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The Power of Forward Guidance in NEMO

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STAFF MEMO

The power of forward guidance in NEMO

NO. 7 | 2019

DRAGO BERGHOLT,
SARA S. MEYER,
YASIN MIMIR AND
ØISTEIN RØISLAND



NORGES BANK

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STAFF MEMO:

THE POWER OF FORWARD GUIDANCE IN NEMO*.

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May, 2019

Abstract: This staff memo revisits the power of forward guidance with particular emphasis on the effectiveness of anticipated policy in Norges Bank’s main policy model NEMO. First we explain, within the context of a simple toy model, why and how forward guidance has implausible effects in standard monetary policy frameworks. Second, we discuss some of the main solutions to the so-called forward guidance puzzle. We argue that existing proposals, including effective discounting as in Gabaix (2018), come with serious limitations once guidance about nominal policy rates is considered. With these lessons in mind, we proceed with a quantitative assessment of forward guidance in NEMO. It is shown that the presence of several real and nominal frictions reduces the net effects of forward guidance compared with the simple model. A powerful expectations channel is still at play: agents in NEMO believe that expansionary interest rate paths will be counteracted at some point in the future, resulting in limited net effects of forward guidance policies. We briefly discuss the realism of this feature.

1 INTRODUCTION

Forward guidance (FG) refers to a central bank’s communication about the intended future path of the policy rate. The aim of such communication is, amongst others, to influence economic outcomes through the expectations channel: current announcements about future policy may induce forward-looking firms and households to adjust their behavior already today. Although this idea has been around for a long time, the low interest rate environment that followed in the wake of the global financial crisis has created renewed interest in communication as a policy measure. Norges Bank for example, started to publish conditional interest rate paths in 2005 and uses FG regularly in monetary policy reports, speeches, and in general communication to the public.

This memo revisits the power of FG in NEMO, the Norwegian Economy Model. NEMO is used extensively by Norges Bank for forecasting, scenario and policy analysis, as well as communication of the bank’s monetary policy stance. Our point of departure is a strand of recent literature which finds implausibly large effects of FG in standard models of monetary policy. Strikingly, these models predict that a given interest rate change is more effective the further into the future it is expected to materialize. This prediction—commonly referred to as the FG puzzle—is both counterintuitive and strongly at odds

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with empirical evidence (Del Negro, Giannoni, and Patterson, 2012, 2015).¹ And it poses a serious concern given the widespread use of such models by many central banks. Of course, the effectiveness of FG relies heavily on private agents' view on future outcomes, the functioning of financial markets, as well as the central bank's credibility in the eyes of the public. Most models in use make rather extreme assumptions along these dimensions: firms and households are commonly assumed to optimize their objectives in a perfectly rational manner, with minimal constraints on credit allocations, and with complete trust in the statements made by monetary policy authorities. In turn, these assumptions pave the way for ample intertemporal adjustment to news about future interest rates. Thus, recent literature has proposed limits on intertemporal decision-making, for example due to information rigidities (Wiederholt, 2015; Kiley, 2016; Angeletos and Lian, 2017), market incompleteness (McKay, Nakamura, and Steinsson, 2016, 2017; Hagedorn, Luo, Manovskii, and Mitman, 2018), cognitive discounting (Gabaix, 2018), or the risk of death (Del Negro et al., 2015).

In light of this literature, we proceed in two steps: first, we revisit the power of FG in the canonical New Keynesian model. The aim is to derive fairly robust, yet tractable predictions about the effectiveness of FG policies. We use the model to explain why and how agents tend to react strongly to interest rate news, and then extend the framework slightly in order to discuss some of the main solutions out there. It is shown that existing proposals come with serious limitations, either because of highly contractionary post guidance dynamics, or because of rather implausible amounts of discounting, well beyond any parametrization used in existing studies. Our findings corroborate well with Farhi and Werning (2017), who propose that an environment in which bounded rationality interacts with market incompleteness may serve as a possible solution.

Second, we investigate quantitatively how FG plays out in NEMO. This allows us to evaluate whether Norges Bank's main policy model can deliver anticipated interest rate paths that are credible, or more precisely whether discretionary changes in those paths should be trusted. We find that the presence of numerous real and nominal rigidities in NEMO significantly dampens the net effects of a future interest rate cut, compared with models used in academic literature. In that respect, the FG puzzle does not represent a major concern for policy makers. However, the model's implied dynamics mask two forces going in opposite directions: (i) a powerful expansion due to FG itself, and (ii) an almost equally powerful contraction due to expected overshooting of interest rates after the FG period. The latter effect results in limited net effects of FG policies. Moreover, we find that extended horizons of FG in NEMO imply arbitrary equilibria quite frequently, as documented in other New Keynesian models by Carlstrom, Fuerst, and Paustian (2015). Those equilibria are rather meaningless from an economic point of view. Our main policy conclusion is, therefore, that central banks that use models like NEMO should be cautious when interpreting their predictions regarding FG. Additional work, in particular on expectation formation and the limits to intertemporal adjustment, is needed.

The rest of the paper is organized as follows: Section 2 analyzes FG in a textbook model and discusses ways to limit the expectations channel. Section 3 quantifies the power of FG in NEMO and documents the importance of various frictions. Finally, Section 4 concludes.

¹See also Campbell, Evans, Fisher, and Justiniano (2012), Campbell, Fisher, Justiniano, and Melosi (2017), and Andrade and Ferroni (2018) for empirical evidence on the macroeconomic effects of FG.

2 FORWARD GUIDANCE IN A TEXTBOOK FRAMEWORK

As a starting point we find it useful to review how the FG puzzle appears in the textbook New Keynesian model. This framework allows us to illustrate how expectations shape outcomes in standard frameworks for monetary policy analysis, at the cost of being too simple to lend itself to quantitative conclusions. We limit our attention to a closed economy environment in the main text, but show in the appendix that FG in a small open economy is isomorphic to guidance in the model considered here.

2.1 A BASELINE MODEL

The model consists of a forward-looking equation for aggregate demand or output, a forward looking supply side equation for inflation, as well as a specification of a monetary policy rule. The former two read:

$$y_t = \mathbb{E}_t y_{t+1} - \frac{1}{\sigma} (i_t - \mathbb{E}_t \pi_{t+1}) \quad (1)$$

$$\pi_t = \beta \mathbb{E}_t \pi_{t+1} + \kappa y_t \quad (2)$$

Output, inflation and the policy rate in period t are denoted by y_t , π_t and i_t , respectively. \mathbb{E}_t represents agents' expectations conditional on the information available in period t . Usually one assumes full rationality, i.e. that \mathbb{E}_t represents the rational expectations operator. This assumption is pursued here as well. Nominal price stickiness allows monetary policy to influence economic outcomes via the real interest rate, defined as $r_t = i_t - \mathbb{E}_t \pi_{t+1}$. For now we imagine that authorities in charge of monetary policy target the real interest rate directly, although it should be understood that the instrument itself is the policy rate. The question, then, is how news about future real interest rates affect current inflation and output. As in McKay et al. (2016) we approach this question by using the law of iterated expectations to solve equation (1) forward:

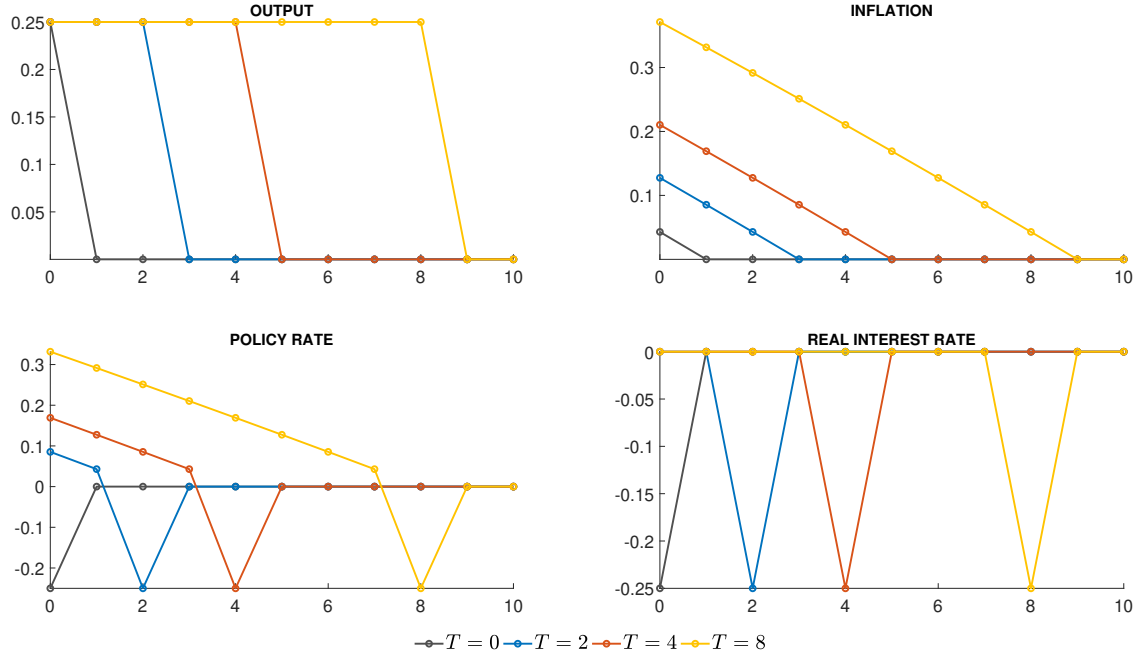
$$y_t = -\frac{1}{\sigma} \sum_{s=t}^{\infty} \mathbb{E}_t r_s$$

It is immediately clear that current output depends on the entire expected path of real interest rates. Moreover, the output response to a one-time shift in $\mathbb{E}_t r_{t+T}$, i.e. the expected real interest rate T periods ahead, does not depend on the choice of T . Thus, news about interest rates far into the future have the same effect on current output as news about current rates. A corollary is that the effect on cumulative output, $\sum_{s=t}^{\infty} \mathbb{E}_t y_s$, is linearly increasing in T . These observations seem quite unreasonable. To understand the implications for inflation, we solve equation (2) forward:

$$\pi_t = \kappa \sum_{s=t}^{\infty} \beta^{s-t} \mathbb{E}_t y_s$$

This expression states that current inflation depends on cumulative output, properly discounted. The discount factor β is usually set close to one (if the model is calibrated to quarterly data), implying that the impact response of inflation to a one-time change in

Figure 1: FG about the real interest rate in the baseline model



Note: vertical axes display the responses in percent, horizontal axes show time in quarters.

r_{t+T} is almost linearly increasing in T . In fact, we can combine the two forward solutions in order to obtain:

$$\pi_t = -\frac{\kappa}{\sigma} \mathbb{E}_t \left[r_t + (1 + \beta) r_{t+1} + (1 + \beta + \beta^2) r_{t+2} + \dots + \frac{1}{1 - \beta} r_\infty \right]$$

Thus, current inflation responds to news about real interest rates infinitely far into the future about $(1 - \beta)^{-1}$ times stronger than to news about the current real rate r_t . It is, therefore, clear that the textbook model predicts a rather extreme power of FG at longer horizons—both in absolute terms and relative to contemporaneous monetary policy shocks. This prediction is known as the FG puzzle.

Next we describe a simple, numerical experiment that allows us to evaluate how various extensions to the baseline model affect the power of FG. The experiment we consider is one where, in period t , the central bank announces a particular path for the real interest rate. This announcement consists of the following information:

“We plan to keep the interest rate fixed for the next $T - 1$ periods, followed by an interest rate reduction equal to 25 basis points in period $t + T$. Afterwards, we expect to conduct monetary policy as normal.”

This statement is equivalent to the announcement of a series of anticipated monetary policy shocks, $\{\varepsilon_{t,t}, \dots, \varepsilon_{t+T,t}\}$, such that the desired interest rate path $\{r_t, \dots, r_{t+T}\}$ is obtained in expectation. The question, then, is how the effects of such FG depend on the planning horizon T . A few remarks are in order: first, the announcement makes the entire interest rate path public in period t . Second, this path needs only to hold in expectation. Ex post, the occurrence of new information might justify deviations. Third, one has to specify the meaning of “monetary policy as normal” because agents’ current behavior

depends on monetary policy after the FG period as well. Here we suppose that monetary policy in normal times is strict inflation targeting.² Formally, we consider interest rate policies that achieve

$$\pi_t = 0. \quad (3)$$

Thus, equations (1)-(3) constitute the baseline model, although equation (3) is replaced by a credible promise to achieve $\{r_t, \dots, r_{t+T}\}$ in times of FG. We use the algorithm developed by Laséen and Svensson (2011) in order to calculate the shock series $\{\varepsilon_{t,t}, \dots, \varepsilon_{t+T,t}\}$ consistent with the desired interest rate path.^{3,4}

Figure 1, which serves as a useful benchmark, plots the impulse responses associated with FG about real interest rates in the baseline model. We compare a contemporaneous monetary policy shock ($T = 0$) with FG for half a year ($T = 2$), one year ($T = 4$), and two years ($T = 8$). The impulse responses illustrate the points made so far: qualitatively, FG resembles a conventional monetary policy shock in the sense that both output and inflation increase. Quantitatively, however, macroeconomic responses clearly depend on the planning horizon T . A promise to lower the real interest rate in a couple of years is substantially more expansionary for current inflation, compared with a real rate reduction of the same magnitude in the near future. Note, also, that in order to justify the announced path of real interest rates $\{r_t, \dots, r_{t+T}\}$, policy rates must rise in tandem with inflation expectations.

2.2 “BELLS AND WHISTLES”

Nominal price stickiness makes pricing decisions highly forward-looking. This is why inflation responds so strongly to interest rate news in the baseline model. However, more quantitative versions of the New Keynesian model usually feature additional ingredients that effectively make the model dynamics backward-looking as well. One could, therefore, expect that these ingredients would dampen the power of FG. We will show that such a conclusion tends to be flawed. To fix ideas, consider the baseline model extended with the twist that non-optimizing price setters index prices to lagged inflation.⁵ This assumption implies the following equation for aggregate supply:

$$\pi_t - \gamma\pi_{t-1} = \beta (\mathbb{E}_t\pi_{t+1} - \gamma\pi_t) + \kappa y_t \quad (4)$$

Now it is the quasi first-difference of inflation that depends on output. $\gamma = 1$ implies full indexation to lagged inflation while $\gamma = 0$ brings us back to the baseline model. Thus, γ

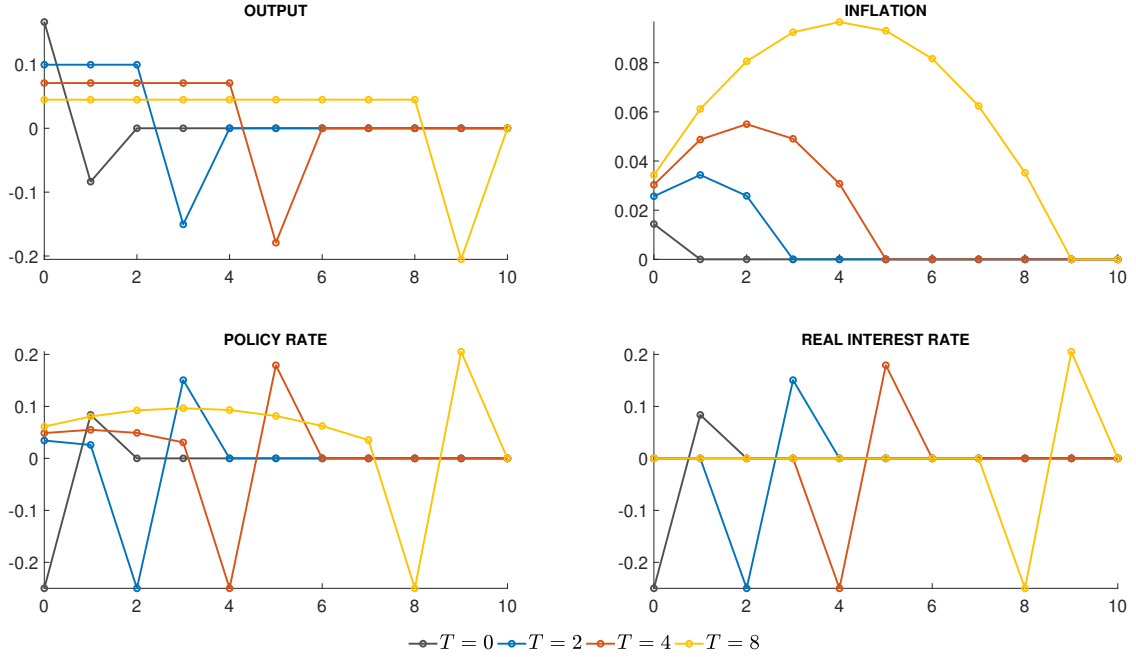
²Strict inflation targeting is close to optimal policy in the textbook model. Moreover, it implies that nominal and real interest rates coincide in period T , making it easier to compare FG across models. However, qualitatively the results presented here hold for other regimes as well, including Taylor type rules for the policy rate.

³Note that contemporaneous monetary policy shocks move $\varepsilon_{t,t}$ only, while FG imposes restrictions on the entire shock series $\{\varepsilon_{t,t}, \dots, \varepsilon_{t+T,t}\}$.

⁴The calibration underlying our numerical experiments is standard (Woodford, 2003; Galí, 2008): $\beta = 0.99$, $\sigma = 1$, $\kappa = 0.17$. The calibration of κ is consistent with a unitary Frisch elasticity and an average price duration of one year in the Calvo model.

⁵Here we focus on indexation, although similar arguments also apply to other model extensions such as habit formation in consumption, etc.

Figure 2: FG with full indexation



Note: vertical axes display the responses in percent, horizontal axes show time in quarters.

governs the degree of inflation indexation. The forward solution for π_t under indexation is stated below:

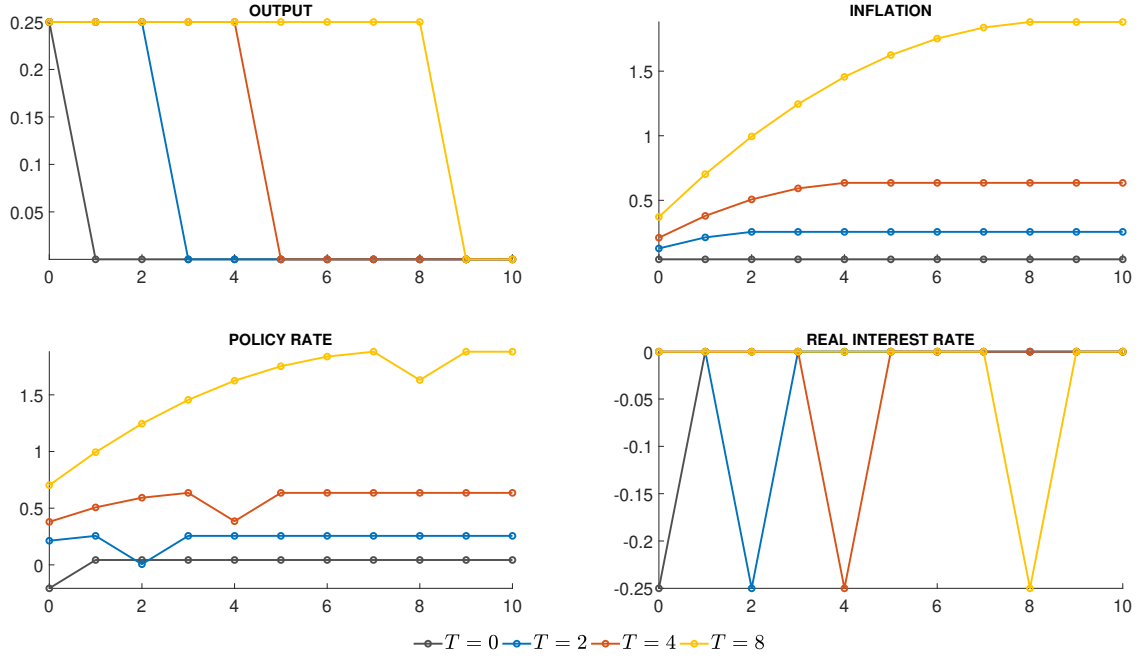
$$\pi_t = \gamma\pi_{t-1} + \kappa \sum_{s=t}^{\infty} \beta^{s-t} \mathbb{E}_t y_s$$

Aggregate demand is still given by equation (1) while the monetary policy regime is given by (3). It follows that the impact effect on inflation of a given real rate path is unaffected by the degree of inflation indexation. After the first period, however, inflation also propagates due to its own lag, implying even stronger inflation responses to interest rate news.

Figure 2 traces the dynamics associated with FG when $\gamma = 1$. At first glance indexation does not appear to amplify the effects: in particular, the impulse responses are substantially dampened compared with their counterparts in Figure 1, although the impact and peak responses of inflation still depend positively on T . Thus, a naive comparison of Figure 1 and Figure 2 might suggest that inflation indexation reduces the power of FG. However, this conclusion is premature. To see why, note that $\gamma = 1$ implies an overshooting of the real interest rate in period $T + 1$. Due to indexation, the central bank must engineer a temporary interest rate hike in order to bring inflation back to target. But this counteracts the expansionary effects during the FG period. The counteracting force is particularly strong exactly because the overshoot takes place further out in the future, rather than today. Thus, while indexation implies smaller net effects on output and inflation, it does so for the wrong reasons. The expectations channel is still implausibly powerful.

Figure 3 confirms this view. There we redo the FG exercise assuming that the central bank commits to a strict output gap target instead of the inflation target. Strict output gap

Figure 3: FG with full indexation in absence of interest rate overshooting



Note: vertical axes display the responses in percent, horizontal axes show time in quarters.

targeting allows us to consider FG in the absence of interest rate overshooting.⁶ Thus, by comparing Figure 3 with Figure 1 we can directly gauge the implications of γ . Formally, equation (3) is replaced by

$$y_t = 0, \quad (5)$$

while the rest of the model is given by equations (1) and (4) with $\gamma = 1$. Except for the impact response, inflation clearly reacts much more strongly to FG when $\gamma = 1$. Full indexation even implies a unit root process for inflation and the monetary policy rate, given the strict focus on output stability. The introduction of backward looking features such as inflation indexation does not, therefore, address the FG puzzle in any meaningful way.

2.3 DISCOUNTING

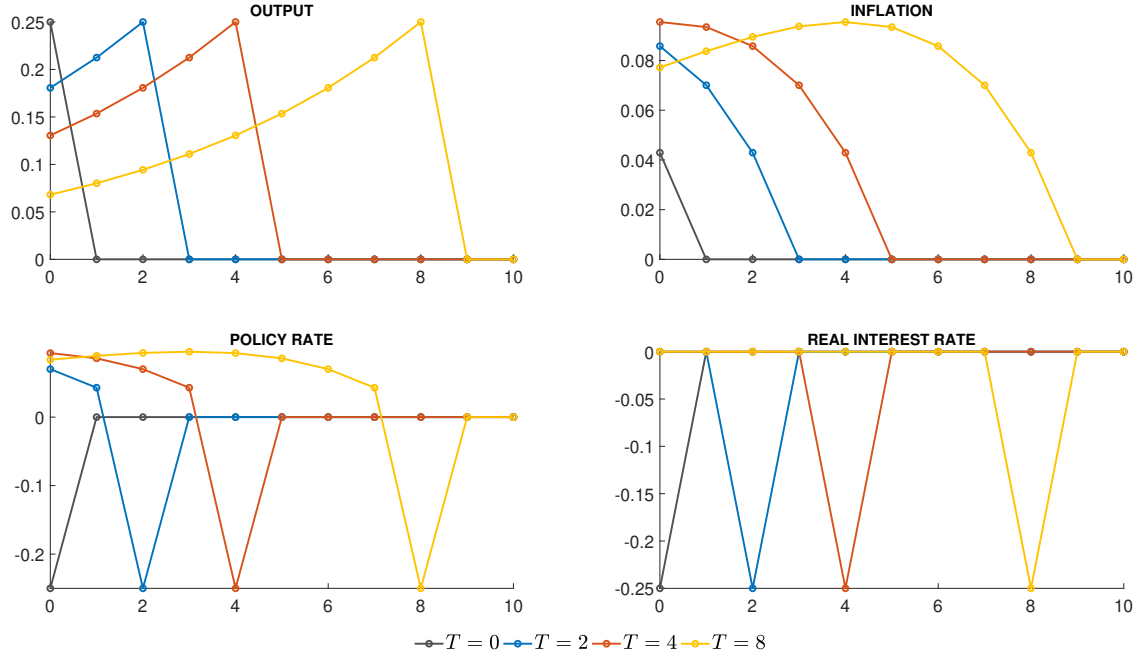
Various solutions to the FG puzzle have been proposed in the literature, including features such as market incompleteness, credibility issues, imperfect information, and bounded rationality. They all have in common an effective discounting of future outcomes. In order to illustrate how discounting affects the power of FG, we follow Gabaix (2018) and write the baseline model in the following way:

$$y_t = \alpha_y \mathbb{E}_t y_{t+1} - \frac{1}{\sigma} (i_t - \mathbb{E}_t \pi_{t+1}) \quad (6)$$

$$\pi_t = \alpha_\pi \beta \mathbb{E}_t \pi_{t+1} + \kappa y_t \quad (7)$$

⁶The real interest rate paths in Figure 3, hence also the output paths, are identical to those in Figure 1.

Figure 4: FG about the real interest rate – the role of discounting



Note: vertical axes display the responses in percent, horizontal axes show time in quarters.

Equations (6)-(7) are similar to (1)-(2), except for the introduction of two discounting parameters α_y and α_π . They are bounded between 0 and 1, and might capture cognitive inattention to news about the future (Gabaix, 2018), or the implications of credit constraints for households (McKay et al., 2016, 2017), or the risk of death (Del Negro et al., 2015). $\alpha_y = \alpha_\pi = 1$ brings us back to the baseline model. In any case we can solve the two equations forward:

$$y_t = -\frac{1}{\sigma} \sum_{s=t}^{\infty} \alpha_y^{s-t} \mathbb{E}_t r_s$$

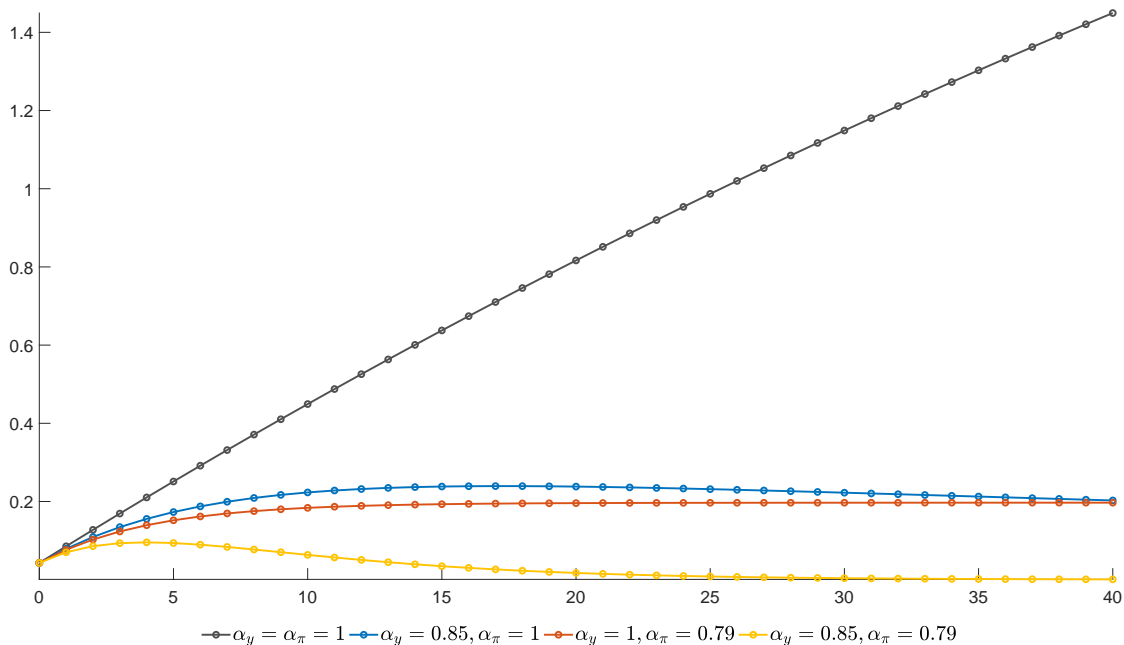
$$\pi_t = \kappa \sum_{s=t}^{\infty} (\alpha_\pi \beta)^{s-t} \mathbb{E}_t y_s$$

When combined, these expressions allow us to establish a direct link between current inflation and future interest rates:

$$\pi_t = -\frac{\kappa}{\sigma} \mathbb{E}_t \left[r_t + (1 + \alpha_\pi \beta) \alpha_y r_{t+1} + (1 + \alpha_\pi \beta + (\alpha_\pi \beta)^2) \alpha_y^2 r_{t+2} + \dots + \frac{\alpha_y^\infty}{1 - \alpha_\pi \beta} r_\infty \right]$$

Consider, first, a situation where discounting only takes place in the equation determining aggregate supply ($\alpha_y = 1, \alpha_\pi < 1$). An interest rate change in the indefinite future will in this case be $(1 - \alpha_\pi \beta)^{-1}$ times more effective than a contemporaneous change of the same size. The baseline model, in contrast, predicts this ratio to be $(1 - \beta)^{-1}$. Thus, $\alpha_\pi < 1$ helps to dampen the power of FG in absolute terms, although it is still the case that news about more distant rates have larger effects than news about rates in the short run. This latter issue is solved by also setting $\alpha_y < 1$. Then the effect of FG goes to

Figure 5: Impact responses of inflation for different FG horizons T



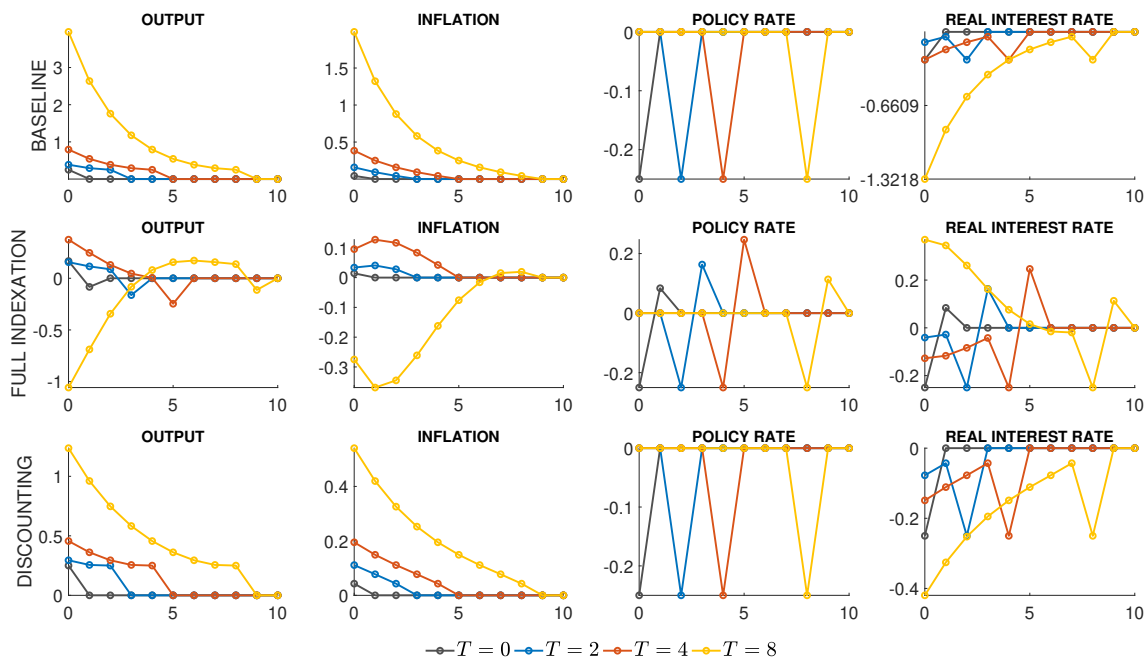
Note: the impact response of inflation (vertical axis) as a function of an announced reduction in the real interest rate T periods ahead (horizontal axis).

zero as T goes to infinity. This implies that there must be some critical period length \bar{T} for which an additional delay of the interest rate cut becomes less effective in terms of moving current output and inflation.⁷

In order to illustrate the role of discounting, we compute the impulse responses to FG conditional on the calibration proposed by Gabaix (2018). In particular we set $\alpha_y = 0.85$ and $\alpha_\pi = 0.79$. The remaining parameters are left unchanged. Figure 4 shows the results. Now the impact response of output is strictly decreasing in T , while for inflation the impact response associated with $T = 8$ is smaller than that associated with $T = 4$. Thus, it is not necessarily the case anymore that news about the distant future matters more for current outcomes. Figure 5 confirms this observation. There we plot the impact response of inflation associated with FG from $T = 0$ (a contemporaneous monetary policy shock) and all the way up to $T = 40$. We compare four calibrations: the baseline model, a version with discounting only in aggregate demand, a version with discounting only in aggregate supply, and finally the model preferred by Gabaix with discounting in both equations. Current inflation reacts substantially less when expectation terms are discounted, compared with the rational expectations benchmark. Moreover, $\alpha_y = 0.85$ implies a declining role of FG beyond some threshold period length \bar{T} . This threshold period is 17 quarters with $\alpha_\pi = 1$, but only 4 quarters with $\alpha_\pi = 0.79$. Thus, Gabaix's preferred discounting scheme implies that FG becomes less powerful if the guidance horizon is extended by about one year. This is arguably a much more realistic prediction than the counterpart in the baseline model without discounting.

⁷It is easy to show that \bar{T} satisfies the condition $\left[1 + \frac{(\alpha_\pi \beta)^{\bar{T}}}{1 + \alpha_\pi \beta + \dots + (\alpha_\pi \beta)^{\bar{T}-1}}\right] \alpha_y < 1$, which in turn requires that $\alpha_y < 1$.

Figure 6: FG about the nominal interest rate



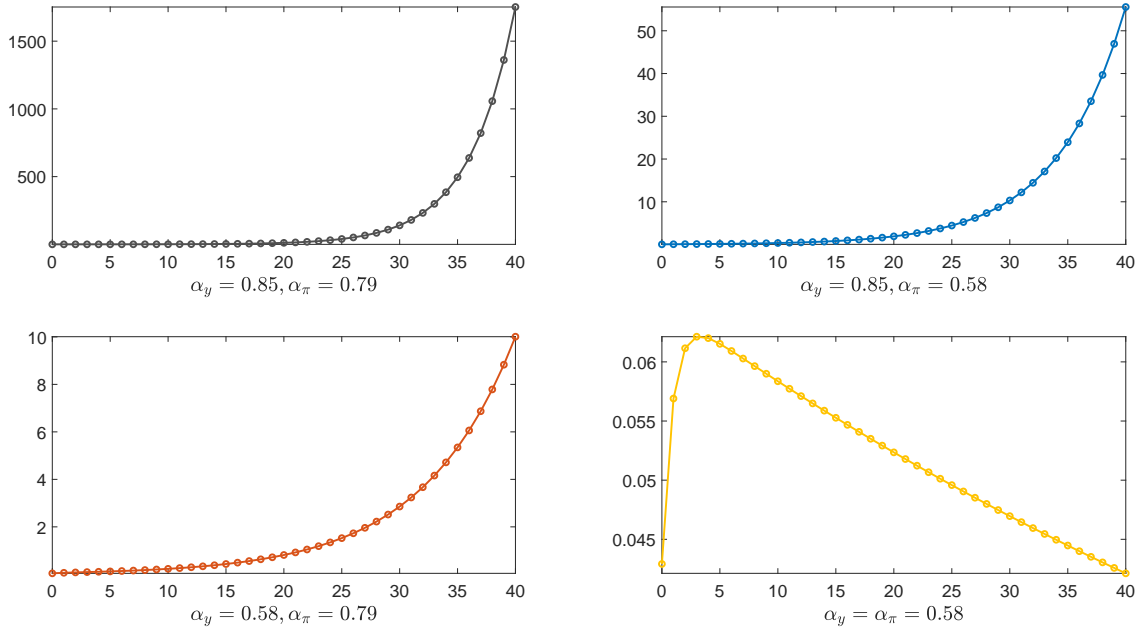
Note: vertical axes display the responses in percent, horizontal axes show time in quarters.

2.4 FORWARD GUIDANCE IN PRACTICE – POLICY RATE PATHS

We have previously seen how intertemporal discounting helps to dampen the expectations channel in standard models of monetary policy. Still it should not, in our view, be treated as any panacea for the FG puzzle. To understand why, note that all exercises discussed so far have conditioned on a given real interest rate path. Here we shift focus to FG about nominal interest rates set by monetary policy. If anything, this is the type of FG pursued by most central banks. We stress that such guidance unleashes a forceful feedback loop: a given cut in future policy rates will raise inflation expectations today, implying a contemporary real interest rate decline. Lower real rates stimulate demand, causing inflation expectations to rise even further. This feedback loop calls for far more discounting than the calibrations considered by existing literature. We find the amount of discounting needed rather implausible.

As an illustration, let us consider the following situation: a fixed policy rate is announced for $T - 1$ quarters, followed by a reduction of 25 basis points. Afterwards, the central bank reverts to strict inflation targeting. Importantly, the only change in setup is the conditioning on a nominal rate path $\{i_t, \dots, i_T\}$ rather than an unobservable, real interest rate path $\{r_t, \dots, r_T\}$. Resulting impulse responses are shown in Figure 6. The first row summarizes implications in the baseline model given by equations (1)-(3). The intention to lower policy rates in the future while keeping them fixed today implies higher expected inflation and, therefore, a real interest rate decline. The feedback loop going back to inflation expectations is extremely powerful: under our calibration, two years ahead FG implies an impact effect on inflation almost 50 times as large as the impact effect of a contemporaneous monetary policy shock of the same size. Clearly, any model that shares this feature is rather futile for policy makers who want to quantify the effects

Figure 7: Discounting, impact responses of inflation, and guidance about policy rates



Note: impact responses of inflation (vertical axes) as a function of an announced reduction in the nominal interest rate T periods ahead (horizontal axes) for four different calibrations of α_y and α_π .

of FG policies.

The second row shows the effects assuming full indexation. The model is now given by equations (1), (3) and (4) with $\gamma = 1$. Note that, by setting $T = 8$, we actually obtain a large fall in inflation and output. Carlstrom et al. (2015) analyze this puzzling result in more detail. They show that, in the presence of inflation indexation, the responses of inflation and output “become arbitrarily large as the duration of FG approaches some critical value, but they then switch signs and become arbitrarily negative as this critical value is exceeded”. This sign reversal comes about from the contractionary interest rate overshoot once FG has ended and is yet another example of implausibly large expectation effects at longer horizons.

The third row in Figure 6 provides impulse responses when we allow for discounting. The resulting model is given by equations (3), (6) and (7), and we stick to the calibration $\alpha_y = 0.85$ and $\alpha_\pi = 0.79$. Clearly, an interest rate cut in two years causes a substantial rise in current output and inflation, compared with a contemporaneous monetary policy shock of the same size. Thus, even the rather significant amount of discounting proposed by Gabaix (2018) cannot take us away from the FG puzzle in this setting. The reason is that feedback from inflation expectations to real interest rates dominates the dampening effects of intertemporal discounting. Of course, a more moderate calibration of α_y and α_π , for example following McKay et al. (2017), would make results even worse.

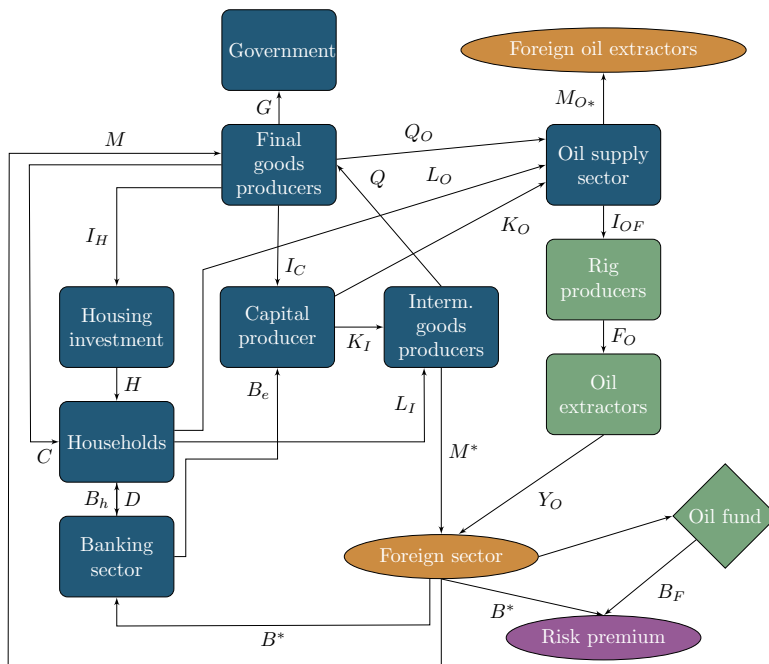
Figure 7 summarizes the impact responses of inflation for selected combinations of α_y and α_π , given $T = \{0, \dots, 40\}$. It seems clear that one would need ample discounting in order to break the convex relationship between T and impact responses. The calibration $\alpha_y = \alpha_\pi = 0.58$ is sufficient (see the bottom right plot), but even slightly different numbers, for example $\alpha_y = \alpha_\pi = 0.59$, brings us back to the puzzle. Thus, while one can

get around the FG puzzle by imposing a sufficient amount of discounting, it seems clear that “sufficient” in this context also means “substantial”. With that observation in mind, we do see a need for more work on the limits to forward-looking behavior in models of monetary policy. One potential avenue in this respect is the work by Farhi and Werning (2017). In the next section we quantify the power of FG in NEMO, Norges Bank’s main policy model.

3 THE POWER OF FORWARD GUIDANCE IN NEMO

This section investigates the power of FG in NEMO (Norwegian Economic Model), the main macroeconomic model used for forecasting and policy analysis at Norges Bank. The motivation stems from the fact that Norges Bank uses an explicit type of FG as it publishes policy rate forecasts three years ahead. Since NEMO is used for producing these forecasts, we would like to assess the power of FG in the model. We expect that the FG puzzle is also present in NEMO as it shares the same core structure as a simple New Keynesian (NK) model. However, as the model includes various real and nominal rigidities in order to fit the data better, the magnitude of the puzzle might be different from that in the simple model.

Figure 8: A schematic illustration of NEMO



NEMO is a large-scale New Keynesian DSGE model of a small open economy, estimated based on the Norwegian data with Bayesian methods. The model consists of several economic agents: Households, banks, intermediate goods firms, final goods firms, capital and housing producers, oil supply and oil extraction sectors, a fiscal authority, and the central bank. The model features a number of real and nominal rigidities such as external habit formation, investment adjustment costs, variable capacity utilization as well

as price and wage adjustment costs. Moreover, it includes credit constraints on households and entrepreneurs in the form of loan-to-value restrictions. The model also features long-term debt and partly backward-looking expectations regarding house prices to generate long cycles in house prices and credit as observed in the data. The central bank sets the short-term nominal interest rate according to an optimal interest rate rule that mimics optimal policy in order to achieve price and output stability.⁸ Figure 8 provides a bird-eye view of the model structure of NEMO.⁹

Along the lines of the previous section, we conduct two main experiments assessing the power of FG in NEMO. First, we consider FG about the real interest rate. After FG ends, the central bank will implement monetary policy as normal and follow the optimal policy rule. This experiment is highly useful as it helps us to understand the underlying mechanisms behind the FG puzzle more clearly. Second, we consider the experiment where the central bank announces a nominal policy rate path as this is closer to how most central banks implement FG in practice. We conduct both experiments for $T = 0, 2, 4,$ and 8 , where $T = 0$ refers to a contemporaneous shock. In order to isolate the FG effect, we set the persistence in the monetary policy innovation, which normally follows an AR(1) process, to zero.

3.1 ANTICIPATED REAL INTEREST RATE PATH

We start with FG about the real interest rate. Figure 9 shows the impulse responses of some key macro variables to a 1 percentage point annualized anticipated real interest rate cut at $T = 0, 2, 4,$ and 8 quarters-ahead. Because NEMO features several real and nominal rigidities compared to the standard NK model, the responses of macroeconomic variables are more sluggish and hump-shaped than what we found in the previous section. However, the basic transmission mechanism of a monetary policy shock remains the same.

The effect of FG in NEMO mainly works through three channels: (i) the standard consumption Euler equation, (ii) the Phillips curve, and (ii) the real exchange rate, which are elaborated in more detail in the previous section. An anticipated cut in the future real interest rate stimulates aggregate demand, leading to higher output and higher real wages. This causes the CPI and wage inflation rates to pick up. In addition, the real rate cut leads to a real exchange rate depreciation and higher imported inflation, which also feeds into aggregate inflation. The effects of a future monetary policy shock are qualitatively quite similar to those under a contemporaneous shock. However, both the impact and the peak effects increase as the horizon of the FG is extended. The figure also shows that longer durations of an expansionary FG policy lead to more policy tightening after time $t + T$.

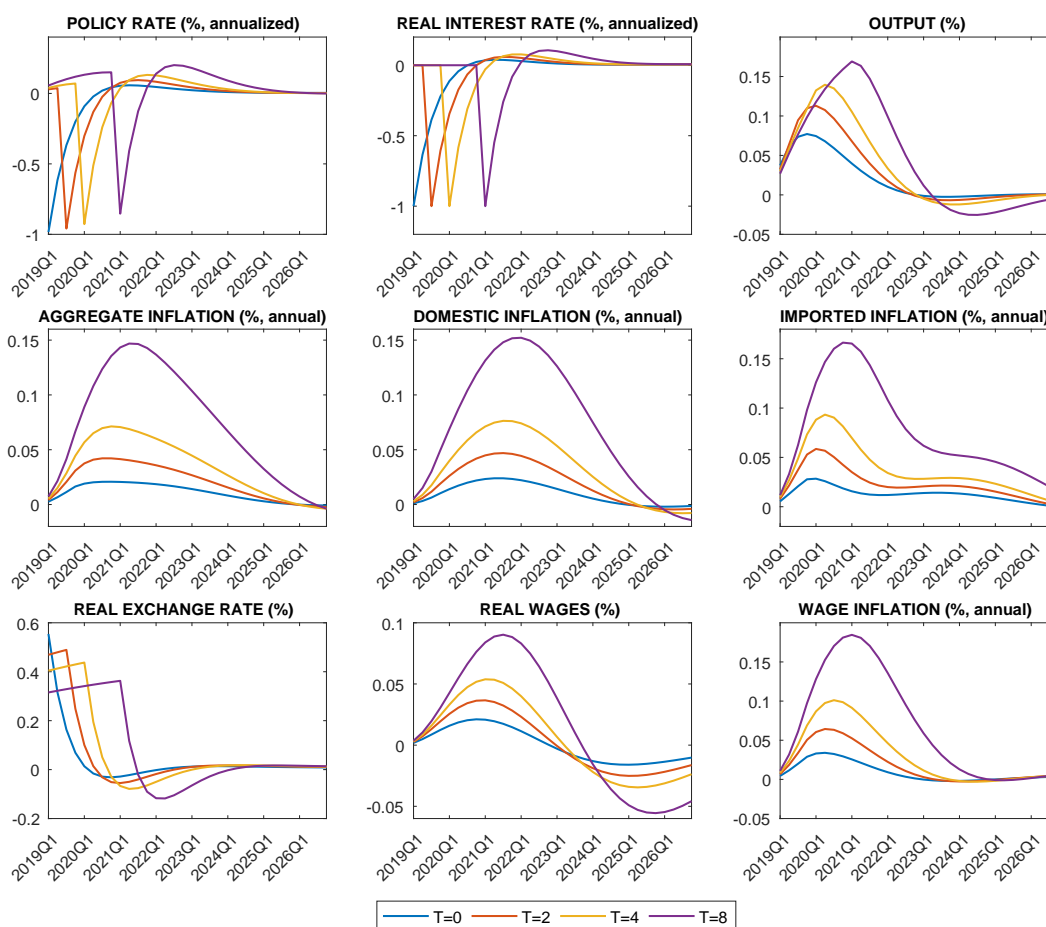
We then examine how aggregate inflation responds to extended horizons of FG about the real interest rate. Figure 10 shows the impact response of aggregate inflation, and its responses 1 year and 2 years ahead for different FG horizons relative to the response to a contemporaneous real interest rate cut of the same magnitude.¹⁰ Figure 10 indicates that

⁸When the model is used in the monetary policy process, it is solved with optimal policy under discretion. Our analyses show that the power of FG is stronger under optimal policy with discretion than that under the mimicking policy rule.

⁹Kravik and Mimir (2019) documents the latest version of the model and the technical appendix is given by Kravik, Mimir, and Paulsen (nd).

¹⁰The reason why we depict the response for current period, 1 year and 2 years ahead is that it takes several quarters for aggregate inflation to reach its peak due to a high degree of persistence in inflation induced

Figure 9: FG about the real interest rate in NEMO

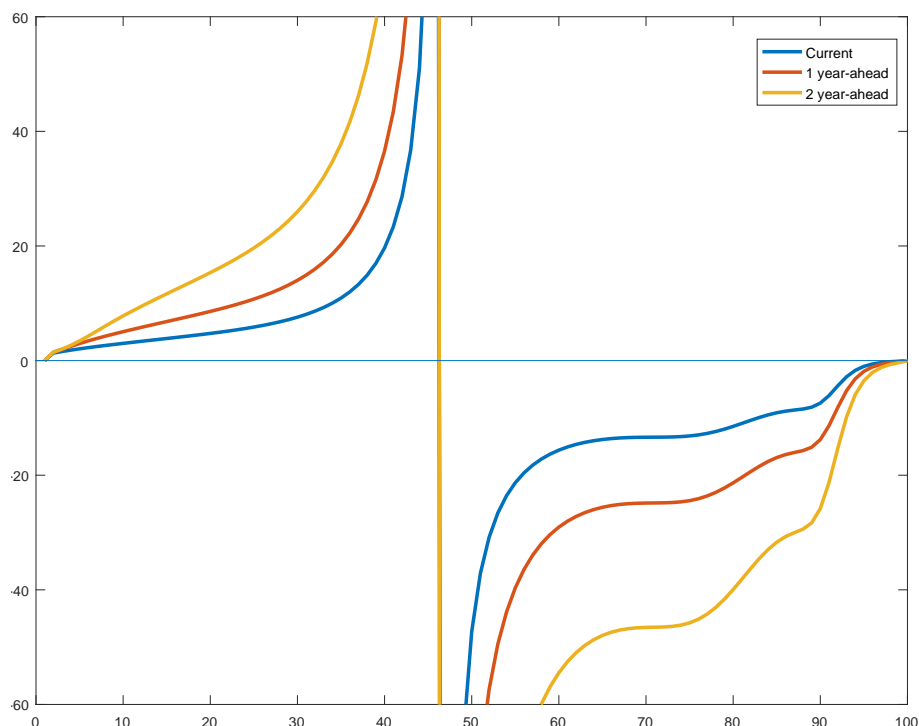


the largest response in inflation to FG is reached around quarter 46. The response to FG becomes contractionary for policy horizons exceeding 46 quarters. Although the relative responses of inflation do not seem to be severe in shorter horizons of FG, we observe less reasonable responses when the horizon of FG is extended.

As in any standard small open economy model, the real exchange rate plays an important role in the transmission of monetary policy in NEMO and is primarily determined by an uncovered interest rate parity (UIP) condition. This condition states that the real interest rate differential between the domestic economy and abroad is equal to the relative change in the real exchange rate from the previous period. The response of the real exchange rate to the FG is given by the accumulated real interest rate change induced by the anticipated monetary policy shock, holding risk premium constant. Although the bottom-left panel of Figure 9 shows that the real exchange rate depreciates more on impact for shorter horizons of FG, it remains weak for longer as the FG horizon is extended, making the total real exchange rate depreciation larger for longer policy horizons. This result is apparent in Figure 11, which shows the cumulative real exchange rate depreciation in response to FG about the real interest rate path for different policy horizons ($T = 0, 2, 4,$ and 8). A higher cumulative real exchange rate depreciation increases imported inflation

by the assumption of full indexation in NEMO (See Figure 9).

Figure 10: Inflation responses for different FG horizons T in NEMO



Note: The figure shows the response of inflation (current, one year or two years ahead) to an anticipated real interest rate change at different horizons of FG (horizontal axis) relative to response of inflation to current real interest rate change.

and results in a more severe impact on aggregate inflation for longer horizons of FG.

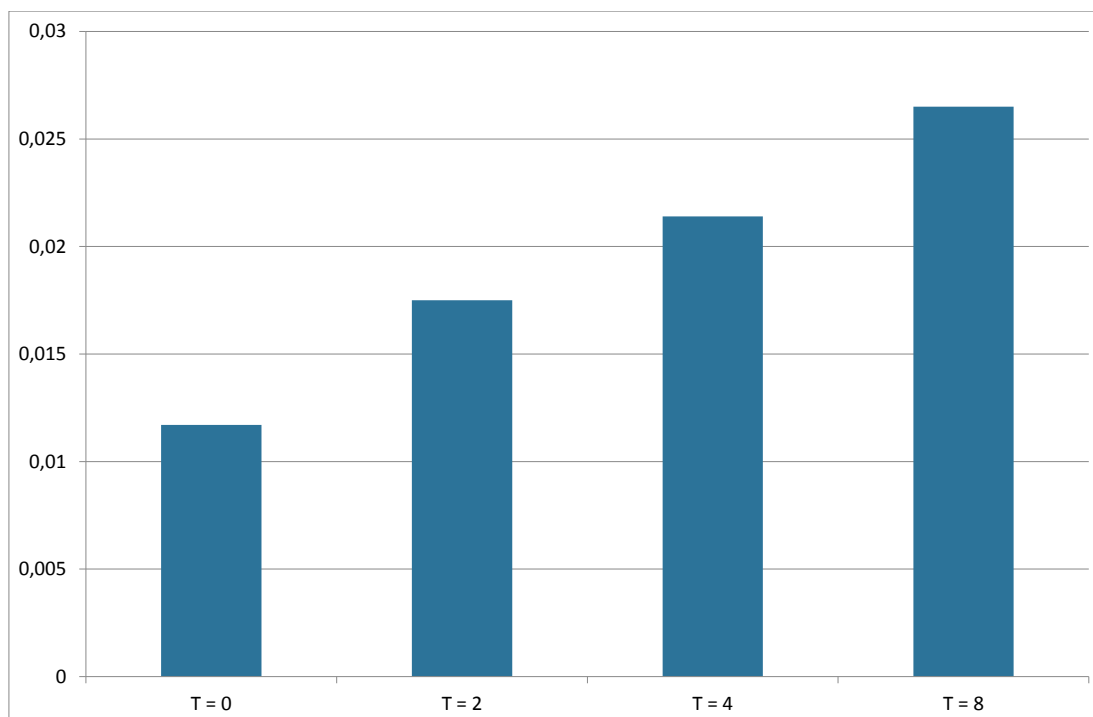
This section has showed that NEMO exhibits the FG puzzle as observed in a canonical NK model. However, NEMO features various real and nominal rigidities, which essentially make the model more backward-looking compared to the standard NK model. These features might reduce the power of FG. In the next section, we will analyze how different rigidities affect the power of FG under the anticipated real interest rate path.

3.2 WHICH MODEL INGREDIENTS AFFECT THE POWER OF FORWARD GUIDANCE IN NEMO

NEMO features several types of real and nominal rigidities that might potentially affect the size of the FG puzzle. In addition to these rigidities, open economy features such as openness to trade and imperfect exchange rate pass-through can also alter the magnitude of FG. To assess the effect of these features, we conduct sensitivity analyses by adjusting the degree of real and nominal rigidities in the model. We focus on the rigidities that we think are the most relevant. The sensitivity analyses displaying the impulse responses to an anticipated real interest rate cut of 1 pp. at $T = 0$ and $T = 4$ for the baseline and the alternative models are presented in Appendix B.

We first start with the degree of habit persistence (see Figure 14). The baseline NEMO has a habit persistence parameter of 0.94, while we set the parameter to 0 in the alternative model. A higher degree of habit persistence reduces the impact of a contemporaneous real

Figure 11: FG and the real exchange rate



Note: The figure shows total real exchange rate depreciation in response to an anticipated real interest rate cut of 1 percentage point at different horizons T .

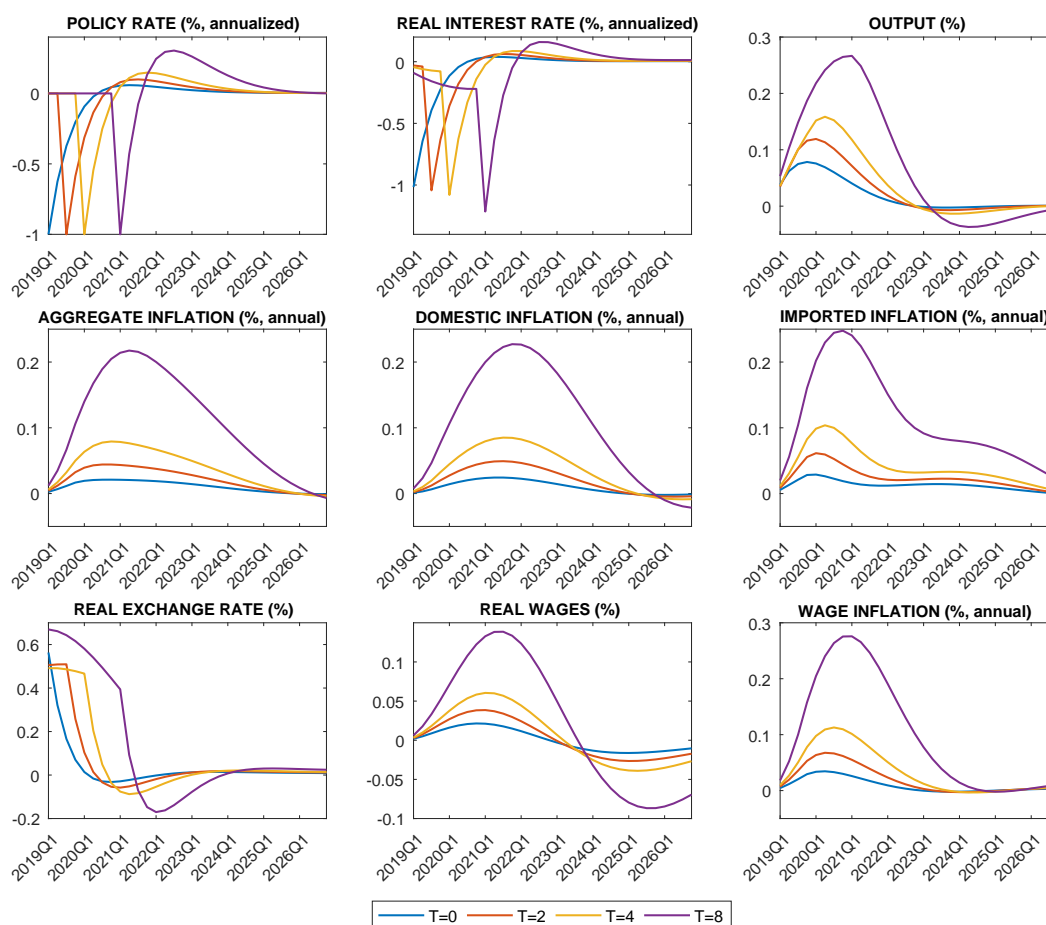
rate shock on aggregate inflation and output. Similarly, the effect of FG about a future real interest rate cut is also smaller under a higher degree of habit persistence.

We then continue with the role of credit constraints (see Figure 15). NEMO features loan-to-value (LTV) constraints on both households and entrepreneurs. In this exercise, we change the tightness of the LTV constraint on households by reducing it from 85% to 1%. This means that households can borrow less in equilibrium. Aggregate inflation responds less to the anticipated rate shock under a tighter LTV constraint. In response to the changes in the real interest rate, households might have less room to change their consumption profiles as they are allowed to borrow less compared to the case of higher LTV ratios, which is similar to the argument made by McKay et al. (2016). However, the reduction in the response of inflation across different LTV ratios is not very pronounced.

We also assess the role of openness in explaining the power of FG (see Figure 16). The baseline model features a domestic goods share of 0.65 in final goods production while we set it to 0.35 in the alternative model. The latter model economy can be classified as more open compared to the former. The effect of a contemporaneous real interest rate cut on aggregate inflation is higher under a more open economy due to the increased impact of exchange rate pass-through on imported inflation. This effect is also present in response to an anticipated future rate shock. In an absolute sense, the magnitude of the FG puzzle increases as the degree of openness gets higher.

Our next experiment is to investigate the role of stickiness in domestic prices, import prices (exchange rate pass-through) and in wages, respectively (see Figures 17, 18, and 19). We reduce the value of price adjustment cost parameters for all three price defini-

Figure 12: FG about the nominal interest rate in NEMO

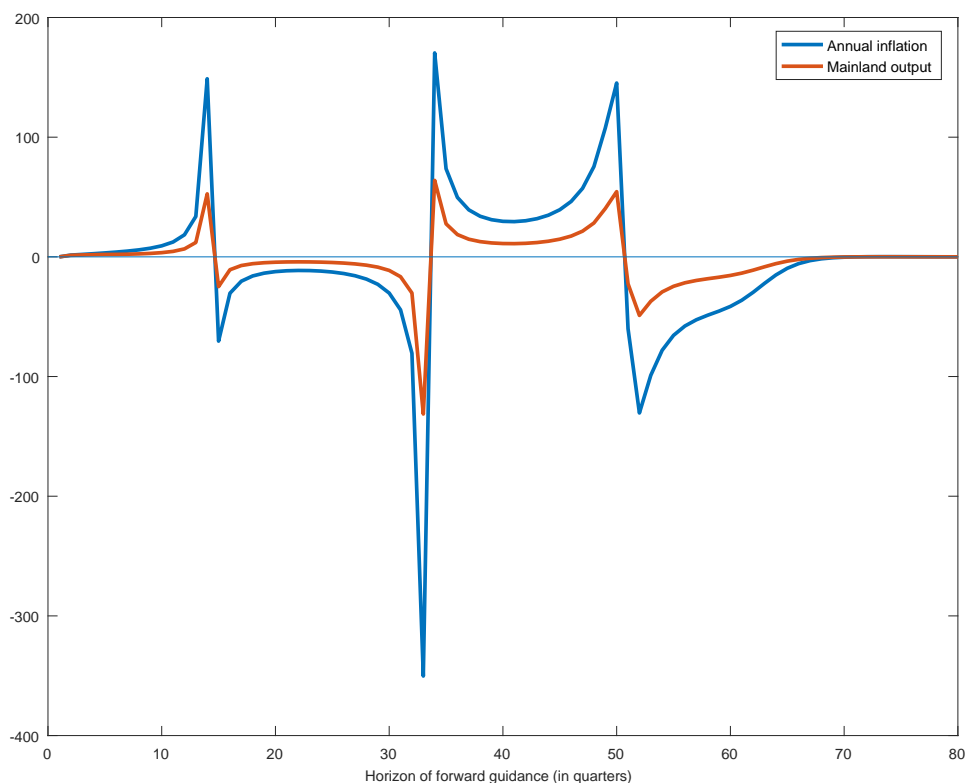


tions to nearly half of that in the baseline model. The figures show that lower degrees of stickiness in all three cases increase the power of FG.

Finally, we analyze the role of inflation indexation. We analyze full and partial indexations to past domestic price inflation, to past imported inflation and to past wage inflation, respectively (see Figures 20, 21, and 22). NEMO currently features full indexation to all of these inflation rates whereas the alternative model features a partial inflation indexation parameter of 0.35 for all. The partial indexation to past inflation in all three cases seems to mitigate the power of FG by limiting the effect of monetary policy shocks on aggregate inflation in an absolute sense.

Overall, higher degrees of real and nominal rigidities seem to mitigate the power of FG in NEMO for shorter horizons. However, as we will show in the next section, they do not prevent the model from displaying the so-called *sign reversal puzzle* for longer horizons of FG.

Figure 13: Inflation responses for different FG horizons T in NEMO



Note: The figure shows the ratio of the response of inflation (output) one year ahead to an anticipated nominal interest rate shock T quarters ahead (horizontal axis) to the response of inflation (output) one-year ahead to a contemporaneous nominal interest rate shock.

3.3 ANTICIPATED NOMINAL RATE PATH AND THE SIGN REVERSAL PUZZLE

In this section, we explore FG about the nominal interest rate path, which might be considered as more policy relevant. Figure 12 shows the impulse responses to a 1 percentage point anticipated nominal policy rate cut at $T = 0, 2, 4,$ and 8 quarters ahead. Figure 12 indicates that the response of aggregate inflation increases with the horizon of FG. If we compare the impulse responses for FG about the real and nominal interest rates, we see that the power of FG is greater for the nominal interest rate than for the real rate, specifically when looking at the peak effects on output and inflation. It is also evident from Figure 12 that FG about more distant policy rate changes requires more monetary policy tightening after the FG period ends (see the top-left panel of Figure 12). This policy rate overshooting when the central bank switches from the FG policy to conventional interest rate policy results in partly muted effects of FG on the aggregate inflation. This confirms that the expectations channel in NEMO is quite powerful and that the model displays the FG puzzle.

As we extend the horizon of FG, the aggregate inflation response becomes negative at $T = 14$. This might reflect the fact that the monetary stimulus provided by long periods of FG about lower policy rates and perhaps the consequent policy tightening after the FG period ends become sufficiently large to destabilize the model, as evident in Figure 13.

This phenomenon is called the *sign reversal puzzle*. The responses of aggregate inflation and output reach asymptotes and move into negative territory repeatedly as the horizon of FG is extended. This is a consequence of the various real and nominal rigidities included in NEMO, leading to more state variables and more backward-looking features. The latter reduces the weight attached to the forward-looking expectations. Although they seem to dampen the magnitude of the FG puzzle in NEMO in the short run (see Section 3.2), they contribute to making the model more sensitive to the anticipated policy shocks in terms of sign reversals under full inflation indexation for extended horizons of FG. Changing the degrees of various real and nominal rigidities does not prevent the model from exhibiting the sign reversal puzzle for extended horizons of FG (see Figures 23, 24, 25, 26, and 27).

4 CONCLUSION

This staff memo assesses the power of FG in Norges Bank's main macroeconomic model, NEMO, which is used extensively by the Bank's staff for forecasting, scenario and policy analysis. We first use a fairly standard NK model as a laboratory to explore the power of FG and how FG policies work in a simpler and more tractable setup. We then quantitatively investigate the power of FG in the policy model NEMO as it is used to produce policy rate forecasts three years ahead.

We confirm the well-known finding in the literature that the FG puzzle is highly pervasive in canonical NK models. The experiments we conducted in this simple model suggest that the existing solutions proposed in the literature have important limitations, either due to highly contractionary post FG guidance dynamics, or due to implausibly large degree of discounting that is well beyond any parametrization used in existing studies. More work still needs to be done on the possible solutions to the FG puzzle.

We also find that NEMO suffers from the FG puzzle. However, the presence of various real and nominal rigidities in NEMO somewhat mitigates the macroeconomic effects of future anticipated interest rate cuts for shorter horizons of FG compared to canonical NK models used in the literature. Having said this, we argue that the observed contraction due to interest rate overshooting after the FG period ends points towards a highly powerful expectations channel in the model. In addition, we find that extended periods of FG in NEMO lead to the sign reversal puzzle, implying arbitrary equilibria.

To sum up, we conclude that policymakers at central banks should be careful in evaluating the predictions about FG policies in models similar to NEMO. The expectations channel in this class of models appears to be implausibly strong both from empirical and theoretical points of view as we believe that interest rate changes today should be more effective for current decisions of economic agents than those happening in the future. We take this into account while using the model for monetary policy analysis by adding substantial judgement for policy decisions. Although we employ some modeling tricks to obtain plausible effects of expectations about future policy decisions (for example, unanticipated future monetary policy shocks), we also regularly develop NEMO for the model to continue to be a useful tool for monetary policy analysis over time.

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APPENDIX

A IMPLICATIONS OF ECONOMIC OPENNESS

The simple model in the main text abstracts from economic openness. Here we highlight that FG, in a textbook small open economy (SOE), is isomorphic to FG in the closed economy. Exchange rate pass-through in particular makes inflation more sensitive to interest rate news, but the relative importance of news about the distant future remains unchanged. The textbook SOE model can be summarized by two equations in output and domestic inflation, see Galí and Monacelli (2005):

$$y_t = \mathbb{E}_t y_{t+1} - \frac{1}{\sigma_h} (i_t - \mathbb{E}_t \pi_{h,t+1}) \quad (8)$$

$$\pi_{h,t} = \beta \mathbb{E}_t \pi_{h,t+1} + \kappa_h y_t \quad (9)$$

Qualitatively, two differences separate this model from its closed economy counterpart: first, the domestic real producer rate $r_{h,t} = i_t - \mathbb{E}_t \pi_{h,t+1}$, rather than the real consumer rate $r_t = i_t - \mathbb{E}_t \pi_{t+1}$, determines output. Second, aggregate supply pins down domestic inflation $\pi_{h,t}$ rather than aggregate consumer price inflation π_t . The latter, instead, is a weighted average of domestic and imported inflation:

$$\pi_t = \alpha \pi_{h,t} + (1 - \alpha) \pi_{f,t}$$

Note that the structure given by equations (8)-(9) is identical to that in (1)-(2). The FG puzzle in our SOE is, therefore, isomorphic to that in the closed economy if we consider real producer rates. Quantitatively the effects depend on σ_h^{-1} and κ_h , which may or may not be larger than their closed economy counterparts σ^{-1} and κ .¹¹ However, the relative importance of interest rates at different horizons is unchanged. In order to understand how economic openness interacts with FG about real consumer rates, we need to establish a relationship between r_t and $r_{h,t}$. Their definitions imply that

$$r_t - r_{h,t} = \mathbb{E}_t (\pi_{h,t+1} - \pi_{t+1}) = \frac{1 - \alpha}{\alpha} \mathbb{E}_t (\pi_{t+1} - \pi_{f,t+1}),$$

where the last equality follows from the expression for aggregate consumer price inflation given above. We impose two commonly used assumptions in order to get rid of the expectations term: (i) the law of one price (LOOP) on imported goods and (ii) uncovered interest rate parity (UIP). The first assumption implies that $\pi_{f,t} = \Delta q_t + \pi_t$, where Δq_t represents the one-period change in the real consumer exchange rate. The second assumption implies a no-arbitrage condition of the form $r_t = r_t^* + \mathbb{E}_t \Delta q_{t+1}$, where r_t^* denotes the foreign real interest rate. These two assumptions allow us to manipulate the equation above in order to express the consumer rate as a weighted average of domestic and global interest rates:

$$r_t = \alpha r_{h,t} + (1 - \alpha) r_t^*$$

¹¹ σ_h^{-1} and κ_h depend on the elasticity of substitution between imports and domestically produced goods. In the SOE model considered here, one can show that $\sigma_h < \sigma$ and $\kappa_h < \kappa$ if and only if that elasticity is greater than σ^{-1} .

Moreover, the SOE assumption implies that global interest rates are unaffected by domestic events. Thus, holding the foreign rate fixed, $r_t = \alpha r_{h,t}$ and FG about either rate is proportional to the other in terms of inflationary effects. In particular, we can solve for $\pi_{h,t}$ as a function of future real interest rates:

$$\begin{aligned}\pi_{h,t} &= -\frac{\kappa_h}{\sigma_h} \mathbb{E}_t \left[r_{h,t} + (1 + \beta) r_{h,t+1} + \dots + \frac{1}{1 - \beta} r_{h,\infty} \right] \\ &= -\frac{\kappa_h}{\alpha \sigma_h} \mathbb{E}_t \left[r_t + (1 + \beta) r_{t+1} + \dots + \frac{1}{1 - \beta} r_\infty \right]\end{aligned}$$

it follows that economic openness ($\alpha < 1$) amplifies the responsiveness of domestic inflation to news about future real consumer rates. However, the relative importance of news about the distant future remains unchanged. Turning to aggregate consumer price inflation, we note that the LOOP implies

$$\begin{aligned}\pi_t &= \pi_{h,t} + \frac{1 - \alpha}{\alpha} \Delta q_t \\ &= \pi_{h,t} - \frac{1 - \alpha}{\alpha} q_{t-1} - \frac{1 - \alpha}{\alpha} \mathbb{E}_t \sum_{s=t}^{\infty} (r_s - r_s^*)\end{aligned}$$

It follows that π_t , compared with $\pi_{h,t}$, gets an additional push from exchange rates when expectations are revised. But after the first period, expectations align once more and $\pi_t = \pi_{h,t}$.

B SENSITIVITY ANALYSIS IN NEMO

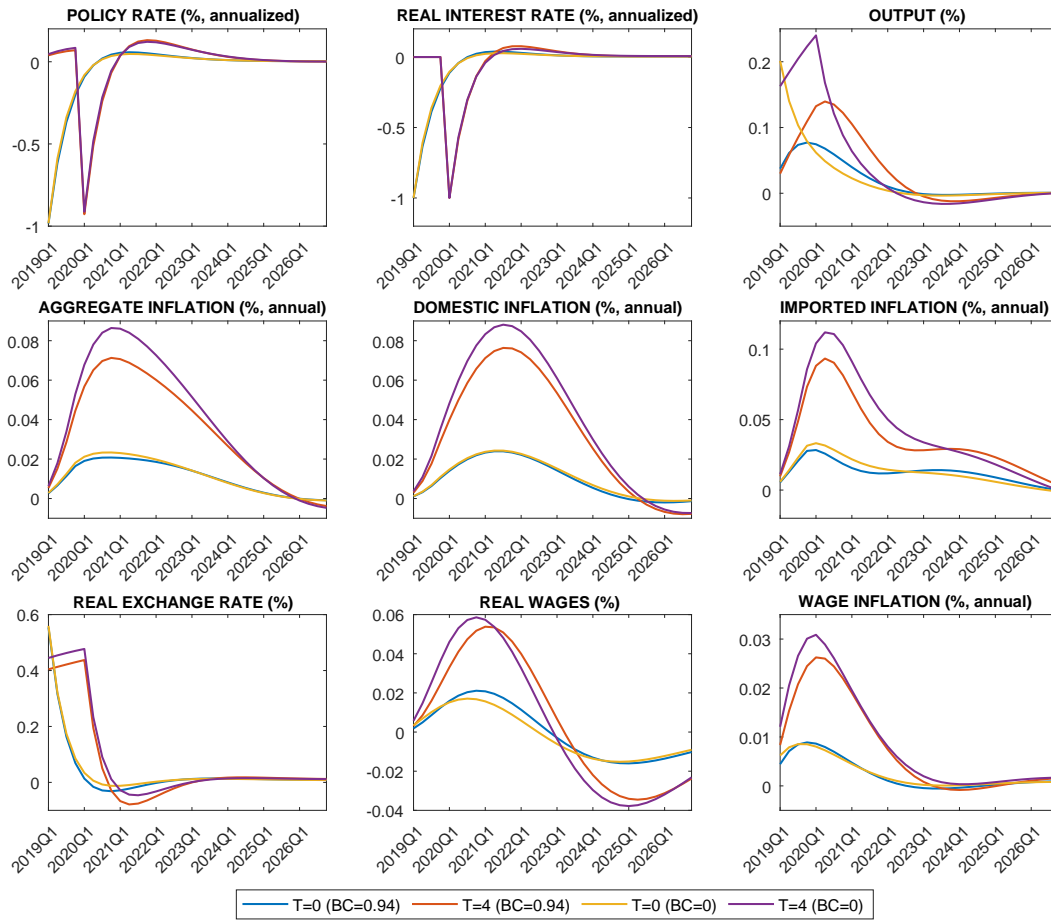


Figure 14: *Impulse responses to an anticipated real interest rate cut of 1 pp at different horizons: The role of habit persistence*

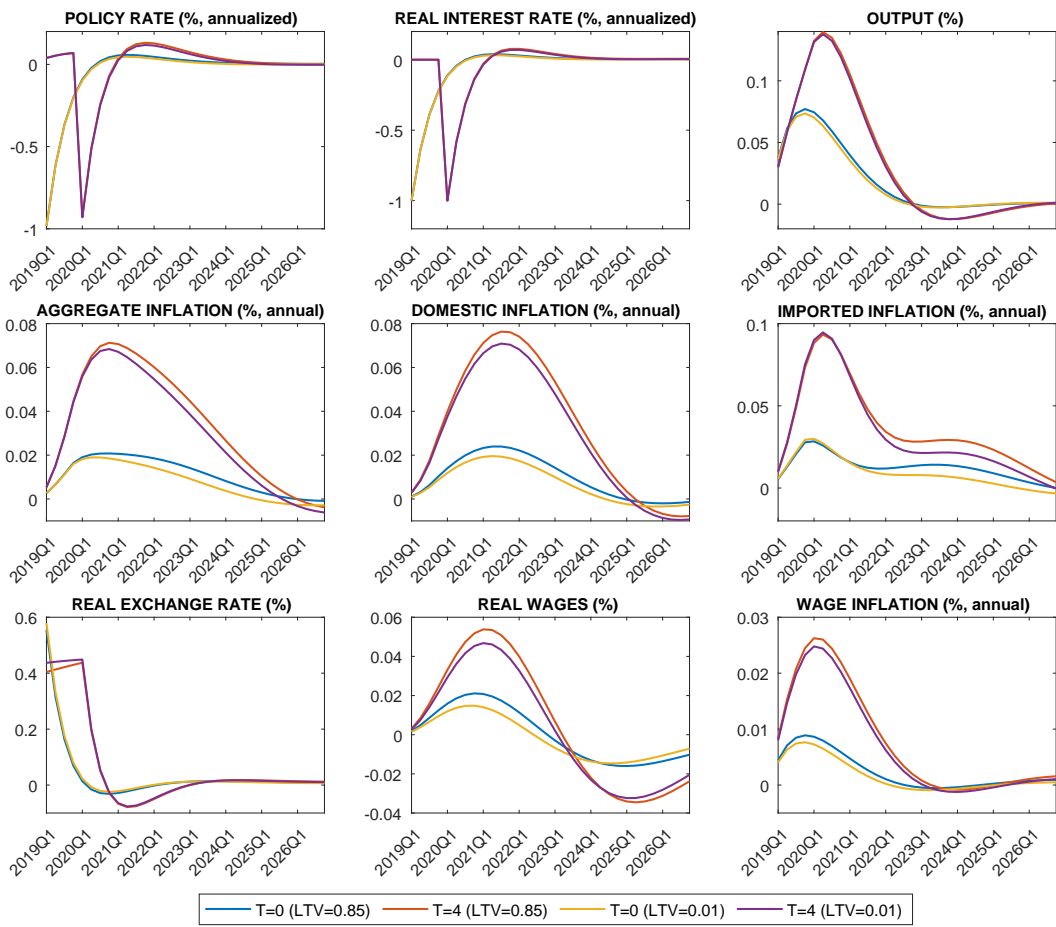


Figure 15: Impulse responses to an anticipated real interest rate cut of 1 pp at different horizons: The role of credit constraints

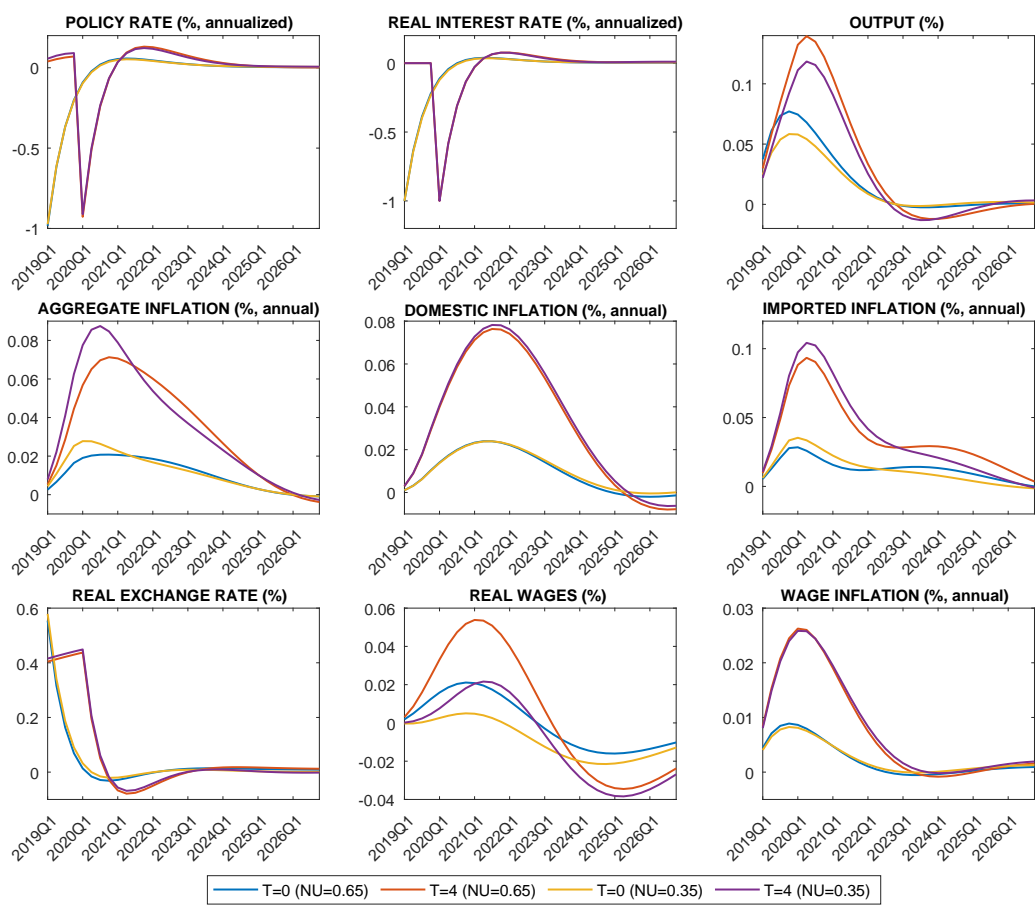


Figure 16: *Impulse responses to an anticipated real interest rate cut of 1 pp at different horizons: The role of openness*

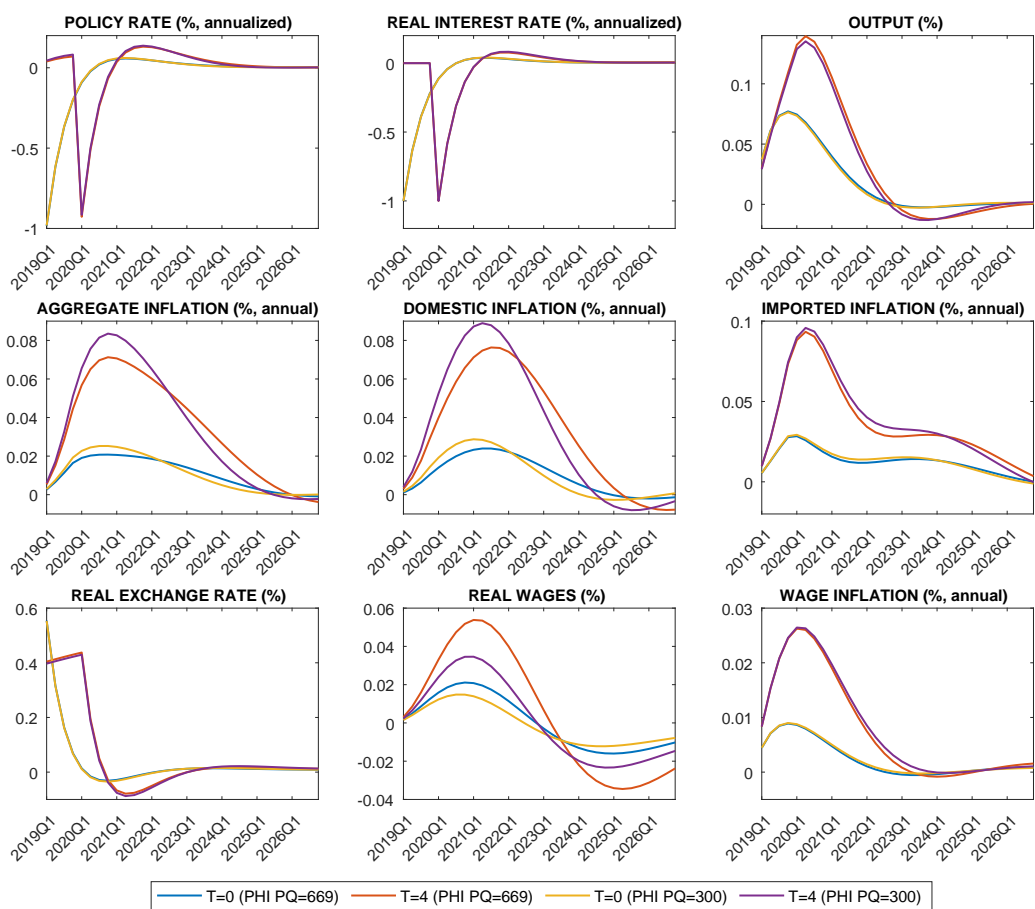


Figure 17: *Impulse responses to an anticipated real interest rate cut of 1 pp at different horizons: The role of sticky domestic prices*

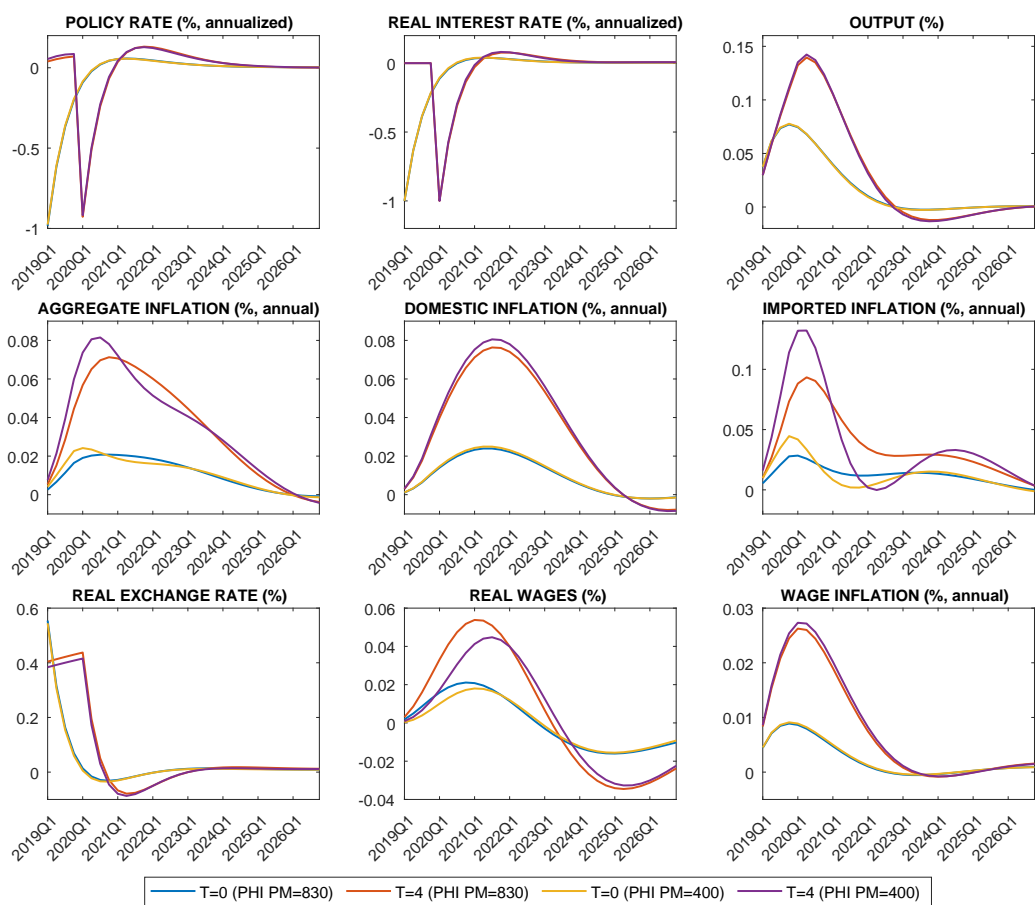


Figure 18: *Impulse responses to an anticipated real interest rate cut of 1 pp at different horizons: The role of imperfect ER pass-through*

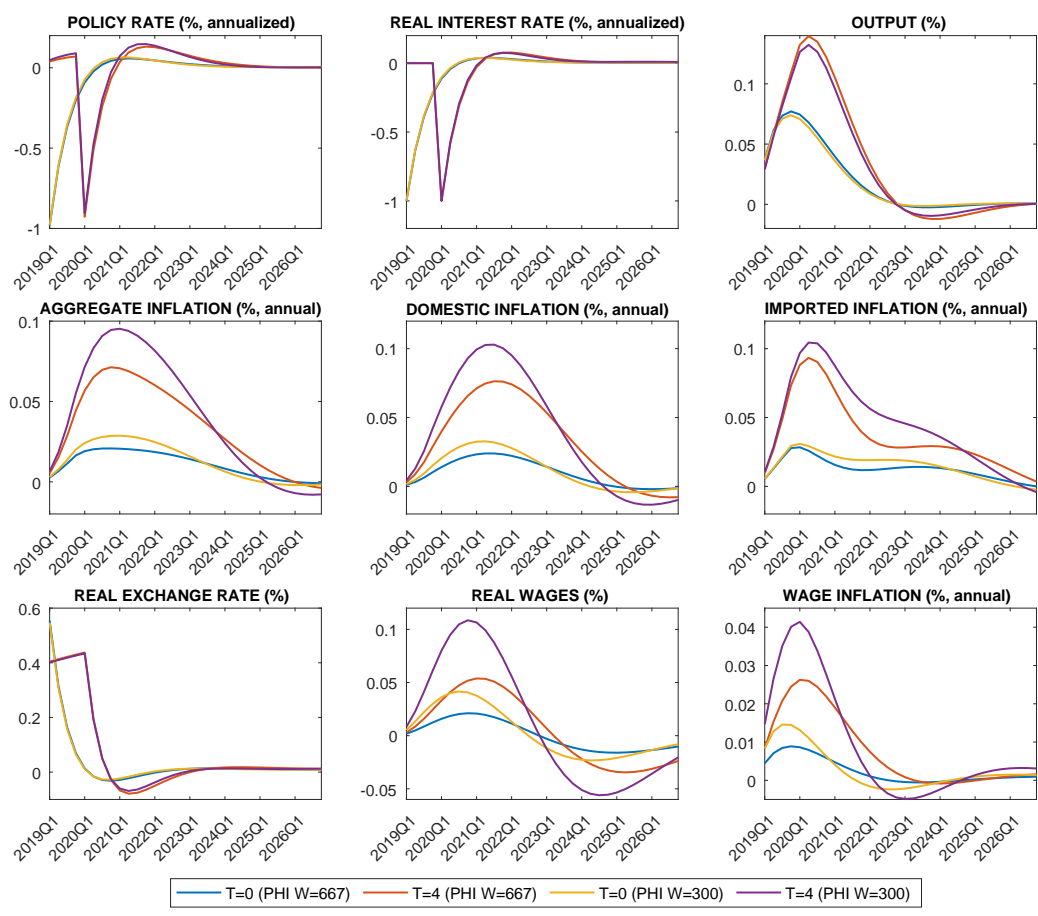


Figure 19: *Impulse responses to an anticipated real interest rate cut of 1 pp at different horizons: The role of wage stickiness*

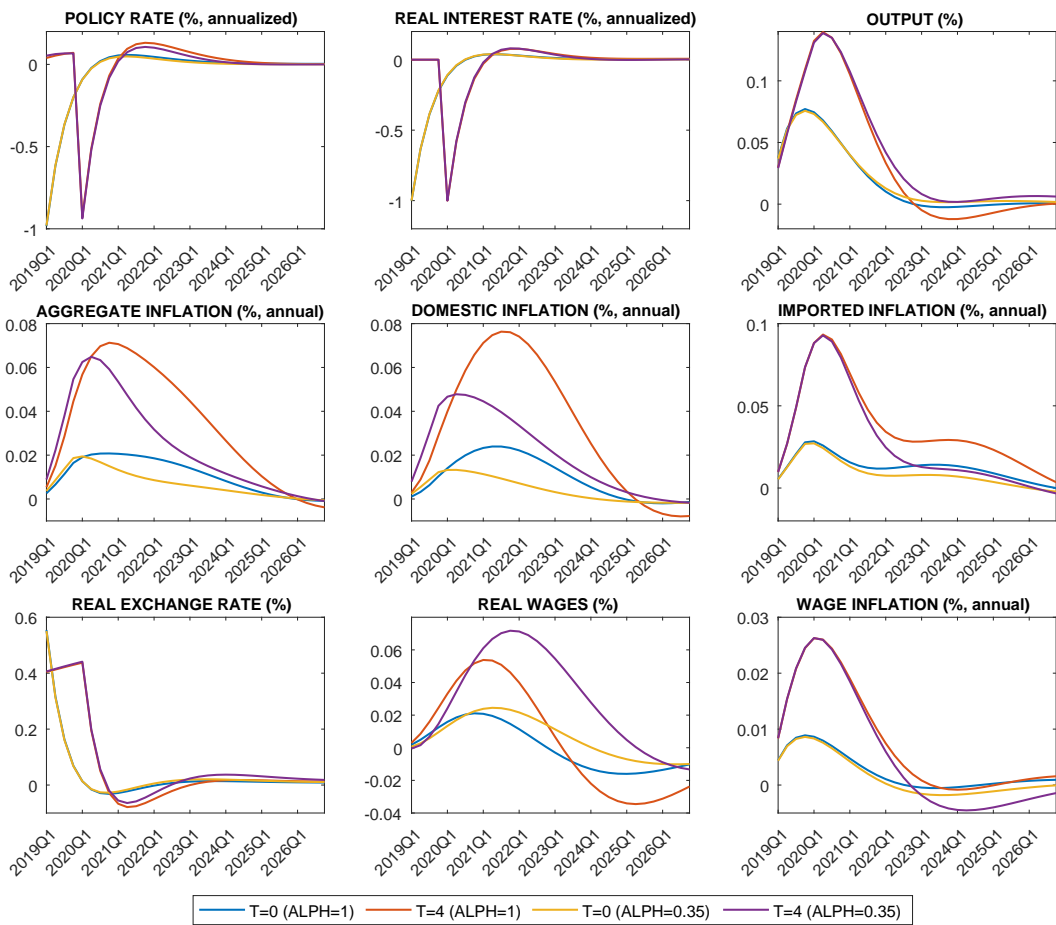


Figure 20: *Impulse responses to an anticipated real interest rate cut of 1 pp at different horizons: The role of partial indexation to past domestic price inflation*

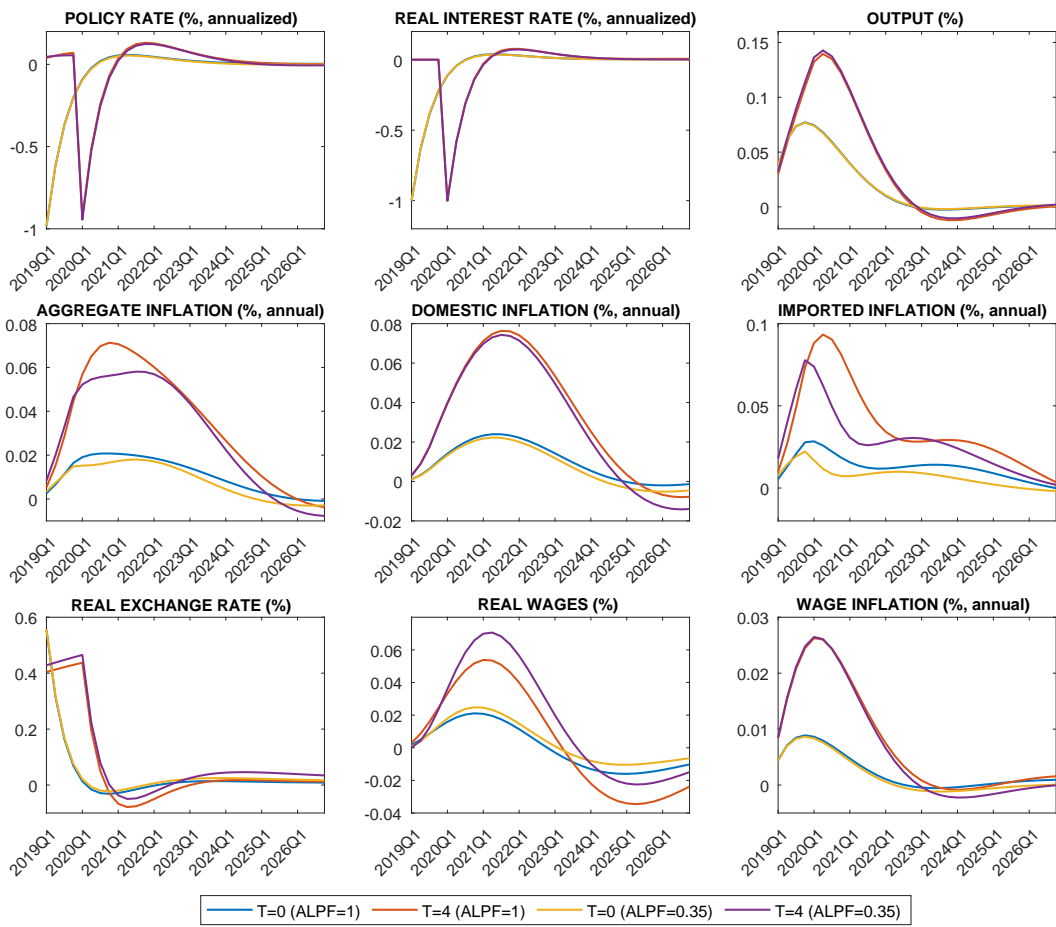


Figure 21: Impulse responses to an anticipated real interest rate cut of 1 pp at different horizons: The role of partial indexation to past import price inflation

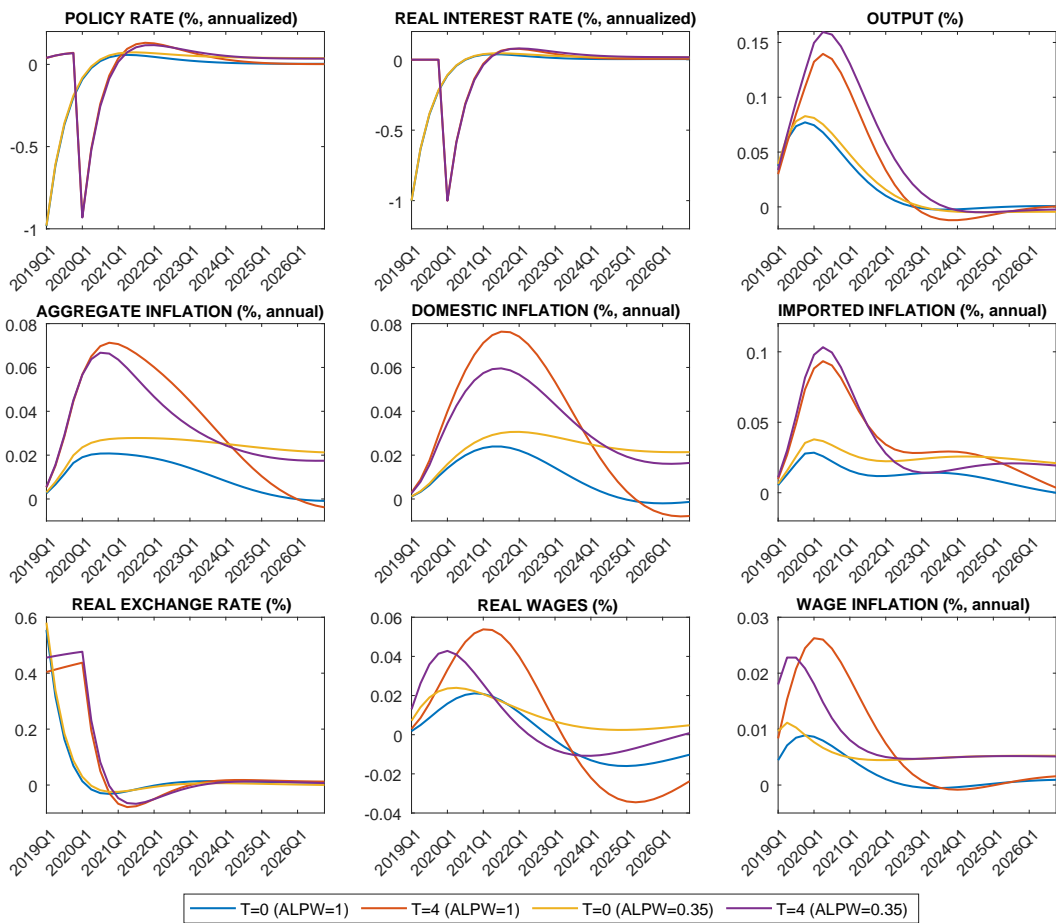


Figure 22: Impulse responses to an anticipated real interest rate cut of 1 pp at different horizons: The role of partial indexation to past wage inflation

Figure 23: Sign reversal puzzle under no habit persistence

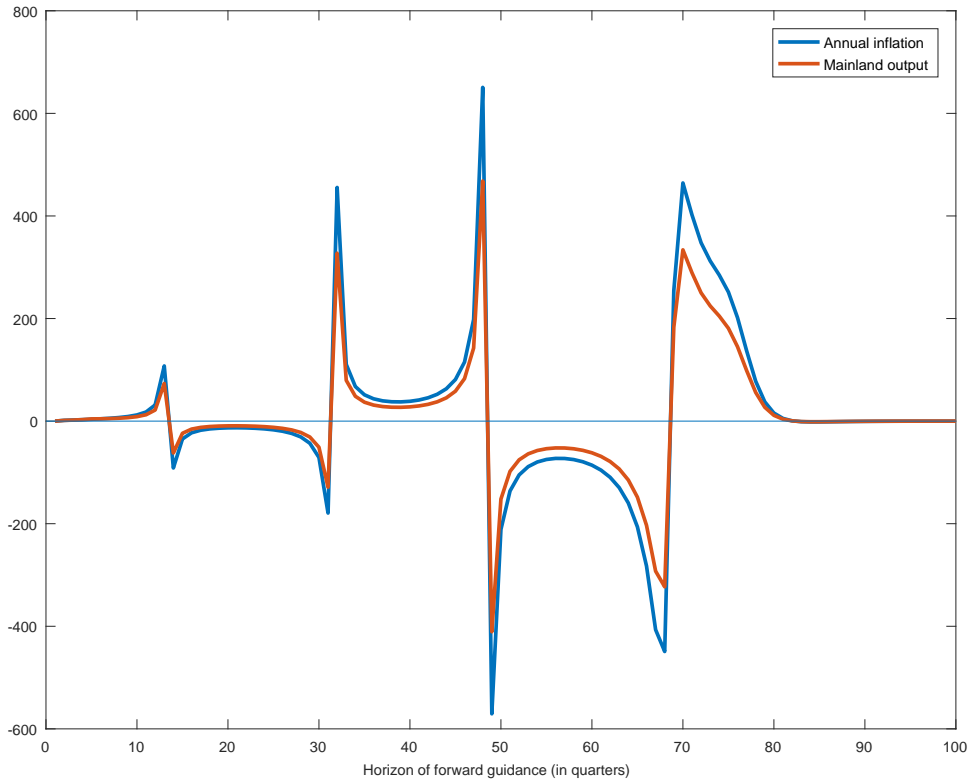


Figure 24: Sign reversal puzzle under tighter credit constraints

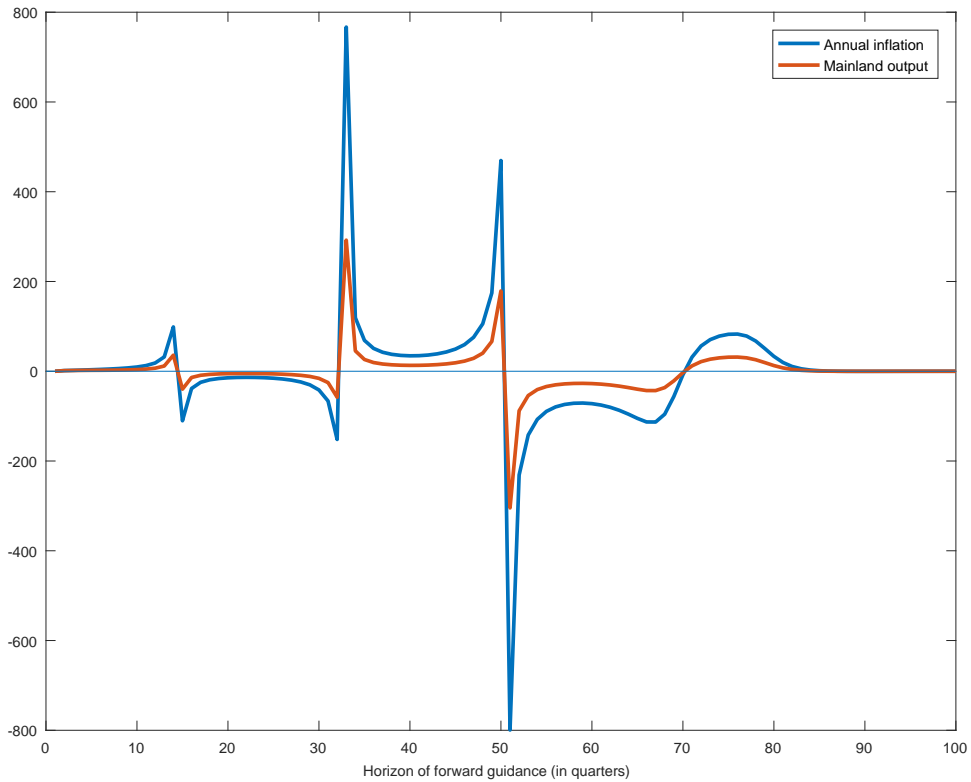


Figure 25: Sign reversal puzzle under more open economy

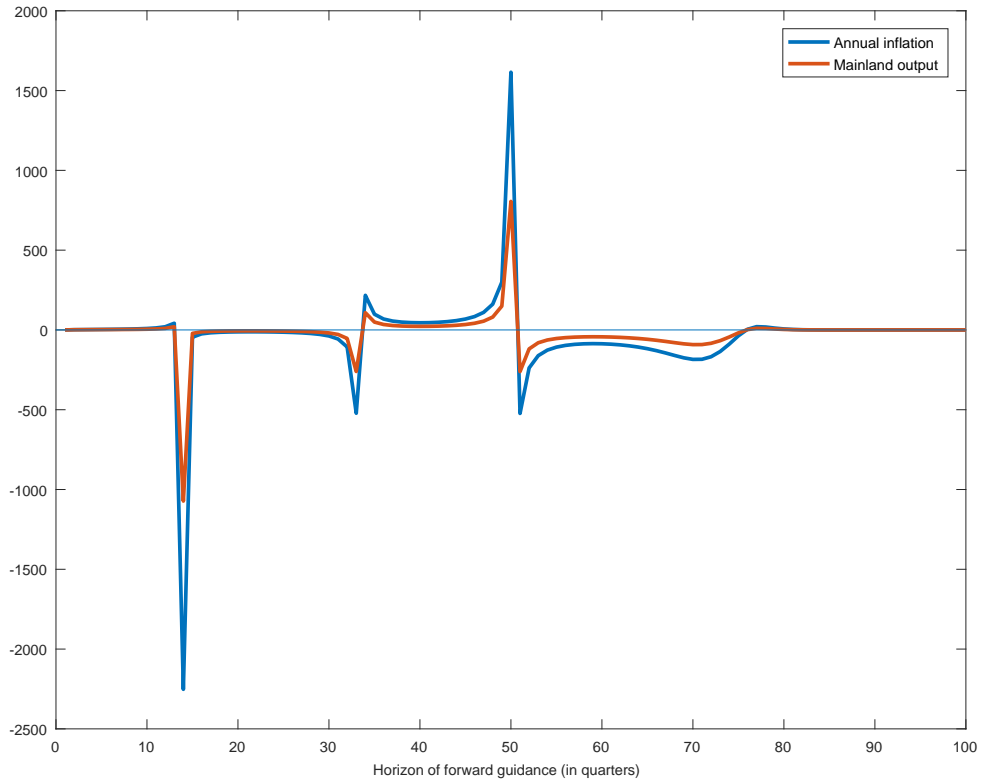


Figure 26: Sign reversal puzzle under less sticky wages

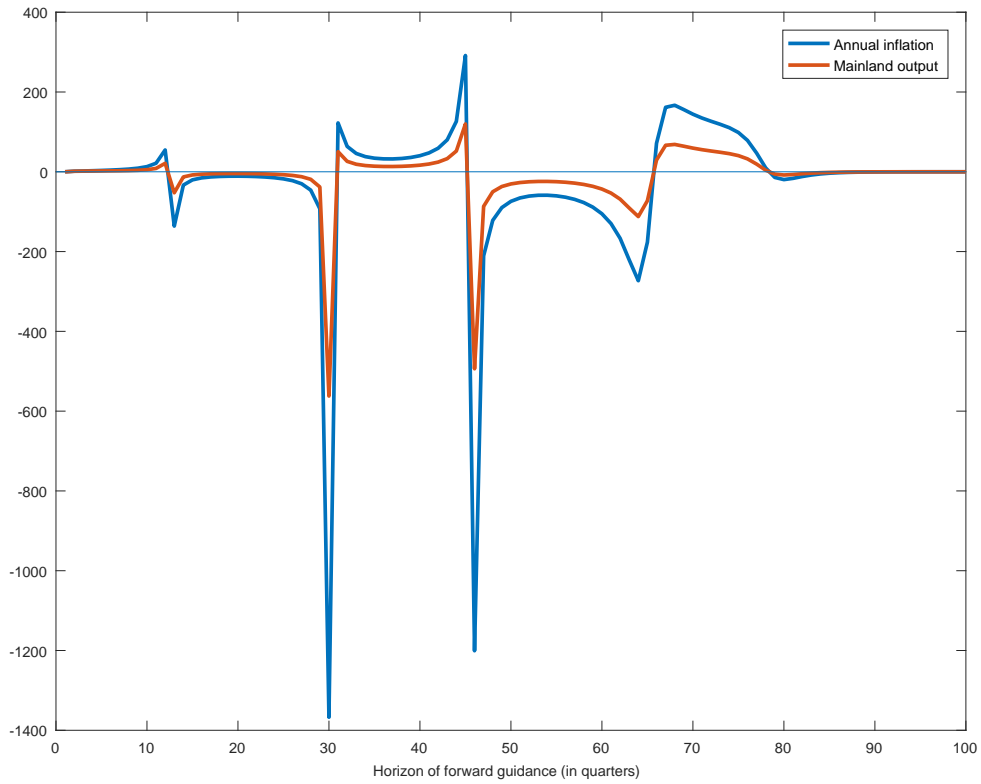


Figure 27: Sign reversal puzzle under partial inflation indexation

