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Forward guidance investigation in new Keynesian models

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ABSTRACT

Forward guidance is widely considered a useful tool for improving monetary policy transmission. This paper introduces endogenous Delphic guidance in which future policy targets are time-varying and dependent on the future economy. The results show that the performance of inflation-targeting forward guidance depends partially on the forward horizon and the agents' expectation, while announcing an interim output target could stimulate the economy only under a rational expectation environment and requires a short forward horizon. We also discuss the effectiveness of Odyssean forward guidance which incorporates monetary authorities' preferences. The results indicate that the effect of a commitment on future paths of an interest-rate rule is based on the agents' expectations.

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1. Introduction

The outbreak of Covid-19 has had a wide influence on almost all areas, including financial markets worldwide since 2020. The sudden stop in economic activity and lockdown durations lead to severe damage to the economy, including significant declines in GDP growth in the majority of countries. Continuously falling economic growth significantly affects monetary policy transmission, forcing central banks to implement unconventional monetary policies, for example, forward guidance. By using forward guidance, central banks communicate with the public about future responses to the economy. Should a central bank adopt forward guidance when facing an exogenous shock? Could forward guidance have a beneficial influence on the economy continuously? Does the effectiveness of monetary policy vary due to the macroeconomic environment?

Monetary authorities' communication of forward guidance mainly occurs through two ways: providing a potential policy target to private sectors, referred as Delphic forward guidance, or offering a commitment on following a future interest-rate rule, which is commonly called Odyssean guidance (Fujiwara & Waki, 2021; Hallett & Acocella, 2018). Andrade and Ferroni (2021) discuss Delphic and Odyssean guidance

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and find empirical evidence that these two approaches have an opposite effect on macroeconomics. Goy et al. (2022) argue that both forms of guidance could improve social welfare, especially Odyssean forward guidance. However, De Graeve et al. (2014) discuss the effectiveness of two types of different guidance and point out that imperfect information would have a substantial effect on the policy. In this paper, we will further investigate Delphic and Odyssean forward guidance and then examine the effectiveness of announcing forward guidance under different economic conditions.

There is a growing body of literature discussing the formation and effectiveness of forward guidance. Allard et al. (2013) investigate the forward horizon on fiscal policy and find that the intensity of central bank communication has increased since the financial crisis. Gersbach et al. (2021) examine central banks' behaviors under different forward guidance. By using Delphic guidance, policymakers should choose a policy target to communicate with the public. Inflation and price level targets are most frequently used in the literature (Acuna-Roa & Parra-Polania, 2016; Clarida, 2019; Coletti et al., 2021; Guender & Oh, 2006). Eusepi and Preston (2010) discuss the effect of forward guidance on communicating the inflation target. Nicolay and de Oliveira (2019) find evidence that central bank communication on inflation targets is a superior tool in emerging economies. Cole (2018, 2020) analyze Delphic guidance on inflation and price-level targets, and the results show that the economy could benefit from forward guidance if central banks issuing a future price-level target rather than an inflation target. In their models, forward guidance is added as an exogenous term to the policy targets, which is decided somewhat arbitrarily by a central bank, and the policy targets will be kept constant over certain periods. However, it is not reasonable to assume that the policy target levels will remain constant; they might vary, at least in the short term when the economic environment changes. One way to incorporate these findings is to have an interim inflation target, opportunistic policymakers use an interim inflation target and find that it could be used to reduce inflation and eventually achieve the ultimate inflation target (Aksoy et al., 2006; Helle & Walter, 2010).

Delphic guidance publishes potential policy outcomes but does not need to commit to a certain policy, however, a specific commitment is required when using Odyssean forward guidance. Leif et al. (2021) investigate the effect of the market yield curve when central banks communicate a future policy rate path. Bassetto (2019) show that communication through Odyssean guidance has social value, which has been approved by Andrade and Ferroni (2021), who find empirical evidence that the aggregate demand is enhanced in the Euro Area after announcing Odyssean forward guidance. Furthermore, Goy et al. (2022) show that Odyssean forward guidance has a beneficial effect on reducing social welfare loss. By implementing Odyssean guidance, the private sectors know in advance about central banks' future monetary policy rules, and central banks commit to the planned policy after certain periods. Therefore, it is necessary to take central banks' preferences into consideration when designing Odyssean forward guidance. The behavior of policymakers has been widely discussed in the literature, arguing that central banks have asymmetric preferences, the behavior of central banks is typically not stable over time and tends to behave

asymmetrically around inflation and output stabilization under different circumstances (Clarida et al., 2000; Cukierman & Muscatelli, 2008; Dolado et al., 2004; Koijen et al., 2008; Lubik & Schorfheide, 2004; Sims & Zha, 2006). Lo and Piger (2005) find that monetary policy reacted significantly to negative variations in output in the US, similar results have been found for the Euro Area by Peersman and Smets (2001) and for the UK by Nelson (2001).

The investigation of forward guidance in this paper is built on the standard New Keynesian model, starting from a homogeneous rational expectation hypothesis (Galí, 2009; Woodford, 2003), and then extends to assuming that agents have heterogeneous expectations (Bartolomeo et al., 2016; Gasteriger, 2014; Massaro, 2013). This paper contributes to the existing literature in several ways. First, instead of using a predetermined policy target when issuing forward guidance, the main contribution of this paper is introducing time-varying Delphic forward guidance which depends on the economy endogenously. More precisely, in our model, the announced future policy targets would be temporary targets, which partially depend on agents' potential wealth forecasted by monetary authorities based on the superior information they have.

In addition to the inflation targeting policy, output targeting has also been discussed in the literature. Lima and Setterfield (2014) analyze the economic consequences under inflation and output targeting, and Leshoro and Kollamparambil (2016) argue that the central bank should target aggregate growth rather than inflation. Therefore, in addition to communicating with a future inflation target, the second contribution is to take the output targeting into consideration when making a forward guidance announcement. Similar to forward guidance on a potential inflation target, the planned output target endogenously depends on public wealth and changes over time.

We find that the performance of Delphic forward guidance varies depending on the duration of the forward horizon and agents' expectation. Under the rational expectation hypothesis, forward guidance could achieve lower welfare losses when a central bank applies a short forward duration, regardless of which policy target is used in the announcement. However, the performance becomes complex after considering the boundedly agents. On the one hand, when a central bank issues a future inflation target, the probability that forward guidance outperforms a conventional policy increases when the number of rational agents rises or when the policy is associated with a short horizon. On the other hand, forward guidance on a potential path of future output targets has a beneficial influence on the economy only under a rational expectation environment and when a short forward horizon is applied.

Then, we examine whether an interim target would have a superior effect. We find that in most cases, having a temporary inflation targeting does have a significant effect on stimulating the economy; however, the economy suffers more losses when a central bank issues a time-varying output target. The result is consistent with the empirical finding that the central bank cares more about output than inflation during recession (Foerster, 2016).

Goy et al. (2022) investigate Odyssean forward guidance by announcing that the nominal interest rate will be set to zero after the forward horizon. However, central banks' asymmetric preference towards stabilizing aggregate demand and controlling

inflation have not been taken into consideration. The third contribution is that we extend the analysis by applying different interest-rate rules that have various weights attached to inflation and the output gap in different periods. In particular, by announcing Odyssean forward guidance, a central bank commits to follow an interest-rate rule that has higher strength on output stabilization. We find that a commitment to a future interest-rate rule does improve monetary policy transmission, and welfare losses decrease significantly compared to the policy without forward guidance. The results are robust as long as more than half of the agents are rational forecasters.

Next, we compare the outcomes under Delphic and Odyssean guidance, the performances vary and depend on the forward horizon and the number of rational agents. Finally, sensitivity analysis has been conducted to investigate the model performance, the results indicate that the evaluation of forward guidance is robust even if the setting of the structural parameters changes. The remainder of the paper is organized as follows. Section 2 presents a New Keynesian model with Delphic and Odyssean forward guidance introduced. Section 3 illustrates the implications and comparisons of forward guidance, and Section 4 presents our conclusions.

2. The model

Our model is developed on an extension of the standard DSGE model introduced by Galí (2009). In the model, only a proportion of households $(1-\theta_w)$ are able to reoptimize their nominal wages, and only a fraction of firms $(1-\theta_p)$ have the power to reset their prices; a central bank commits to follow an interest-rate rule. Different from the standard New Keynesian model, several extensions are applied in the current model: first, the private sectors are assumed to be heterogeneous forecasters: for simplicity, the heterogeneous expectation is introduced into the model by assuming that a share of agents are rational and the remaining agents are bounded forecasters[1]; second, monetary authorities are able to communicate with the public by issuing Delphic and Odyssean forward guidance; third, forward guidance is designed endogenously based on the economic situation[2].

2.1. The macroeconomic environment

We start from the standard New Keynesian model which consists of all rational agents, subject to sticky prices (Calvo, 1983) and wage stickiness. The IS curve is

$$y_t = E_t y_{t+1} - \sigma^{-1}(i_t - E_t \pi^P_{t+1}) + g^y_t \tag{1}$$

where σ is the inverse intertemporal elasticity of substitution, y_t is the output gap, which is the deviation between output and its natural level, π^P_t is the price inflation and i_t is the nominal interest rate which is set by the central bank. g^y_t stands for the demand shock, following an AR(1) process: $g^y_t = \rho_y g^y_{t-1} + \varepsilon_y$, with ε_y is the stochastic shock term. The Phillips curve is

$$\pi^P_t = \beta E_t \pi^P_{t+1} + \kappa_p y_t + \lambda_p w_t \tag{2}$$

where β is the household's preference discount factor, $\kappa_p = \frac{(1-\theta_p)(1-\beta\theta_p)}{\theta_p}\frac{1-\alpha}{1-\alpha+\alpha\varepsilon_p}\left(\sigma+\frac{\varphi+\alpha}{1-\alpha}\right)$. The wage inflation is given by:

$$\pi_t^w = \beta E_t \pi_{t+1}^w + \kappa_w y_t - \lambda_w w_t \tag{3}$$

where π_t^w are wage inflation, $\lambda_w = \frac{(1-\theta_w)(1-\beta\theta_w)}{\theta_w(1+\varepsilon_w)}$ $\kappa_w = \lambda_w\left(\sigma+\frac{\varphi}{1-\alpha}\right)$, the real wage gap is denoted by

$$w_t = w_{t-1} + \pi_t^w - \pi_t^p \tag{4}$$

where w_t is the real wage gap, which is the deviation between the real wage and the natural real wage.

2.2. Monetary policy

In this section, we focus on discussing the different types of monetary policy rules used in this paper. Starting from the original Taylor rule, we then introduce the endogenous Delphic and Odyssean forward guidance, finally, the modified interest-rate rules which incorporate central banks' communication will be discussed.

Initially, the central bank is assumed to follow a forward-looking Taylor-type rule:

$$i_t = \rho i_{t-1} + h(E_t \pi_{t+1}^P - \pi^{P*}) + b(E_t y_{t+1} - y^*) \tag{5}$$

where π^{P*} and y^* are the long-run equilibrium targets for inflation and output gap respectively, h and b are the weights assigned to inflation and the output gap which are chosen by central banks. In this standard interest-rate rule, the strength put on stabilizing inflation and minimizing the output gap are kept constant over time, which appears to be efficiency as long as there is no substantial shock (see e.g. Ball, 2012; Rudebusch & Svensson, 1999; Woodford, 2001).

However, it has been argued that the simple rule is not able to capture a central bank behavior when facing various shocks, and monetary policy transmission becomes less efficient especially when the nominal interest rate hits the zero lower bound. To improve monetary policy transmission, forward guidance becomes a useful tool for monetary authorities (Andrade & Ferroni, 2021; Bernanke, 2013; Woodford, 2005). Based on these observations, we make two main extensions to the standard policy rule by introducing central bank communication through forward guidance, in particular, Delphic guidance and Odyssean guidance.

2.2.1. Delphic forward guidance

By adopting Delphic forward guidance, central banks inform the public of their potential policy actions based on policymakers' superior information about the future macroeconomy (Andrade & Ferroni, 2019; Campbell et al., 2012; Fujiwara & Waki, 2022). Cole (2018) and Cole (2020) add forward guidance on the future inflation target, in their models, the future inflation target depends exogenously on the central bank, and the path is fixed once forward guidance is issued. In this paper, two extensions have been investigated: first, except for discussing the guidance on the future

inflation target, we also investigate the effect of forward guidance if central banks implement an output target; and second, instead of giving ad-hoc guidance based on central banks' behavior towards the future, we model that guidance could be determined based on the economy itself and, more importantly, changes dynamically with the economic situation.

Cole (2020) injects central bank communication into the model through the future inflation target, so private sectors will be informed in advance that the inflation target will be modified in the future based on the monetary authorities' decision, and the new target will remain for certain periods. However, Aksoy et al. (2006) and Bomfim and Rudebusch (2000) find that the economy could be more stimulated by implementing a short-term temporary inflation target than by using a deliberate inflation target, especially when facing substantial shocks. To incorporate these findings, we assume that the central bank gives guidance on the future short-run inflation target, which is endogenously determined by the model. As the future inflation target is assumed to be an interim target, forward guidance could be denoted by a series of inflation targets:

$$\pi_{T+i}^{FG_\pi} = \rho_\pi \pi_{T+i-1}^{P*} + \sum_{l=1}^{L} \nu_{T+i,\,T-l}^{FG_\pi}, i \in (0, k) \tag{6}$$

where $\pi_{T+i}^{FG_\pi}$ is a series of future inflation targets starting from period T, which is known to agents in period $T - l$. The forward guidance horizon is denoted as l, where $l \in (0, L)$; ρ_π stands for the rigidity degree of inflation targeting. $\sum_{l=1}^{L} \nu_{T+i,\,T-l}^{FG_\pi}$ represents forward guidance terms.

Areosa and Areosa (2016) point out that the responsiveness of consumption to the change of interest rate varies across agents with different wealth, which is consistent with the finding by Kaplan et al. (2018), further arguing that the transmission of policy rates partially depends on the change of private sector income. These findings indicate that households' wealth affects the aggregate demand, the responsiveness of price and output to a monetary shock varies with households' earnings, therefore, to improve the monetary policy transmission, central banks should pay more attention to households' wages. In addition, Olivei and Tenreyro (2010) find empirical evidence that the effect of monetary policy transmission is significantly related to the wage rigidity. The varying levels of additional wages lead to various behaviors in monetary policy transmission. Based on these contributions, therefore, we assume that central banks would take the wage gap into consideration when communicating to the public about future policy targets. Under this circumstance, instead of assuming the forward guidance shock is chosen arbitrarily by policymakers (Cole, 2018, 2020), we assume the forward guidance is affected endogenously by household wealth. More precisely, the forward guidance on future inflation targets depends partially on the real wage gaps:

$$\sum_{l=1}^{L} \nu_{T+i,\,T-l}^{FG_\pi} = \phi_\pi w_{T+i|T-l} \tag{7}$$

where $w_{T+i|T-l}$ is the expected real wage gap at period $T+i$, which is predicted by the central bank when issuing forward guidance at period T – l. Practically, monetary authorities announce a guidance on inflation at period T – l, based on the forecasted information about the future real wage gap after forward guidance horizon l. ϕ_π measures the influence of the expected real wage gap on the forward guidance on inflation, the more effect the households' wealth on inflation, the more consideration should be taken into the central banks' communication. Therefore, ϕ_π is assumed to take the value of the marginal contribution of real wage to inflation, that is $\phi_\pi = \frac{\partial \pi_{T+i|T-l}}{\partial w_{T+i|T-l}} = \lambda_p$.

Finally, the endogenous forward guidance on the future inflation targets $\pi^{FG_\pi}_{T+i}$ could be expressed as:

$$\begin{cases} \pi^{FG_\pi}_{T} = \rho_\pi \pi^{P*}_{T+i-1} + \lambda_p w_{T|T-l}, & i = 0 \\ \pi^{FG_\pi}_{T+1} = \rho_\pi \pi^{P*}_{T+i-1} + \lambda_p w_{T+1|T-l}, & i = 1 \\ \dots \\ \pi^{FG_\pi}_{T+k} = \rho_\pi \pi^{P*}_{T+i-1} + \lambda_p w_{T+k|T-l}, & i = k \end{cases} \tag{8}$$

$\pi^{FG_\pi}_{T+i}, i \in (o, k)$ represents that the future inflation target after l periods, more precisely, it is a time-varying interim target that depends on the marginal contribution of real wage gap. This is a key novelty of this paper. Prior research investigates ad-hoc forward guidance, and the target will remain constant in the future.

To communicate a future interim inflation target to the public, the central bank could incorporate the forward guidance to an interest-rate rule, therefore, the Taylor rule with Delphic guidance could be written as:

$$i^{FG_\pi}_{T+i} = \rho i_{T+i-1} + h(E_t \pi^{P}_{T+i+1} - \pi^{FG_\pi}_{T+i}) + b(E_t y_{T+i+1} - y^*), i \in (0, k) \tag{9}$$

where $i^{FG_\pi}_{T+i}$ is the future nominal interest rates at period $T+i$, if a central bank adopt a Delphic forward guidance on inflation.

In addition to investigating forward guidance on the future inflation target, we also discuss the effect if the policy target changes to aggregate growth. Similar to inflation targets, central banks issue forward guidance on the future potential output targets could be written as:

$$y^{FG_y}_{T+i} = \rho_y y^*_{T+i-1} + \sum_{l=1}^{L} \nu^{FG_y}_{T+i,\,T-l}, i \in (0, k) \tag{10}$$

where $y^{FG_y}_{T+i}$ is a series of interim future output targets starting at period T which is published by monetary authorities T – l periods ahead, ρ_y represents the persistency factor of the output target. Similar to the structure of forward guidance on inflation target, the forward guidance terms $\sum_{l=1}^{L} \nu^{FG_y}_{T+i,\,T-l}$ is determined by the effect of the predicted real wage to the output gap:

$$\sum_{l=1}^{L} \nu^{FG_y}_{T+i,\,T-l} = \phi_y w_{T+i|T-l} \tag{11}$$

where ϕ_y is the degree that measures the effect of households' income on the aggregate growth, taking the value of the marginal contribution of real wage to the output gap, $\phi_y = \frac{\partial y_{T+i|T-l}}{\partial w_{T+i|T-l}} = \sigma^{-1}\lambda_p$.

More precisely, forward guidance on the output, $y_{T+i}^{FG_y}$ is written as:

$$\begin{cases} y_T^{FG_y} = \rho_y y_{T+i-1}^* + \sigma^{-1}\lambda_p w_{T|T-l}, & i = 0 \\ y_{T+1}^{FG_y} = \rho_y y_{T+i-1}^* + \sigma^{-1}\lambda_p w_{T+1|T-l}, & i = 1 \\ \cdots \\ y_{T+k}^{FG_y} = \rho_y y_{T+i-1}^* + \sigma^{-1}\lambda_p w_{T+k|T-l}, & i = k \end{cases} \tag{12}$$

Intuitively, when monetary authorities issue forward guidance on the future output, a message has been sent to the public that the output target would become a time-varying interim target that is determined endogenously by the economy itself after l periods.

Finally, to introduce the Delphic guidance on output to a policy rule, the Taylor rule could be rewritten as:

$$i_{T+i}^{FG_y} = \rho i_{T+i-1} + h(E_t\pi_{T+i+1}^P - \pi^{P*}) + b(E_t y_{T+i+1} - y_{T+i}^{FG_y}), i \in (o, k) \tag{13}$$

where $i_{T+i}^{FG_y}$ is the future nominal interest rates at period $T+i$ if an output-targeting Delphic forward guidance is announced.

2.2.2. Odyssean forward guidance

Chakrabarty and Roy (2021) investigate a two-period monetary decision strategy: in the first period, the government reacts immediately when shocks occur and then responds again in the second period based on the observation of the effect on the policy implemented in the first period. A sequential step-by-step approach has been observed in monetary policy during the pandemic period in China (Funke & Tsang, 2020). However, discretionary policy might have a negative effect on the economy as responsiveness to monetary policy becomes inefficient due to lack of commitment. Under this circumstance, Odyssean guidance might be a useful tool.

Delphic guidance issues potential policy targets to the public but with no restrictions to force central banks to commit to a specific policy. Odyssean guidance requires the monetary authorities' commitment to a certain policy (Fujiwara & Waki, 2022; Goy et al., 2022; Hallett & Acocella, 2018). In this paper, Odyssean guidance is introduced on monetary policy: policymakers adjust the nominal interest rate immediately after the shock happens; and in the meantime, they communicate to private sectors about the subsequent interest-rate policy adjustment that will be applied after certain periods based on the prediction of the future.

When an exogenous shock hits the economy, monetary authorities would issue Odyssean forward guidance at period $t = T-l$, indicating that after l periods, the interest-rate policy would switch to a new rule:

$$i_{T+i}^{FG} = \rho i_{T+i-1} + h^{FG}(\pi_{T+i+1|T-l}^P - \pi^{P*}) + b^{FG}(y_{T+i+1|T-l} - y^*), i \in (0, k) \tag{14}$$

where i^{FG}_{T+i} represents a planned interest-rate rule that central banks will commit starting from period T, announcing by central banks l periods ahead. $\pi^{P}_{T+i-1|T-l}$ and $y_{T+i-1|T-l}$ are the future paths for inflation and the output gap respectively, predicted by central banks at $T - l$, h^{FG} and b^{FG} are the weights that central banks commit to assign to controlling inflation and stabilzing the output gap after forward horizon. Once the Odyssean guidance announced, private agents know that the type of policy that central banks intent to implement in the future, but the monetary policy will not change until period T.

2.3. Private sector expectation

In our model, we relax the assumption of rational expectations, assuming agents will be heterogeneous when forming expectations. Taking the idea of Gasteriger (2014), we assume that only some agents (α_{RE}) are rational forecasters, and the remaining agents (1-α_{RE}) are adaptive learning agents. The adaptive learners could be considered naive forecasters who believe the movements in the current period are exactly the same as those in the last period. Following Goy et al. (2022), we assume that the credit believers take the announced future policy targets as their expectations for macroeconomic variables during the duration of the forward horizon. Therefore, the aggregate expectation for inflation and the output gap during the forward horizon are:

$$\hat{E}_t\pi_{t+i+1} = \alpha_{RE}\pi^{FG_\pi}_{T+i} + (1-\alpha_{RE})\pi_{T+i-1} \tag{15}$$

$$\hat{E}_t y_{t+i+1} = \alpha_{RE} y^{FG_y}_{T+i} + (1-\alpha_{RE}) y_{T+i-1} \tag{16}$$

where $t \in (T-l, T)$. Once the new policy is applied, rational agents believe central banks are able to recover the economy back to equilibrium after applying the new rule; therefore, rational forecasters would take the long-run equilibrium value of these targets when forming the expectation:

$$\hat{E}_t\pi_{t+i+1} = \alpha_{RE}\pi^{P*} + (1-\alpha_{RE})\pi_{T+i-1} \tag{17}$$

$$\hat{E}_t y_{t+i+1} = \alpha_{RE} y^{*} + (1-\alpha_{RE}) y_{T+i-1} \tag{18}$$

where $t \in (T, T+k)$.

In this paper, the simulated economy would go through several periods. At the beginning ($t = 0$), the economy remains in equilibrium, and all macroeconomic variables are near their corresponding targets. During this stage, the central bank will not need to take any particular action but stick to a conventional policy. Then the economy experiences a negative shock, and the central bank adopts forward guidance in order to improve the policy transmission effect. To be precise, monetary authorities announce their potential policy to the public at period $t = T\text{-}l$, stating that the new policy will be applied after certain periods (denoted by l, $l \in (0, L)$). Finally, at period

Table 1. Benchmark calibration.

Parameters	Value	Description	Motivation
β	0.99	Discount factor	Assumption
σ	2.609	Risk aversion	Le et al. (2021)
φ	2.191	Inverse Frisch elasticity	Le et al. (2021)
α	0.65	Elasticity of labour	Le et al. (2021)
ε_p	2.5428	Elasticity of substitution	Le et al. (2021)
θ_p	0.7497	Price stickiness	Le et al. (2021)
θ_w	0.6178	Wage stickiness	Le et al. (2021)
ρ_π	0.7	Inflation target smoothing	Assumption
ρ_y	0.7	Output gap target smoothing	Assumption
ρ	0.9621	Interest rate smoothing	Le et al. (2021)
h	1.5	Inflation coefficient in the Taylor rule	Assumption
b	0.5	Output gap coefficient in the Taylor rule	Assumption
α_{RE}	1	Share of rational agents	Assumption

Source: Authors.

T, the new monetary policy is issued and will last for $T+k$ ($k \in (0, \infty)$) periods until new monetary responses are announced.

3. Dynamics under Delphic and Odyssean forward guidance

In the paper, we will investigate the responsiveness of Delphic and Odyssean forward guidance under different macroeconomic conditions. In the benchmark, we take Chinese data as an example to set the structural parameters, which are calibrated by the estimates obtained by Le et al. (2021), shown in Table 1. The elasticity of labor α and the elasticity of differential goods ε_p are 0.65 and 2.5428 respectively. The risk aversion σ is set to 2.609, and the inverse Frisch elasticity φ value is 2.191. The price and wage rigidities (θ_p and θ_w) are assumed to be 0.7497 and 0.6178, respectively. In addition, we assume that the elasticity of substitution among labor varieties ε_w equals 0.5. The interest-rate smoothing is 0.9621, which is consistent with the prudent monetary policy target in China, and the discount factor β is 0.99.

The parameters in the monetary policy take the values of $h = 1.5$ and $b = 0.5$ for simplicity. The forward guidance horizon is chosen to be 2 in the benchmark, indicating that a new policy will be applied after 6 months. The policy smoothing parameter, ρ_π and ρ_y is assumed to be 0.7. In addition, we assume that all agents are rational forecasters in the benchmark. Although these values are selected arbitrarily, robustness tests of the results will be investigated in later sections.

3.1. Delphic forward guidance investigation

We start to investigate the dynamic effects under the rational expectation hypothesis. In the benchmark, agents would take the central bank's guidance on inflation and output to form their expectations during the forward guidance horizon; after that, their expectations would switch to the long-run equilibrium level as rational agents believe that the central bank has the ability to recover the economy. Figure 1 shows that the economy is at equilibrium initially, and then variables start to deviate after experiencing a negative demand shock. The blue solid line indicates the economic responses when the central bank applies a normal monetary rule with no guidance.

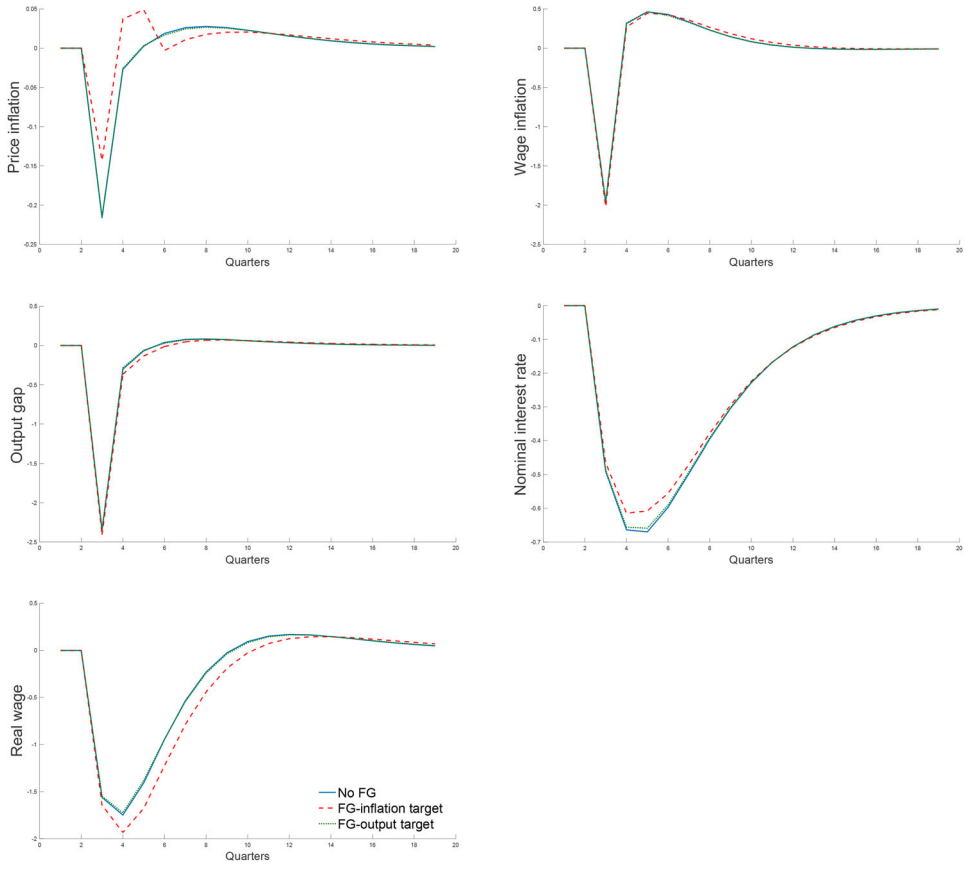


Figure 1. Dynamics under Delphic forward guidance.
Notes: The impulse responses are plot under the normal interest-rate policy without forward guidance (blue solid line), an inflation-targeting forward guidance (red dashed line) and an output-targeting forward guidance (green dashed line).
Source: Authors.

The red dashed line and the green dashed line show the dynamics under inflation-targeting and output-targeting forward guidance respectively. The results show similar trends when no forward guidance is applied or using output-targeting forward guidance. This might be explained by the fact that the marginal contribution of real wages to the output gap is limited when all agents are rational. However, the economy could achieve moderate deviations if a central bank announces forward guidance on inflation.

The responsiveness to an exogenous shock shown in Figure 1 is based on an assumption that the central bank announces that the forward guidance duration equals 2 quarters. Figure 2 examines the effect of different forward guidance horizons and illustrates the standard deviations of key variables. The blue solid line shows the standard deviations obtained by a monetary policy without forward guidance. The deviations decrease when the central bank extends the forward horizon, and moreover, when the forward horizon is exceptionally high, the deviations approach the results obtained by a policy without any guidance intervention. This might indicate

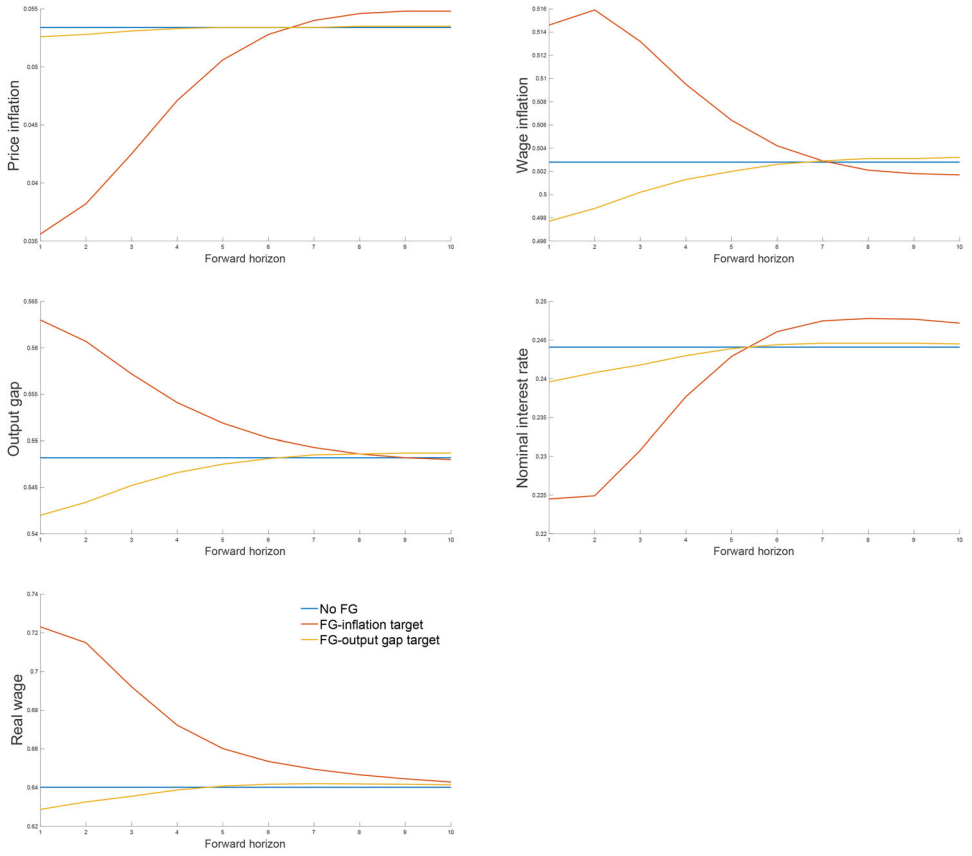


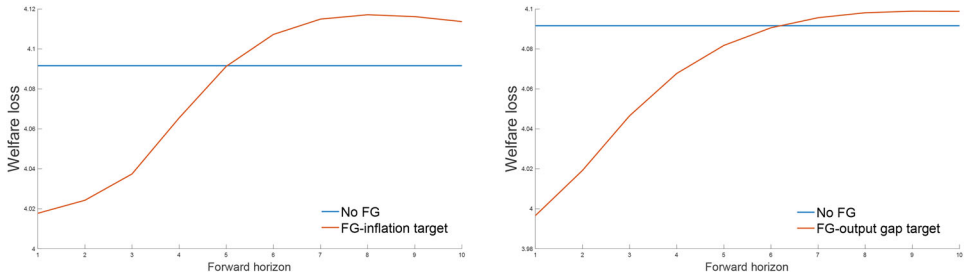
Figure 2. The standard deviations under Delphic forward guidance.
Notes: The standard deviations of different variables are plot under the normal interest-rate policy without forward guidance (blue solid line), an inflation-targeting forward guidance (red dashed line) and an output-targeting forward guidance (yellow dashed line).
Source: Authors.

that the effect of forward guidance marginally diminishes with increasing forward duration, which might suggest that central banks should take the duration of the forward horizon into consideration when engaging in communication with the public. In addition, variables experience larger standard deviations when the central bank issues forward guidance on the inflation target, compared to the results obtained by an output-targeting forward guidance.

After analyzing the standard deviations of key variables, we are interested in the effect of social welfare losses if monetary authorities announce forward guidance. Before we conduct further investigation, the welfare loss function is introduced in line with Galí (2009):

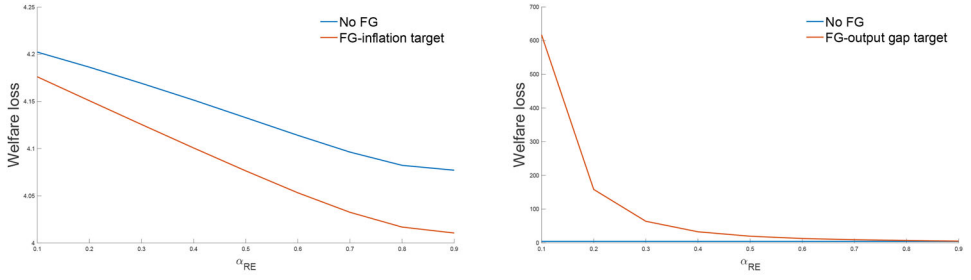
$$L(y_t, \pi_t^p, \pi_t^w) = \left(\sigma + \frac{\varphi}{1-\alpha}\right) var(y_t) + \frac{\varepsilon_p}{\lambda_p} var(\pi_t^p) + \frac{\varepsilon_w(1-\alpha)}{\lambda_w} var(\pi_t^w) \tag{19}$$

Figure 3 compares the welfare loss with or without forward guidance. Regardless of the types of policy targets, the social welfare loss increases when the duration of



(A) Inflation targeting (B) Output targeting

Figure 3. The welfare losses under Delphic forward guidance.
Notes: Panel A compares the welfare losses obtained by using an inflation-targeting forward guidance and the normal policy without forward guidance; the welfare comparison under an output-targeting forward guidance are shown in Panel B.
Source: Authors.



(A) Inflation targeting (B) Output targeting

Figure 4. The welfare losses under Delphic forward guidance with heterogeneous agents.
Notes: Panel A compares the welfare losses obtained by using an inflation-targeting forward guidance and the normal policy without forward guidance; the welfare comparison under an output-targeting forward guidance is shown in Panel B.
Source: Authors.

forward guidance increases; however, the marginal effect diminishes with a longer horizon. In particular, when a central bank announces a shorter forward horizon, the welfare loss is significantly lower than the normal policy, indicating that the central bank could enjoy the benefit of applying forward guidance. However, forward guidance fails to achieve lower welfare losses when the forward duration is longer than approximately 5 or 6 quarters; under these circumstances, applying a monetary policy without forward guidance outperforms a policy that communicates about central banks' future actions. This effect is more significant when the central bank uses an inflation target. The results provide further evidence that the forward horizon should be a key controlling factor when announcing forward guidance.

Instead of assuming homogeneous rational expectation, we now allow agents to be heterogeneous when forming the expectation. Figure 4 examines welfare performance under various proportions of rational agents. The results show that the adaptive learning expectation has a negative impact on social welfare: the more bounded agents the economy has, the higher welfare losses experience, and moreover, the effect is much more significant when the central bank adopts the output as the policy target.

Table 2. Effectiveness of monetary policy

Panel A: Inflation targeting

α_{RE} \ L	1	2	3	4	5	6	7	8	9	10
0.1	FG	FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG
0.2	FG	FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG
0.3	FG	FG	FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG
0.4	FG	FG	FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG
0.5	FG	FG	FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG
0.6	FG	FG	FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG
0.7	FG	FG	FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG
0.8	FG	FG	FG	FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG
0.9	FG	FG	FG	FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG
1	FG	FG	FG	FG	FG	No-FG	No-FG	No-FG	No-FG	No-FG

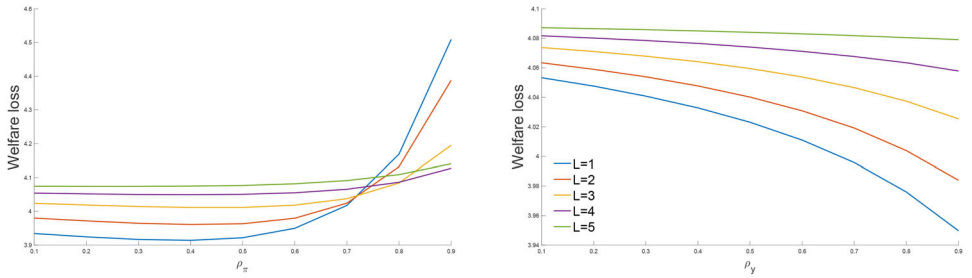
Panel B: Output targeting

α_{RE} \ L	1	2	3	4	5	6	7	8	9	10
0.1	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG
0.2	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG
0.3	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG
0.4	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG
0.5	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG
0.6	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG
0.7	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG
0.8	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG
0.9	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG
1	FG	FG	FG	FG	FG	FG	No-FG	No-FG	No-FG	No-FG

Notes: FG and No-FG represent a policy rule associated with Delphic forward guidance and a conventional monetary policy. Panel A shows the best rule when using an inflation target, while Panel B demonstrates the best rule obtained if a central bank uses an output target.
Source: Authors.

Panel A in Figure 4 illustrates the welfare performance when the central bank issues forward guidance on inflation, which always outperforms the standard monetary policy. In particular, the effect of forward guidance is enhanced when most of the private sector is rational. However, when the central bank chooses output-targeting forward guidance, it is always dominated by a monetary policy without any intervention, especially if there are fewer rational agents (shown in Panel B). This might indicate that having forward guidance on a temporary output target fails to achieve favorable outcomes when agents have heterogeneous expectations.

Table 2 shows the monetary policy associated with the lowest welfare losse under different circumstances. FG and No-FG represent a monetary policy with or without forward guidance respectively. Panel A shows the best policy obtained when using inflation as the policy target. The results indicate that the effectiveness of monetary policy depends on both the share of rational agents and the duration of the forward horizon. If central banks choose a shorter forward horizon (e.g. less than 6 months), then forward guidance on inflation could achieve a better outcome regardless of the share of rational agents. Although the outperformance of forward guidance is diminishing as the forward duration increases, the policy with forward guidance still dominates the normal monetary policy when the economy contains a large proportion of rational agents. However, an opposite outcome has been found when a longer forward duration is selected (eg. longer than a year): a conventional monetary policy outperforms instead. These results provide further evidence that the forward horizon is a key factor that influences the efficiency of forward guidance, and a shorter



(A) Inflation targeting (B) Output targeting

Figure 5. The welfare losses under Delphic forward guidance with various targeting smoothing parameters.

Notes: Panel A compares the welfare losses obtained by using an inflation-targeting forward guidance with different forward durations; the welfare comparison under an output-targeting forward guidance is shown in Panel B. The blue, red, yellow, purple and green line represent the welfare losses under a forward guidance with duration equals to one, two, three, four and five quarters.

Source: Authors.

forward horizon might be a proper duration to improve monetary policy transmission, especially when most agents tend to form their expectations based on the adaptive learning process.

In addition, the policy performance under output targeting is illustrated in Panel B. It is surprised to find that forward guidance with an output target only outperforms the normal policy when the policy has a shorter forward horizon and all agents should be rational. The results might indicate that having an interim output target is not able to stimulate the economy in most cases; in other words, the monetary authorities should pay more attention to stabilizing output when facing exogenous shocks.

After investigating the effectiveness of forward guidance, it seems that the economy could benefit more from a temporary inflation target rather than an output target in most cases. To further examine how the policy target persistency affects the outcome of forward guidance, we calculate the welfare losses under inflation and output targets. Figure 5 examines the performance of forward guidance obtained by varying the policy target smoothing parameters[3]. Based on our analysis, guidance only works well when assigning shorter forward horizons; therefore, we show the results that is obtained by using forward guidance with shorter horizons. Several results have been found. First, the performance of forward guidance depends significantly on the target smoothing parameters, and in particular, when the duration of the forward horizon is decreasing, the effect of forward guidance is more sensitive to the targeting smoothing factor. Second, the influence on welfare losses is different between inflation targeting and output targeting: when a central bank communicates future inflation with the public, welfare loss increases when the smoothing parameter increases; however, the opposite effect has been found when the output target is used as a communication tool—welfare loss drops when monetary authorities adopt a more persistent output target.

Therefore, a lower welfare loss could be found when there is a less smoothing inflation target or a more persistent output target applied. Based on these findings, the economy could be better off when the inflation target temporarily deviates from its long-run equilibrium level, or the output gap target remains relatively stable. This result is

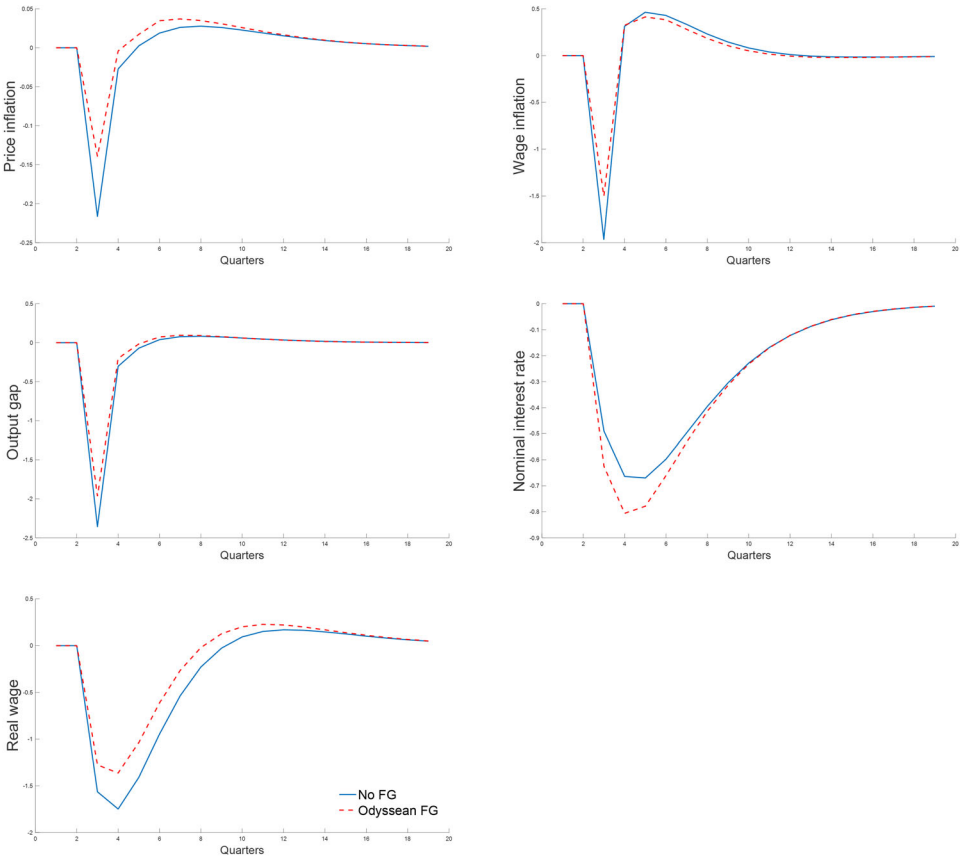


Figure 6. Dynamics under Odyssean forward guidance.
Notes: The impulse responses are plot under the assumption of homogeneous rational expectations and the forward guidance duration is assumed equals to 2. The blue solid line shows the normal interest-rate policy without forward guidance, and the red dashed line shows the Odyssean forward guidance.
Source: Authors.

consistent with the empirical findings such as the central bank would be more tolerant of inflation than that in normal times during recession (Foerster, 2016), or an interim inflation target would be a suitable way to reduce inflation and eventually achieve the ultimate inflation target (Aksoy et al., 2006; Helle & Walter, 2010).

3.2. Odyssean forward guidance investigation

In this section, we will discuss the effect of a commitment to a specific policy rule. Odyssean forward guidance is shown in Equation (14). In the previous section, we find that the economy could achieve a lower welfare loss when monetary authorities allow an interim inflation target and keep a relatively stable output target. Based on this finding, we assume that the central bank issues Odyssean forward guidance on a future interest-rate rule with more attention focused on stabilizing the output and less attention on controlling inflation. In particular, the values of h^{FG} and b^{FG} are set to 2.25 and 1, respectively, which double the value of the weight attached to the

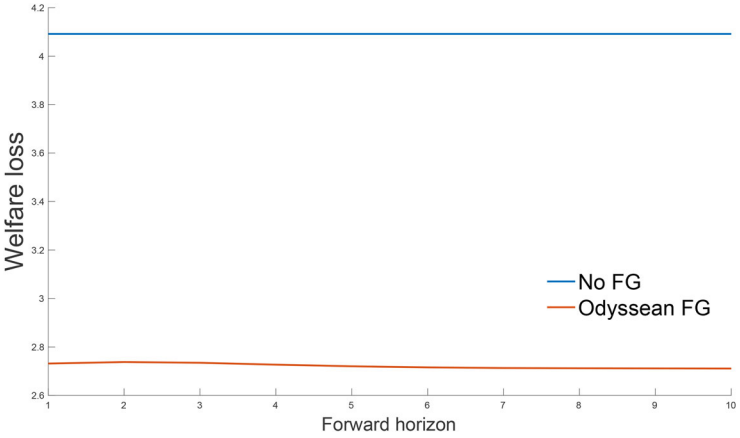


Figure 7. Welfare losses under Odyssean guidance.
Source: Authors.

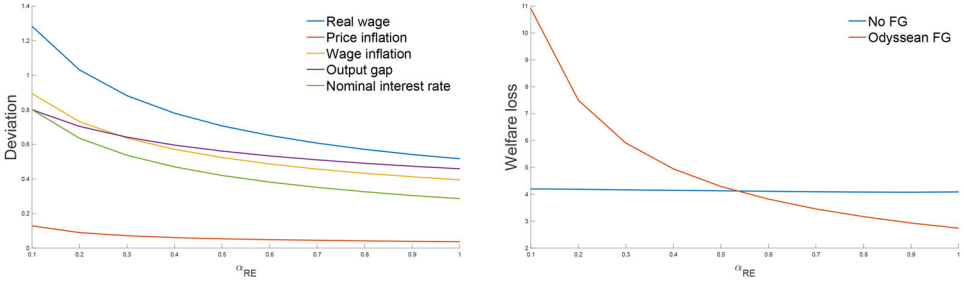


Figure 8. The standard deviations and welfare losses under Odyssean guidance with heterogeneous agents.
Notes: Panel A shows the standard deviations of different variables under the condition that a central bank commits to follow a future interest-rate rule, while Panel B compares welfare losses if Odyssean guidance is issued or a conventional policy applied. The forward horizon considered here is 2 quarters, following the assumption used in the benchmark calibration.
Source: Authors.

output gap while increasing the weight attached to inflation by 50%, compared to the values taken in the conventional rule.

Under the rational agents assumption, Figure 6 compares the impulse responses to a negative demand shock under a conventional interest-rate rule and a rule with guidance on a future interest-rate policy. Intuitively, when a potential monetary policy is communicated to private sectors, agents know the monetary authorities would commit to a policy with more weights on stabilizing output after 6 months, and almost all variables deviate less compared to the normal monetary policy, except for the nominal interest rate.

Next, we will perform robustness tests on some key variables. First, we examine the effect of communication of future monetary policy with different forward horizons. Figure 7 indicates that the welfare performance of a commitment to a future monetary policy significantly outperforms a conventional policy, no matter the length of forward guidance is chosen. This might suggest that the economy would always be

Table 3. Effectiveness of monetary policy.

α_{RE} \ L	1	2	3	4	5	6	7	8	9	10
0.1	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG
0.2	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG
0.3	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG
0.4	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG
0.5	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG
0.6	FG	FG	FG	FG	FG	FG	FG	FG	FG	FG
0.7	FG	FG	FG	FG	FG	FG	FG	FG	FG	FG
0.8	FG	FG	FG	FG	FG	FG	FG	FG	FG	FG
0.9	FG	FG	FG	FG	FG	FG	FG	FG	FG	FG
1	FG	FG	FG	FG	FG	FG	FG	FG	FG	FG

Notes: FG and No-FG represent a policy rule associated with Odyssean forward guidance and a conventional monetary policy.
Source: Authors.

better off when a central bank issues Odyssean guidance, as long as the agents are rational forecasters.

As the duration of the forward horizon has no effect on the performance of monetary policy under the assumption of rational agents, we next examine how the bounded agents affect the outcome of the monetary policy by relaxing the homogeneous expectation assumption. The left panel in Figure 8 illustrates the standard deviations of different variables obtained by forward guidance, which decrease with the increasing share of rational agents. A similar trend has been found in welfare loss, which decreases when the number of rational agents increases. More importantly, compared to the conventional monetary policy rule, issuing a planned future interest-rate rule outperforms under the condition that the proportion of rational agents is higher. When an economy consists of fewer rational agents, the normal monetary policy dominates (shown in the right panel of Figure 8). Under this circumstance, the agents' expectation would have a significant influence on outcomes of Odyssean guidance.

Finally, we compare the welfare losses obtained using a monetary policy with or without further communication of a future interest-rate rule. Table 3 shows the best rule which is associated with the lowest welfare loss. The results provide further evidence that the forward duration has no influence on the performance of monetary policy. Instead, the efficiency of monetary policy depends on the share of rational agents: a conventional monetary policy achieves the best welfare performance if more agents adopt an adaptive learning process when forming their expectations, while announcing a planned future interest-rate rule outperforms when the number of rational agents increases. This might indicate that to improve monetary policy transmission, forward guidance on a future interest-rate rule is preferred when most of agents are rational; otherwise, monetary authorities should adhere to the normal monetary policy when there are fewer rational agents.

3.3. Robustness tests

The above analysis uses different situations to show whether forward guidance could achieve a better welfare performance, however, the results are based on an assumption that the structural parameters are fixed as shown in Table 1. To examine the

Table 4. Calibrations for four different economies.

	σ	φ	θ_p	θ_w	ρ	L	*Sources*
The United States	3.08	0.24	0.69	0.97	0.71	9	Iwasaki et al. (2021)
The Euro Area	1.42	1.91	0.864	0.747	0.85	3	Hohberger et al. (2019)
China	2.609	2.191	0.7497	0.6178	0.9621	1	Le et al. (2021)
Japan	1.404	4.689	0.809	0.693	0.854	1	Iiboshi et al. (2015)

Source: Authors.

Table 5. Robustness tests on the effectiveness of monetary policy.

Panel A: Delphic-Inflation targeting

Economy \ α_{RE}	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
The United States	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG
	–	–	–	–	–	–	–	–	–	–
The Euro Area	FG	FG	FG	FG	FG	FG	FG	FG	FG	FG
	No-FG	No-FG	–	–	–	–	–	–	–	–
China	FG	FG	FG	FG	FG	FG	FG	FG	FG	FG
	–	–	–	–	–	–	–	–	–	–
Japan	FG	FG	FG	FG	FG	FG	FG	FG	FG	FG
	–	–	–	–	–	–	–	–	–	–

Panel B: Delphic-Output targeting

Economy \ α_{RE}	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
The United States	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG
	–	–	–	–	–	–	–	–	–	–
The Euro Area	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG
	–	–	–	–	–	–	–	–	–	–
China	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG
	–	–	–	–	–	–	–	–	–	–
Japan	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG	No-FG
	–	–	–	–	–	–	–	–	–	–

Panel C: Odyssean

Economy \ α_{RE}	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
The United States	No-FG	No-FG	No-FG	No-FG	FG	FG	FG	FG	FG	FG
	–	–	–	–	No-FG	–	–	–	–	–
The Euro Area	No-FG	No-FG	No-FG	No-FG	FG	FG	FG	FG	FG	FG
	–	–	–	–	No-FG	–	–	–	–	–
China	No-FG	No-FG	No-FG	No-FG	No-FG	FG	FG	FG	FG	FG
	–	–	–	–	–	–	–	–	–	–
Japan	No-FG	No-FG	No-FG	No-FG	FG	FG	FG	FG	FG	FG
	–	–	–	–	No-FG	–	–	–	–	–

Notes:

1. FG and No-FG represent a policy rule associated with Delphic forward guidance and a conventional monetary policy. Panel A, B, C show the best rule obtained under Delphic guidance using an inflation target, Delphic guidance using an output target, and Odyssean forward guidance respectively.
2. - indicates that the best rule obtained for a specific economy is consistent to the rule suggested by a model in which the structural parameters are taken the values calibrated in the benchmark.

Source: Authors.

robustness of these conclusions, we investigate four different economies (the United States, the Euro Area, China and Japan) to cover various economic conditions. In order to exploit the effect of different structural parameters in the model, the selected economies are associated with various values of risk aversion, inverse Frisch elasticity, price and wage stickiness and policy smoothing parameters. In addition, these four economies also experience various forward horizons[4]. The calibrations for the four economies are similar to the estimation in literature, shown in Table 4.

Table 5 illustrates the best rule obtained for each economy when the economies are associated with different shares of rational agents. In the table, each economy has

two lines of results, the above line shows the best rule obtained by using the value of macroeconomic parameters for individual economies, while the bottom line indicates whether these results are consistent with the best rules suggested by a model where the setting of structural parameters is the same as the benchmark calibration. To be specific, if the results are not consistent, the second line shows the best rule obtained by the model in which only the forward horizon and the share of rational agents take the calibration for the individual economy, and the remaining structural parameters are taken the value shown in the benchmark; otherwise, a consistent result is shown by a '-', meaning that the model gives a robust result even if the value of structural parameters changes.

As shown in Table 5, consistency is found in almost all the scenarios, with only a few exceptions that the opposite results are obtained: (1) when some central banks adopt Odyssean forward guidance and in the meantime, the economies have half of the private sectors are rational forecasters, (2) or when the Euro Area experiences a large number of bounded agents, Delphic guidance on inflation becomes the best rule. The robustness tests suggest that our conclusion is not always valid, indicating that the performance of forward guidance may vary when the share of rational agents takes some extreme values. However, given the broad setting of structural parameters we have chosen and the inconsistency only happens in rare cases, we might conclude that although the model is not fully independent of the setting of the structural parameters, the effect is limited on the evaluation of forward guidance performance, the model could give a robust result regarding the forward guidance evaluation.

After analyzing the performance of Delphic and Odyssean forward guidance, this paper provides some suggestions for monetary authorities. First, if the forward horizon is ambiguous, choosing to announce a commitment to a specific future policy rule might be a proper way to achieve higher welfare when the economy consists of a higher proportion of rational agents; otherwise, a conventional policy is preferred if fewer agents are rational. Second, if the central bank is confident about the duration of forward guidance, monetary authorities could rely on Delphic guidance as limited attention is needed regarding the agents' expectations. Guidance on future policy targets outperforms when the horizon is shorter, while conventional monetary policy is preferred when there is a longer forward horizon. In addition, the results also indicate that the economy could benefit from a time-varying inflation target or a relatively stable output target when facing an exogenous shock. Therefore, having an interim inflation target could be a useful tool for improving social welfare during recessions.

4. Conclusion

Forward guidance has been widely used as an unconventional tool for improving the monetary policy transmission. The central bank could either publish a future policy target (Delphic guidance) or commit to follow a specific policy rule (Odyssean guidance). In this paper, we investigate forward guidance in a more elaborate way and then compare the performance of Delphic and Odyssean forward guidance under different economic environments.

We develop an approach to endogenous Delphic forward guidance—the future policy targets are assumed to be time-varying and depend on the households' wealth. By examining the inflation target and the output target, we find that the inflation-targeting forward guidance outperforms if central banks announce a shorter duration of forward horizon, however, it fails to achieve a beneficial effect if a relatively long duration is applied, especially when agents have heterogeneous expectations. On the other hand, the output-targeting forward guidance could stimulate the economy only with a shorter horizon and all agents have to be rational. In addition, we find that the economy could benefit more from having an interim inflation target, or a stable output target.

This paper also investigates Odyssean forward guidance, which incorporates the central bank's preference towards the future economy. We assume that monetary authorities commit to follow a future interest-rate rule that has more strength on stabilizing output and allows inflation to temporarily deviate from the target. The results show that the effectiveness of Odyssean guidance depends mainly on the agents' expectations—a beneficial effect could be observed when the majority of agents are rational forecasters. Furthermore, sensitivity analysis has been conducted, the results show that the setting of structural parameters has limited influence on the model, there is a high probability that the model could be relied on to give policy suggestions. Finally, we understand that all the analyses we performed in this paper are based on a New Keynesian model, and the policy design is far more complex than the simple model we considered in this paper. However, our results attempt to suggest some ideas that policymakers might be aware of when using forward guidance.

Notes

1. Details about the heterogeneous expectation will be discussed in Section 2.3.
2. Delphic and Odyssean guidance will be introduced and discussed in Section 2.2.
3. As forward guidance with output target only works with rational agents, Figure 5 only shows the results under the rational expectation hypothesis.
4. The forward horizons are taken the values studied by Ehrmann et al. (2019).

Disclosure statement

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