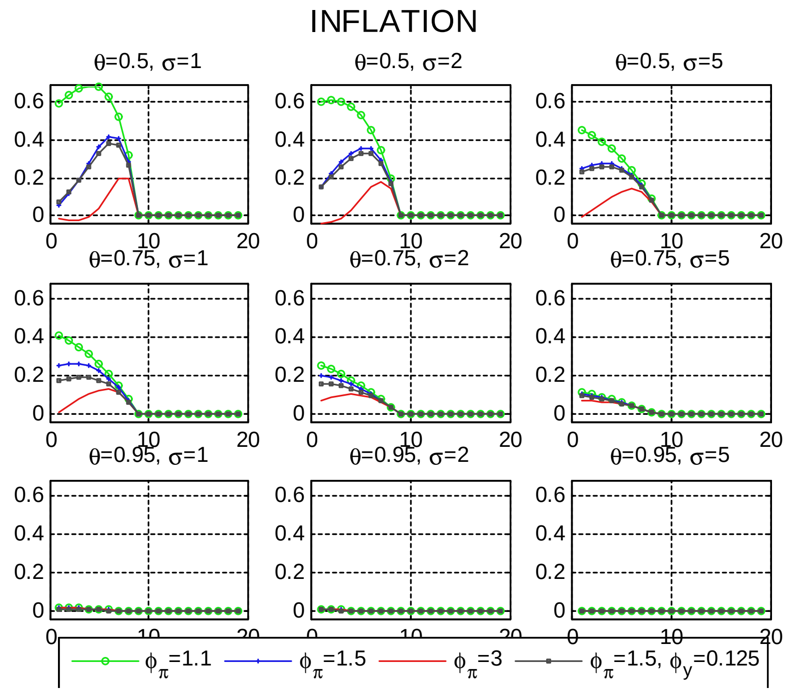


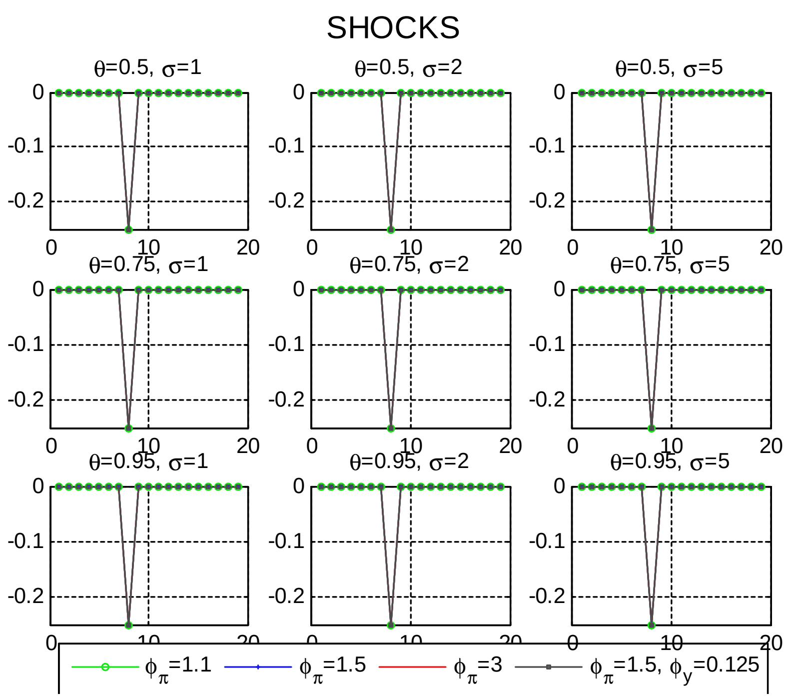
REAL LONG RATE



OUTPUT




INFLATION
θ=0.5, σ=1
θ=0.5, σ=2
θ=0.5, σ=5
θ=0.75, σ=1
θ=0.75, σ=2
θ=0.75, σ=5
θ=0.95, σ=1
θ=0.95, σ=2
θ=0.95, σ=5
ϕ_π=1.1
ϕ_π=1.5
ϕ_π=3
ϕ_π=1.5, ϕ_y=0.125


SHOCKS
θ=0.5, σ=1
θ=0.5, σ=2
θ=0.5, σ=5
θ=0.75, σ=1
θ=0.75, σ=2
θ=0.75, σ=5
θ=0.95, σ=1
θ=0.95, σ=2
θ=0.95, σ=5
ϕ_π=1.1
ϕ_π=1.5
ϕ_π=3
ϕ_π=1.5, ϕ_y=0.125

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Visiting address: Brunkebergs torg 11
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Website: www.riksbank.se
Telephone: +46 8 787 00 00, Fax: +46 8 21 05 31
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