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Tools for endogenous monetary policy analysis: optimal projections and instrument rules

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Andrea Alati, Martín Arazi, John Barrdear, Andrew Gimber, Alex Haberis, Elspeth Hughes, Lien Laureys, Simon Lloyd, Ozgen Ozturk, Jack Page, Kate Reinold, Eric Tong, Matthew Tong and Matt Waldron

A series designed to document models, analysis and conceptual frameworks for monetary policy preparation – they are written by Bank staff to encourage feedback and foster continued model development.

Macro Technical Paper Series

Dr Bernanke's 2024 **review** of the monetary policymaking processes at the Bank of England provided a number of constructive recommendations for reform which we are taking forward.

This included improving our model maintenance and development. Macroeconomic models and frameworks play an important role in the monetary policy process. To maximise the value of macroeconomic models, they must be well documented and continuously improved as time goes on.

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Importantly, while each MTP will provide insights about a particular model or modelling framework that is an 'input' to policy, no single model can possibly capture all the relevant features to perform even just one of those roles adequately. Models will inevitably have to be updated and will improve over time, including as they are adapted to different constellations of macroeconomic conditions. This is a natural part of real-time monetary policy making. So, inevitably, no MTP will provide definitive answers.

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Clare Lombardelli
Deputy Governor for Monetary Policy

Bank of England

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Abstract

Optimal policy projections (OPPs) and simple instrument rules can be used to compare macroeconomic projections under different assumptions about monetary policy. This paper explains how both are used as inputs to the monetary policy process at the Bank of England. The underlying algorithms for endogenous policy analysis are flexible and can be applied to a range of macroeconomic models. Using a medium-scale DSGE model for the UK economy, we first explain the intuition underpinning the macroeconomic outcomes that OPPs and simple rules deliver. We then highlight the uses, as well as some challenges, of endogenous policy analysis in practice.

Key words: Endogenous policy, optimal policy, simple rules.

JEL classification: E43, E52, E58, E61.

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1 Introduction

Monetary policy makers consider a range of different approaches and analysis when formulating policy (Haberis et al., 2025). Many approaches rely on a forward projection for economic outcomes, such as inflation and economic activity. Given that those outcomes depend on monetary policy, such forward projections—be it a 'central' projection or a scenario (Bank of England, 2025d)—must make an assumption about the path for policy. One option is to assume the path is exogenous. For example, in its first few *Inflation Reports*, the Monetary Policy Committee's (MPC) published inflation forecasts assumed that Bank Rate would remain constant throughout the forecast period. Since May 1998, the MPC has also published forecasts conditioned on an estimate of market-implied expectations for Bank Rate. Another is to construct *endogenous* policy paths, which account for systematic feedback between monetary policy and economic outcomes (in both directions). As is common at many other central banks, policymakers at the Bank of England are regularly shown a range of such endogenous paths to inform their deliberations (see, e.g., Yellen, 2012; Saunders, 2016; Tenreyro, 2018; Haskel, 2019; Broadbent, 2022; Lombardelli, 2025; Mann, 2025).[1]

In this *Macro Technical Paper*, we describe how staff construct endogenous policy simulations at the Bank of England. The methods we describe can be applied to a broad class of models. Starting from a given forward projection, they can be used to study a range of policy instruments in addition to Bank Rate (including, but not limited to, quantitative easing and tightening). We also explain how such simulations are used in practice.

An assumption about a central bank's approach for setting monetary policy is central to computing endogenous policy paths and their corresponding economic outcomes. In constructing endogenous policy simulations, Bank staff typically use two tools: 'Optimal Policy Projections' (OPPs) and 'simple instrument rules', as popularised by Taylor (1993). While valuable inputs to policymaking, neither captures all aspects of a policy strategy in practice. So no single method is preferred.

OPPs are a useful benchmark. The OPPs described in this paper provide an answer to the question: *for given objectives of a policymaker, a given forward projection and a given model for the monetary policy transmission mechanism, what are the best macroeconomic outcomes that can be achieved, and what policy rate path would achieve them?* Through the lens of the OPPs, the (so-called) 'optimal' policy minimises 'losses' that can capture the remits of central banks, as well as other policymaker preferences. Here, we focus on losses that reflect deviations of inflation from target and output from potential—and therefore potential trade-offs between the two—

[1] For more technical detail on different central-bank approaches to endogenous policy analysis, see, for example, Svensson and Tetlow (2005) and Hebden and Winkler (2021) from the Federal Reserve, Adolfson et al. (2011) from the Riksbank, de Groot et al. (2021) from the European Central Bank, and Dengler et al. (2024) from the Bundesbank. Many of these approaches share common features, though a full comparison of alternative technical approaches is beyond the scope of this paper.

as well as a desire to avoid large changes in interest rates. However, interpreting the drivers of the policy rate path implied by the OPPs can be challenging, because that path depends on the evolution of the 'state vector' that determines the projected path of the model economy in a potentially complicated way.

Simple instrument rules, and their corresponding endogenous macroeconomic outcomes, can complement OPPs. These rules transparently capture how policy instruments relate to macroeconomic variables, and can be easily adapted to assess sensitivities to alternative parametrisations. Moreover, simple rules can capture certain desirable elements of a monetary strategy. That includes the principle that monetary policy should be systematic, reacting in predictable ways to economic conditions, and countercyclical, 'leaning against' macroeconomic fluctuations; features that are also present in OPPs. However, simple rules are usually agnostic about the specific shocks affecting the economy and therefore might not always capture policymakers' preferred responses to the outlook.

Endogenous policy simulations never provide a complete guide for policy. Both OPPs and simple rules capture real-world systematic monetary policy behaviour in a stylised and simplified manner. So they are unlikely to accurately reflect the MPC's collective, or individual Committee members', reaction function. In addition, as we detail in this paper, endogenous policy simulations rely on various assumptions. For example, they are derived from an initial projection constructed using an exogenous policy path, and hence—without a corresponding assessment of the balance of risks—abstract from uncertainty about possible paths for macroeconomic variables. As a consequence, endogenous policy simulations will only be as 'good' as the projections they are based on. They also require an assumption about how policy affects economic outcomes (i.e., the monetary transmission mechanism), which is highly uncertain—in part due to time- and state-dependency (see, e.g., Burr and Willems, 2024).

Uses in practice. Nevertheless, presenting a range of endogenous paths—sometimes for a range of different outlooks—can be useful for policymakers. Each quarter, Bank staff present the MPC with endogenous policy paths associated with the relevant forward projections, as part of the broader set of inputs to monetary policymaking. In doing so, staff typically emphasise the following practical uses of endogenous policy analysis.

First, the suite of endogenous policy paths and associated economic outcomes illustrate how alternative policy approaches can affect the economic outcomes that can be achieved, through the lens of a model, for a given forward projection. That includes what alternative policy approaches imply for the period over which inflation deviates from the target and any corresponding deviation of activity from potential.

Second, endogenous policy simulations can be used to assess how a given policy approach performs across forward projections based on alternative assumptions. To this end, policy approaches can be compared across a range of alternative scenarios, which capture different transmission mechanisms (i.e., 'model' uncertainty) and/or a different constellation of economic shocks (i.e., 'future shock' uncertainty). This facilitates policymakers' assessments of which approach, if any, might deliver better outcomes across the distribution, given the uncertainty about the structure of the economy and the economic outlook considered.

Outline. The remainder of the paper is structured as follows. Section 2 outlines a general approach to constructing endogenous policy simulations via OPPs and simple rules. Section 3 describes their underlying intuition. Section 4 illustrates how endogenous policy tools have been used in practice. Section 5 concludes.

2 Implementing Projections with Endogenous Policy

MPC projections are typically built assuming an exogenous path for Bank Rate—e.g., an estimate of marked-implied expectations. They are also constructed from many models (see, e.g., Burgess et al., 2013) and can often incorporate off-model judgements. As a consequence, Bank staff first rationalise those projections within a general model setup before implementing endogenous policy within that.

In this section, we first introduce the general setup within which endogenous policy simulations are implemented. We then describe the approach to solving for the optimal policy. We follow this with a description of the intuition underlying the optimal policy prescriptions in a textbook New Keynesian model in order to highlight some benchmark insights from the literature. Finally, we outline an alternative approach to computing endogenous policy simulations using simple instrument rules, describing some of the specifications Bank staff use in practice.

2.1 General Setup

We implement endogenous policy simulations within the 'Model Analysis & Projection System' (MAPS) toolkit developed at the Bank of England (Burgess et al., 2013). That toolkit is designed to operate with discrete time, infinite-horizon linear(ised) models. Time is indexed by $t = 1, ..., \infty$. The models considered have the general form:

$$\mathbf{H}^F \mathbb{E}_t \mathbf{x}_{t+1} + \mathbf{H}^C \mathbf{x}_t + \mathbf{H}^B \mathbf{x}_{t-1} = \mathbf{\Psi} \mathbf{z}_t, \tag{1}$$

where $\mathbf{x}_t$ is an $n_x \times 1$ vector of endogenous variables, $\mathbf{z}_t$ is an $n_z \times 1$ vector of exogenous disturbances, and $\mathbb{E}_t$ represents the mathematical expectation operator conditional on period-t information. The $n_x \times n_x$ matrices $\mathbf{H}^F$, $\mathbf{H}^C$, $\mathbf{H}^B$ and the $n_x \times n_z$ matrix $\mathbf{\Psi}$ contain coefficients.

A wide range of models can be cast in this form. Dynamic Stochastic General Equilibrium (DSGE) models, like that described in Albuquerque et al. (2025), are a common example. In this case, equation (1) will typically stack (log-linearised) first-order conditions to optimisation problems and accompanying constraints; for example, equations governing private-sector behaviour, such as IS and Phillips curves, and rules governing the behaviour of policy, such as a Taylor rule (or, for models with unconventional monetary policy, rules for asset purchases), that are necessary to define an equilibrium in this model class. Entries in the coefficient matrices will then be functions of 'deep' model parameters that describe preferences and technology.

A rational expectations solution to the model (1) is given by:

$$\mathbf{x}_t = \mathbf{B}\mathbf{x}_{t-1} + \mathbb{E}_t \sum_{s=0}^{\infty} \mathbf{F}_s \mathbf{\Phi} \mathbf{z}_{t+s}, \tag{2}$$

where $\mathbf{F}_s\mathbf{\Phi}$ pre-multiplies current *and* expected-future disturbances $\mathbb{E}_t\mathbf{z}_{t+s}$. The exact approach to solving for the matrices $\mathbf{B}$, $\mathbf{F}$ and $\mathbf{\Phi}$ is application dependent. For simple rules, $\mathbf{B}$ can be computed using the 'AIM' algorithm (Anderson and Moore, 1985); $\mathbf{F}_s \equiv \mathbf{F}^s$ with $\mathbf{F} = -(\mathbf{H}^C + \mathbf{H}^F\mathbf{B})^{-1}\mathbf{H}^F$ and $\mathbf{\Phi} = (\mathbf{H}^C + \mathbf{H}^F\mathbf{B})^{-1}\mathbf{\Psi}$. For the OPPs under discretion, as we discuss further in Section 2.2, $\mathbf{F}_s$ varies across horizons s and is computed following the approach laid out in Harrison and Waldron (2021), which builds on the algorithm of Dennis (2007).

This solution can be paired with a measurement equation linking model variables to data:

$$\mathbf{y}_t = \mathbf{d} + \mathbf{G}\mathbf{x}_t + \mathbf{V}\boldsymbol{\omega}_t, \tag{3}$$

where $\mathbf{y}_t$ is an $n_y \times 1$ vector of model observables and $\boldsymbol{\omega}_t$ is an $n_\omega \times 1$ vector of measurement errors. Both the disturbances $\mathbf{z}_t$ and measurement errors $\boldsymbol{\omega}_t$ are assumed to be independent of each other and across time (i.i.d.) with standard normal distributions.

Given this setup, the starting point for Bank staff when producing endogenous policy simulations is past observations for model observables, $\{\mathbf{y}_t\}_{t=1}^{T}$, and a corresponding projection (be that a forecast or scenario) up to period $T + H$, $\{\mathbf{y}_{T+s}\}_{s=1}^{H}$. These must be mapped to the model via the measurement equation. To do so, the Kalman filter and smoother is applied to equations (2) and (3) to recover estimates of $\{\mathbf{x}_t\}_{t=1}^{T}$, given the past observations. The model is then inverted to find the set of anticipated shocks, $\{\mathbf{z}_{T+s}\}_{s=1}^{H}$, that rationalise the projection, from $T + 1$ to $T + H$.[2] Crucially, this framework facilitates endogenous policy analysis within a structural model, even when the underlying projection incorporates judgements—i.e., not necessarily built within a formal model—or is constructed using multiple models.

The overall algorithm we apply is common to the OPP and simple-rule approaches, and proceeds as follows:

1. Use the Kalman filter and smoother to recover the unobserved state variables from the (past) data, given the model.

2. Take a given projection of the future evolution of the observed data and use the 'inversion algorithm' in Burgess et al. (2013) (Appendix C) to find the set of (anticipated) shocks that explain that projection.

3. Discard the monetary policy shocks—i.e., those shocks which explain the deviation of the projected path for monetary policy from the model's monetary policy rule.

4. Re-solve the model under the endogenous policy approach of interest (i.e., OPP or simple rules).

5. (Re-)project the updated model from step 4 on the basis of the state vector obtained in step 1 and the remaining non-policy shocks from step 3 to obtain the endogenous policy paths and associated macroeconomic outcomes.

2.2 Optimal Policy Projections

In this paper, our focus is on OPPs in which policy is set in a time-consistent fashion—under so-called 'discretion'.[3] At the start of each period, the policymaker observes the state of the economy and then sets instruments optimally, taking private-sector expectations functions as given. They do so by minimising a loss function, subject to the structural constraints of the economy. Having observed the policymaker's optimal instrument setting, the private sector

[2]See Section 6 and Appendix C of Burgess et al. (2013) for more details on how this is operationalised within the MAPS toolkit. In practice, Bank staff carry out this inversion to a period, $T + H$, well beyond the end of the three-year MPC forecast horizon, allowing model variables to return to their steady-state values. This therefore requires an extension of the three-year projection and a corresponding assumption about the model's underlying trends, including for the equilibrium real interest rate R^*. To action this, Bank staff currently apply a steady-state vector autoregression, which ensures variables return to their steady state over a 10 to 15-year period. Nevertheless, they regularly assess the robustness to a range of alternatives, including a variety of up-to-date estimates for R^*.

[3]The OPPs can also be produced under commitment, a case in which a policymaker formulates a time-invariant plan that accounts for the entire sequence of constraints, minimising their full sequence of losses. Harrison and Waldron (2021) outline how this can be done within the general setup set out here. The case of commitment is generally not used internally, given the strength of some of its assumptions. In practice, current policymakers are unable to 'commit' future policymakers. Moreover, such a plan may be undesirable because it is 'time inconsistent': even if the economy were to evolve exactly in line with policymakers' expectations at the time of pinning down their plan for the instrument, they might want to revise that plan when they next take a decision. Nevertheless, there may be occasions when it is useful to consider the commitment benchmark alongside other policy experiments.

makes their decision, given expectations about the future state of the economy. Both the policymaker and the private sector take the future optimal behaviour of the policymaker as given when making decisions, and so the resulting policy is time consistent.

To compute the OPPs, we follow the steps laid out in Harrison and Waldron (2021) to re-solve the model (at step 4 of the algorithm laid out above), which we summarise below.[4] This approach is closely related to the optimal policy projections method developed in Svensson and Tetlow (2005) and the Constrained Optimal Policy Projections (COPPs) proposed by de Groot et al. (2021). These alternative approaches—alongside related 'sufficient-statistics' approaches (as in Barnichon and Mesters, 2023; McKay and Wolf, 2023b)—do not necessarily require a fully-specified structural model, merely a baseline path for the variables in the policymaker's loss function and impulse responses of those variables to changes in the policy instruments. Subject to differences arising from the equilibrium definition and the number of available impulse response functions, the different algorithms produce the same results.

As a first step to solving for the OPP, it is necessary to adjust the equations describing the structural constraints faced by the policymaker. In particular, as described in step 3 of the algorithm above, we separate out the n_r variables that are used as instruments to implement optimal policy under discretion from the other $n_{\tilde{x}}$ endogenous variables (where $n_x = n_{\tilde{x}} + n_r$) to remove policy shocks. This requires the following partitioned version of equation (1):

$$\widetilde{\mathbf{H}}_{\tilde{x}}^F \mathbb{E}_t \widetilde{\mathbf{x}}_{t+1} + \widetilde{\mathbf{H}}_{\tilde{x}}^C \widetilde{\mathbf{x}}_t + \widetilde{\mathbf{H}}_{\tilde{x}}^B \widetilde{\mathbf{x}}_{t-1} + \widetilde{\mathbf{H}}_r^F \mathbb{E}_t \mathbf{r}_{t+1} + \widetilde{\mathbf{H}}_r^C \mathbf{r}_t = \widetilde{\mathbf{\Psi}} \widetilde{\mathbf{z}}_t \tag{4}$$

where $\widetilde{\mathbf{x}}_t$ denotes the $n_{\tilde{x}} \times 1$ vector of endogenous variables with policy instruments removed, $\mathbf{r}_t$ is the $n_r \times 1$ vector of policy instruments, and $\widetilde{\mathbf{z}}_t$ represents the vector of shocks with policy shocks removed. The matrices $\widetilde{\mathbf{H}}_{\tilde{x}}^F$, $\widetilde{\mathbf{H}}_{\tilde{x}}^C$ and $\widetilde{\mathbf{H}}_{\tilde{x}}^B$ are constructed by removing the row(s) indexing the policy rule(s) and the column(s) indexing the instrument(s). The matrices $\widetilde{\mathbf{H}}_r^F$ and $\widetilde{\mathbf{H}}_r^C$ are built by removing the row(s) indexing the policy rule(s) and all columns except those indexing policy instruments. The matrix $\widetilde{\mathbf{\Psi}}$ removes the row(s) indexing policy rule(s) and the column(s) indexing policy shock(s). Lags of policy instruments are excluded from (4) without loss of generality to ensure that the instruments are not state variables in the system.

Subject to equation (4), then, the policymaker chooses a series of outcomes $\tilde{\mathbf{x}}$ and associated

[4]In this paper, our focus in on the class of linear models. Brendon et al. (2020) provide an extension to solve for optimal policy with an effective lower bound on the policy rate. Harrison and Waldron (2021) discuss extensions that allow for piecewise linear solutions with occasionally-binding inequality constraints on instruments and/or equations governing private-sector behaviour.

policy instruments $\mathbf{r}$ to minimise the loss function:

$$\begin{aligned}\mathcal{L}_t &\equiv \mathbb{E}_t \sum_{s=0}^{\infty} \beta^i \left\{ \widetilde{\mathbf{x}}'_{t+s} \mathbf{W} \widetilde{\mathbf{x}}_{t+s} + \mathbf{r}'_{t+s} \mathbf{Q} \mathbf{r}_{t+s} \right\} \\ &= \widetilde{\mathbf{x}}'_t \mathbf{W} \widetilde{\mathbf{x}}_t + \mathbf{r}'_t \mathbf{Q} \mathbf{r}_t + \beta \mathbb{E}_t \mathcal{L}_{t+1},\end{aligned} \tag{5}$$

where $\beta \in (0, 1)$ is the policymaker's discount factor, and $\mathbf{W}$ and $\mathbf{Q}$ are $n_{\tilde{x}} \times n_{\tilde{x}}$ and $n_r \times n_r$ positive semi-definite weighting matrices. The quadratic form of the loss function reflects the assumption that losses are symmetric around targets for each variable.[5] $\mathbf{W}$ is an $n_{\tilde{x}} \times n_{\tilde{x}}$ matrix containing the (relative) weights on the stabilisation of endogenous variables in $\widetilde{\mathbf{x}}_t$, such as 'Lambda (λ)' (Carney, 2017)—the policymaker's preference for output-gap stabilisation relative to inflation stabilisation. $\mathbf{Q}$ is an $n_r \times n_r$ matrix of instrument weights. For example, this can include a relative weight on changes in interest rates to reflect a preference for 'gradualism' on the part of the policymaker (see, e.g., Bernanke, 2004). Within the OPPs, the exact influence of interest rate smoothing depends on the underlying projections and other policymaker preferences encoded in the loss function. A preference for interest rate smoothing can be included to reflect the empirical observation that changes in policy rates are typically gradual (Coibion and Gorodnichenko, 2012). In addition, normatively, policy rate paths embodying gradualism can contribute to financial stability (Stein, 2014), impart more influence on long rates (Goodfriend, 1991; Bernanke, 2004), and might better approximate optimal Ramsey policy (Woodford, 2003b; Debortoli et al., 2015; Teranishi, 2015).

Harrison and Waldron (2021) (Section 4 and Appendix B) show that the solution to this problem has the form:

$$\widetilde{\mathbf{x}}_t = \mathbf{B}_{\tilde{x}\tilde{x}} \widetilde{\mathbf{x}}_{t-1} + \sum_{s=0}^{H} \left(\mathbf{F}_{s,\tilde{x}\tilde{x}} \mathbf{\Phi}_{\tilde{x}\tilde{z}} + \mathbf{F}_{s,\tilde{x}r} \mathbf{\Phi}_{r\tilde{z}} \right) \widetilde{\mathbf{z}}_{t+s} \tag{6}$$

$$\mathbf{r}_t = \mathbf{B}_{r\tilde{x}} \widetilde{\mathbf{x}}_{t-1} + \sum_{s=0}^{H} \left(\mathbf{F}_{s,r\tilde{x}} \mathbf{\Phi}_{\tilde{x}\tilde{z}} + \mathbf{F}_{s,rr} \mathbf{\Phi}_{r\tilde{z}} \right) \widetilde{\mathbf{z}}_{t+s} \tag{7}$$

where $\mathbf{B}_{\tilde{x}\tilde{x}}$, $\mathbf{B}_{r\tilde{x}}$, $\mathbf{\Phi}_{\tilde{x}\tilde{x}}$ $\mathbf{\Phi}_{r\tilde{x}}$, $\mathbf{F}_{s,\tilde{x}\tilde{x}}$, $\mathbf{F}_{s,\tilde{x}r}$, $\mathbf{F}_{s,r\tilde{x}}$ and $\mathbf{F}_{s,rr}$ are matrices that depend on the model's deep parameters. In general, this solution can only be derived numerically. To do this, Bank staff apply a variant of the algorithm described in Dennis (2007), where the optimal allocation is solved for via a fixed-point problem, adjusted to account for anticipated disturbances. See Harrison and Waldron (2021) for more details.

[5]An important consequence of this linear-quadratic framework is that certainty-equivalence holds. Policymakers only require estimates of mean outcomes to solve the problem and do not need to track higher-order moments of the distribution of possible outcomes.

2.3 A Three-Equation New Keynesian Model

Although solving the optimal policy problem generally requires numerical approaches, there are special cases that admit an analytical solution. This section illustrates the preceding analysis in the context of a textbook three-equation New Keynesian model (Woodford, 2003a; Galí, 2015). To see how optimal policy operates in this simple setting, we consider the following version of that model, written in (log) deviations from steady state, which is comprised of a forward-looking IS curve, a forward-looking Phillips curve and a Taylor rule:

$$y_t = \mathbb{E}_t y_{t+1} - \sigma \left(i_t - \mathbb{E}_t \pi_{t+1} - r_t^* \right) \tag{8}$$

$$\pi_t = \beta \mathbb{E}_t \pi_{t+1} + \kappa y_t + u_t \tag{9}$$

$$i_t = \phi^y y_t + \phi^\pi \pi_t \tag{10}$$

where y_t is the output gap, π_t is inflation, i_t is the nominal interest rate, r_t^* is an i.i.d. exogenous natural-rate shock, u_t is an i.i.d. exogenous cost-push shock, σ is the intertemporal elasticity of substitution, β is the discount factor, κ is the Phillips curve slope, and ϕ^y and ϕ^π are feedback coefficients in the Taylor rule.

The nominal rate i_t is the policy instrument. The coefficient matrices in the partitioned structural equations (4) are:

$$\widetilde{\mathbf{H}}_{\tilde{x}}^F = \begin{bmatrix} 1 & \sigma \\ 0 & \beta \end{bmatrix}, \quad \widetilde{\mathbf{H}}_{\tilde{x}}^C = \begin{bmatrix} -1 & 0 \\ \kappa & -1 \end{bmatrix}, \quad \widetilde{\mathbf{H}}_{\tilde{x}}^B = \begin{bmatrix} 0 & 0 \\ 0 & 0 \end{bmatrix},$$

$$\widetilde{\mathbf{H}}_{r}^F = \begin{bmatrix} 0 \\ 0 \end{bmatrix}, \quad \widetilde{\mathbf{H}}_{r}^C = \begin{bmatrix} -\sigma \\ 0 \end{bmatrix}, \quad \widetilde{\mathbf{\Psi}} = \begin{bmatrix} -\sigma & 0 \\ 0 & -1 \end{bmatrix}.$$

This (arbitrarily) orders the IS curve above the Phillips curve, output above inflation (i.e., $\widetilde{\mathbf{x}}_t = [y_t, \pi_t]'$) and the natural-rate shock above the cost-push shock (i.e., $\widetilde{\mathbf{z}}_t = [r_t^*, u_t]'$). Since this simple example includes neither endogenous states nor anticipated disturbances, the $\widetilde{\mathbf{H}}_{\tilde{x}}^B$ matrix and $\widetilde{\mathbf{H}}_{r}^F$ vector contain zeros.

The loss function has the following form:

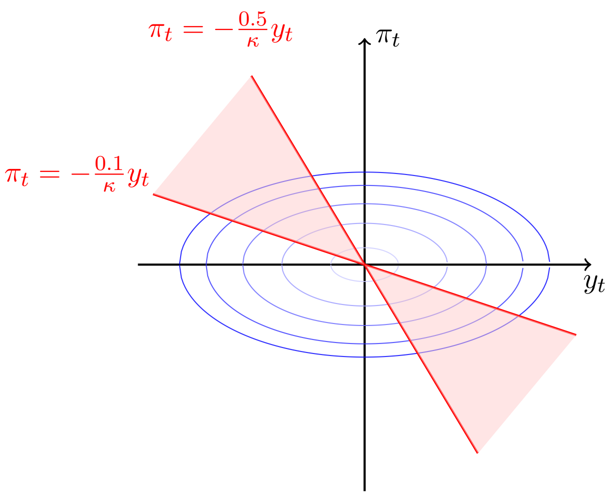
$$\mathcal{L}_t \equiv \mathbb{E}_t \sum_{s=0}^{\infty} \beta^s \left\{ \lambda y_{t+s}^2 + \pi_{t+s}^2 \right\}$$

such that

$$\mathbf{W} = \begin{bmatrix} \lambda & 0 \\ 0 & 1 \end{bmatrix}, \quad \mathbf{Q} = 0.$$

where λ represents the policymaker's relative preference for output-gap stabilisation. The fact that $\mathbf{Q} = 0$ implies that this simple example abstracts from interest rate smoothing.

Figure 1: Targeting rules and policy trade-off regions



Notes: The figure shows the isoquants for a loss function (blue ellipses) with a weight on output-gap stabilisation of $\lambda = 0.25$. The optimal targeting rules (red lines) represent the policymaker's preferred equilibrium trade-off for different relative preferences for output-gap stabilisation ($\lambda = 0.1$ and 0.5).

The resulting optimal targeting rule under discretion is:[6]

$$\pi_t = -\frac{\lambda}{\kappa}y_t \tag{11}$$

which states that the output gap is proportional to inflation.

Figure 1 is helpful for understanding the intuition underpinning the optimal allocation implied by the targeting rule (11). Here, the blue ellipses denote different outcomes that each deliver the same losses, with the lowest losses achieved at the intersection of the axes. The red lines represent the optimal targeting rules for different λ.

Within the three-equation setup, realisations of inflation and the output gap in the upper-right and lower-left quadrants arise from natural-rate shocks r_t^*. In this simple setting, optimal policy faces no trade-off in returning inflation to target and output to potential following demand-side shocks. Stabilising inflation automatically stabilises the output gap. This 'divine coincidence' (Blanchard and Galí, 2007) does not extend to more general settings, however, where demand-side disturbances can generate some trade-off for policymakers—as we come onto describe in Section 3 for medium-scale models that incorporate richer frictions.

Realisations in the upper-left and lower-right quadrants arise from cost-push shocks u_t and can generate a trade-off for policymakers. The targeting rule reflects a policymaker's preferred management of such a trade-off in equilibrium, mapping the size of the shortfall of output below potential that the policymaker is prepared to tolerate for a given overshoot of

[6]Through the lens of the optimal policy solution (6)-(7), $\mathbf{B}_{r\tilde{x}} = \mathbf{0}$ and $\mathbf{B}_{\tilde{x}\tilde{x}} = \mathbf{0}$ in this example.

inflation from target, and vice versa. The flatter the red line (i.e., the lower is λ), the less weight the policymaker places on output-gap stabilisation, resulting in smaller deviations of inflation from the target for a given size of shock.

From Targeting to Instrument Rules. The optimal targeting rule in equation (11) can be difficult to operationalise in practice given that both the output gap and inflation are not under the direct control of policymakers. In general, the solution for the nominal rate is a complex function of all the state variables in the model.

However, in this simple framework, it is possible to cast the targeting rule equivalently as an instrument rule—i.e., an equation that links the nominal interest rate to the endogenous variables in the economy.[7] To see this, note that the model solution implies that the nominal rate will follow this specific functional form: $i_t = r_t^* + \phi^u u_t$, where $\phi^u = \kappa/(\lambda+\kappa^2)\sigma$. This can be mapped to the inflation coefficient in equation (10) so that, in equilibrium, the economy achieves the allocation implied by the optimal targeting rule.[8] Of course, there are other types of instrument rules that do not necessarily replicate the optimal discretionary allocation, but have other desirable properties for setting monetary policy in practice. We discuss some of these 'simple' rules next.

2.4 Simple Instrument Rules

Simple monetary policy instrument rules typically specify a relationship between the central bank's policy rate and a small number of variables capturing inflation and economic activity. For example, in the Taylor (1993) rule the policy rate is specified as:

$$i_t = i^* + \phi^\pi(\pi_t - \pi^*) + \phi^y y_t \tag{12}$$

where i_t is the nominal interest rate, π_t is the rate of inflation, π^* is the central bank's inflation target, $i^* = R^* + \pi^*$ is the nominal long-run trend equilibrium interest rate, R^* is the real long-run trend equilibrium interest rate, and y_t is the output gap. The coefficients ϕ^π and ϕ^y denote the response of policy to changes in inflation and activity.

Simple rules such as this have some attractive features. First, they focus on instruments that central banks can directly control, so their implications for monetary policy are transparent. Just by looking at a rule on its own, one can immediately see exactly how the policy rate depends on a handful of other variables. Second, while in general not optimal, they can capture, in a parsimonious way, particular elements of monetary policy strategy that

[7] See Galí (2015) for further discussion.

[8] For example, for the following rule $i_t = r_t^* + \tilde{\phi}^\pi \pi_t$, we can choose $\tilde{\phi}^\pi \equiv \kappa/\sigma\lambda$ to ensure that the optimal targeting rule allocation is achieved. Note that equilibrium determinacy still requires $\kappa/\sigma\lambda > 1$. A detailed derivation can be found in Appendix A.

are recognised as desirable. For example, simple rules can reflect a 'Taylor principle'—the notion that, following an increase in inflation, the nominal interest rate should be increased by more than one-for-one to increase the real interest rate. Applied within a textbook New Keynesian model (such as in Section 2.3), this systematic, sufficiently forceful monetary policy response can ensure inflation returns to target following unanticipated shocks. Third, contrary to the optimal targeting rule in equation (11) and its associated instrument rule, simple rules can be applied directly without knowledge of the deep structural parameters of the economy (e.g., the slope of Phillips curve, κ in the simple example in Section 2.3). However, following a simple policy rule implies that the policymaker forgoes discretion for (a degree of) commitment, such that the strategy they embody is time-inconsistent. That is, even if the economy were to evolve in line with policymakers' expectations, they may have an incentive to deviate from it in the future.

A large academic literature has developed around the design and evaluation of simple policy rules.[9] However, their implications for policy can differ greatly across rules and the environments in which they are applied. In this paper, we summarise three illustrative simple rules as examples, where t denotes time in quarters:

$$i_t = \rho i_{t-1} + (1-\rho)(i^* + \phi^{\widehat{\pi}^E}\widehat{\pi}_t^E + \phi^{\widehat{\pi}^N}\widehat{\pi}_t^N + \phi^y y_t) \tag{13}$$

$$i_t = \rho i_{t-1} + (1-\rho)(i^* + \phi^{\pi}(\pi_{t+5|t} - \pi^*) + \phi^y y_{t+5|t}) \tag{14}$$

$$\Delta i_t = \phi^{\pi}(\pi_{t+3|t} - \pi^*) + \phi^{\widetilde{y}}\Delta\widetilde{y}_{t+3|t} \tag{15}$$

where i_t refers to the quarterly nominal interest rate and rates of inflation are incorporated in quarterly terms.

Rule (13) is an inertial version of the simple policy rule put forward by Taylor (1993), with inflation divided into its energy and non-energy components as described in Albuquerque et al. (2025), where $\widehat{\pi}_t^E$ and $\widehat{\pi}_t^N$ denote the deviation of these from steady state, respectively. In addition, ρ dictates the relative weight placed on the level of the policy rate in the previous period. By introducing last period's policy rate as an additional right-hand side variable, we can mimic preferences for gradualism (Bernanke, 2004; Coibion and Gorodnichenko, 2012). However, unlike interest-rate smoothing in the OPPs, it is encoded into the simple rules in a more mechanical fashion—not sensitive to the paths in the projection and trade-offs with other outcomes. A key strength of this rule is that it clearly links the setting of monetary policy to the observable inflation data and estimates of the output gap. Moreover, given the widespread adoption of Taylor-type rules in academia and policymaking institutions, it provides a useful benchmark that will be widely recognised.

[9] Among others, see Clarida et al. (1998); Woodford (2001); Ascari and Ropele (2009); Benigno and Rossi (2021); McKay and Wolf (2023a); Holden (2024); Nakamura et al. (2025).

Rule (14) is a forward-looking, inertial variant of the same rule, where $\pi_{t+5|t}$ and $y_{t+5|t}$ are five-period-ahead forecasts of CPI inflation and the output gap, respectively. In general, forward-looking rules can be justified on the grounds that in practice, policymakers might base their decisions on their expectations for the future evolution of the economy, given lags in the transmission of monetary policy. Batini and Haldane (1999) argued that responding to a five-quarter-ahead forecast can be desirable in cases in which some inflation shocks are known to be purely transitory. And further, that forward-looking rules allow for better control over inflation and economic activity compared to rules that respond to contemporaneous variables.

Finally, rule (15) is a 'first-difference' rule in the tradition of Orphanides and Williams (2002). Here, the change in the nominal interest rate Δi_t is specified in terms of three-quarter-ahead forecasts for the deviation of CPI inflation from target and for quarterly output growth $\Delta\widetilde{y}_{t+3|t}$ (which is adjusted for the steady-state rate of growth in the model). The three-quarter-ahead horizon here reflects the baseline specification in Orphanides and Williams (2002). Because first-difference rules are specified in terms of changes in the interest rate rather than levels, they remove the need to specify an intercept and, hence, abstract from any particular value for the long-run trend equilibrium real interest rate R^*.[10] Moreover, replacing the output gap with growth as the indicator of activity bypasses the need for estimating potential output. Orphanides and Williams (2002) demonstrate that difference rules, while not optimal, may be robust (i.e., they insure against significant policy mistakes) when unobserved variables such as R^* and the output gap are poorly estimated.[11]

On the one hand, rules can be interpreted as an illustration of a plausible range of monetary policy strategies or, when estimated, a description of the average past behaviour of policymakers.[12] On the other hand, rules can be interpreted as prescribing an approach for setting monetary policy with certain desirable properties. Indeed, Taylor and Williams (2010) argue that simple rules can be robust, performing well across a range of models and methods of evaluation, and often outperform the optimal policy approach.[13]

Starting from a given forward projection, we compute endogenous policy paths and associated macroeconomic outcomes when policymakers follow a simple rule by following the steps outlined at the end of Section 2.1. Rather than using the optimal targeting rule in step 4 of that algorithm, as for OPPs, instead the model is re-solved using the simple rule. By

[10] Although, by relying on a structural model, the algorithm we describe in Section 2.1 still requires an assumption about R^* within a given model to be implemented.

[11] Instead of output growth, Orphanides and Williams (2002) formally use the unemployment gap in their specification of the difference rule.

[12] Bank staff are currently analysing the properties of more descriptive rules, estimated on UK data (including those discussed in Nakamura et al., 2025).

[13] Simple monetary policy rules have been found to deliver similar outcomes to the optimal policy approach in a wide variety of macroeconomic models, where outcomes are defined as the weighted sum of the variance of inflation and the output gap. In addition, the optimal policy approach has been found to perform poorly when the reference model is misspecified. See Williams (2003) for a discussion.

solving for macroeconomic outcomes endogenously, the paths these simulations deliver will differ from calculations that simply plug outcomes or projections for inflation and activity into simple rules without calculating their implications for macroeconomic outcomes in general equilibrium.

3 Illustrative Endogenous Policy Exercises

Having laid out how we implement endogenous policy simulations, we now describe their underlying intuition when applied to a medium-scale DSGE model. To do so, we analyse how different shocks affect the response of monetary policy and so macroeconomic outcomes. For these illustrative exercises, we assume that the policymaker sets a single instrument, the short-term interest rate i_t. We compare the OPP outcomes to those from the contemporaneous rule (13) and a forward-looking rule (14) as examples.

3.1 Practical Considerations

Before discussing the intuition underlying endogenous policy simulations, we first discuss some practical considerations.

Choice of Model. As discussed, the endogenous policy simulation tools described in this paper can be applied to a wide class of linear models, including DSGE and semi-structural ones. In this paper, and in many practical applications of the toolkit, we use a variant of COMPASS, the Bank's medium-scale DSGE model described in Albuquerque et al. (2025). This model variant, outlined in Albuquerque et al. (forthcoming), has been extended to incorporate myopia in household and firm expectations (assuming bounded-rationality à la Gabaix, 2020). The addition of myopia helps to alleviate the 'Forward Guidance puzzle' (McKay et al., 2016; Del Negro et al., 2023) within the model, so reflecting a more realistic transmission of future interest rate changes to economic conditions today—an important feature when modelling the feedback between policy rates and macroeconomic outcomes in the endogenous policy toolkit.

Choice of Loss Function for OPPs. We assume that the policymaker's per-period loss function is of the quadratic form:

$$L_t = (\pi_t - \pi^*)^2 + \lambda\, y_t^2 + \delta\, (\Delta i_t)^2, \tag{16}$$

where π_t denotes annual CPI inflation, π^* denotes the annual inflation target, λ captures the policymaker's preference for output-gap stabilisation, and δ reflects a desire to smooth (quarterly) changes in interest rates over time.

Choice of λ for OPPs. The λ parameter in the OPP loss function (16) captures the weight a policymaker places on output-gap stabilisation versus inflation stabilisation. In practice, Bank staff explore a range of values for λ, including the $\lambda = 0$ extreme which captures the preferences of an 'inflation nutter' focused entirely on stabilising inflation (King, 1997). Positive values capture the recognition in the MPC's remit that—following trade-off-inducing shocks—attempts to maintain inflation at target may cause undesirable volatility in output, such that a temporary deviation of inflation from target may be desirable. While not intended to be precise, in this paper, our benchmark calibration is $\lambda = 0.25$, a choice which is partly informed by past outturns for inflation and the output gap (as outlined in Carney, 2017).

Choice of δ for OPPs. The δ parameter indicates how much variability in the interest rate changes policymakers are willing to sacrifice in order to reduce inflation variability. Given the parametrisation of equation (16), in each quarter, policymakers equally dislike a one percentage point deviation of inflation from target, $1/\sqrt{\lambda}$ deviations in the output gap and $1/\sqrt{\delta}$ changes in the policy rate. Since there is little agreement in the literature on its best calibration, Bank staff routinely explore a wide range of calibrations for δ—including the $\delta = 0$ extreme. That calibration can be informed by analysing the policy paths implied by the OPPs and comparing them to historical paths for Bank Rate—for example, by comparing Bank Rate around its peaks and troughs to 'reversals' implied by the OPPs. Depending on the exact specification of that comparison and the time span considered, that procedure typically yields a range of smoothing values between 30 and 90 for the DSGE model applied here. For the remainder of this paper, we set δ to the mid-point of that range, 60, as a benchmark.

Calibration of Simple Instrument Rules. In this paper, for the rules shown in equations (13)-(14), we explore calibrations that broadly align with those presented in the Federal Reserve's most recently published Tealbook (Board of Governors of the Federal Reserve System, 2019). This approach means that the endogenous policy paths implied by the policy rules are *illustrative*; that is, they show plausible possible strategies that the policymaker could pursue. This contrasts with rules that are estimated on UK data and are therefore more *descriptive* of past MPC behaviour (see, e.g., Nakamura et al., 2025, for a recent such example), and also with rules that seek to minimise a loss function (or in instances where parameters in simple rules are 'optimised' to minimise losses) which are therefore more easily interpretable as *prescriptive*, presenting a model-dependent recommendation for policy. Specifically, for the contemporaneous rule (13) we calibrate $\rho = 0.85$, $\phi^{\widehat{\pi}^E} = 0.375$, $\phi^{\widehat{\pi}^N} = 1.5$, and $\phi^y = 0.5$. For the forward-looking rule (14), we calibrate $\rho = 0.85$, $\phi^{\pi} = 1.5$, and $\phi^y = 0.5$. In each case, the real trend equilibrium interest rate R^* is assumed to be 1%, consistent with a nominal trend equilibrium interest rate i^* of 3% and an inflation target π^* of 2% (all on an annualised basis).

The calibration of R^* is purely illustrative.

3.2 Policy Responses to Demand-Side Shocks

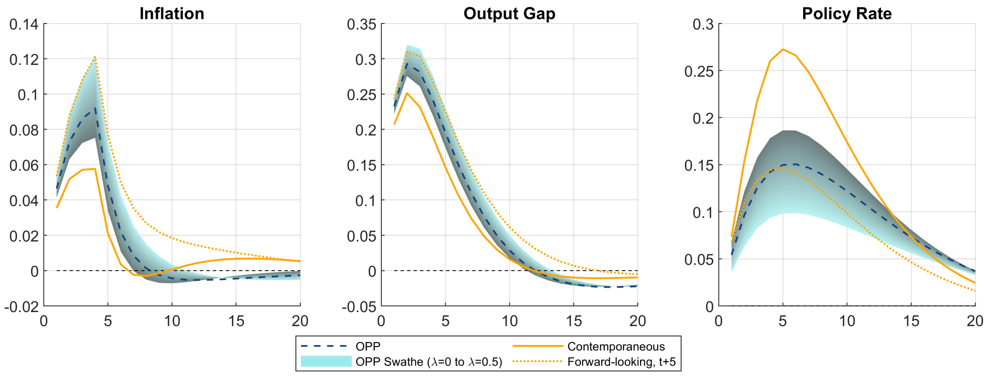
We first consider endogenous policy responses to demand-side shocks. As discussed in Section 2.3, the three-equation New Keynesian model generates a stark prediction for optimal policy in the face of such shocks: 'divine coincidence', where policy can immediately stabilise inflation and the output gap in the face of demand-side shocks. However, such a coincidence typically breaks down in medium-scale models with richer frictions. Within the variant of COMPASS used here (Albuquerque et al., 2025, forthcoming), divine coincidence breaks down for several reasons, including, but not limited to: the existence of wage rigidities (Blanchard and Galí, 2007); the fact inflation is stabilised away from zero and prices are partially indexed (Alves, 2014); the Two-Agent New Keynesian structure (Debortoli and Galí, 2024); and the open-economy setting in which prices are invoiced in the export market's currency and international financial markets are incomplete (Corsetti et al., 2010).

With this background, Figure 2 shows impulse responses to a persistent demand shock, formally implemented through a one standard deviation (expansionary) shock to the risk premium within the model.[14] All else equal, this shock boosts demand, raising inflation above target and pushing output above potential. In response, the policy rate rises. With the calibrated values for λ and δ, the OPP delivers a gradual increase in the policy rate, which dampens somewhat the increase in inflation and output due to the shock. The policy rate peaks at around 0.15p.p. above its steady-state value after about five quarters, with inflation returning to target after around eight quarters. The corresponding OPP swathe demonstrates how outcomes differ for alternative values of λ, between 0 and 0.5. When the relative weight on stabilising inflation is higher (i.e., lower λ), Bank Rate increases by more (peaking at nearly 0.2p.p. above steady state) and inflation returns to target sooner (after around seven quarters), with a smaller increase in output above potential. Although variation in inflation and the output gap is smaller when the preference for policy-rate smoothing δ in the OPPs is lower, deviations from target are not eliminated—reflecting the fact that divine coincidence does not hold in this medium-scale DSGE model.

Policy is mechanically tightened under both the contemporaneous and forward-looking rules. The forward-looking rule reaches a peak policy rate comparable to the OPP, but reverses faster thereafter, partly reflecting the fact that the rule contains *future*, as opposed to contemporaneous, inflation. This results in a more accommodative overall stance relative to the OPP. As a consequence, inflation returns to target more slowly and output remains above potential for longer than in the OPP. By contrast, the contemporaneous rule, which

[14] In Albuquerque et al. (2025), this shock is denoted by ε_t^b. In this experiment, the autoregressive parameter on the risk-premium shock, ρ_b, is set to an illustrative value of 0.8.

Figure 2: Monetary policy responses and economic outcomes following a persistent demand shock



Notes: This chart shows the response of inflation and the output gap under different endogenous policy paths to an expansionary one standard deviation risk-premium shock ε_t^b in COMPASS with myopia (Albuquerque et al., forthcoming), with $\rho_b = 0.8$. The darker shade denotes OPP with $\lambda = 0$ and the lighter shade denotes OPP with $\lambda = 0.5$. δ is set to 60. All variables are expressed as percentage point deviations from their steady states.

mechanically responds to the near-term inflation generated by the shock, generates a larger near-term tightening in policy than in the OPPs over the first few years of the simulation. This initially returns inflation to target after around six quarters, but somewhat unsustainably as inflation temporarily rises slightly above target from quarter ten before returning thereafter.

3.3 Policy Responses to Supply-Side Shocks

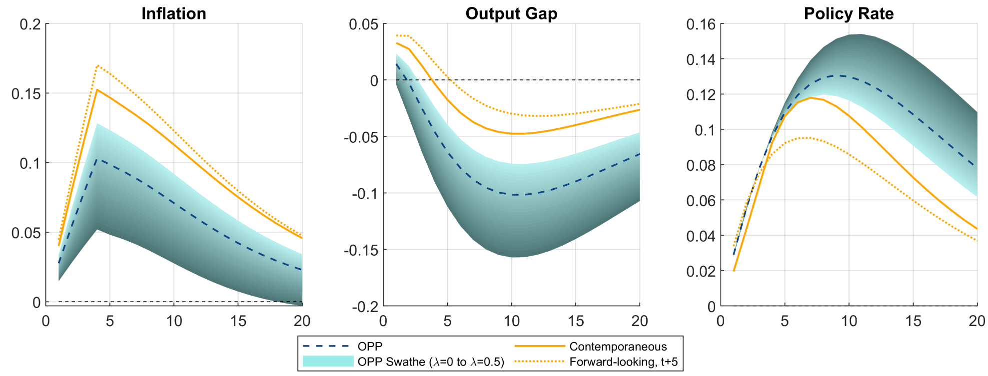
To consider endogenous policy responses to supply-side shocks, we simulate a one standard deviation wage mark-up shock. All else equal, this shock is inflationary, but weighs on demand over the medium term. However, the results for policy, especially using simple rules, can differ notably with respect to the persistence of the shock.

Transitory Cost-Push Shock. As a starting point, we analyse a transitory cost-push shock with zero persistence.[15] Figure 3 illustrates the endogenous policy responses and macroeconomic outcomes. In all the simulations, policy is tightened to contain the rise in inflation but at the expense of weaker activity.

The OPPs generate the most forceful responses in policy. With our benchmark calibration for λ and δ, the policy rate increases by around 0.13p.p. This results in the smallest rise in inflation above its steady-state value. Reflecting the trade-off policymakers face, the accompanying swathe demonstrates that, when the relative preference for inflation stabilisation is higher (i.e., lower λ), policy is tightened by more. This contains the increase in inflation further, albeit with the output gap becoming more negative. The swathe around the

[15] In Albuquerque et al. (2025), the wage mark-up shock is denoted by μ_t^w. Its persistence is denoted by ρ_w, which is set to 0 in this experiment—a value that is close to the estimated degree of this shock's persistence in Albuquerque et al. (forthcoming).

Figure 3: Monetary policy responses and economic outcomes following a transitory cost-push shock



Notes: This chart shows the response of inflation and the output gap under different endogenous policy paths to an inflationary one standard deviation wage mark-up shock μ_t^w in COMPASS with myopia (Albuquerque et al., forthcoming), with $\rho_w = 0$. The darker shade denotes OPP with $\lambda = 0$ and the lighter shade denotes OPP with $\lambda = 0.5$. δ is set to 60. All variables are expressed as percentage point deviations from their steady states.

policy rate is narrow in the initial quarters, reflecting both a low initial trade-off and the fact that monetary transmission operates with a lag. Owing to these lags within the model's monetary transmission mechanism, little can be done to prevent the initial rise in inflation, so different preferences over output stabilisation deliver similar near-term policy choices.

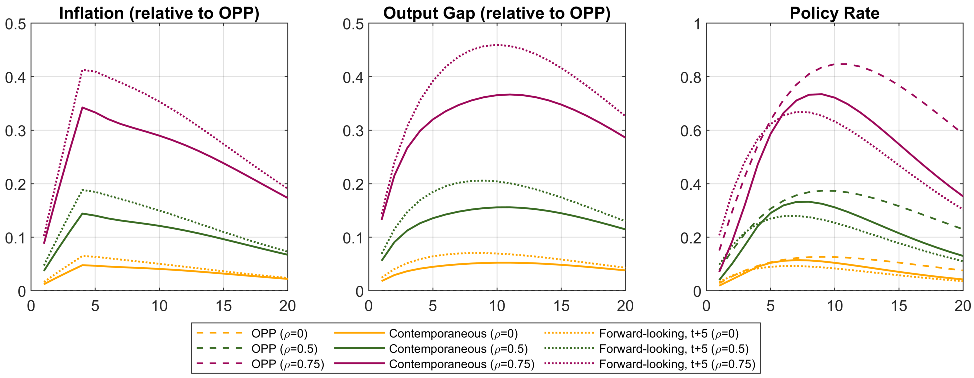
The policy rate responses implied by simple instrument rules are milder with the illustrative calibration used here. Consequently, the resulting outcomes for inflation are somewhat higher, although the trough in output gap less negative. The forward-looking rule delivers the mildest tightening, in effect 'looking through' the near-term peak in inflation caused by the transitory cost-push shock.

Varying the Degree of Cost-Push Shock Persistence. To illustrate how policy responses vary with the persistence of cost-push shocks, we repeat the previous exercise, varying the persistence of the cost-push shock from 0 (yellow, as reported in the example above) to 0.5 (green) and 0.75 (purple), as shown in Figure 4. To highlight how policy responses implied by the illustratively calibrated simple rules differ across these experiments, the left and middle panels report outcomes *relative* to those under the OPPs, while the right panel shows the corresponding policy rate paths in percentage points (including the OPPs).

Overall, with the illustrative calibration used here, monetary policy responds more forcefully as the shock becomes more persistent with both the OPP and simple rules. The policy rate paths for the most persistent shock ($\rho_w = 0.75$ in purple) lie above the policy-rate paths for the intermediate shock persistence ($\rho_w = 0.5$ in green), which in turn lie above the paths for the transitory shock ($\rho_w = 0$ in yellow).

However, for a given degree of persistence and with the illustrative calibration used here,

Figure 4: Monetary policy responses and economic outcomes under different degrees of cost-push shock persistence



Notes: This chart shows the response of inflation and the output gap under different endogenous policy paths to an inflationary one standard deviation wage mark-up shock μ_t^w in COMPASS with myopia (Albuquerque et al., forthcoming). Yellow lines denote a transitory shock (ρ_w=0). Green lines denote intermediate persistence (ρ_w=0.5), and purple lines denote high persistence (ρ_w=0.75). λ and δ are set to 0.25 and 60, respectively. For brevity, the two panels on the left report inflation and the output gap relative to the outcome under the OPP, while the right panel shows the corresponding policy paths in percentage points.

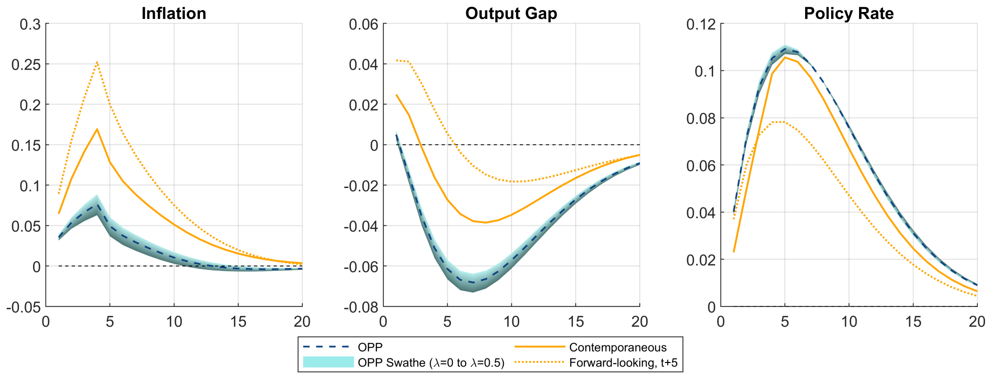
the forward-looking rule typically prescribes the mildest overall response, especially over the medium term when compared to the contemporaneous rule. In part, this reflects the fact that the forward-looking rule, by construction, 'look through' the near-term inflationary impacts of cost-push shocks, which is consequential to the economic outcomes.[16] Because of this, (peak) deviations of inflation and the output gap from target under the forward-looking rule increase with the degree of shock persistence, and are higher than comparable values from the contemporaneous rule for each level of persistence.

Cost-Push Shocks with a Steeper Wage Phillips Curve. Policy prescriptions can differ depending on the underlying features of the model too. Bank staff often construct policy scenarios to examine these differences. For example, here, we consider the same shock as before in an environment of greater wage flexibility. Following the scenario setup within COMPASS outlined in Albuquerque et al. (2025), and part of one of the scenarios presented in the May 2025 *Monetary Policy Report* (Bank of England, 2025a), we decrease the Calvo parameters of the wage and final goods Phillips Curves from 0.86 and 0.85, respectively, to 0.7. This implies that prices are adjusted every 3.3 quarters, compared to approximately seven quarters in the baseline case. One effect of lowering the Calvo parameters is a steeper Phillips Curve.

Figure 5 presents the results. Compared with Figure 3, a cost-push shock generates a larger increase in inflation on impact when the Phillips Curve is steeper. Inflation persistence is lower,

[16] Two further points are noteworthy. First, as persistence rises, the forward-looking rule shows a tighter stance in the early quarters. Second, the OPP is generally closer to the contemporaneous rule than to the forward-looking rule, reflecting that the contemporaneous rule captures the stance of the OPP more closely.

Figure 5: Monetary policy responses and economic outcomes following a cost-push shock with a steeper Phillips curve



Notes: This chart shows the response of inflation and the output gap under different endogenous policy paths to an inflationary one standard deviation wage mark-up shock μ_t^w in COMPASS with myopia (Albuquerque et al., forthcoming), with $\rho_w = 0$. Within the model, the wage Phillips curve slope is increased, adjusting the Calvo-Wage parameter from 0.86 to 0.7. The darker shade denotes OPP with $\lambda = 0$ and the lighter shade denotes OPP with $\lambda = 0.5$. δ is set to 60. All variables are expressed as percentage point deviations from their steady states.

reducing the overall cost of inflation and the trade-off faced by the policymaker.

Because monetary transmission is stronger in this environment, a smaller sacrifice in output is required to achieve a given reduction in inflation. Consequently, OPPs with different preferences on output-gap stabilisation λ deliver a similar optimal policy stance, illustrated by the relatively narrow swathe. Inflation returns to target sooner in Figure 5 than in Figure 3, reflecting the fact that monetary policy is more effective in an environment where the nominal frictions are decreased. Simple rules also tighten, but by somewhat less than the OPP.

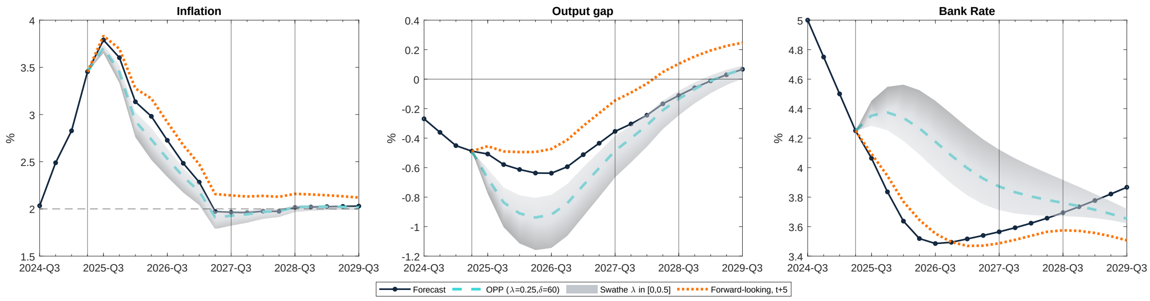
4 Endogenous Policy in Practice

In this section, we illustrate how endogenous policy simulations have been used in practice at the Bank of England. In contrast to the illustrative exercises presented in Section 3, real-world policy makers are not confronted with individual shocks whose properties are perfectly understood in real time. Instead, the outlook for the economy is always uncertain and driven by a range of shocks and their interactions. As explained in Haberis et al. (2025), quantitative solutions to simplified versions of the monetary problem—such as the endogenous policy paths implied by OPPs and simple rules explored in this paper—have no mechanical link to real-world policy decisions. Consequently, drawing insights from endogenous policy simulations is challenging and requires a clear articulation of what can, and cannot, be learned from them. However, they can provide qualitative insights to inform policymakers.

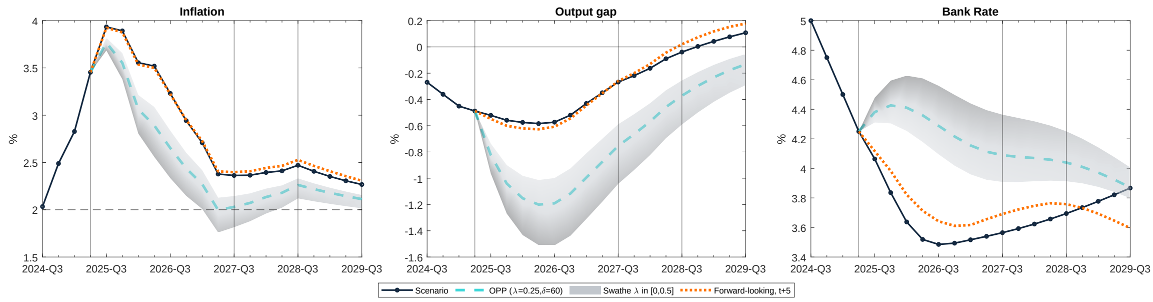
To demonstrate how we draw insights in light of these challenges, we first explore the central projection from the August 2025 *Monetary Policy Report* (Bank of England, 2025b). In

Figure 6: Optimal Policy Projections and Interest Rate Rules in the August 2025 Forecast

(a) Baseline Forecast



(b) Inflation Persistence Scenario



Notes: The figure plots the optimal policy projections (OPPs) and the forward-looking $t + 5$ interest rate rule (as in (14)) in the Baseline August 2025 Forecast (panel a) and the Scenario with higher inflation persistence (panel b). The dashed-aqua lines report the OPPs for λ equal to 0.25 and an interest rate smoothing δ of 60. The shaded areas report the OPPs for different output gap weights ($\lambda \in [0, 0.5]$), lighter colours indicate a higher weight. Vertical lines indicate the last quarter in the data, Year 2 and Year 3 in the forecast horizon, respectively.

this paper, we compare this to an accompanying 'inflation persistence' scenario, which explored one way in which inflationary pressures might have been more persistent than assumed in the baseline. In practice, staff analysis will often consider many endogenous policy simulations (across parametrisations, functional forms and models) and multiple macroeconomic scenarios, but here we focus on a subset to draw out key messages. We then briefly look at the February 2018 and 2023 forecasts, using the same simple rules for direct comparison, to illustrate the endogenous policy simulations at different points of the policy cycle, before discussing caveats around their practical uses.

4.1 The August 2025 Central Projection and an 'Inflation Persistence' Scenario

Figure 6a shows the August 2025 central projection conditioned on the market curve that prevailed in the period up to the release of that *Monetary Policy Report* (solid black lines), as well as the endogenous policy paths and associated outcomes when the endogenous policy is implemented assuming either the optimal policy approach underpinning the OPPs (dashed cyan lines) or the simple forward-looking instrument rule (14) (dotted orange lines). The central projection was characterised by: a near-term hump in inflation—owing to developments in energy, food and administered prices, as well as the continued unwinding of second-round effects from past inflationary shocks—followed by disinflation back to target, and a negative output gap that broadly closed by the end of the forecast horizon.

Within the August 2025 central projection, the shocks driving the near-term inflation hump were not expected to lead to additional second-round effects on domestic inflationary pressures. Annual CPI inflation was projected to peak at 4.0% in September 2025, before falling back thereafter towards the 2% target. But there were risks to this assessment and the Committee remained alert to the risk that this temporary increase in inflation could put additional upward pressure on the wage- and price-setting process (highlighted, e.g., by Bailey, 2025b). Recent research has highlighted that UK inflation expectations are especially sensitive to increases in food price inflation (Anesti et al., 2025), and that above a certain threshold of around 3.5–4%, agents in the economy become more attentive to inflation (Pfäuti, 2023; Pill, 2025). Therefore, given the nature of the shock, there was a risk that inflation persistence could be greater than captured in the baseline forecast due to stronger second-round effects fuelled by an increase in inflation expectations.

To capture these risks, we draw on an 'inflation persistence' scenario presented in the May 2025 *Monetary Policy Report* (Bank of England, 2025a), updated for the August 2025 central projection.[17] As with the central projection, Figure 6b shows this scenario conditioned on a path for Bank Rate based on estimates of market expectations, as well as the endogenous policy paths and associated outcomes when the policymaker followed either the OPP (dashed cyan lines) or the simple forward-looking instrument rule (dotted orange lines). Here, the near-term inflation hump was assumed to lead to additional second-round effects in domestic price- and wage-setting via increased backward-lookingness, amplified by weak potential productivity growth. While only illustrative, the scenario was calibrated to provide a quantification of how alternative economic mechanisms could result in plausible alternative paths for the UK economy. Relative to the central projection, inflation in the scenario peaked at a higher rate in 2025 Q3 and subsequent disinflation was slower, remaining above the 2% target at the end of the forecast horizon.

This scenario was merely one example of a wide range of different paths the economy could take. In addition to inflation persistence, the MPC considered many other risks—as outlined in the August 2025 *Monetary Policy Report* (Bank of England, 2025b). Amongst these was the risk that demand could be substantially weaker than in the central projection. To support this, Bank staff drew on insights from a 'weaker demand' scenario, presented in the May 2025 *Monetary Policy Report* (Bank of England, 2025a). As described in Albuquerque et al. (2025), that scenario was constructed in COMPASS by imposing (negative) risk-premium shocks—akin to those discussed in Figure 2—over the forecast horizon, in combination with investment cost shocks. In the scenario, UK demand was weaker and domestic inflationary

[17] See Bailey (2025a) for a discussion of the use of scenarios.

pressures faded more quickly than in the central projection. Consistent with the monetary responses discussed in Figure 2, endogenous policy simulations on that weaker demand scenario delivered a less restrictive stance for policy than equivalent simulations on the central projection or the inflation persistence scenario.

4.1.1 Strategy Implications

In the run up to its August 2025 decision, the MPC's approach to removing monetary policy restraint had been described in successive monetary policy statements as "*gradual and careful*". This approach was reflected in the market curve, which embodied both a restrictive monetary stance and a "gradual" reduction in the degree of restriction as the underlying disinflationary process progressed. However, the MPC emphasised that Bank Rate was not on a pre-set path, with the Committee remaining responsive to the accumulation of evidence. The timing and pace of future reductions in the restrictiveness of policy would depend on the extent to which underlying disinflationary pressures continued to ease (e.g., Bank of England, 2025b).

These communications revealed that the strategy underpinning the "gradual and careful" approach was state-contingent. If risks crystallised and further inflation persistence was observed, as in the 'inflation persistence' scenario, then a different monetary policy response may have been warranted. Therefore, the state-contingency embodied in the "gradual and careful" approach described the MPC's optionality given different possible trajectories for the economy.

One challenge associated with OPPs and simple instrument rules in this context is that they do not, in general, differentiate between the shocks driving inflation and, consequently, do not imply a different policy response when inflation is driven by the direct effects of a cost-push shock as opposed to when inflation is driven by the indirect- and second-round effects of that shock.[18] Moreover, the outlook for inflation in the August 2025 central projection and 'inflation persistence' scenario was driven by both (albeit to varying degrees) the direct effect of cost-push shocks and their second-round effects, and was thus more complex than the simple setup outlined in Section 3.3.

However, endogenous policy simulations do help inform an assessment of economic outcomes when policy follows a strategy that responds to the near-term hump in inflation, compared to when policy follows a strategy that does not respond to inflation in the near term and instead focuses on medium-term developments. To investigate the former, we can examine the endogenous policy paths and associated outcomes when policy follows the optimal targeting rule underpinning the OPPs. Here, the policy path results from a

[18] Research has argued that monetary policy should accommodate—or 'look through'—the direct effects of transitory cost-push shocks like those driving the near-term hump in inflation and instead should respond to their indirect- and second-round effects. See, for example, Aoki (2001), Benigno (2004), and Woodford (2004) for the established view on 'looking through' relative-price changes.

minimisation of a loss function (see equation (16)), which contains deviations of inflation from target irrespective of their source, and consequently responds to near-term inflation. To investigate the latter, we compare the OPPs to the case in which policy follows the simple forward-looking instrument rule. Here, policy will not react to near-term inflation as, by construction, the rule specifies the nominal rate as a function of inflation five-quarters ahead.

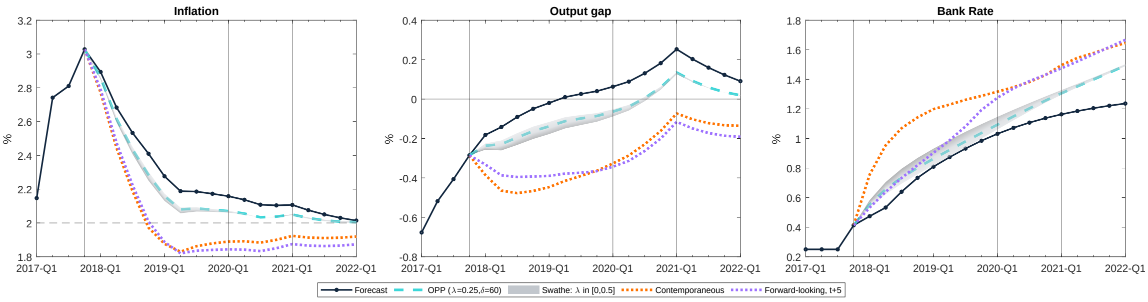
In the central projection, the OPP path for Bank Rate is relatively flat over 2025 (falling within the 25b.p. intervals at which Bank Rate is typically adjusted), before declining at a gradual pace over 2026 and 2027 (dashed cyan lines, Figure 6a). Such an approach would squeeze out additional pressures and return inflation sustainably to target within the forecast period, albeit at the expense of a more negative output gap. Instead, if policy were to follow the simple forward-looking instrument rule, the resulting path for Bank Rate would be similar to the market curve until early 2027. Thereafter, Bank Rate is lower, and inflation stabilises at just above its target (dotted orange lines, Figure 6a).

In the 'inflation persistence' scenario, the OPP path for Bank Rate is again relatively flat over the first year (dashed cyan lines, Figure 6b). Relative to the central projection, a slower pace of cuts would be implemented thereafter, implying a more restrictive stance of policy that would lean against the additional second-round effects in domestic price- and wage-setting that play out in the scenario. This would, however, come at the expense of a negative output gap. If policy were instead set mechanically using the simple forward-looking instrument rule, the resulting path for Bank Rate would be similar to that implied by the forward-looking strategy in the central projection, at least in the near term (dotted orange lines, Figure 6b). This follows from the fact that this strategy implies the policymaker (in effect) does not respond to near-term inflation. However, economic outcomes would differ significantly. While inflation would return sustainably towards target in the baseline forecast, it would overshoot throughout the three-year horizon in the scenario.

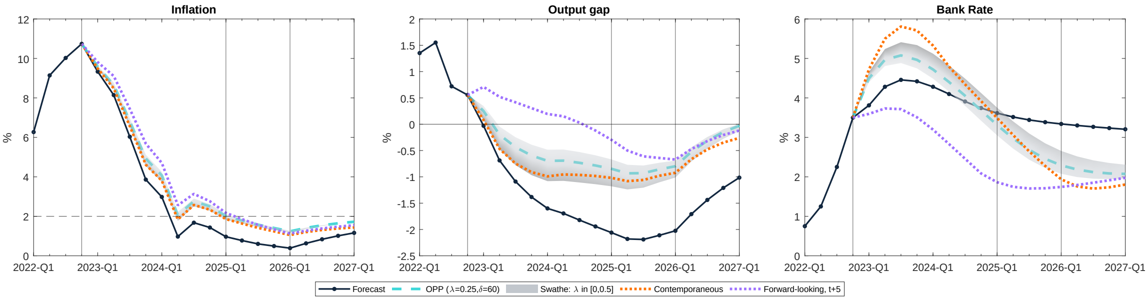
This analysis suggests that the appropriateness of continued gradual reductions in Bank Rate would depend, among other things, on the progress in underlying disinflation. If the near-term hump in inflation did generate excess second-round effects, then—through the lens of the model—a policy path similar to the market curve could plausibly have resulted in inflation remaining persistently above target. On the other hand, if demand was weaker and disinflation more rapid—as in, e.g., the weaker demand scenario discussed in the May 2025 *Monetary Policy Report*—then model analysis could plausibly suggest a less restrictive policy stance to be warranted. While illustrating that endogenous policy projections can be useful devices for interrogating different approaches to policy, they alone cannot furnish policymakers with all the inputs needed to reach a final judgment about a preferred monetary policy strategy.

Figure 7: Optimal Policy Projections and Interest Rate Rules

(a) February 2018 Forecast



(b) February 2023 Forecast



Notes: The figure plots the optimal policy projections (OPPs) and three instrument rules around the February 2018 and February 2023 forecasts. The dashed-aqua line reports the OPPs for λ equal to 0.25 and an interest rate smoothing δ of 60. The shaded areas report the OPPs for different output gap weights ($\lambda \in [0, 0.5]$), lighter colours indicate a higher weight. Vertical lines indicate the last quarter in the data, Year 2 and Year 3 in the forecast horizon, respectively. The *Contemporaneous* and *Forward-looking*, $t{+}5$ instrument rules are based on (13) and(14), respectively.

4.2 OPPs and Simple Instrument Rules Under Previous Outlooks

In this section we discuss two previous forecasts that further illustrate how OPPs and simple rules can be used at different points in the policy cycle.

Figure 7 plots the OPPs and the simple rules (the same as Figure 6 for direct comparison) for the February 2018 and February 2023 forecasts. In February 2018, policy was at the beginning of a hiking cycle. The outlook, shown in Figure 7a, was characterised by a trade-off in the near term, with inflation above target and a negative output gap over the first half of the forecast period.[19] The policy stance implied by both the contemporaneous and forward-looking rules is tight relative to the market curve, especially in the second-half of the forecast period. This explains the persistently negative output gap and the undershoot of inflation, relative to its target. The OPP, instead, balanced the inflation-output trade off in the forecast, by gradually tightening policy over the forecast period, delivering a more sustainable return to inflation to target and a less negative output gap relative to the rules. In this instance, the market yield curve was close to the model-implied OPP, especially in the first half of the forecast period.

In February 2023, policy was instead in the middle of a hiking cycle. The outlook was also

[19] The ‘kinked’ shape of the projection (for the output gap, especially) from 2021 Q1 is an artefact of how the projection is extended beyond its third year, as outlined in footnote 2 above.

characterised by a trade-off in the near term, with falling inflation in the short term and an output gap opening up throughout the forecast period, as shown in Figure 7b. In these circumstances the policy prescription from the contemporaneous and the forward-looking rule were different. The forward-looking rule indicated a materially looser stance for policy relative to the contemporaneous rule. This was driven by the falling inflation rate and the opening up of the output gap over the forecast horizon. Policy under the contemporaneous rule, by responding more strongly to the short-term inflation peak, instead reached a higher peak than implied by contemporary estimates of market expectations over the first year of the forecast, before reversing quickly to counterbalance the worsening output gap. The OPP, in this example, sits between these two cases, indicating a series of short-term hikes, over and above those implied by the yield curve, before reversing policy at a slower pace than that implied by the contemporaneous rule.

4.3 Caveats

Analysis of the kind presented above can be a useful input to monetary policy makers' decision-making process. However, it is critical that its limitations are understood appropriately. It is a single piece of information that should be supplemented with a broader set of analysis that underpins a holistic understanding of the economy and its future evolution. What are these limitations?

First, forward-looking endogenous policy simulations are only as 'good' as the forecasts they are based on. If the forecasts do not adequately represent how the economy might evolve, conditional on the information set available, or if they do not reflect policymakers' views of the outlook, the resulting endogenous policy simulations are unlikely to approximate a path for policy that a policymaker may find reasonable. Unexpected shocks can shift the appropriate path for policy, as a comparison between Figures 7a and 7b illustrates. From the perspective of the central projection made in February 2018, inflation was forecast to return to near its 2% target by 2022 Q1. However, as Figure 7b shows, realised outcomes for inflation, and so Bank Rate, were very different in 2022 to those implied by the endogenous policy simulations constructed in February 2018—in part due to imported inflation following Russia's invasion of Ukraine (Cunliffe, 2022; Lloyd et al., 2025).

Second, endogenous policy simulations are model-specific. The insights they provide for policy differ depending on the model used to produce them—and the model used is necessarily a simplification of reality. Importantly, they depend on the model's view of the monetary transmission mechanism, as the experiment in Figure 5 demonstrated by varying the slope of the Phillips curve and so the monetary transmission mechanism. Monetary transmission is a feature of the economy that is always estimated with uncertainty and which can vary over time (as noted by Burr and Willems, 2024). As an example to reflect this, documentation prepared by Bank staff ahead of the February 2016 MPC decision,[20] when Bank Rate was at 0.5% explicitly noted how the impact of changes in Bank Rate might vary with its *level*. Moreover, as we have discussed in this paper, the implementation of endogenous policy simulations requires an assumption about the long-run trend equilibrium real interest rate R^*, which anchors the projections but for which there is marked uncertainty around estimates (as emphasised, e.g., in Box A of Bank of England, 2025c).

Third, some strong assumptions are needed irrespective of whether we consider the OPPs or simple instrument-rule approach. These include the assumption that agents in the economy understand the projection, the model of the economy, and the policymaker's reaction function; and moreover, that agents are at least partially forward looking and understand that the policymaker will follow a rule or targeting criterion systematically, such that the entire forward path of the policy rate impacts macroeconomic outcomes. An implication of this is that, within the endogenous policy simulations, the stance implied by a given tool can only be achieved if all agents in the model expect its full path to be pursued. Therefore, in reality, in instances where market expectations are relatively far away from a simulated path for Bank Rate, then achieving the model outcomes associated with that simulated path would also require real-world expectations for Bank Rate to move commensurately.

Fourth, as produced, these simulations do not capture some important elements relevant to setting monetary policy. For example, they do not allow for a possible de-anchoring of inflation expectations, hysteresis effects following shortfalls in output, or other potential non-linearities in the economy. As discussed further in Haberis et al. (2025), a risk-management approach to policy might prescribe taking the full distribution of outcomes into account—for example, either to achieve good outcomes in lots of different states of the world or to deliver better outcomes in the worst imaginable state of the world. In reality, exactly how these risks are weighed up will differ across policymakers. However, this does underscore the value of considering *various* endogenous policy simulations for different views on the outlook as an input to the monetary policy process.

Overall, therefore, endogenous policy simulations can never be applied mechanically to the real-world issues facing the MPC.

5 Conclusions

This paper has described how endogenous policy simulations are constructed at the Bank of England. We have explained how these tools are used in practice, using (as an example) a

[20] Accessible here: https://www.bankofengland.co.uk/monetary-policy/mpc-documentation/2016.

variant of the Bank's medium-scale DSGE model, which incorporates myopia in agents' expectations to generate a more realistic monetary transmission mechanism for changes in future interest rates (Albuquerque et al., forthcoming).

Reflecting their generality, the OPP and simple-rule tools can be applied to a range of models. Moreover, they can be readily extended to reflect salient aspects of the economic conjuncture. These include utilise extensions in which agents ascribe discrete probabilities to alternative outcomes and cases with a lower bound on interest rates (Brendon et al., 2020), as well as other occasionally-binding constraints on model variables (Harrison and Waldron, 2021). They can also be applied to settings with both quantitative easing (or tightening) and Bank Rate as instruments (Harrison, 2024).

Staff will continue to develop the toolkit to capture, among other things, a broader set of rules, imperfect information and more complex 'learning' by agents and the policymaker. Moreover, we intend to broaden the range of models in which we conduct endogenous policy simulations to capture a wider range of transmission channels and associated uncertainties.

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Appendix

A Further Details on the Three-Equation New Keynesian Model

A solution to the three-equation New Keynesian model in Section 2.3 implies finding the following policy functions: $\pi_t = \pi(u_t, r_t^*)$, $y_t = y(u_t, r_t^*)$ and $i_t = i(u_t, r_t^*)$.

Given the simplified framework, we can 'guess and verify' that the policy functions under optimal discretion take the form: $\pi_t = \Psi u_t + \Phi r_t^*$, $y_t = \Psi_y u_t + \Phi_y r_t^*$ and $i_t = \phi^u u_t + \Phi_i r_t^*$.

From the targeting rule, we know that $y_t = -\frac{\kappa}{\lambda}\pi_t$. Therefore the New Keynesian Phillips Curve (9) can be rewritten as

$$\pi_t = \beta \mathbb{E}_t \pi_{t+1} - \frac{\kappa^2}{\lambda}\pi_t + u_t. \tag{A.1}$$

Then, using our guess for $\pi(u_t, r_t^*)$ in (A.1) and exploiting the fact that u_t and r_t^* are i.i.d with mean zero we get:

$$\Psi u_t + \Phi r_t^* = -\frac{\kappa^2}{\lambda}(\Psi u_t + \Phi r_t^*) + u_t.$$

As the shocks are independent, we can solve for each coefficient separately, so

$$\begin{aligned} \Psi u_t &= -\tfrac{\kappa^2}{\lambda}\Psi u_t + u_t, \\ \Phi r_t^* &= -\tfrac{\kappa^2}{\lambda}\Phi r_t^*, \end{aligned}$$

which implies $\Psi = \frac{\lambda}{\lambda+\kappa^2}$ and $\Phi = 0$.

Then, from the targeting rule, we know that $y_t = -\frac{\kappa}{\lambda}\pi_t \Rightarrow y_t = -\frac{\kappa}{\lambda}\Psi u_t$. Using both $y_t = -\frac{\kappa}{\lambda}\Psi u_t$ and $\pi_t = \Psi u_t$ in the dynamic-IS (8) we get:

$$i_t = r_t^* + \phi^u u_t, \text{ with } \phi^u \equiv \frac{\Psi\kappa}{\lambda\sigma}.$$

This completes the solution of the model.[21]

Therefore, a policy rule such as $i_t = r_t^* + \phi_\pi \pi_t$ can achieve the same solution as optimal discretion as long as $\phi_\pi = {}^{\phi^u}/_{\Psi}$. This implies:

$$\phi_\pi = \frac{\Psi\kappa}{\lambda\sigma}\frac{1}{\Psi} = \frac{\kappa}{\sigma\lambda}.$$

Therefore, with $i_t = r_t^* + \frac{\kappa}{\sigma\lambda}\pi_t$ and if ${}^{\kappa}/_{\sigma\lambda} > 1$ the three equation model in Section 2.3 would deliver the same unique equilibrium as the optimal discretionary policy.

[21]Note that in this simple setting, under optimal discretion the central bank is always able to fully stabilise inflation and the output gap after natural rate shocks simply by tracking movements in r_t^*, as highlighted from Φ and Φ_y being zero.