Unanticipated Inflation, Unemployment Persistence and the New Keynesian Phillips Curve

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Abstract

This paper puts forward an analytically tractable dynamic stochastic general equilibrium model, with both labor and product market frictions. Frictions in the labor market arise from the power of labor market insiders to periodically pre-set nominal wages, without full current information. Product market frictions arise from monopolistic competition and staggered pricing. The model results in a dynamic expectations-augmented New Keynesian Phillips Curve (DEANKPC) that transcends the main limitations of the benchmark and hybrid NKPCs based on staggered pricing, as: (i) it is expressed in terms of unanticipated inflation since current inflation depends on prior expectations about its level; (ii) unemployment (output) and inflation persistence are endogenous; and (iii) the divine coincidence between the stabilization of inflation and employment (output) does not apply, rendering a Taylor-type interest rate rule optimal. Dynamic simulations reveal multifaceted inflation dynamics shaped by the interplay of price stickiness and labor market persistence. An empirical application to the Euro Area validates the DEANKPC's superior forecasting performance, highlighting its relevance for understanding inflation dynamics and guiding effective monetary policy design.

Keywords: Unanticipated inflation, unemployment persistence, wage setting, staggered pricing, monetary policy.

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1 Introduction

Understanding the nature of short-term inflation dynamics and their interaction with the business cycle is a central issue in macroeconomics. Modern macroeconomic theory often relies on dynamic stochastic general equilibrium (DSGE) models, with the benchmark "New Keynesian Phillips Curve" (NKPC) as a cornerstone for analyzing inflation dynamics and guiding monetary policy.[1] The NKPC links inflation to deviations of unemployment (or output) from their natural rates and expected future inflation, reflecting the assumptions of monopolistic competition and Calvo (1983) staggered pricing. However, despite its theoretical appeal, the NKPC suffers from significant empirical and theoretical limitations.

One major shortcoming of the NKPC is its inability to account for the observed persistence of inflation and unemployment. Empirical evidence shows that inflation and real variables adjust more gradually to nominal and real shocks than the NKPC predicts. To address this, ad hoc lagged inflation terms are often added to create a "hybrid" NKPC, but this approach lacks theoretical justification.[2] Another issue is the "divine coincidence" proposed by Blanchard and Gali (2007), which suggests that stabilizing inflation automatically stabilizes output and unemployment. This contradicts the observed trade-offs faced by central banks, particularly in the presence of real shocks.

This paper proposes an analytically tractable DSGE model that explicitly incorporates labor and product market frictions to address the shortcomings of the benchmark NKPC. In the labor market, following Alogoskoufis (2018), we adopt an insider-outsider wage-setting mechanism, where insiders periodically set nominal wages based on prior expectations. This framework endogenously generates persistence in unemployment and output deviations through gradual adjustments in employment.[3] In the product market, staggered pricing amplifies forward-looking inflation expectations, enabling the model to capture persistent inflation dynamics more accurately.[4] Together, these frictions produce feedback loops between inflation and real activity, providing a unified theoretical basis for observed macroeconomic dynamics while avoiding ad hoc modifications. By incorporating these mechanisms, our model transcends the limitations of the benchmark NKPC, offering a richer and more realistic representation of inflation and unemployment persistence.

The model extends the framework of Alogoskoufis (2018) and Blanchard and Gali (2010), ad-

[1]See, for example, Blanchard (2009), Chari and Kehoe (2006), and Woodford (2009) for discussions on DSGE models and their implications.

[2]See Gali and Gertler (1999) and Rudd and Whelan (2007) for discussions on the limitations of the benchmark NKPC and the hybrid model.

[3]An overview of the theoretical and empirical literature on unemployment persistence can be found in Cross (1988) and O' Shaughnessy (2011). Moreover, Bakas and Makhlouf (2020) provide important empirical evidence for the role of insider-outsider theory as a key source of unemployment persistence.

[4]Inflation persistence is crucial for understanding inflation dynamics. Bobeica and Jarocinski (2019) highlighted that during the Great Recession, inflation in the US and Euro Area did not decline as much as expected, partly because existing models failed to account for persistent inflation. Our model addresses this gap by capturing the high persistence of inflation.

dressing key limitations while maintaining analytical tractability. Unlike Alogoskoufis (2018), which assumes fully flexible prices, our model incorporates staggered pricing, enriching inflation dynamics by amplifying the role of forward-looking expectations and enabling the model to account for observed inflation persistence. Additionally, we close the model using a Taylor rule, reflecting the rules-based monetary policy typically adopted by central banks, whereas Alogoskoufis (2018) assumes optimal monetary policy. Compared to Blanchard and Gali (2010), which relies on exogenous real wage rigidity to break the divine coincidence, our model endogenizes unemployment persistence using an insider-outsider framework. This approach generates deviations of real activity from its natural rate while addressing trade-offs between inflation and real activity stabilization. By integrating staggered pricing with labor market frictions, the model captures richer inflation dynamics driven by forward-looking expectations, providing a comprehensive framework for understanding inflation persistence and informing monetary policy design.

A notable implication of the model is the breakdown of the divine coincidence, as real shocks create a trade-off between stabilizing inflation and real variables. This finding supports the use of a Taylor-type rule, balancing the stabilization of inflation with the minimization of deviations in output and unemployment. These insights are particularly relevant for central banks operating in environments characterized by significant price stickiness and labor market persistence, highlighting the importance of designing monetary policies that account for structural rigidities.

The model results in a "Dynamic Expectations-Augmented New Keynesian Phillips Curve" (DEANKPC). Unlike the benchmark NKPC, the DEANKPC links current inflation to both prior expectations and future expectations of inflation, capturing the interplay between backward-looking and forward-looking components. Crucially, the DEANKPC endogenously generates persistence in inflation and unemployment, providing a theoretically consistent explanation for their gradual adjustment to shocks. Moreover, the divine coincidence no longer holds: real shocks create a short-run trade-off between inflation and unemployment stabilization, rendering a Taylor-type interest rate rule optimal.

Simulation exercises demonstrate the model's ability to capture more nuanced inflation dynamics than the benchmark NKPC. These dynamics arise from the interaction of structural frictions in product and labor markets, which together create feedback loops between inflation and real activity. When price adjustments are more constrained, forward-looking inflation expectations become the dominant driver of inflation persistence. Conversely, in settings where price flexibility is greater, labor market persistence exerts a stronger influence, often resulting in deflationary pressures following nominal shocks. These findings highlight the role of structural rigidities in shaping macroeconomic outcomes and provide valuable insights for the formulation of monetary policy.

To validate the theoretical predictions, we conduct an empirical analysis using data for the Euro

Area (1999Q1-2022Q3). By leveraging inflation forecasts from the ECB's Survey of Professional Forecasters (SPF), we compare the performance of the DEANKPC with the benchmark and hybrid NKPCs. The results confirm that the DEANKPC not only aligns well with observed inflation dynamics but also exhibits superior forecasting performance, underscoring its practical relevance for monetary policy design.

The remainder of the paper is organized as follows: Section 2 outlines the theoretical foundations of the model, including household behavior and the wage-setting process. Section 3 presents the dynamic simulations, highlighting the model's responses to nominal and real shocks. Section 4 delves into the mechanics of inflation dynamics, explaining the interplay between structural parameters and inflation persistence. Section 5 evaluates the empirical performance of the DEANKPC. Finally, Section 6 concludes with policy implications and broader insights for macroeconomic modeling.

2 Insiders and Outsiders in a DSGE Model with Staggered Pricing

This paper extends the frameworks of Alogoskoufis (2018) and Blanchard and Gali (2010) by incorporating key modifications that enhance its ability to capture inflation dynamics and inform monetary policy. Unlike Alogoskoufis (2018), which assumes fully flexible prices, our model includes staggered pricing, a feature that amplifies forward-looking expectations and accounts for inflation persistence. Additionally, we close the model using a Taylor rule, reflecting the rules-based practices of modern central banks, rather than assuming optimal monetary policy. Compared to Blanchard and Gali (2010), which relies on ad hoc real wage rigidity, our model employs an insider-outsider framework to endogenize unemployment persistence. These advancements allow the model to address inflation persistence and the trade-offs faced by monetary policymakers, while preserving analytical tractability.

2.1 The Representative Household

We assume the economy consists of a continuum of identical households, indexed by $i \in [0, 1]$. Each household member can supply one unit of indivisible labor, with unemployment affecting all households uniformly.[5] Consistent with Woodford (2003), we consider a cashless economy.

The representative household maximizes lifetime utility:

$$E_t \sum_{s=0}^{\infty} \left(\frac{1}{1+\rho} \right)^s \left(V_{t+s}^C \frac{C_{t+s}^{1-\theta}}{1-\theta} \right), \tag{1}$$

[5] These assumptions align with models of indivisible labor, as in Hansen (1985) and Rogerson (1988).

where ρ is the pure rate of time preference, θ denotes the inverse of the elasticity of intertemporal substitution, C represents consumption, and V^C is an exogenous stochastic shock to the utility from consumption.

Under monopolistic competition, consumption consists of differentiated goods indexed by $j \in [0, 1]$, with aggregate consumption defined as:

$$C_t = \left(\int_{j=0}^{1} C_t(j)^{\frac{\varepsilon-1}{\varepsilon}} \, dj \right)^{\frac{\varepsilon}{\varepsilon-1}}, \tag{2}$$

where $\varepsilon > 1$ is the elasticity of substitution between goods.

The household's budget constraint is:

$$B_{t+1} = (1 + i_t)B_t + W_t N_t + T_t - P_t C_t, \tag{3}$$

where i_t is the nominal interest rate, W_t is the nominal wage, B_t represents nominal bond holdings, P_t is the aggregate price level, and T_t denotes net transfers.

The optimal allocation of consumption expenditure among goods is given by:

$$C_t(j) = \left(\frac{P_t(j)}{P_t} \right)^{-\varepsilon} C_t, \tag{4}$$

where $P_t(j)$ is the price of good j and P_t is the aggregate price level.

The (log-linearized) household optimality condition for consumption is:

$$c_t = E_t c_{t+1} - \frac{1}{\theta} \left(i_t - E_t \pi_{t+1} - \rho \right) + \frac{1}{\theta} \left(v_t^C - E_t v_{t+1}^C \right), \tag{5}$$

where lower-case variables denote logarithms, and $\pi_t = p_t - p_{t-1}$ is the inflation rate.

We now turn to the behavior of firms in product markets.

2.2 The Representative Firm and Optimal Pricing

Several "New Keynesian" models of gradual price adjustment under monopolistic competition exist in the literature. We focus on the Calvo (1983) model, which is based on staggered pricing. Following Calvo (1983), firms face a constant probability $1 - \gamma$ of adjusting their prices in any given period. Consequently, a fraction $1 - \gamma$ of firms adjusts their prices each period, while the remaining fraction γ does not. The expected duration of a price contract is given by:

$$(1 - \gamma) \sum_{s=0}^{\infty} s\gamma^s = \frac{\gamma}{1 - \gamma}. \tag{6}$$

Using the definition of the price level and assuming uniform pricing by firms resetting in period t, it follows that:

$$P_t = \left(\gamma(\widehat{P}_{t-1})^{1-\varepsilon} + (1-\gamma)(\overline{P}_t)^{1-\varepsilon}\right)^{\frac{1}{1-\varepsilon}}, \tag{7}$$

where $\widehat{P}_{t-1}$ is the lagged price level relative to the steady state, and $\overline{P}_t$ is the price set by firms adjusting their prices in the current period.

Log-linearizing around a steady-state inflation rate π^* yields:

$$\widehat{p}_t - \widehat{p}_{t-1} \simeq (1-\gamma)(\overline{p}_t - \widehat{p}_{t-1}). \tag{8}$$

Equation (8) implies that inflation exceeds its steady-state level when firms resetting prices in the current period choose higher prices than the average price of the previous period, adjusted for steady-state inflation. Analyzing inflation dynamics requires understanding how firms optimally set prices, anticipating future constraints while competitors may adjust theirs.

Output is produced by a continuum of firms indexed by $j \in [0,1]$, each producing a differentiated product under monopolistic competition. All firms have access to the same production technology, defined by the production function:

$$Y(j)_t = A_t L(j)_t^{1-\alpha}, \tag{9}$$

where $A_t > 0$ and $0 < \alpha < 1$ are exogenous technological parameters, common to all firms. Here, $L(j)_t$ denotes the labor employed by firm j in period t, α is constant, and A_t follows an exogenous stochastic process.

Firms resetting prices in period t maximize the expected present value of profits:

$$\sum_{s=0}^{\infty} \gamma^s E_t \prod_{z=0}^{s} \frac{1}{1+i_{t+z}} \left(\overline{P}_t Y_{t+s}^t - \widehat{W}_{t+s} L_{t+s}^t\right), \tag{10}$$

subject to the production function (9) and the demand constraint (4).

The first-order condition shows that firms set prices as a markup over expected marginal costs:

$$\overline{p}_t \simeq (1-\beta\gamma)\sum_{s=0}^{\infty}(\beta\gamma)^s E_t\Big(\widehat{p}_{t+s} + \omega\big(\mu + w_{t+s} - p_{t+s} + \alpha l_{t+s} - a_{t+s}\big)\Big), \tag{11}$$

where $\beta = \frac{1}{1+\rho+\pi^*}$ and $\omega = \frac{1-\alpha}{1+\alpha(\varepsilon-1)}$, with $0 < \beta, \omega < 1$.

Substituting into the price adjustment equation (8) and rearranging, inflation dynamics are governed by:

$$\pi_t = (1-\beta)\pi^* + \beta E_t \pi_{t+1} + \frac{(1-\gamma)(1-\beta\gamma)}{\gamma}\omega\big(\mu + w_t - p_t + \alpha l_t - a_t\big), \tag{12}$$

where $\pi_t = p_t - p_{t-1}$ is the rate of inflation.

Equation (12), which underpins the NKPC, implies that deviations of current inflation from steady-state inflation exceed discounted expected future deviations if the current marginal cost of labor plus the markup μ is higher than the current price level p. This occurs because firms resetting prices raise them more than the discounted expected future inflation to offset the higher current marginal cost.

If all firms freely adjust their prices ($\gamma = 0$), the price level equals the marginal cost of production augmented by the fixed markup μ, and inflation equals the steady-state level in all periods. Hence, a positive relation between inflation and employment in (12) requires staggered pricing, characterized by $\gamma > 0$.

We now turn to the labor market and the determination of nominal wages.

2.3 Wage Setting and Employment in an Insider-Outsider Model

Building on Alogoskoufis (2018), our wage-setting framework incorporates two key labor market distortions.

First, we introduce a "nominal rigidity" by assuming that nominal wages are set at the beginning of each period based on prior expectations of wage setters regarding variables such as productivity, aggregate demand, and the price level. These wages remain fixed for one period and are renegotiated at the start of the following period. This setup, which reflects one-period nominal wage stickiness, follows the frameworks of Gray (1976) and Fischer (1977).

Second, we incorporate a "real rigidity" in the form of insider-outsider dynamics, inspired by the wage determination models of Lindbeck and Snower (1986), Blanchard and Summers (1986), Gottfries and Horn (1987), and Gottfries (1992). In this framework, an asymmetry exists between "insiders" (workers already employed) and "outsiders" (those seeking employment). Nominal wages are set in a decentralized manner by the insiders of each firm, while outsiders are excluded from the wage-setting process.

Following Blanchard and Summers (1986), we assume that insiders at the start of each period comprise an exogenous pool of "core insiders" and workers employed by the firm in the previous period. Insiders aim to maximize their nominal wage, subject to rational expectations regarding aggregate demand, the price level, and productivity, while minimizing deviations from their employment target. This target is defined as a weighted average of the firm's core employees and the previously employed, leading to a state-dependent pool of insiders. The employment target for insiders in period t is given by:

$$\bar{n}(j)_t = \delta l(j)_{t-1} + (1 - \delta)\bar{n}(j), \tag{13}$$

where $l(j)_{t-1}$ is the logarithm of employment in the previous period, $\bar{n}(j)$ is the logarithm of the firm's core employees (assumed exogenous), and δ represents the weight assigned to recently employed workers relative to core employees.

The interaction between these two rigidities - "nominal wage stickiness" and "insider-outsider dynamics" - results in persistent employment and wage dynamics. The nominal rigidity delays wage adjustments in response to shocks, while the real rigidity ensures that wage-setting decisions prioritize insiders, leaving outsiders disenfranchised from the labor market.

Wage-setting expectations are based on information available at the end of period $t-1$ and exclude aggregate demand, prices, or productivity in period t. Insiders choose a wage path that minimizes deviations of expected employment from the employment target while respecting firms' pricing constraints. Formally, this involves minimizing the quadratic intertemporal loss function:

$$\min E_{t-1} \sum_{s=0}^{\infty} \beta^s \frac{1}{2} \left(l(j)_{t+s} - \bar{n}(j)_{t+s} \right)^2 , \tag{14}$$

subject to the employment target $\bar{n}(j)_t$ defined in (13). Here, $\beta = 1/(1+\rho) < 1$ is the discount factor, with ρ representing the pure rate of time preference. Crucially, outsiders (i.e., the unemployed) have no influence on wage-setting decisions.

To ensure a strictly positive natural unemployment rate, we assume:

$$\int_{j=0}^{1} \bar{n}(j) dj = \bar{n} < n, \tag{15}$$

where n is the logarithm of the total labor force.

The first-order conditions for minimizing (14) yield the maximum wage path consistent with expected employment:

$$E_{t-1} l(j)_t = \frac{\beta\delta}{1+\beta\delta^2} E_{t-1} l(j)_{t+1} + \frac{\delta}{1+\beta\delta^2} l(j)_{t-1} + \frac{(1-\beta\delta)(1-\delta)}{1+\beta\delta^2} \bar{n}(j). \tag{16}$$

Aggregating across firms, expected aggregate employment satisfies:

$$E_{t-1} l_t = \frac{\beta\delta}{1+\beta\delta^2} E_{t-1} l_{t+1} + \frac{\delta}{1+\beta\delta^2} l_{t-1} + \frac{(1-\beta\delta)(1-\delta)}{1+\beta\delta^2} \bar{n}. \tag{17}$$

Equation (17) parallels (16) without the firm index j. Following Alogoskoufis (2018), the rational expectations solution of (17) is:

$$E_{t-1} l_t = \delta l_{t-1} + (1-\delta)\bar{n}. \tag{18}$$

This formulation corresponds directly to the wage contract proposed by Blanchard and Summers (1986): nominal wages are set at the maximum level that ensures expected employment is a weighted average of core employees and the recently employed, consistent with the insider-outsider framework. The implied contract wage can be derived by substituting the log-linear version of the optimal pricing condition (12) into the employment equation (19).

2.4 The Relation Between Output and Unemployment Persistence

The expected employment equation (18) can be transformed into an expected unemployment equation. Subtracting (17) from the logarithm of the labor force n and rearranging terms, we obtain:

$$E_{t-1}u_t = \delta u_{t-1} + (1-\delta)\bar{u}, \tag{19}$$

where $u_t \simeq n - l_t$ is the current unemployment rate, and $\bar{u} \simeq n - \bar{n} > 0$ is the natural rate of unemployment. In this model, the natural rate of unemployment is defined as the difference between the labor force and the number of core employees. It represents the equilibrium rate to which the economy converges in the absence of shocks.

If (19) holds and wage setters have rational expectations, deviations of unemployment from its natural rate follow an AR(1) process:

$$u_t - \bar{u} = \delta(u_{t-1} - \bar{u}) + \zeta_t^u, \tag{20}$$

where ζ_t^u represents exogenous shocks to unemployment. Thus, the persistence of employment and unemployment translates into persistent fluctuations in output.

Taking the logarithm of the production function (9) for the representative firm yields:

$$y_t = a_t + (1-\alpha)l_t. \tag{21}$$

Adding and subtracting $(1-\alpha)(n-\bar{n})$ to (21) gives:

$$y_t = \bar{y}_t - (1-\alpha)(u_t - \bar{u}), \tag{22}$$

where:

$$\bar{y}_t = (1-\alpha)\bar{n} + a_t \tag{23}$$

is the logarithm of the natural rate of output.

Equation (22) is a relation similar to Okun (1962), suggesting that fluctuations in output around its natural rate are negatively related to fluctuations in the unemployment rate around its natural rate. Since deviations of employment and unemployment from their natural rates are persistent, so too are fluctuations in output.

The persistence of output deviations arises from the state dependence of insiders' employment targets in the labor market. Consequently, deviations of output from its natural rate follow:

$$y_t - \bar{y}_t = \delta(y_{t-1} - \bar{y}_{t-1}) - (1-\alpha)\zeta_t^u. \tag{24}$$

Thus, deviations of output from its natural rate follow an AR(1) process with the same degree of persistence, δ, as unemployment.

2.5 A Dynamic Expectations-Augmented New Keynesian Phillips Curve

Nominal wages in period t are set at the beginning of the period based on information available until the end of $t-1$. Wages are determined to ensure that expected employment equals the target of labor market insiders, as implied by equation (19).

Using the log-linear version of the optimal pricing condition (12) to substitute for employment in (19), the implied contract wage is given by:

$$\begin{aligned} w_t =& \frac{\gamma}{(1-\gamma)(1-\beta\gamma)\omega}\Big(E_{t-1}(\pi_t - \pi^*) - \beta(E_{t-1}\pi_{t+1} - \pi^*)\Big) \\ &+ E_{t-1}p_t - \mu + E_{t-1}a_t - \alpha\big(\delta l_{t-1} + (1-\delta)\bar{n}\big), \end{aligned} \tag{25}$$

where π^* is the target inflation rate. Substituting (25) into the New Keynesian Phillips Curve (12) and rearranging terms yields:

$$\begin{aligned} \pi_t =& E_{t-1}\pi_t + \beta\Big(E_t\pi_{t+1} - E_{t-1}\pi_{t+1}\Big) - \frac{(1-\gamma)(1-\beta\gamma)\omega}{\gamma}\Big(\pi_t - E_{t-1}\pi_t\Big) \\ &+ \frac{(1-\gamma)(1-\beta\gamma)\omega}{\gamma}\Big(\alpha\big(l_t - \delta l_{t-1} - (1-\delta)\bar{n}\big) - (a_t - E_{t-1}a_t)\Big). \end{aligned} \tag{26}$$

Using the approximation $l_t - \delta l_{t-1} - (1-\delta)\bar{n} \simeq -(u_t - \delta u_{t-1} - (1-\delta)\bar{u})$, we solve for current inflation:

$$\begin{aligned} \pi_t =& E_{t-1}\pi_t + \frac{\beta\gamma}{\gamma + (1-\gamma)(1-\beta\gamma)\omega}\Big(E_t\pi_{t+1} - E_{t-1}\pi_{t+1}\Big) \\ &- \frac{(1-\gamma)(1-\beta\gamma)\omega}{\gamma + (1-\gamma)(1-\beta\gamma)\omega}\Big(\alpha\big((u_t - \bar{u}) - \delta(u_{t-1} - \bar{u})\big) + (a_t - E_{t-1}a_t)\Big). \end{aligned} \tag{27}$$

Equation (27) is a *dynamic expectations-augmented New Keynesian Phillips Curve* (DEANKPC). It is *dynamic* because past inflation affects current inflation due to labor market-induced persistence in unemployment and output deviations from their natural rates. It is *expectations-augmented* because current inflation depends on prior expectations of current inflation. It is *New Keynesian* because it incorporates forward-looking expectations of future inflation. The DEANKPC combines the effects of staggered pricing, which introduces forward-looking inflation dynamics, and predetermined nominal wage contracts, which introduce backward-looking dynamics through past expectations of current inflation. Additionally, it incorporates both the current and lagged unemployment rates, reflecting the dynamics of labor market insiders.

Using the Okun-type relation (22), the DEANKPC can be expressed in terms of output deviations from the natural rate:

$$\begin{aligned}\pi_t =& E_{t-1}\pi_t + \frac{\beta\gamma}{\gamma+(1-\gamma)(1-\beta\gamma)\omega}\Big(E_t\pi_{t+1} - E_{t-1}\pi_{t+1}\Big) \\ &+ \frac{(1-\gamma)(1-\beta\gamma)\omega}{\gamma+(1-\gamma)(1-\beta\gamma)\omega}\Big(\frac{\alpha}{1-\alpha}\big((y_t-\bar{y}_t) - \delta(y_{t-1}-\bar{y}_{t-1})\big) - (a_t - E_{t-1}a_t)\Big).\end{aligned} \tag{28}$$

In what follows, we use this version of the DEANKPC. For analyses requiring unemployment, we use the Okun-type equation (22).

2.6 Equilibrium, Behavioral Equations, and Shocks

Product market equilibrium implies that output equals consumption: $Y_t = C_t$. This condition allows us to substitute output for consumption in the Euler equation for consumption (5), yielding the optimal aggregate output demand function:

$$y_t = E_t y_{t+1} - \frac{1}{\theta}\left(i_t - E_t\pi_{t+1} - \rho\right) + \frac{1}{\theta}\left(v_t^C - E_t v_{t+1}^C\right). \tag{29}$$

Equation (29) is the product market equilibrium condition, often referred to as the IS curve.

The real interest rate is defined by the Fisher (1896) equation:

$$r_t = i_t - E_t\pi_{t+1}. \tag{30}$$

The natural real interest rate is determined by the product market equilibrium condition when output is at its natural rate. Using (23), (29), and (30), we derive the natural real interest rate as:

$$\bar{r}_t = \rho - \theta\left(a_t - E_t a_{t+1}\right) + \left(v_t^C - E_t v_{t+1}^C\right). \tag{31}$$

The natural real interest rate equals the pure rate of time preference but is also influenced by real shocks, such as deviations of current productivity and preference shocks from their expected future values. Thus, real shocks affect the natural rate of interest.

Under nominal wage rigidity and staggered pricing, the current equilibrium real interest rate deviates from its natural rate to the extent that output deviates from its natural rate. Solving the IS

curve (29) for the real interest rate and using (31), we find:

$$r_t = \bar{r}_t - \theta(1-\delta)\left(y_t - \bar{y}_t\right). \tag{32}$$

Deviations of the current real interest rate from its natural rate depend negatively on deviations of output from its natural rate. Since these output deviations are persistent, real interest rate deviations also exhibit persistence. Shocks to inflation or productivity that temporarily increase output relative to its natural rate reduce the current real interest rate relative to its natural rate.

For simplicity, we assume that the logarithms of the exogenous shocks to preferences and productivity follow stationary $AR(1)$ processes:

$$v_t^C = \eta_C v_{t-1}^C + \varepsilon_t^C, \tag{33}$$

$$a_t = \eta_A a_{t-1} + \varepsilon_t^A, \tag{34}$$

where $0 < \eta_C, \eta_A < 1$, and ε_t^C, ε_t^A are white noise processes.[6]

With these assumptions, fluctuations in output and inflation are determined by the IS relation (29) and the DEANKPC (27). Expressing these in terms of deviations from natural rates gives:

$$y_t - \bar{y}_t = -\frac{1}{\theta(1-\delta)}\left(i_t - E_t\pi_{t+1} - \bar{r}_t\right), \tag{35}$$

$$\begin{aligned}\pi_t =& E_{t-1}\pi_t + \frac{\beta\gamma}{\gamma + (1-\gamma)(1-\beta\gamma)\omega}\left(E_t\pi_{t+1} - E_{t-1}\pi_{t+1}\right) \\ &+ \frac{(1-\gamma)(1-\beta\gamma)\omega}{\gamma + (1-\gamma)(1-\beta\gamma)\omega}\left(\frac{\alpha}{1-\alpha}\left((y_t - \bar{y}_t) - \delta\left(y_{t-1} - \bar{y}_{t-1}\right)\right) - \varepsilon_t^A\right).\end{aligned} \tag{36}$$

The natural rates of real variables evolve as functions of the exogenous shocks. From (33) and (34), the natural output and real interest rate are:

$$\bar{y}_t = (1-\alpha)\bar{n} + a_t, \tag{37}$$

$$\bar{r}_t = \rho - \theta\left(1-\eta_A\right)a_t + \left(1-\eta_C\right)v_t^C. \tag{38}$$

Thus, deviations of real output from its natural rate depend on the current nominal interest

[6]The assumption of $AR(1)$ processes could be generalized to $AR(n)$ processes without affecting the qualitative nature of the results, as only the unanticipated components of these shocks affect deviations of real and nominal variables from their natural rates.

rate, expected future inflation, and shocks to the natural real interest rate. Inflation dynamics are determined by the DEANKPC (36).

Our model displays richer inflation dynamics than the standard "new Keynesian" model, stemming from the interaction of staggered price-setting and labor market rigidities. These dynamics are captured in the DEANKPC, where inflation depends not only on expectations of future inflation but also on past inflation and the persistence of unemployment and output deviations. This contrasts with standard New Keynesian Phillips Curves, which lack such explicit links to unemployment persistence. Understanding these dynamics requires solving the model under a Taylor rule, which introduces nominal interest rate adjustments to stabilize inflation and output.

2.7 Analytical Solution of the Model under a Taylor Rule

In order to solve the model one needs an assumption about the determination of the nominal interest rate. We shall assume that this is determined by the central bank, which follows a Taylor (1993) rule of the form,

$$i_t = \bar{r}_t + \pi^* + \phi_\pi(\pi_t - \pi^*) + \phi_y(y_t - \bar{y}_t) + \varepsilon_t^i, \tag{39}$$

where $\phi_\pi, \phi_y > 0$ are policy parameters, and ε_t^i is a white noise monetary policy shock.

The rule specifies that the central bank adjusts the nominal interest rate to stabilize inflation and output by targeting deviations from their respective natural rates.[7]

Substituting the Taylor Rule (39) into the IS equation (35) and using the DEANKPC (36) to substitute for output deviations, we derive an inflation equation in terms of inflation, real shocks, and monetary shocks. This transformed inflation process is:

$$\begin{aligned}\hat{\pi}_t =& E_{t-1}\hat{\pi}_t + \kappa_1\left(E_t\hat{\pi}_{t+1} - E_{t-1}\hat{\pi}_{t+1}\right) \\ &- \kappa_2\left[\kappa_3\left(\phi_\pi\left(\hat{\pi}_t - \delta\hat{\pi}_{t-1}\right) - \left(E_t\hat{\pi}_{t+1} - \delta E_{t-1}\hat{\pi}_t\right) + \varepsilon_t^i - \delta\varepsilon_{t-1}^i\right) + \varepsilon_t^A\right],\end{aligned} \tag{40}$$

where $\hat{\pi}_t = \pi_t - \pi^*$ is the deviation of inflation from the central bank's target, and the coefficients are defined as:

$$\kappa_1 = \frac{\beta\gamma}{\gamma + (1-\gamma)(1-\beta\gamma)\omega}, \quad \kappa_2 = \frac{(1-\gamma)(1-\beta\gamma)\omega}{\gamma + (1-\gamma)(1-\beta\gamma)\omega}, \quad \kappa_3 = \frac{\alpha}{1-\alpha}\frac{1}{\theta(1-\delta)+\phi_y}. \tag{41}$$

The degree of price stickiness (γ) plays a crucial role in shaping the inflation process, as reflected

[7] The Taylor rule is expressed in terms of output deviations, but using the Okun-type relation (22), equivalent results hold for unemployment deviations. The central bank also adjusts to shocks affecting the natural real interest rate, $\bar{r}_t$, which is not constant.

in the definitions of κ_1 and κ_2. As γ increases, κ_1 rises, amplifying the influence of forward-looking inflation expectations, while κ_2 falls, reducing the immediate sensitivity of inflation to real shocks. The interplay between γ – through κ_1 and κ_2 – and these mechanisms becomes more evident in Section 3, where we numerically simulate the model's response to monetary and real shocks. Moreover, the implications of γ for inflation persistence and the central bank's role in moderating these dynamics are explored further in Section 4, emphasizing how structural parameters influence equilibrium adjustments.

Taking expectations of (40) conditional on information available up to $t-1$ yields:

$$E_{t-1}\hat{\pi}_t = \frac{1}{\delta+\phi_\pi}E_{t-1}\hat{\pi}_{t+1} + \frac{\delta\phi_\pi}{\delta+\phi_\pi}\hat{\pi}_{t-1} + \frac{\delta}{\delta+\phi_\pi}\varepsilon^i_{t-1}. \tag{42}$$

The process (42) is stable if and only if:

$$\frac{1+\delta\phi_\pi}{\delta+\phi_\pi} < 1 \tag{43}$$

It is straightforward to show that a necessary and sufficient condition for (43) to hold is that,

$$\phi_\pi > 1. \tag{44}$$

Condition (44), known as the *Taylor principle*, ensures that nominal interest rates respond strongly enough to deviations of inflation from its target to stabilize inflation expectations. If (44) holds, the expected inflation process has two roots: δ (the smaller root) and ϕ_π (the larger root). Solving (42), we find:

$$E_{t-1}\hat{\pi}_t = \delta\hat{\pi}_{t-1} + \frac{\delta}{\phi_\pi}\varepsilon^i_{t-1}. \tag{45}$$

Using (45), current and future expected inflation can be expressed as:

$$\begin{gathered} E_{t-1}\hat{\pi}_{t+1} = \delta E_{t-1}\hat{\pi}_t \\ E_t\hat{\pi}_{t+1} = \delta\hat{\pi}_t + \tfrac{\delta}{\phi_\pi}\varepsilon^i_t \end{gathered} \tag{46}$$

Substituting (45) and (46) into (40), the rational expectations solution for inflation is:

$$\hat{\pi}_t = \delta\hat{\pi}_{t-1} - \psi_1\varepsilon^A_t - \psi_2\varepsilon^i_t + \psi_3\varepsilon^i_{t-1}, \tag{47}$$

where:

$$\psi_1 = \frac{\kappa_2}{\phi_\pi \kappa_2 \kappa_3 - \delta(\kappa_1 + \kappa_2 \kappa_3) + 1}, \quad \psi_2 = \frac{(\phi_\pi - \delta)\kappa_2\kappa_3 - \delta\kappa_1}{\phi_\pi(\phi_\pi \kappa_2 \kappa_3 - \delta(\kappa_1 + \kappa_2\kappa_3) + 1)}, \quad \psi_3 = \frac{\delta}{\phi_\pi}. \tag{48}$$

The parameters ψ_1, ψ_2, and ψ_3 encapsulate the influence of key structural and policy parameters - δ, ϕ_π, and γ - on inflation dynamics. As γ increases, ψ_1 decreases, reducing the sensitivity of inflation to productivity shocks (ε_t^A) due to the dampening effect of price stickiness on real shocks. In contrast, ψ_2 and ψ_3 increase with γ, reflecting the heightened influence of monetary policy shocks (ε_t^i) and the amplification of forward-looking expectations. The central bank's inflation responsiveness (ϕ_π) plays a stabilizing role, as a higher ϕ_π reduces the inflationary effect of monetary shocks by anchoring expectations more effectively. Meanwhile, the persistence parameter (δ) governs the degree to which past inflation influences current dynamics, introducing an additional layer of inertia.

So, the rational expectations solution of the model under the Taylor rule results in inflation persistence. In Appendix 6, we show that inflation persistence is not unique to the Taylor rule but also characterizes the optimal time-consistent monetary policy. This reflects the central bank's deliberate strategy to allow inflation fluctuations to mitigate deviations of unemployment from its natural rate. Notably, while inflation persistence arises under optimal policy, it does not affect the persistence of unemployment, as wage setters internalize anticipated inflation in their expectations. Having solved for inflation, the solution of the rest of the model is straightforward.

Substituting the Taylor rule (39) into the IS relation (35), using the solution for inflation (47), and solving out for $\hat{y}_t$, and we get the rational expectations solution for the output gap:

$$\hat{y}_t = \delta \hat{y}_{t-1} + \frac{1}{\theta(1-\delta) + \phi_y}\left(\xi_1 \varepsilon_t^A - \xi_2 \varepsilon_t^i\right) \tag{49}$$

where:

$$\xi_1 = (\phi_\pi - \delta)\psi_1, \quad \xi_2 = 1 - \psi_3 - (\phi_\pi - \delta)\psi_2. \tag{50}$$

Using the Okun relation (22) in conjunction with (49), we can solve for the fluctuations of the unemployment rate around its natural rate as

$$\hat{u}_t = \delta \hat{u}_{t-1} - \frac{1}{(1-\alpha)(\theta(1-\delta) + \phi_y)}\left(\xi_1 \varepsilon_t^A - \xi_2 \varepsilon_t^i\right), \tag{51}$$

Finally, using the Fisher equation (30) and the Taylor rule (39), we obtain the rational expectations solutions for the real and nominal interest rates:

$$\hat{r}_t = \delta \hat{r}_{t-1} - \frac{\theta(1-\delta)}{\theta(1-\delta)+\phi_y}\left(\xi_1 \varepsilon_t^A - \xi_2 \varepsilon_t^i\right), \tag{52}$$

$$i_t = \delta i_{t-1} + (1-\delta)(\rho + \pi^*) - \lambda_1 \varepsilon_t^A + \lambda_2 \varepsilon_t^i, \tag{53}$$

where:

$$\lambda_1 = \phi_\pi \psi_1 - \frac{\phi_y}{\theta(1-\delta)+\phi_y}\xi_1, \quad \lambda_2 = 1 - \phi_\pi \psi_2 - \frac{\phi_y}{\theta(1-\delta)+\phi_y}\xi_2. \tag{54}$$

Fluctuations in nominal variables, such as inflation, and real variables, such as output and unemployment deviations from their natural rates, exhibit the same degree of persistence. This arises from the conflicting objectives of the central bank and labor market insiders. While the central bank aims to stabilize inflation and output deviations via the Taylor rule, labor market insiders prioritize securing wages aligned with their employment goals, which depend on lagged employment and the natural rate. The resulting tension forces wage setters to adapt their inflationary expectations to the central bank's policy. As nominal interest rates respond to persistent output deviations, inflation and its expectations also display persistence, mirroring the dynamics of output and unemployment.[8]

The analytical solution of the model under the Taylor rule highlights how structural parameters, such as γ (price stickiness), δ (persistence), and policy responsiveness (ϕ_π), interact to shape inflation dynamics and the model's equilibrium properties. These relationships underpin the rich inflation responses explored in the subsequent sections. Section 3 numerically simulates the model's dynamic adjustment paths to nominal and real shocks, illustrating the relative contributions of forward-looking expectations and unemployment persistence to inflation dynamics. Section 4 delves deeper into the mechanisms driving these responses, emphasizing the moderating role of monetary policy and the structural determinants of inflation persistence. Finally, the Appendix 6 examines the implications of these dynamics for the model's stability and determinacy, offering a comprehensive perspective on the interaction between structural parameters and policy rules. Together, these sections provide a holistic view of the mechanisms and implications of the modelâs inflation dynamics.

2.8 Inflation Stabilization and the Divine Coincidence

It is important to note that, unlike the benchmark "new Keynesian" model with staggered prices and wages, this model is not characterized by the "divine coincidence" of output stabilization when inflation itself is stabilized. Stabilization of inflation around the target inflation rate of the central bank does not automatically lead to output and employment stabilization around their "natural rates".

[8]This point is elaborated in Alogoskoufis (2018) in the context of a simpler insider outsider model.

This is because of the labor market distortions implied by the wage setting behavior of insiders.[9]

To see this assume that the central bank allows its response to deviations of inflation from its target ϕ_π to become infinite. Then, from the definition of the ψ 's in (48), ψ_1, ψ_2 and ψ_3 would be driven to zero, and neither nominal nor real shocks would affect inflation. Inflation would converge to the target rate of the central bank π^*, and the variance of inflation would driven to zero. Inflation would thus be fully stabilized.

However, from (49) and (51), real shocks would continue to affect deviations of real output and unemployment and output from their "natural rates", even if ϕ_π is driven to infinity.

Thus, the "divine coincidence" does not hold in this model. In the presence of real shocks, inflation stabilization does not result in unemployment and output stabilization, as there is always a tradeoff between the stabilization of inflation and the stabilization of unemployment around its "natural rate" in the presence of real shocks.

The "divine coincidence" also has important implications for monetary policy analysis in a "new keynesian" framework. As shown by Alogoskoufis and Giannoulakis (2025), the optimal monetary policy rule in the context of the benchmark "new Keynesian" model, due to the "divine coincidence" between output and inflation, is the Fisher rule of absolute inflation stabilization. When the "divine coincidence" does not apply, as in the model of this paper, the optimal monetary policy rule takes the form of a Taylor rule, the parameters of which depend on the structural and policy parameters of the model.

3 A Dynamic Simulation of the Model

To evaluate the dynamic properties of the model, we simulate it for specific parameter values and present the corresponding impulse response functions. These simulations highlight how staggered pricing and unemployment persistence interact to shape inflation dynamics, showcasing the distinctive features of the DEANKPC framework. By comparing alternative scenarios, we emphasize how the model extends beyond standard New Keynesian predictions, offering deeper insights into inflation persistence and the transmission of shocks.

The simulations use the following parameter values: $\beta = 0.99$, $\varepsilon = 6$, $\theta = 2/3$, $a = 1/3$, $\gamma = 2/3$, $\phi_\pi = 1.50$, $\phi_y = 0.125$, and $\delta = 0.52$. The persistence parameter δ reflects the estimated persistence of unemployment in the EU during 1999Q1-2022Q3, derived from an AR(2) process on deviations of unemployment from its natural rate, with the latter approximated using a Hamilton (2018) filter.

[9] See Blanchard and Gali (2007) for a discussion of the "divine coincidence". In order to deal with this problem in the benchmark new Keynesian model with staggered prices and wages, one has to superimpose ad hoc additional labor market distortions. This is not the case with the model in this paper, as labor market distortions are part and parcel of the model and not an afterthought.

Inflation is expressed as percentage deviations from the central bank's target rate, assumed to be zero for simplicity. The impulse response functions explore three scenarios: a baseline case with flexible prices ($\gamma = 0$), a staggered price case ($\gamma = 2/3$), and a staggered price case with zero unemployment persistence ($\delta = 0$).

Figure 1 depicts the responses to a 1% productivity shock. Under both flexible ($\gamma = 0$, blue lines) and staggered pricing ($\gamma = 2/3$, red lines), inflation initially decreases due to lower production costs, while output rises above its natural rate. Nominal and real interest rates, as well as unemployment, fall below their respective steady-state natural levels. However, the magnitude and persistence of these responses differ significantly across scenarios. Flexible pricing results in larger and more immediate adjustments, while staggered pricing dampens these effects by delaying price adjustments. When unemployment persistence is introduced, the effects of the productivity shock become more prolonged, as labor market frictions sustain deviations in real activity. Without unemployment persistence ($\delta = 0$, black dotted lines), the persistence of all variables vanishes, and the model behaves as if facing an *iid* shock.

Figure 2 presents the impulse response functions of the model following an unanticipated temporary 1% shock to the nominal interest rate i_t. Such a nominal shock does not affect the "natural rates" of real variables, which depend solely on real shocks. While the responses of real variables, such as output and unemployment, are qualitatively similar under flexible and staggered prices, the inflation dynamics differ markedly. Under flexible prices (blue line), inflation initially falls due to reduced aggregate demand, as firms lower prices to maintain market equilibrium. In contrast, under staggered pricing (red line), inflation initially rises.

This counterintuitive inflationary response arises from the interaction of forward-looking price-setting behavior and unemployment persistence. A contractionary monetary shock reduces aggregate demand, prompting firms that can reset prices to lower them to retain market share. However, firms also anticipate future recovery in aggregate demand. Because the Calvo (1983) Pricing Model restricts their ability to reset prices in subsequent periods, firms preemptively raise prices in anticipation of future demand recovery. This forward-looking behavior amplifies inflation dynamics when γ is high, as fewer firms can adjust prices immediately, making current price-setting more dependent on expectations of future conditions.

The degree of price stickiness (γ) plays a pivotal role in shaping inflation dynamics, particularly through its interaction with unemployment persistence (δ). When γ is high (e.g. 2/3, red solid line in Figure 2), most firms are unable to adjust their prices immediately. This constraint amplifies the role of forward-looking expectations in determining inflation. Firms that can reset prices anticipate future demand recovery as unemployment deviations persist and gradually dissipate due to structural

Figure 1: Impulse Response Functions following a 1% Unanticipated Persistent Shock to Productivity

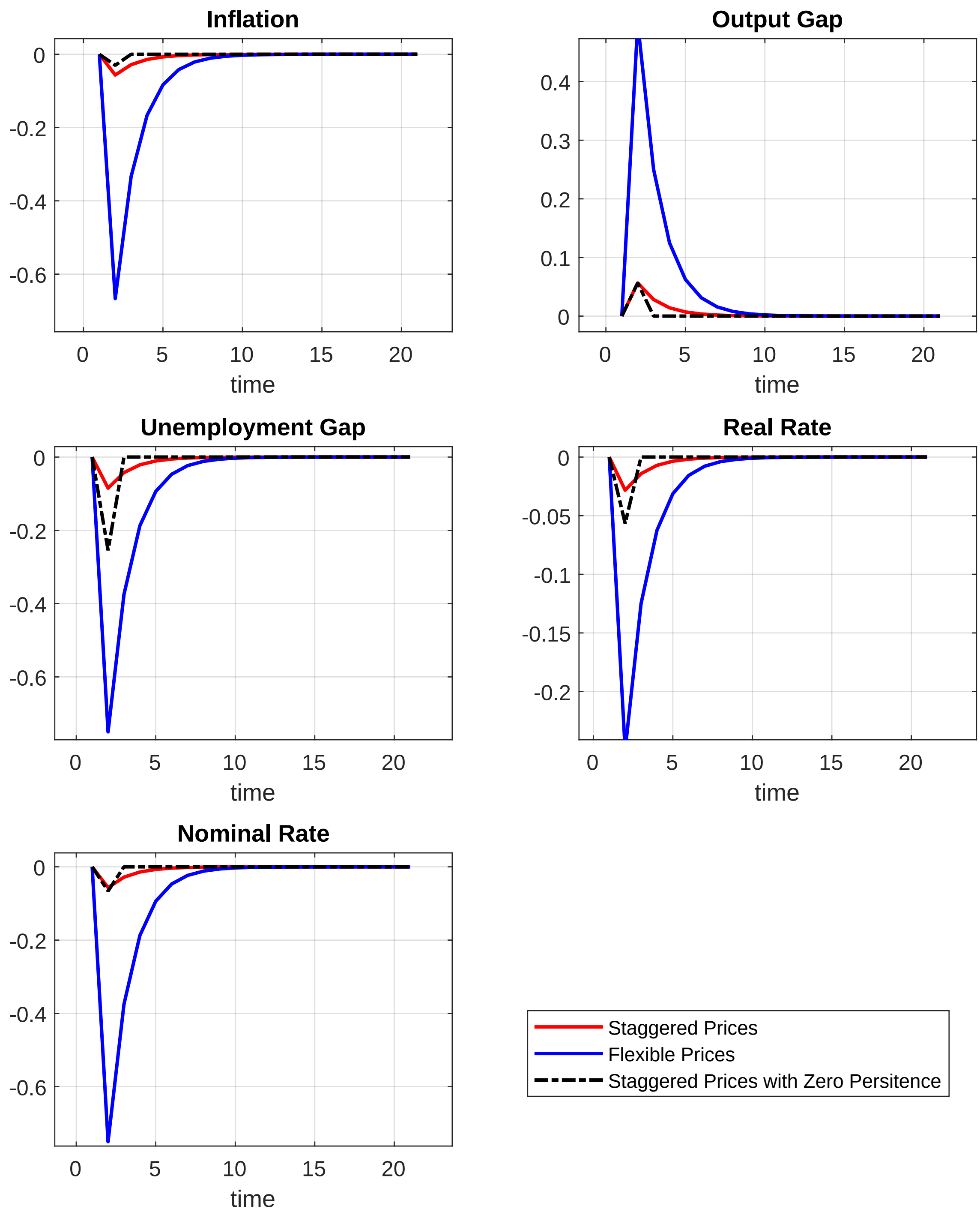
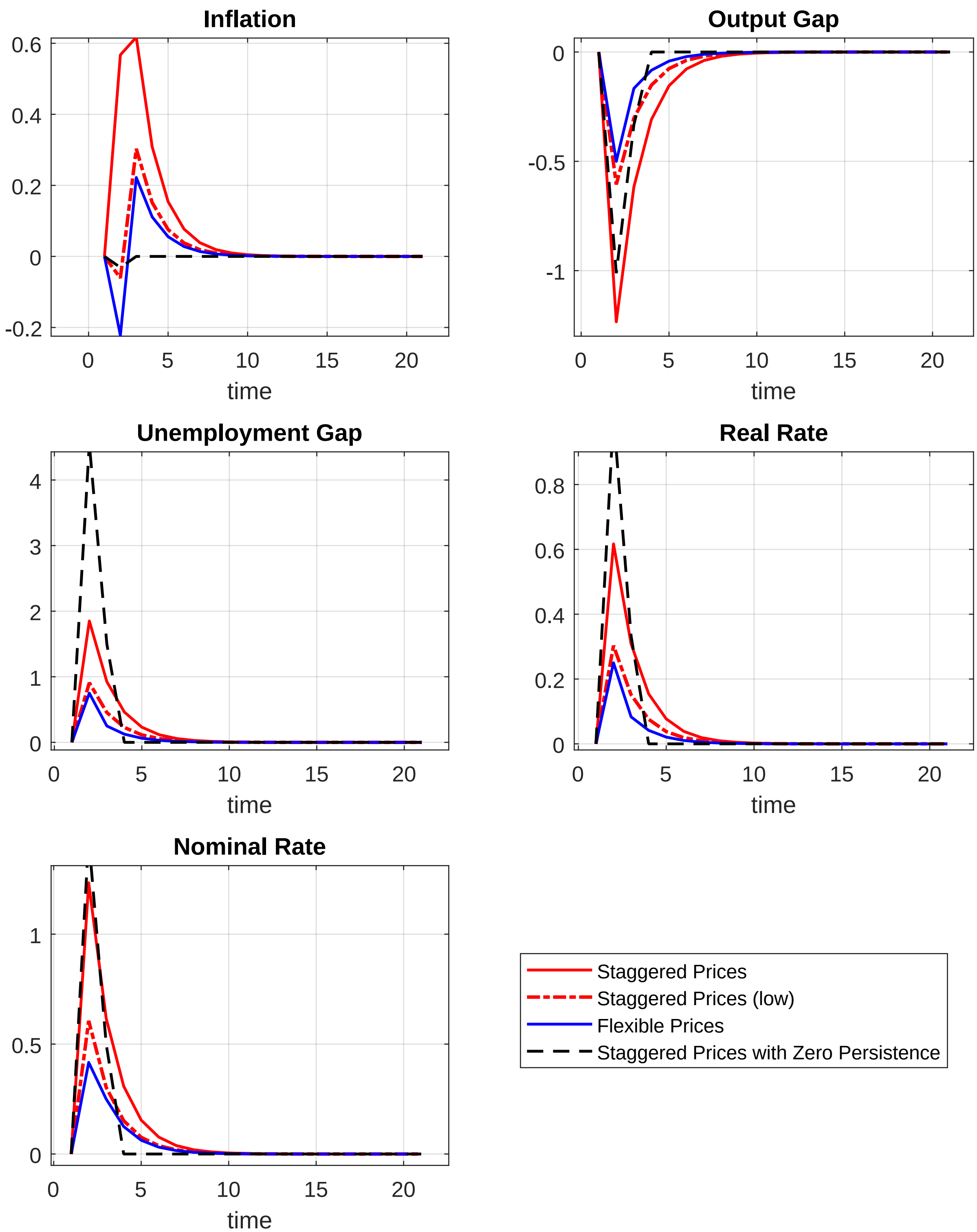


Figure 2: Impulse Response Functions following a 1% Unanticipated Persistent Shock to Nominal Interest Rate



labor market frictions. These firms raise their current prices to account for expected future inflation, creating prolonged inflationary pressures. The persistence of unemployment sustains deviations in real activity, which acts as a bridge between real and nominal variables, reinforcing the inflationary effects of forward-looking price-setting behavior.

Conversely, when γ is low (e.g. 0.1, red dashed line in Figure 2), a larger fraction of firms adjust prices immediately, reducing the influence of forward-looking expectations on inflation dynamics. In this case, persistent unemployment exerts a more direct effect on inflation through suppressed aggregate demand. As unemployment persists, household income and consumption decline, lowering aggregate demand and prompting firms to reduce prices to maintain market share. This dynamic leads to an initial decline in inflation, as the downward pressure from subdued real activity outweighs any inflationary force from forward-looking behavior. The interplay between γ and δ thus governs whether inflation rises or falls after a nominal shock, revealing how structural parameters shape the relative importance of forward-looking expectations versus real activity persistence.[10]

The inflation dynamics of the model are driven by the interaction between staggered pricing and labor market persistence, formalized in detail in Section 4. These dynamics reveal a key trade-off for policymakers: high γ (greater price stickiness) amplifies inflation persistence and necessitates stronger monetary responses, but this can exacerbate deviations in real activity due to persistent unemployment. Conversely, low γ (greater price flexibility) reduces inflation persistence but increases vulnerability to deflationary pressures from real activity deviations. Effective monetary policy must balance inflation stabilization with minimizing disruptions to real activity, accounting for the structural features of both product and labor markets.

4 Mechanics of Inflation Responses to Monetary Policy

This section provides a detailed explanation of the inflationary response to a positive nominal interest rate shock, complementing the dynamic simulations presented in Section 3. The inflation dynamics are governed by the Dynamic Expectations-Augmented New Keynesian Phillips Curve (DEANKPC), presented in Equation (27) of the manuscript:

$$\hat{\pi}_t = E_{t-1}\hat{\pi}_t + \kappa_1 \left(E_t\hat{\pi}_{t+1} - E_{t-1}\hat{\pi}_{t+1} \right) - \kappa_2 \left\{ a \left[(u_t - \bar{u}) - \delta(u_{t-1} - \bar{u}) \right] - \varepsilon_t^A \right\}. \tag{55}$$

[10] The degree of staggered stickiness, γ, determines whether forward-looking inflationary effects outweigh the deflationary effects of unemployment persistence. Numerical simulations reveal a critical threshold of $\gamma = 0.12$: below this value, deflationary effects dominate, leading to an initial decline in inflation after a nominal shock, while above it, forward-looking inflationary responses prevail.

The coefficients are defined as:

$$\kappa_1 = \frac{\beta\gamma}{\gamma + (1-\gamma)(1-\beta\gamma)\omega}, \quad \kappa_2 = \frac{(1-\gamma)(1-\beta\gamma)\omega}{\gamma + (1-\gamma)(1-\beta\gamma)\omega},$$

where $\kappa_1 > 0$ increases with the degree of price stickiness γ, while $\kappa_2 > 0$ decreases with γ.

The inflation dynamics in Equation (61) reflect three components. The first term, $A = E_{t-1}\hat{\pi}_t$, represents prior expectations of current inflation. The second term, $B = (E_t\hat{\pi}_{t+1} - E_{t-1}\hat{\pi}_{t+1})$, captures unanticipated future inflation driven by forward-looking price-setting behavior. The third term, $C = \{a\left[(u_t - \bar{u}) - \delta(u_{t-1} - \bar{u})\right] - \varepsilon_t^a\}$, reflects the role of real economic activity comprising unemployment persistence and productivity shocks.

According to Equation (45), the A-term can be expanded as:

$$A = E_{t-1}\hat{\pi}_t = \delta\hat{\pi}_{t-1} + \frac{\delta}{\phi_\pi}\varepsilon_{t-1}^i. \tag{56}$$

At $t = 1$, when a nominal shock ε_t^i realizes, $A = 0$.

Similarly, according to Equation (46), the B-term can be expanded as:

$$B = E_t\hat{\pi}_{t+1} - E_{t-1}\hat{\pi}_{t+1} = \delta(\hat{\pi}_t - \delta\hat{\pi}_{t-1}) + \frac{\delta}{\phi_\pi}(\varepsilon_t^i - \delta\varepsilon_{t-1}^i). \tag{57}$$

At $t = 1$, this simplifies to:

$$B = \delta\hat{\pi}_t + \frac{\delta}{\phi_\pi}\varepsilon_t^i.$$

Using (56) and (57), the DEANKPC (61) at $t = 1$ simplifies to:

$$\hat{\pi}_t = \frac{\delta\kappa_1}{(1-\delta\kappa_1)\phi_\pi}\varepsilon_t^i + \frac{\kappa_2}{(1-\delta\kappa_1)}(-C) = w_B\varepsilon_t^i + w_C(-C). \tag{58}$$

where $w_B > 0$ and $w_C > 0$ are the weights of the two driving forces of inflation dynamics: forward-looking inflation expectations and unemployment persistence.

Equation (58) demonstrates that inflation dynamics after a nominal interest rate shock (ε_t^i) are influenced by two opposing forces.

The first force, captured by $w_B\varepsilon_t^i$, reflects the inflationary pressure arising from unanticipated changes in future inflation expectations. When a nominal shock ε_t^i occurs, it alters the path of expected future inflation, as agents revise their expectations about the economy's trajectory. This adjustment in expectations is particularly impactful in models with forward-looking price-setting behavior, such as the DEANKPC.

The second force, captured by $w_C(-C)$, reflects the inflationary impact of unemployment persistence. A positive nominal shock (ε_t^i) indirectly increases C by raising unemployment above its natural rate ($u_t - \bar{u} > 0$), creating an initial deflationary force as reduced output and higher unemployment dampen price pressures. Due to persistence (δ), unemployment deviations dissipate gradually, allowing C to transition from negative to positive over time as the economy recovers. This delayed positive contribution amplifies inflation in later periods, highlighting how unemployment persistence extends the inflationary response to nominal shocks by prolonging the adjustment process in the labor market.

The degree of price stickiness, γ, plays a pivotal role in shaping the relative strength of the two forces driving inflation dynamics. A higher γ increases w_B, amplifying the forward-looking channel. Greater price stickiness implies that fewer firms can adjust prices immediately, making future inflation expectations more influential in current price-setting decisions. As a result, inflation becomes more sensitive to forward-looking elements, intensifying the inflationary response to nominal shocks through the term $w_B\varepsilon_t^i$. Conversely, as γ increases, w_C decreases, attenuating the deflationary impact of unemployment persistence. With higher price stickiness, the influence of real activity and unemployment persistence on inflation diminishes, as firms' limited ability to adjust prices reduces their responsiveness to changes in current economic conditions.

To illustrate these dynamics, a numerical exercise was conducted to evaluate how γ affects the weights w_B and w_C in Equation (58). Figure 3 demonstrates that as γ increases, the weight on forward-looking expectations (w_B) rises, while the weight on unemployment persistence (w_C) diminishes. For low values of γ, the deflationary impact of unemployment persistence ($w_C(-C)$) dominates the inflationary force of unanticipated changes in future inflation expectations ($w_B\varepsilon_t^i$). This dynamic causes inflation to initially decrease in response to a positive nominal shock, as the unemployment gap widens and real activity contracts. Over time, as unemployment gradually recovers due to persistence, inflation begins to rise. In contrast, for high values of γ, the inflationary effect of forward-looking expectations ($w_B\varepsilon_t^i$) outweighs the deflationary pressure from unemployment persistence, leading to an immediate rise in inflation following a nominal interest rate shock. A numerical exercise has revealed, that the critical value of $\gamma = 0.12$ reflects the point at which the influence of forward-looking expectations begins to outweigh the effects of unemployment persistence, shifting the dynamics of inflation responses to nominal shocks.

While γ primarily drives the observed inflation dynamics, the central bank's responsiveness to inflation, encapsulated by ϕ_π, acts as a crucial moderating factor. A higher ϕ_π reflects a more aggressive monetary policy stance, reducing inflationary pressures arising from unanticipated changes in future inflation expectations ($w_B\varepsilon_t^i$). By anchoring inflation expectations more effectively, ϕ_π curtails the potential for inflation to escalate following a positive nominal shock. However, the central bank's influence on the persistence of unemployment deviations remains constrained, as w_C is structurally determined by γ and inherent labor market rigidities.

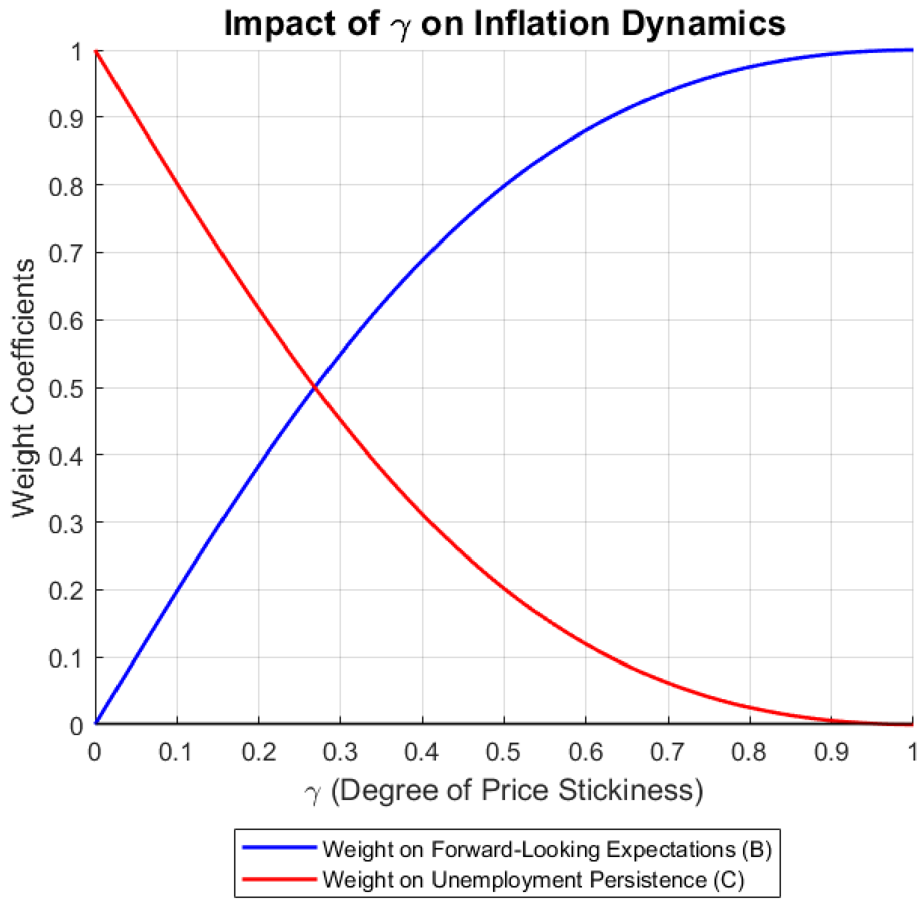


Figure 3: Impact of γ on Inflation Dynamics

Notes: The figure illustrates how the degree of price stickiness (γ) affects the weights w_B and w_C in Equation (58), which capture the relative contributions of forward-looking expectations and unemployment persistence to inflation dynamics after a nominal interest rate shock. As γ increases, the weight on forward-looking expectations (w_B) grows, amplifying the inflationary response through anticipated future inflation. Conversely, the weight on unemployment persistence (w_C) diminishes, reducing the deflationary impact of real activity deviations.

Furthermore, as discussed in Appendix 6, ϕ_π must exceed a critical threshold to ensure the model's determinacy. This threshold decreases with higher γ, reflecting the stabilizing effect of greater price stickiness on inflation dynamics. These findings highlight how structural characteristics of the economy, such as price stickiness and forward-looking behavior, influence the design of effective monetary policies aimed at ensuring both stability and determinacy.

This analysis demonstrates how structural features such as price stickiness and unemployment persistence interact to shape inflation dynamics following nominal shocks. The interplay between γ and δ introduces trade-offs for policymakers, where high γ amplifies forward-looking inflationary responses and necessitates aggressive monetary interventions, while low γ reduces inflation persistence but exposes the economy to deflationary pressures from real activity deviations. These dynamics, explored further in Section 3, highlight the importance of designing monetary policies that balance inflation stabilization with minimizing disruptions to real activity. The moderating role of monetary policy, captured by ϕ_π, further underscores the need for tailored approaches in addressing inflation persistence in economies with significant price stickiness and labor market frictions.

5 An Empirical Appraisal of the DEANKPC

The model put forward in this paper results in a *dynamic expectations-augmented new Keynesian Phillips Curve* (equation 36) that deviates importantly from the *benchmark* NKPC. Previous tests of the empirical performance of the *benchmark* NKPC revealed the (statistically) significant impact of lagged inflation on current inflation, leading to a rejection of the *benchmark* NKPC in favor of a *hybrid* one with ad hoc lagged inflation terms. The DEANKPC we propose in this study allows current inflation to depend on the past values of unemployment (and thus of inflation) endogenously and not through the addition of ad hoc lagged inflation terms. In addition, the DEANKPC allows current inflation to depend on both prior expectations for current inflation and current expectations for future inflation, encompassing the characteristics of both the *expectations-augmented Phillips Curve* and the *benchmark NKPC*.

A natural question that may arise here is whether the above two features make the DEANKPC to exhibit a better empirical performance than the *benchmark* and *hybrid* NKPCs. To this end, we are performing a comparative assessment of the empirical performance of the aforementioned three versions of the NKPCs using quarterly data for the Euro Area. Our approach consists of two steps. First, we perform an econometric estimation of the three NKPCs. Second, we evaluate the forecasting performance of these models by comparing their out-of-sample predictions using standard error metrics.

5.1 Econometric Estimation of Alternative NKPCs

Following Blanchard and Gali (2007), the *benchmark* and *hybrid* NKPCs can be expressed by the following econometric specifications:

Benchmark NKPC

$$\hat{\pi}_t = \alpha_0 + \alpha_1 E_t \hat{\pi}_{t+1} + \alpha_2 \hat{u}_t + \epsilon_t^{(1)} \tag{59}$$

Hybrid NKPC

$$\hat{\pi}_t = \beta_0 + \beta_1 \hat{\pi}_{t-1} + \beta_2 E_t \hat{\pi}_{t+1} + \beta_3 \hat{u}_t + \epsilon_t^{(2)} \tag{60}$$

Inflation is expressed in deviations from the monetary authorities' inflation target, while unemployment in deviations from its natural level.

According to the theory, the estimated values for the parameters of the above two reduced-form Phillips Curves should be as follows: α_1 and β_2 should be positive (as they correspond to the rate of time preference), α_2 and β_3 should be negative since unemployment is negatively related to inflation, and the persistence parameter β_1 should lie between 0 and 1 to ensure the stability of specification (5.1).

In the same spirit, we can express the DEANKPC (36) as follows:

$$[\hat{\pi}_t - E_{t-1}\hat{\pi}_t] = \gamma_0 + \gamma_1 [E_t \hat{\pi}_{t+1} - E_{t-1}\hat{\pi}_{t+1}] + \gamma_2 \hat{u}_t + \gamma_3 \hat{u}_{t-1} + \epsilon_t^{(3)} \tag{61}$$

The DEANKPC has two important differences from the *benchmark* and *hybrid* NCPCs. First, it is dynamic comprising a lagged unemployment term as a result of the endogenous persistence arising from the power of labor market insiders to periodically pre-set nominal wages, without full current information. This term offsets the ad hoc lagged inflation term of the hybrid NKPC. Second, the DEANKPC is expectations-augmented as it is expressed in terms of unanticipated inflation, i.e. deviations of current inflation from prior expectations for its level. This is due to the fact that nominal wages are set in advance, on the basis of the prior expectations of wage setters about current variables, and remain fixed for one period. Since current shocks to productivity and aggregate demand are not known when nominal wages are determined, unanticipated current inflation reduces real wages and causes employment to increase, like in the "original" models of the "expectations augmented Phillips curve".

For the estimation of specifications (59)-(61), we utilize data for the Euro Area at a quarterly frequency. The data for inflation (measured as the annualized quarterly change of the CPI) and unemployment rates were obtained from the database of the Organization for Economic Cooperation and Development (OECD). We model $\hat{\pi}_t$ as the difference between the current inflation rate (from OECD) and the European Central Bank (ECB)'s inflation target of 2%. We approximate the deviation of the unemployment rate from its natural level, $\hat{u}_t$, by using the Hamilton (2018) filter.[11]

Finding the appropriate proxy for inflation expectations is a more complex issue. There are two main approaches in the relevant literature. The first one utilizes survey data based on questionnaires to consumers or firms about their expectations on the evolution of inflation (see for instance Roberts

[11]The Hamilton (2018) filter avoids the two-sided nature of the Hodrick and Prescott (2019) filter, which relies on future data and introduces a forward-looking bias. Unlike the HP filter, the Hamilton filter estimates the trend based on a rolling regression, making it more suitable for real-time analysis.

(1995)). The most widespread source for such data for the Euro Area is the *Consumer Expectations Survey (CES)* of the ECB. An important drawback of this survey is that comprises data up to one year ahead inflation expectations. However, the presence of the deviations of current from past expectations for future inflation, $[E_t\hat{\pi}_{t+1} - E_{t-1}\hat{\pi}_{t+1}]$, in the DEANKPC requires data for two years ahead inflation expectations for its proper estimation.

The second approach utilizes inflation forecasts from central banks as proxies for inflation expectations. Building on the work of Brissimis and Magginas (2008) and Zhang et al. (2009), we proxy inflation expectations by using ECB's inflation forecasts, obtained from the *Survey of Professional Forecasters (SPF)*. An important advantage of these forecasts is that they are available for both the short- and the long-term (there are available forecasts for up to five years ahead inflation). The data is available at quarterly frequency for the period 1999Q1-2022Q3.

Therefore, we utilize ECB's one-year ahead inflation forecast as a proxy for the current expectations for future inflation, $E_t\hat{\pi}_{t+1}$. In the same spirit, $E_{t-1}\hat{\pi}_t$ and $E_{t-1}\hat{\pi}_{t+1}$, denoting the past expectations for the current and future inflation, are proxied by the lagged values of the one- and two-year ahead ECB's inflation forecasts, respectively.

To deal with potential measurement errors that may arise from the use of inflation forecasts as proxies for (unobservable) inflation expectations we utilize a two-stage GMM estimator with robust (heteroskedasticity- and autocorrelation-consistent, or HAC) standard errors. Following Brissimis and Magginas (2008), our instrument set includes lags of the (real-time) inflation, the output and unemployment gaps (obtained from the OECD Database), and of the change in Brent crude oil prices for Europe (obtained from the FRED Database). The number of lags was selected to ensure that the null hypothesis of joint instrument validity, as tested by the Hansen's J test for over-identifying restrictions, is not rejected in any of the estimated models. All variables were tested for unit roots (we employed the Augmented Dickey-Fuller Fisher type test).

Table 1 presents the results from the estimation of models (95)-(97). Starting with the *benchmark* and *hybrid* versions of the NKPC, we can see that the estimated coefficients of the parameters have the correct sign and are statistically significant. Current inflation is positively related with (one-year ahead) inflation expectations and negatively with the unemployment rate. Also, inflation exhibits significant persistence as the *hybrid* NKPC reveals.

Turning to the DEANKPC, we can see that unanticipated inflation is positively affected by the deviations of current from past expectations for future inflation. This relationship is notably stronger than the one between current and expected future inflation described by models (59) and (61). Moreover, the unanticipated inflation is negatively affected by the current but positively by the lagged unemployment rate. This means that (endogenous) unemployment persistence is solidly connected

Table 1: Estimation of Benchmark, Hybrid and Dynamic NKPC for the Euro Area

	Benchmark NKPC	**Hybrid NKPC**	**Dynamic EANKPC**
	$\hat{\pi}_t$	$\hat{\pi}_t$	$\hat{\pi}_t - E_t\hat{\pi}_t$
$\hat{\pi}_{t-1}$		0.521***	
		(0.089)	
$E_t\hat{\pi}_{t+1}$	1.523***	1.352***	
	(0.072)	(0.254)	
$E_t\hat{\pi}_{t+1} - E_{t-1}\hat{\pi}_{t+1}$			1.877***
			(0.102)
$\hat{u}_t$	-0.226***	-0.507**	-0.410***
	(0.082)	(0.158)	(0.143)
$\hat{u}_{t-1}$			0.210***
			(0.043)
R^2 **(uncentered)**	0.574	0.835	0.858
Hansen's J-Test	0.141	0.105	0.577

Notes: This table presents the estimation results for the *benchmark* (eq. 59), the *hybrid* (eq. 5.1) and the *dynamic expectations-augmented* NKPC (eq. 61). We utilize a two-stage GMM estimator to deal with potential measurement errors that may arise from the use of inflation forecasts as proxies for (unobservable) inflation expectations. Our instrument set includes lags of the (real-time) inflation, the output and unemployment gaps, and of the change in Brent crude oil prices for Europe. The statistic of the Hansen's J Test for over-identifying restrictions shows that the null hypothesis of the joint validity of all instruments is not rejected for any of the estimated models. We use robust (heteroskedasticity- and autocorrelation-consistent) standard errors. The intercepts of models (59)-(61) were excluded from the analysis as they are not justified by the theory.

with unanticipated inflation as our theoretical model suggests.[12]

5.2 Forecasting Performance of Alternative NKPCs

To further evaluate the empirical performance of the models, we conduct an out-of-sample forecasting analysis. Specifically, we divide the sample into two periods: the *training sample* (1999Q1–2016Q4) and the *testing sample* (2017Q1–2022Q3). Using the parameter estimates obtained from the training sample, we generate out-of-sample forecasts for the testing sample and compare the models based on two standard metrics: the Root Mean Square Error (RMSE) and the Mean Absolute Error (MAE).

Table 2 summarizes the forecasting performance of the three NKPC specifications, while Figure 4 visually compares the predicted inflation paths with the actual inflation during the testing period.

Figure 4 illustrates the predictive performance of the three models relative to actual inflation during the testing period. The benchmark NKPC struggles to capture turning points in inflation, particularly

[12] The explanatory power of the DEANKPC is at least as good as that of the *benchmark* and *hybrid* versions of the NKPC, as the R^2 implies. Of course, R^2 is a very loose measure of the goodness of fit for GMM estimators since it is not bounded between 0 and 1 as for OLS estimators.

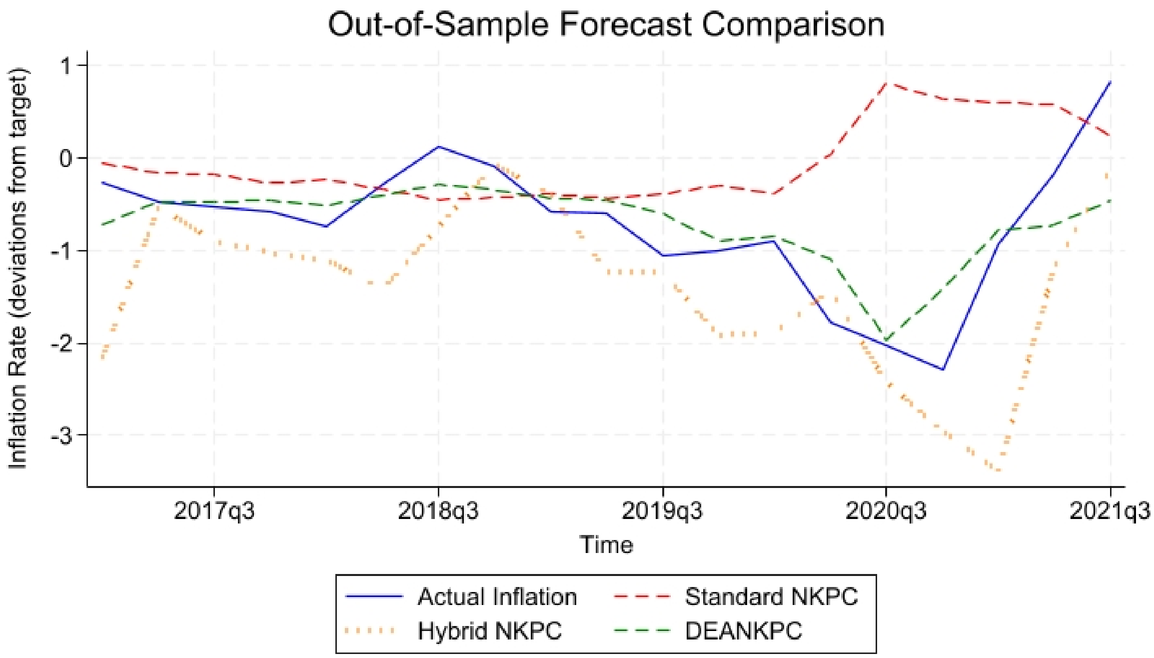


Figure 4: Out-of-Sample Forecast Comparison of NKPC Models

Notes: This Figure compares the out-of-sample inflation forecasts generated by the *benchmark* (eq. 59), the *hybrid* (eq. 5.1), and the *dynamic expectations-augmented* NKPC (eq. 61) for the testing period (2017Q1–2022Q3). The forecasts are based on parameter estimates obtained from the training sample (1999Q1–2016Q4). The figure shows how closely each model tracks actual inflation dynamics, with the DEANKPC consistently providing a closer fit to the observed data.

during periods of sharp movements. For instance, after 2020Q1, when actual inflation begins to decline markedly, the benchmark NKPC forecasts continue to rise. This overestimation reflects the model's inability to adapt to changes in inflation dynamics, as it relies solely on forward-looking expectations and the unemployment gap without incorporating persistence or adjustment mechanisms. Consequently, the benchmark NKPC fails to reflect the downward momentum of inflation, misaligning with observed data during this phase.

The hybrid NKPC improves upon the benchmark by introducing a lagged inflation term, which helps account for inflation persistence and produces a closer approximation to the observed path. However, the hybrid model tends to overreact to sharp movements in inflation. This behavior is evident after 2020Q1, where the hybrid NKPC forecasts a steeper decline in inflation than what is observed in the data. The reliance on the lagged inflation term amplifies recent trends excessively, causing the model to overshoot during periods of rapid inflation adjustments. While the hybrid NKPC performs better than the benchmark, its inability to moderate its response undermines its predictive accuracy in such instances.

In contrast, the DEANKPC tracks inflation dynamics with far greater precision, particularly during periods of volatility and turning points. After 2020Q1, when actual inflation declines, the DEANKPC forecasts follow this downward trajectory closely, avoiding the overestimation seen in the hybrid NKPC and the persistent rise forecasted by the benchmark NKPC. The dynamic structure of the DEANKPC, which incorporates the lagged unemployment gap as an endogenous source of persistence, allows it to respond more flexibly to changes in inflation. Additionally, the inclusion of deviations between current and past expectations for future inflation enhances the model's ability to adapt to inflation shocks in a measured and realistic manner. This feature proves especially valuable in periods of significant adjustments, as it enables the DEANKPC to capture both inflation persistence and turning points effectively.

Table 2: Forecasting Performance of the Benchmark, Hybrid, and DEANKPC

Model	**RMSE**	**MAE**
Standard NKPC	1.159	0.808
Hybrid NKPC	0.945	0.729
DEANKPC	**0.458**	**0.324**

Notes: This Table presents the out-of-sample forecasting performance of the *benchmark* (eq. 59), the *hybrid* (eq. 5.1), and the *dynamic expectations-augmented* NKPC (eq. 61). The sample is split into the training period (1999Q1–2016Q4) and the testing period (2017Q1–2022Q3). Forecasts are generated using parameter estimates from the training sample, and performance is evaluated using RMSE and MAE. Lower values indicate better predictive accuracy, with the DEANKPC outperforming the other specifications.

The superior performance of the DEANKPC is also evident in the error metrics presented in Table 2. The DEANKPC achieves the lowest RMSE and MAE values among the three models, confirming its enhanced predictive accuracy. By combining labor market dynamics with deviations in inflation expectations, the DEANKPC provides a robust framework for explaining and predicting inflation. Unlike the benchmark, which lacks persistence mechanisms, and the hybrid, which overreacts to recent trends, the DEANKPC balances these dynamics, offering a more accurate depiction of inflation behavior.

Overall, the analysis highlights the strengths of the DEANKPC in tracking inflation dynamics under both gradual and abrupt changes. Its ability to adapt to shifting inflation trends while avoiding overreaction underscores its theoretical and empirical relevance, particularly in periods of heightened volatility, such as the deflation episode following 2020Q1.

6 Conclusions

This paper proposes an analytically tractable DSGE model that incorporates both labor and product market frictions. Labor market frictions stem from the power of insiders to periodically set nominal wages without access to full current information, while product market frictions arise from monopolistic competition and staggered pricing. Aggregate fluctuations are analyzed under a Taylor rule for monetary policy and an optimal monetary policy framework, providing a comprehensive perspective on inflation and real activity dynamics.

The model results in a "Dynamic Expectations-Augmented New Keynesian Phillips Curve" (DEANKPC). It is *dynamic* as labor market frictions induce persistence in deviations of unemployment and output from their natural rates, linking past inflation to current inflation. It is *expectations-augmented* as current inflation depends on prior expectations about its level. It is *new Keynesian* as current inflation depends on expectations about future inflation.

This framework allows the model to overcome two critical shortcomings of the benchmark NKPC. First, it endogenously generates inflation and unemployment persistence, enabling it to replicate the gradual adjustments observed in macroeconomic data. Second, it eliminates the "divine coincidence" demonstrating that inflation stabilization does not automatically stabilize output and employment in the presence of real shocks. As a result, the model supports the use of a Taylor rule, particularly when the central bank's loss function considers both inflation deviations from target and unemployment deviations from its natural rate.

Simulation exercises demonstrate the model's ability to capture more complex inflation dynamics. These dynamics are shaped by the degree of price stickiness and labor market persistence. High price stickiness amplifies forward-looking inflation expectations, while labor market persistence prolongs the adjustment process, creating a feedback loop between inflation and real activity. Monetary authorities play a critical role in moderating these dynamics through their responsiveness to inflation deviations. A stronger policy stance helps anchor inflation expectations more effectively, potentially curtailing the inflationary pressures generated by forward-looking mechanisms. However, excessively aggressive policies may exacerbate deviations in real activity, as persistent unemployment amplifies the effects of nominal shocks. These trade-offs highlight the need for carefully calibrated monetary policies that account for structural rigidities in both product and labor markets.

The empirical validity of the DEANKPC is evaluated through an application to the Euro Area. The model structure is well-supported by the data, with the DEANKPC outperforming the benchmark and hybrid NKPCs in forecasting inflation. This underscores the model's relevance for understanding inflation persistence and its implications for effective monetary policy design.

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Appendix A: Model's Determinacy and the Role of ϕ_π and γ

In New Keynesian models, the Taylor principle - requiring that the central bank's inflation responsiveness $\phi_\pi > 1$ - is a well-established condition for ensuring the stability and determinacy of the equilibrium. This principle ensures that the central bank adjusts nominal interest rates sufficiently in response to inflation deviations, anchoring expectations and preventing self-fulfilling inflationary or deflationary spirals.

In our model, the dynamics of inflation and the conditions for determinacy are enriched by the degree of price stickiness (γ). The DEANKPC, derived in Section 2.5, encapsulates the dual role of γ in amplifying forward-looking expectations and enhancing the persistence of unemployment-driven inflation dynamics. A higher γ increases the proportion of firms unable to adjust prices, emphasizing future inflation expectations in the price-setting process. Simultaneously, γ interacts with labor market frictions to sustain deviations of unemployment and output from their natural rates, creating a feedback loop that strengthens inflation persistence. This dual mechanism of γ is explored in greater detail in Section 4.

To analyze the determinacy conditions of the model, we reformulate its behavioral equations into a state-space representation, which facilitates a comprehensive stability analysis. The equations include the DEANKPC (27), IS curve (36), Taylor rule (39), Okun's law (28), and the Fisher equation (31). In state-space form, the model is expressed as:

$$Z_t = AZ_{t-1} + D\varepsilon_t, \tag{62}$$

where $Z_t = [\hat{\pi}_t, \hat{y}_t, \hat{i}_t, \hat{u}_t, \hat{r}_t, a_t, u_t^C]^\top$ represents the vector of endogenous variables and shocks, and $\varepsilon_t = [\varepsilon_t^A, \varepsilon_t^C, \varepsilon_t^i]^\top$ denotes the exogenous disturbances. The matrices A and D are functions of the model's structural parameters, including $\kappa_1, \kappa_2, \kappa_3, \phi_\pi, \phi_y, \delta, \eta_a, \eta_C$, and γ.

For the model to achieve determinacy, all eigenvalues of the matrix A must lie strictly within the unit circle. The Taylor principle, $\phi_\pi > 1$, traditionally ensures this condition for inflation dynamics. However, the interplay between ϕ_π and γ introduces nuances, as γ shifts the relative weight of forward-looking expectations and unemployment persistence in the DEANKPC. Numerical simulations conducted with the calibrated parameters from Section 3 reveal that as γ increases, the minimum ϕ_π required for determinacy decreases. This result reflects the stabilizing effect of greater price stickiness, which reduces the sensitivity of inflation to real shocks while amplifying the role of forward-looking behavior.

The determinacy thresholds for ϕ_π are shown in Figure A. For low γ (e.g., $\gamma = 0.1$), inflation dynamics are driven by immediate responses to real shocks, necessitating a more aggressive monetary

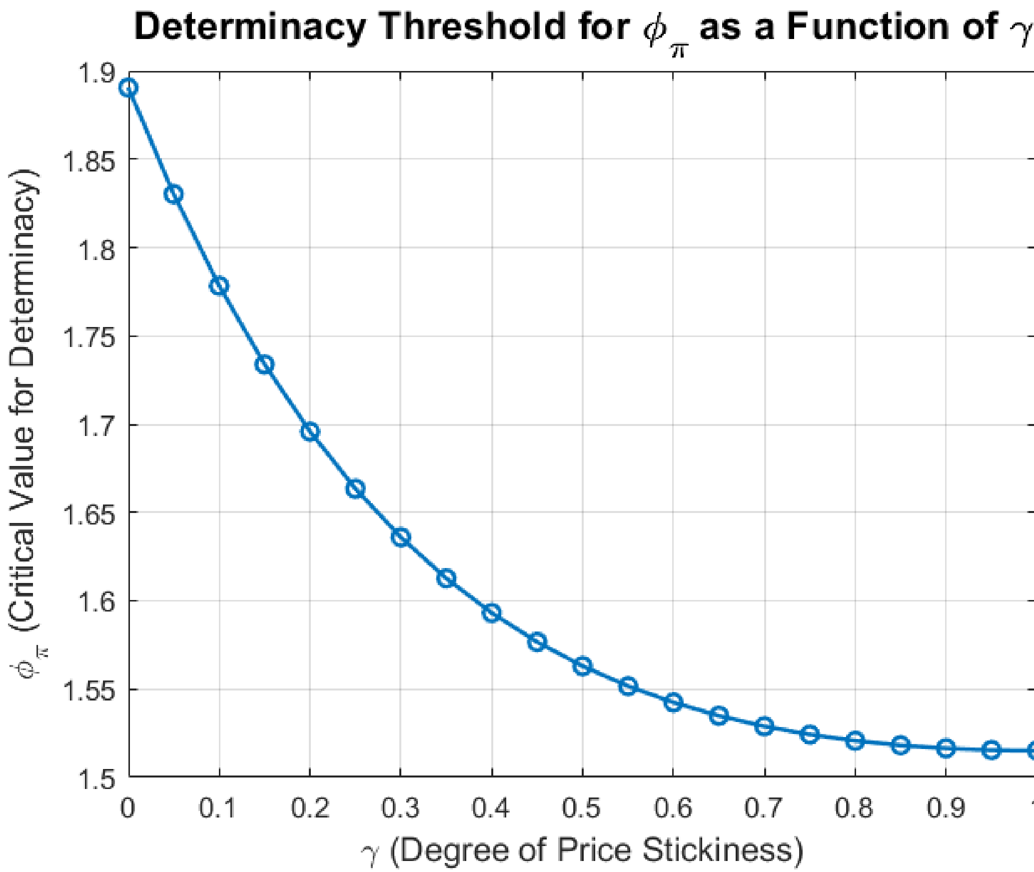

Figure A: Determinacy Threshold of ϕ_π as Function of γ

Notes: The Figure illustrates the results of a numerical exercise designed to assess the critical value of ϕ_π required for determinacy across different levels of price stickiness (γ). For the exercise, we used the parameter values from Section 3. The analysis is based on the state-space representation of the model, where the eigenvalues of the transition matrix A determine stability. For each value of γ, the minimum ϕ_π ensuring all eigenvalues lie inside the unit circle is computed. This exercise captures the interplay between the central bank's inflation responsiveness and the degree of price stickiness in shaping the stability properties of the equilibrium.

policy response ($\phi_\pi \approx 1.9$) to stabilize the system. Conversely, for high γ (e.g., $\gamma = 0.7$), the dominance of forward-looking mechanisms reduces the threshold for ϕ_π ($\phi_\pi \approx 1.5$). These findings illustrate the intricate trade-offs between structural parameters and policy rules in shaping the stability properties of the model.

By connecting the theoretical insights from the DEANKPC and the empirical implications of the numerical exercise, this analysis highlights how ϕ_π and γ jointly determine the stability and determinacy of the equilibrium. These results provide a foundation for understanding the modelâs stability, complementing the inflation dynamics explored in Sections 3 and 4.

Appendix B: Optimal Monetary Policy and Inflation Persistence

In Section 2.7, we have shown that the solution of the model under the Taylor rule results in inflation persistence. In this appendix, we demonstrate that inflation persistence is not unique to the Taylor rule but also arises under the optimal monetary policy. This reflects the central bank's deliberate strategy to allow inflation fluctuations to mitigate deviations of unemployment from its natural rate.[13]

To derive optimal monetary policy, one must specify an appropriate social welfare function. Assuming that the optimal steady-state inflation rate equals π^*, the primary distortion in the model is the deviation of unemployment from its natural rate. Thus, the central bank seeks to minimize an intertemporal loss function that incorporates deviations of inflation from its target π^* and deviations of unemployment from its natural rate u^N. This is written as:

$$\Lambda_t = E_t \sum_{s=0}^{\infty} \beta^s \left[\frac{1}{2}(\pi_{t+s} - \pi^*)^2 + \frac{\zeta}{2}(u_{t+s} - u^N)^2 \right], \tag{B1}$$

where β is the discount factor, $\beta = 1/(1+\rho)$ with ρ as the pure rate of time preference, and ζ is the relative weight the central bank places on unemployment deviations compared to inflation deviations.[14]

The optimal policy minimizes (B1) subject to the expectations-augmented New Keynesian Phillips Curve (36) expressed in terms of unemployment via the Okun-type equation (22):

$$u_t - u^N = \delta(u_{t-1} - u^N) - \frac{1}{\alpha\kappa_2}\left[\pi_t - E_{t-1}\pi_t - \kappa_1(E_t\pi_{t+1} - E_{t-1}\pi_t) + \varepsilon_t^A\right]. \tag{B2}$$

This approach results in what we term the *optimal time-consistent contingent policy*, as the central bank's inflation choice depends on the current state of the economy, summarized by unemployment deviations. Importantly, the policy is time-consistent, meaning the central bank has no incentive to deviate from it ex post.[15]

From the first-order conditions for minimizing (B1) subject to (B2), the inflation process is derived as:

$$\pi_t = \pi^* + \frac{\zeta}{\alpha\kappa_2}(u_t - u^N) + \frac{\beta\zeta}{\alpha\kappa_2}E_t(u_{t+1} - u^N). \tag{B3}$$

Substituting (B2) into (B3) for current and expected future unemployment deviations, the inflation

[13] See Alogoskoufis (2018) for a detailed proof of this proposition and suggested solutions.

[14] In accordance with the conventions in the monetary policy literature, see Barro and Gordon (1983) and Rogoff (1985), (B1) represents the intertemporal welfare costs of inflation and unemployment. However, the model abstracts from systematic inflation bias as the central bank does not aim to reduce unemployment below its inefficiently high natural rate, avoiding the issues highlighted by Kydland and Prescott (1977).

[15] Alogoskoufis (2018) also explores time-inconsistent policy rules that may reduce intertemporal losses further in a simpler insider-outsider model.

process simplifies to:

$$\pi_t = \delta\pi_{t-1} + (1-\delta)\pi^* - \frac{(1+\beta\zeta)}{(\alpha\kappa_2)^2}\left[\pi_t - E_{t-1}\pi_t - \kappa_1(E_t\pi_{t+1} - E_{t-1}\pi_t) + \varepsilon_t^A\right]. \tag{B4}$$

The rational expectations solution of (B4) is given by:

$$\pi_t = \delta\pi_{t-1} + (1-\delta)\pi^* - \frac{(1+\beta\zeta)}{(\alpha\kappa_2)^2}\left[\varepsilon_t^A\right]. \tag{B5}$$

Equation (B5) demonstrates that deviations of the optimal inflation rate from its target π^* exhibit the same persistence as unemployment deviations. This occurs because the central bank allows inflation to adjust in order to stabilize unemployment. As long as unemployment deviations are persistent, inflation deviations will also persist.

It is worth noting that the persistence of inflation under the optimal time-consistent contingent monetary policy does not affect the persistence of unemployment. The reason is that wage setters can anticipate the persistent part of the inflation process, incorporate it in their expectations when they set nominal wages, and neutralize the effects of persistent inflation on unemployment. Thus, the only element of monetary policy that matters for unemployment is the unanticipated part, which is a function of the current productivity shock.