Technical Appendix - Model Overview

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1 The New Keynesian Model

The paper builds on a medium-scale New Keynesian model of Garín et al. (2016). The model makes provision for wage and price stickiness using the Calvo (1983) approach of staggered adjustments. Similarly to Bhatnagar (2023), we introduce the presence of non-Ricardian households.

1.1 Households

Households are heterogeneous and are indexed by $l \in [0,1]$. Households supply differentiated labour (l) that grants them wage-setting power, which is managed by a labour aggregating firm that aggregates various types of labour into a composite good sold to firms at real wage w_t. The labour inputs are aggregated as follows:

$$N_t^d = \left(\int_0^1 N_t(l)^{\frac{\epsilon_w - 1}{\epsilon_w}} dl\right)^{\frac{\epsilon_w}{\epsilon_w - 1}} \tag{1}$$

The parameter ϵ_w measures the degree of substitutability among different types of labour and $\epsilon_w > 1$. The profit maximisation problem of the competitive labour aggregating firm gives rise to the relative demand for labour of type l as a function of its relative wage, with elasticity ϵ_w as well as an aggregate wage index:

$$N_t(l) = \left(\frac{w_t(l)}{w_t}\right)^{-\epsilon_w} N_t^d \tag{2}$$

$$w_t = \left(\int_0^1 w_t(l)^{1-\epsilon_{w,t}} dl\right)^{\frac{1}{1-\epsilon_w}} \tag{3}$$

Households face the following problem:

$$\max_{C_t, N_t(l), w_t(l), B_t} E_0 \sum_{t=0}^{\infty} \beta^t \left(\nu_t \ln(C_t - bC_{t-1}) - \psi \frac{N_t(l)^{1+\eta}}{1+\eta}\right) \tag{4}$$

The discount factor is given by $\beta \in (0,1)$. The exogenous variable ν_t is a consumption preference shock. The b measures the degree of external habit formation. The scaling parameter ψ is the disutility from labour. While η represents the inverse of the Frisch elasticity of labour supply.

1.1.1 Ricardian Households

Ricardian households represent $(1-\omega)$ proportion of all households. Their household problem is subject to the following constraints:

$$(1+\tau_{C,t})C_t^R + B_t \leq (1-\tau_{w,t})W_t(l)N_t(l) + \Pi_t^{Profit} + \frac{\left((1+i_{t-1})(1+rp_{t-1})\right)}{1+\pi_t}B_{t-1} \tag{5}$$

$$N_t(l) = \left(\frac{w_t(l)}{w_t}\right)^{-\epsilon_w} N_t^d \tag{6}$$

$$w_t(j) = \begin{cases} w_t^{\#}(j), & \text{if the household resets in period } t, \\ (1+\pi_t)^{-1}(1+\pi_{t-1})^{\zeta_w}\, w_{t-1}(j), & \text{otherwise.} \end{cases} \tag{7}$$

The budget constraint for Ricardain households is given by (5). Let C_t^R be Ricardian household j's consumption in period t. Profit distributed from firms is represented by Π_t^{Profit}. Households also pay a consumption tax $\tau_{C,t}$ and a labour income tax $\tau_{w,t}$. At the beginning of period t, the household holds B_{t-1} in nominal bonds and chooses B_t, which pays interest i_t at $t+1$. We introduce an exogenous risk premium shock, denoted as $\epsilon_{rp,t-1}$, which creates a disparity between the policy interest rate and the higher return required by households to hold government bonds.

Constraint (6) requires that household labour supply meets demand. Wage-setting is detailed in (7). We define $\pi_t = \frac{P_t}{P_{t-1}} - 1$ as the period-over-period net inflation. We consider a household j that may reset its real wage in period t. The probability that the wage chosen in t remains in place in period $t+s$ is ϕ_w^s. Following Garín et al. (2016), we allow for partial indexation of wages to lagged inflation via the parameter ($\zeta_w \in [0,1]$). When wages are reset with probability $(1-\phi_w^s)$, every updating household sets the same optimal real wage ($w_t^{\#}$).

The first order condition of the household problem where all updating households ($w_t(l)$) update to the same reset wage, $w_t^{\#}$:

$$(1-\tau_{w,t})\left(w_t^{\#}\right)^{1+\epsilon_w\eta} = \frac{\epsilon_w}{\epsilon_w - 1}\frac{\psi w_t^{\epsilon_{w,t}(1+\eta)} {N_t^d}^{1+\eta} + \beta\phi_w E_t(1+\pi_{t+1})^{\epsilon_{w,t}(1+\eta)}(1+\pi_t)^{-\zeta_w\epsilon_{w,t}(1+\eta)} H_{1,t+1}}{\lambda_t w_t^{\epsilon_{w,t}} N_t^d + \beta\phi_w E_t(1+\pi_{t+1})^{\epsilon_{w,t}-1}(1+\pi_t)^{\zeta_w(1-\epsilon_{w,t})} H_{2,t+1}}$$

We can write the above expression more compactly as:

$$\left(w_t^{\#}\right)^{1+\epsilon_w\eta} = \frac{\frac{\epsilon_w}{\epsilon_w - 1}\frac{H_{1,t}}{H_{2,t}}}{(1-\tau_{w,t})} \tag{8}$$

1.1.2 Non-Ricardian Households

The non-Ricardian households differ from Ricardian households in that they have no access to bonds and do not receive profits distributed from firms. They also receive transfers from the government. Bhatnagar (2023), following the framework of Medina and Soto (2016), assumes that each non-Ricardian agent sets its real wage equal to the average wage chosen by the Ricardian households. Since both types face the same labour-demand schedule, the total labour services supplied by the non-Ricardians coincide with the Ricardian average, and their budget constraint can be written as:

$$(1+\tau_{C,t})C_t^{NR} = (1-\tau_{w,t})w_t N_t^d + TR_t^{NR} \tag{9}$$

1.2 Production

Production is divided into two sectors: a final-goods sector and an intermediate-goods sector. In the final-goods sector, a perfectly competitive representative firm aggregates differentiated intermediate inputs into a single homogeneous output. The intermediate-goods sector consists of a continuum of monopolistically competitive firms indexed by $j \in [0,1]$. While the intermediate firms have some price-setting power, prices are subject to stickiness, following the Calvo (1983) mechanism.

1.2.1 Final Goods Sector

A continuum of intermediate goods $Y_t(j)$ is aggregated using a constant elasticity of substitution function to produce the final good Y_t:

$$Y_t = \left(\int_0^1 Y_t(j)^{\frac{\epsilon_p - 1}{\epsilon_p}}\right)^{\frac{\epsilon_p}{\epsilon_p - 1}} \tag{10}$$

The parameter ϵ_p measures the degree of substitution among different types of goods, and $\epsilon_p > 1$. When the final goods firm maximises its profits, it generates a demand curve for each intermediate good and an aggregated price index:

$$Y_t(j) = \left(\frac{P_t(j)}{P_t}\right)^{-\epsilon_p} Y_t \tag{11}$$

$$P_t = \left(\int_0^1 P_t(j)^{1-\epsilon_p} dj \right)^{\frac{1}{1-\epsilon_p}} \tag{12}$$

1.2.2 Intermediate Producers

A typical intermediate goods firm produces goods using a labour-based technology that exhibits constant returns to scale and is subject to a common productivity shock, A_t.

$$Y_t(j) = A_t N_t^d(j) \tag{13}$$

Intermediate firms are not freely able to adjust prices each period. In each period there is a fixed probability of $1-\phi_p$ that a firm can update its price. We allow for indexation of non-updated prices to lagged inflation as in Garín et al. (2016), governed by the parameter $\zeta_p \in [0,1]$. A firm that does not set the optimal price $P_t^{\#}(j)$ in period $t+s$ is stuck with the price it chose in period t:

$$P_t(j) = \begin{cases} P_t^{\#}(j), & \text{if } P_t(j) \text{ is chosen optimally,} \\ (1+\pi_{t-1})^{\zeta_p} P_{t-1}(j), & \text{otherwise.} \end{cases} \tag{14}$$

The intermediate firm faces a cost minimisation problem to minimise total cost subject to the constraint of producing enough output to meet demand. After deriving the first order condition with respect to labour demand, we show that the marginal cost mc is equal to the wage divided by productivity. Since each firm takes the wage as given in a competitive labour market and produces under constant-returns-to-scale technology, its real marginal cost is identical for all firms—hence we drop the j reference.

$$mc(j)_t = mc = \frac{w_t}{A_t} \tag{15}$$

Following Ascari and Sbordone (2014) we denote $p_t^{\#}$ as the relative price of the optimising firm at t where $p_{i,t}^{\#} = \frac{P_{i\,t}^{\#}(j)}{P_t}$, the first order condition of the intermediate firm problem can be written as:

$$p_{i,t}^{\#} = \frac{\epsilon_p}{\epsilon_p - 1} \frac{\lambda_t mc_t Y_t + \phi_p \beta E_t (1+\pi_t)^{-\zeta_p \epsilon_{p,t}} (1+\pi_{t+1})^{\epsilon_{p,t}} x_{1,t+1}}{\lambda_t Y_t + \phi_p \beta E_t (1+\pi_t)^{\zeta_p(1-\epsilon_{p,t})} (1+\pi_{t+1})^{\epsilon_{p,t}-1} x_{2,t+1}}$$

We define net inflation as $(1+\pi_t) = \frac{P_t}{P_{t-1}}$. Furthermore, we write the reset price setting equation above more compactly as:

$$p_{i,t}^{\#} = \frac{\epsilon_p}{\epsilon_p - 1} \frac{x_{1,t}}{x_{2,t}} \tag{16}$$

We show that the aggregate price level evolves as follows:

$$p_{i,t}^{\#} = \left(\frac{1 - \phi_p (1+\pi_t)^{(\epsilon_p - 1)} (1+\pi_{t-1})^{\zeta_p (1-\epsilon_p)}}{(1-\phi_p)} \right)^{\frac{1}{1-\epsilon_p}} \tag{17}$$

In the canonical New Keynesian DSGE framework, and under the assumption of zero trend inflation, the reset price-setting equation can be written as

$$\frac{(1+\pi_t)^{\#}}{(1+\pi_t)} = \frac{\epsilon_p}{\epsilon_p - 1} \frac{x_{1,t}}{x_{2,t}}.$$

In this paper, however, we allow for positive trend inflation and therefore focus on its implications for the aggregate reset price level. The assumption of zero steady-state inflation in the New Keynesian framework is not merely a simplification; it fundamentally alters the model's structure. As Ascari and Sbordone (2014, p. 706) shows, zero inflation causes the markup and price dispersion effects to cancel, making the model behave like one with a representative firm and eliminating price dispersion. The model thus becomes, to a first-order approximation, equivalent to the Rotemberg specification with convex adjustment costs but no staggered pricing, at the cost of erasing key microfoundational features of the Calvo setup. Moreover, when trend inflation rises, deviations of price dispersion from the steady state become more persistent, feeding back into marginal costs and amplifying the persistence of inflation and other macroeconomic variables (Ascari and Sbordone, 2014, p. 714). Although the Calvo and Rotemberg models are treated as macroeconomically equivalent around a zero inflation steady state, positive trend inflation reveals their microeconomic differences, particularly the absence of price dispersion effects in the Rotemberg model (Ascari and Sbordone, 2014, p. 725).

1.3 Monetary Policy

Similar to the specification in Bhatnagar (2023), we assume that the central bank sets interest rates according to a generalised Taylor (1993) type instrument rule. We consider different variants of the generalised rule, which allows us to consider the conduct of monetary policy under an inflation-targeting rule in the following form:

$$\ln(1+i_t) = (1-\rho_i)\ln(1+i^*) + \rho_i \ln(1+i_{t-1}) + \phi_\pi \ln\left(\frac{1+\pi_t}{1+\pi^*}\right) + \phi_y \ln\left(\frac{Y_t}{Y_{t-1}}\right) + \varepsilon_i \tag{18}$$

or

$$1+i_t \;=\; (1+i^*)^{1-\rho_i}\,(1+i_{t-1})^{\rho_i}\left[\left(\frac{1+\pi_t}{1+\pi^*}\right)^{\phi_\pi}\left(\frac{Y_t}{Y_{t-1}}\right)^{\phi_y}\right]^{1-\rho_i} e^{\varepsilon_i} \tag{19}$$

or

$$1+i_t \;=\; (1+i^*)^{1-\rho_i}\,(1+i_{t-1})^{\rho_i}\left(\frac{1+\pi_t}{1+\pi^*}\right)^{\phi_\pi}\left(\frac{Y_t}{Y_{t-1}}\right)^{\phi_y} e^{\varepsilon_i}. \tag{20}$$

Here $\rho_i \in [0,1)$ is a smoothing parameter, and ϕ_π and ϕ_y are nonnegative coefficients on inflation and output growth. The rule allows for the case of positive-trend inflation.

1.4 Fiscal Policy

To finance government expenditures and transfer payments, the fiscal authority imposes distortionary taxes on consumption and labour and issues bonds to cover any budget deficits.

The government's budget constraint:

$$G_t + TR_t^{NR} + \frac{\big((1+i_{t-1})(1+rp_{t-1}\big)}{1+\pi_t} D_{t-1} = \tau_{w,t} w_t N_t^d + \tau_{C,t} C_t + D_t \tag{21}$$

Since the one-period bond B_t is in zero net supply, it is solely relevant for asset pricing through the short-term policy interest rate i_t (Krause and Moyen, 2016).

Treating government expenditure and tax rates as exogenous could lead to explosive debt growth. To maintain debt stability, we ensure that tax rates or government spending are adjusted appropriately when debt deviates from its steady state.

We assume that tax rates follow stationary stochastic processes with shocks and tax rates without a time subscript represent their exogenous steady-state values. The processes for the tax rates are specified as follows:

$$\tau_{w,t} = \left(1-\rho_w\right)\tau_w^* + \rho_w \tau_{w,t-1} + \left(1-\rho_w\right)\gamma_{wd}\left(\frac{D_t}{Y_t} - \frac{D^*}{Y^*}\right) + \left(1-\rho_w\right)\gamma_{wy}\left(Y_t - Y^*\right) + \varepsilon_{\tau_{w},t} \tag{22}$$

$$\tau_{C,t} = \left(1-\rho_c\right)\tau_C^* + \rho_c \tau_{C,t-1} + \left(1-\rho_c\right)\gamma_{cd}\left(\frac{D_t}{Y_t} - \frac{D^*}{Y^*}\right) + \left(1-\rho_c\right)\gamma_{cy}\left(Y_t - Y^*\right) + \varepsilon_{\tau_{C},t} \tag{23}$$

The parameters γ_{wd}, γ_{wy}, γ_{cd}, and γ_{cy} govern how strongly labour and consumption tax rates respond to deviations of debt and output from their steady state targets. To prevent debt from exploding, at least one of these parameters must be sufficiently positive to stabilise the debt dynamics.

Real government spending and real transfers to non-Ricardian households are assumed to be exogenous and obey a stationary stochastic process.

$$\ln G_t = (1-\rho_g)\ln G^* + \rho_g \ln G_{t-1} - (1-\rho_g)\gamma_{gd}\left[\ln\left(D_t/Y_t\right) - \ln\left(D^*/Y^*\right)\right] - (1-\rho_g)\gamma_{gy}\left(\ln Y_t - \ln Y^*\right) + \varepsilon_{G_t} \tag{24}$$

$$\ln tr_t^{NR} = (1-\rho_{tr})\ln tr^{NR*} + \rho_{tr}\ln tr_{t-1}^{NR} - (1-\rho_{tr})\gamma_{trd}\left[\ln\left(D_t/Y_t\right) - \ln\left(D^*/Y^*\right)\right] - (1-\rho_{tr})\gamma_{try}\left(\ln Y_t - \ln Y^*\right) + \varepsilon_{tr_t} \tag{25}$$

We assume that in the steady state, government spending (G^*) and government transfers (tr^{NR*}) to non-Ricardian households are a constant fraction of steady-state output (Y^*). The autoregressive parameters on all fiscal instruments ρ_c, ρ_w, ρ_G and ρ_{tr} each lie between zero and one, and the stochastic error terms are drawn from a standard normal distribution.

Each fiscal instrument follows an AR(1) process with persistence parameters $\rho_c, \rho_w, \rho_G, \rho_{tr} \in (0,1)$ to ensure stationarity.

1.5 Exogenous Processes

Some of our exogenous variables follow AR(1) processes in logs:

$$\ln A_t = \rho_a \ln A_{t-1} + \varepsilon_{a,t} \tag{26}$$

$$\ln v_t = \rho_v \ln v_{t-1} + \varepsilon_{v,t} \tag{27}$$

$$\epsilon_{p,t} = \rho_p \epsilon_{p,t-1} + (1-\rho_p)\epsilon_p + \varepsilon_{p,t} \tag{28}$$

$$1 + rp_t = (1 + rp_{t-1})^{\rho_{rp}}\,(1 + rp)^{1-\rho_{rp}}\left(\frac{D_t/Y_t}{D/Y^*}\right)^{\gamma_{rp}} e^{\varepsilon_{rp,t}} \tag{29}$$

$$\epsilon_{i,t} = \rho_{\epsilon_i}\epsilon_{i,t-1} + \varepsilon_{i,t} \tag{30}$$

All other exogenous disturbances enter additively as iid shocks, for example

$$\varepsilon_{i,t},\ \varepsilon_{G,t},\ \varepsilon_{tr,t},\ \varepsilon_{\tau_w,t},\ \varepsilon_{\tau_C,t},\ \varepsilon_{\mu,t},\ \varepsilon_{\epsilon_w,t} \sim \text{i.i.d. } N\left(0,\sigma_{\cdot}^2\right).$$

1.6 Equilibrium and Aggregation

Aggregate consumption to households is given by:

$$C_t = (1-\omega)C_t^R + \omega C_t^{NR} \tag{31}$$

In equilibrium, the bond holding is always zero: $B_t = 0$. The aggregate resource constraint is given as follows.

$$Y_t = C_t + G_t \tag{32}$$

We define v_t^p as a metric of price dispersion. When there are no pricing frictions and all firms set identical prices, v_t^p is equal to one. In cases where firms charge different prices, v_t^p remains at or above unity.

$$v_t^p = \int_0^1 \left(\frac{P_t(j)}{P_t}\right)^{-\epsilon_{p,t}} dj \tag{33}$$

We can then show the aggregate production function.

$$Y_t = \frac{A_t N_t^d}{v_t^p} \tag{34}$$

Since $v_t^p \geq 1$, price dispersion leads to an output distortion, resulting in lower total output compared to what would be achievable with aggregate productivity A_t and total labour input in the absence of price variations.

We demonstrate that the aggregate price level is a weighted average of the reset price and the lagged price level, both raised to the same power $1-\epsilon_{p,t}$.

$$P_t^{1-\epsilon_{p,t}} = \left(1-\phi_p\right)\left(P_{i,t}{}^{\#}\right)^{1-\epsilon_{p,t}} + \phi_p P_{t-1}^{1-\epsilon_{p,t}}(1+\pi_{t-1})^{\zeta_p(1-\epsilon_{p,t})}$$

To express the equation in terms of inflation rather than the price level, we divide both sides by $P_{t-1}^{1-\epsilon_{p,t}}$ and define reset price as $p_t^{\#} = \frac{P_t^{\#}}{P_t}$ after some rearranging we show:

$$P_t^{\#} = \left(\frac{1-\phi_p(1+\pi_t)^{\epsilon_p-1}(1+\pi_{t-1})^{(\epsilon_p-1)(1-\zeta_p)}}{1-\phi_p}\right)^{\frac{1}{1-\epsilon_p}} \tag{35}$$

Similarly, we show the aggregate real wage index.

$$w_t^{1-\epsilon_{w,t}} = (1-\phi_w)\left(w_t^{\#}\right)^{1-\epsilon_{w,t}} + \phi_w (1+\pi_t)^{\epsilon_{w,t}-1} (1+\pi_{t-1})^{\zeta_w(1-\epsilon_{w,t})} w_{t-1}^{1-\epsilon_{w,t}} \tag{36}$$

The total welfare is measured following Garín et al. (2016) and expanded to include both Ricardian and non-Ricardian households as described in Bhatnagar (2023)[1]. Aggregate welfare for the Ricardian households can be written as the sum of the present discount value of flow utility across Ricardian households:

$$V_t^R(l) = \left(\nu_t \ln(C_t^R - bC_{t-1}^R) - \frac{\psi N_t(l)^{1+\eta}}{1+\eta}\right) + \beta E(V_{t+1}^R(l))$$

We can get the aggregate welfare for Ricardian households by integrating above:

$$W_t^R = \int_0^1 V_t^R(l)dl = \left(\nu_t \ln(C_t^R - bC_{t-1}^R) - \frac{\psi \int_0^1 N_t(l)^{1+\eta} dl}{1+\eta}\right) + \beta E(W_{t+1}^R)$$

We defined the relative demand for labour of type (l) as a function of its relative wage with elasticity $(\epsilon_{w,t})$ from equation (2):

$$N_t(l) = \left(\frac{w_t(l)}{w_t}\right)^{-\epsilon_{w,t}} N_t^d$$

Substituting this into the aggregate welfare for Ricardian households we get:

$$W_t^R = \left(\nu_t \ln(C_t^R - bC_{t-1}^R) - \frac{\psi {N_t^d}^{1+\eta} \int_0^1 \left(\frac{w_t(l)}{w_t}\right)^{-\epsilon_{w,t}(1+\eta)} dl}{1+\eta}\right) + \beta E(W_{t+1}^R)$$

Aggregate welfare for Ricardian households:

$$W_t^R = \left(\nu_t \ln(C_t^R - bC_{t-1}^R) - \frac{\psi {N_t^d}^{1+\eta} v_t^w}{1+\eta}\right) + \beta E(W_{t+1}^R) \tag{37}$$

We define real wage dispersion, v_t^w as the wedge that enters between aggregate labour supply and demand in the economy.

$$v_t^w = \int_0^1 \left(\frac{w_t(l)}{w_t}\right)^{-\epsilon_{w,t}(1+\eta)} dl$$

[1] We note that Bhatnagar (2023) excludes the use of wage dispersion in the non-Ricardian welfare function, and this may potentially be an omission.

$$N = N_t^d v_t^w \tag{38}$$

Since $v_t^w \geq 1$, analogous to price dispersion, wage dispersion leads to a labour distortion, resulting in lower labour demanded by firms as wages rise with trend inflation.

Aggregate welfare for the Non-Ricardian households:

$$W_t^{NR} = \left(\nu_t \ln(C_t^{NR} - bC_{t-1}^{NR}) - \frac{\psi {N_t^d}^{1+\eta}}{1+\eta} \right) + \beta E(W_{t+1}^{NR}) \tag{39}$$

Resulting in aggregate welfare across both households defined as:

$$W_t = \omega_w W^{NR} + (1 - \omega_w) W^R \tag{40}$$

2 Summary of Equilibrium Conditions

A full list of model equations and equilibrium conditions is summarised as follows:

- Households:

$$\lambda_t = \frac{\nu_t}{(1+\tau_{C,t})(C_t^R - bC_{t-1}^R)} \tag{41}$$

$$1 = \beta E_t \left[\frac{\lambda_{t+1}}{\lambda_t} \frac{(1+i_t)(1+rp_t)}{(1+\pi_{t+1})} \right] \tag{42}$$

$$(1+\tau_{C,t}) C_t^{NR} = (1-\tau_{w,t}) w_t N_t^d + tr_t^{NR} \tag{43}$$

$$C_t = (1-\omega) C_t^R + \omega C_t^{NR} \tag{44}$$

$$tr_t = (1-\alpha) tr_t^R + \alpha tr_t^{NR} \tag{45}$$

- Wage-setting:

$$\left(w_t^{\#}\right)^{1+\epsilon_{w,t}\eta} = \frac{\frac{\epsilon_{w,t}}{\epsilon_{w,t}-1} \frac{H_{1,t}}{H_{2,t}}}{(1-\tau_{w,t})} \tag{46}$$

$$H_{1,t} = \psi w_t^{\epsilon_{w,t}(1+\eta)} {N_t^d}^{1+\eta} + \beta \phi_w E_t (1+\pi_{t+1})^{\epsilon_{w,t}(1+\eta)} (1+\pi_t)^{-\zeta_w \epsilon_{w,t}(1+\eta)} H_{1,t+1} \tag{47}$$

$$H_{2,t} = \lambda_t w_t^{\epsilon_{w,t}} N_t^d + \beta \phi_w E_t (1+\pi_{t+1})^{\epsilon_{w,t}-1} (1+\pi_t)^{\zeta_w(1-\epsilon_{w,t})} H_{2,t+1} \tag{48}$$

- Price-setting:

$$1+\pi_t^{\#} = \frac{\epsilon_{p,t}}{\epsilon_{p,t}-1}\,(1+\pi_t)\,\frac{x_{1,t}}{x_{2,t}} \tag{49}$$

$$x_{1,t} = \lambda_t mc_t Y_t + \phi_p \beta E_t\,(1+\pi_t)^{-\zeta_p \epsilon_{p,t}}\,(1+\pi_{t+1})^{\epsilon_{p,t}}\,x_{1,t+1} \tag{50}$$

$$x_{2,t} = \lambda_t Y_t + \phi_p \beta E_t\,(1+\pi_t)^{\zeta_p(1-\epsilon_{p,t})}\,(1+\pi_{t+1})^{\epsilon_{p,t}-1}\,x_{2,t+1} \tag{51}$$

- Firm:

$$mc_t = \frac{w_t}{A_t} \tag{52}$$

- Monetary Policy:

$$1+i_t \;=\; (1+i^*)^{1-\rho_i}\,(1+i_{t-1})^{\rho_i}\left[\left(\frac{1+\pi_t}{1+\pi^*}\right)^{\phi_\pi}\left(\frac{Y_t}{Y_{t-1}}\right)^{\phi_y}\right]^{1-\rho_i} e^{\varepsilon_i}$$

$$\text{or } 1+i_t \;=\; (1+i^*)^{1-\rho_i}\,(1+i_{t-1})^{\rho_i}\left(\frac{1+\pi_t}{1+\pi^*}\right)^{\phi_\pi}\left(\frac{Y_t}{Y_{t-1}}\right)^{\phi_y} e^{\varepsilon_i} \tag{53}$$

- Fiscal Policy:

$$G_t + TR_t^{NR} + \frac{\big((1+i_{t-1})(1+rp_{t-1})\big)}{1+\pi_t} D_{t-1} = \tau_{w,t} w_t N_t^d + \tau_{C,t} C_t + D_t \tag{54}$$

$$\tau_{w,t} = \left(1-\rho_w\right)\tau_w^* + \rho_w \tau_{w,t-1} + \left(1-\rho_w\right)\gamma_{wd}\left(\frac{D_t}{Y_t} - \frac{D^*}{Y^*}\right) + \left(1-\rho_w\right)\gamma_{wy}\left(Y_t - Y^*\right) + \varepsilon_{\tau_{w,t}} \tag{55}$$

$$\tau_{C,t} = \left(1-\rho_c\right)\tau_C^* + \rho_c \tau_{C,t-1} + \left(1-\rho_c\right)\gamma_{cd}\left(\frac{D_t}{Y_t} - \frac{D^*}{Y^*}\right) + \left(1-\rho_c\right)\gamma_{cy}\left(Y_t - Y^*\right) + \varepsilon_{\tau_{C,t}} \tag{56}$$

$$\ln tr_t^{NR} = (1-\rho_{tr})\ln tr^{NR*} + (\rho_{tr})\ln tr_{t-1}^{NR} - (1-\rho_{tr})\gamma_{trd}\big(\ln(D_t/Y_t) - \ln(D^*/Y^*)\big) - (1-\rho_{tr})\gamma_{try}\big(\ln Y - \ln Y^*\big) + \varepsilon_{tr,t} \tag{57}$$

$$\ln G_t = (1-\rho_g)\ln G^* + \rho_g \ln G_{t-1} - (1-\rho_g)\gamma_{gd}\left[\ln\big(D_t/Y_t\big) - \ln\big(D^*/Y^*\big)\right] - (1-\rho_g)\gamma_{gy}\left(\ln Y_t - \ln Y^*\right) + \varepsilon_{G_t} \tag{58}$$

- Aggregate Conditions:

$$(1+\pi_t)^{1-\epsilon_{p,t}} = \left(1-\phi_p\right)\left(1+p_t^{\#}\right)^{1-\epsilon_{p,t}} + \phi_p (1+\pi_{t-1})^{\zeta_p (1-\epsilon_{p,t})} \tag{59}$$

$$w_t^{1-\epsilon_{w,t}} = \left(1-\phi_w\right)\left(w_t^{\#}\right)^{1-\epsilon_{w,t}} + \phi_w \left(1+\pi_t\right)^{\epsilon_{w,t}-1} \left(1+\pi_{t-1}\right)^{\zeta_w (1-\epsilon_{w,t})} w_{t-1}^{1-\epsilon_{w,t}} \tag{60}$$

$$N_t^d = \tfrac{Y_t}{A_t} v_t^p \tag{61}$$

$$v_t^p = (1+\pi_t)^{\epsilon_{p,t}} \left[\left(1-\phi_p\right)\left(p_t^{\#}\right)^{-\epsilon_{p,t}} + \phi_p \left(1+\pi_{t-1}\right)^{-\epsilon_{p,t}\zeta_p} v_{t-1}^p\right] \tag{62}$$

$$N_t = N_t^d v_t^w \tag{63}$$

$$v_t^w = (1-\phi_w)\left(\frac{w_t^{\#}}{w_t}\right)^{-\epsilon_{w,t}(1+\eta)} + \phi_w \left(\left(\frac{w_t}{w_{t-1}}(1+\pi_t)\right)^{\epsilon_{w,t}(1+\eta)} (1+\pi_{t-1})^{-\zeta_w \epsilon_{w,t}(1+\eta)}\right) v_{t-1}^w \tag{64}$$

$$W_t^R = \left(\nu_t \ln(C_t^R - bC_{t-1}^R) - \frac{\psi {N_t^d}^{1+\eta} v_t^w}{1+\eta}\right) + \beta E(W_{t+1}^R) \tag{65}$$

$$W_t^{NR} = \left(\nu_t \ln(C_t^{NR} - bC_{t-1}^{NR}) - \frac{\psi {N_t^d}^{1+\eta}}{1+\eta}\right) + \beta E(W_{t+1}^{NR}) \tag{66}$$

$$W_t = \omega_w W^{NR} + (1-\omega_w) W^R \tag{67}$$

$$Y_t = C_t + G_t \tag{68}$$

$$N^d = \left[\frac{\epsilon_w - 1}{\epsilon_w}\frac{1}{\psi}\frac{1}{\lambda} mc_t \left(\frac{1-\phi_w (1+\pi_t)^{\epsilon_w - 1}(1+\pi_t)^{\zeta_w (1-\epsilon_w)}}{1-\phi_w}\right)^{\frac{1+\epsilon_w \eta}{1-\epsilon_w}} \frac{\frac{1-\phi_w \beta (1+\pi_t)^{\epsilon_w (1+\eta)} (1+\pi_t)^{-\zeta_w \epsilon_w (1+\eta)}}{1-\phi_w \beta (1+\pi_t)^{\epsilon_w - 1} (1+\pi_t)^{\zeta_w (1-\epsilon_w)}}}{(1-\tau_{w,t})}\right]^{\frac{1}{\eta}} \tag{69}$$

- Exogenous Processes:

$$\ln A_t = \rho_a \ln A_{t-1} + \varepsilon_{a,t} \tag{70}$$

$$\ln \nu_t = \rho_v \ln \nu_{t-1} + \varepsilon_{v,t} \tag{71}$$

$$\epsilon_{p,t} = \rho_p \epsilon_{p,t-1} + (1-\rho_p)\epsilon_p + \varepsilon_{p,t} \tag{72}$$

$$1 + rp_t = (1 + rp_{t-1})^{\rho_{rp}} (1+rp)^{1-\rho_{rp}} \left(\frac{D_t/Y_t}{D/Y^*}\right)^{\gamma_{rp}} e^{\varepsilon_{rp,t}} \tag{73}$$

$$\epsilon_{i,t} = \rho_{\epsilon_i} \epsilon_{i,t-1} + \varepsilon_{i,t} \tag{74}$$

- Auxiliary Variables:

$$CII_t = \frac{C_t^R}{C_t^{NR}} \tag{75}$$

3 Steady State

We first solve the steady state under zero trend inflation and then solve for the steady state under a positive trend inflation target following Ascari and Sbordone (2014). In solving the steady state we drop all time subscripts.

3.1 Steady state under zero trend inflation

In the non-stochastic steady state, the production technology parameter is normalised to unity, $A = 1$. Moreover, in the canonical New Keynesian DSGE framework, steady-state inflation is assumed to coincide with the central bank's inflation target, π^* (for notational convenience we assume $\pi^* = \pi$. Under these assumptions, the steady-state reset-price inflation rate, $\pi^{\#}$, satisfies the closed-form expression

$$1+\pi^{\#} = \left(\frac{(1+\pi)^{1-\epsilon_p} - \phi_p (1+\pi)^{\zeta_p(1-\epsilon_p)}}{1-\phi_p} \right)^{\frac{1}{(1-\epsilon_p)}}.$$

In the special case of inflation with zero trend (target), $\pi = 0$, this expression collapses to

$$1+\pi^{\#} = 1 \quad \Longrightarrow \quad \pi^{\#} = 0,$$

thus eliminating any steady-state price dispersion. Henceforth, we adopt $\pi^{\#} = 0$ as our baseline. In the next subsection, we relax the zero-inflation assumption and demonstrate how positive trend inflation reintroduces price-rigidity effects into the steady-state equilibrium.

Steady state price dispersion collapses down if $\pi = \pi^{\#} = 0$, then:

$$v^p = \frac{\left(1-\phi_p\right)\left(\frac{1+\pi}{1+\pi^{\#}}\right)^{\epsilon_p}}{1-\phi_p(1+\pi)^{\epsilon_p}(1+\pi)^{\zeta_p(1-\epsilon_p)}} \quad \Longrightarrow \quad v^p = 1 \tag{76}$$

The steady-state nominal interest rate is:

$$1+i = \frac{1}{\beta}(1+\pi) \quad \Longrightarrow \quad 1+i = \frac{1}{\beta} \tag{77}$$

Now the reset-price equation derived previously depends on two components: the steady-state gross price-markup factor, $\frac{\epsilon_p}{\epsilon_p-1}$, and the dynamic price-adjustment factor, $\frac{x_1}{x_2}$.

$$p^{\#}_{i,t} = \frac{\epsilon_p}{\epsilon_p - 1}\frac{x_1}{x_2}$$

The steady state auxiliary pricing variables are:

$$x_1 = \frac{\lambda mc Y}{1-\phi_p\beta(1+\pi)^{\epsilon_p}(1+\pi)^{-\zeta_p\epsilon_p}} \tag{78}$$

$$x_2 = \frac{\lambda Y}{1-\phi_p\beta(1+\pi)^{\epsilon_p-1}(1+\pi)^{\zeta_p(1-\epsilon_p)}} \tag{79}$$

In the steady state when we take the ratio or dynamic price-adjustment factor we are able to solve for the steady state marginal cost:

$$\frac{x_1}{x_2} = mc\frac{1-\phi_p\beta(1+\pi)^{\epsilon_p-1}(1+\pi)^{\zeta_p(1-\epsilon_p)}}{1-\phi_p\beta(1+\pi)^{\epsilon_p}(1+\pi)^{-\zeta_p\epsilon_p}} \implies mc = \frac{\epsilon_p-1}{\epsilon_p}\underbrace{\frac{1-\phi_p\beta(1+\pi)^{\epsilon_p}(1+\pi)^{-\zeta_p\epsilon_p}}{1-\phi_p\beta(1+\pi)^{\epsilon_p-1}(1+\pi)^{\zeta_p(1-\epsilon_p)}}\frac{1+\pi^{\#}}{1+\pi}}_{\text{Price adjustment factor}}$$

Now, if $\pi = \pi^{\#} = 0$, implies that marginal cost equals the inverse of the steady-state gross markup or the flexible price markup.

$$mc = \frac{\epsilon_p - 1}{\epsilon_p} \tag{80}$$

Next, the optimal reset wage can be expressed relative to the steady-state real wage as

$$w^{\#} = \left(\frac{1-\phi_w(1+\pi)^{\epsilon_w-1}(1+\pi)^{\zeta_w(1-\epsilon_w)}}{1-\phi_w}\right)^{\frac{1}{1-\epsilon_w}} w. \tag{81}$$

This expression shows that the reset wage is proportional to the steady-state wage. In the special case of perfectly flexible wages, ($\phi_w = 0$), one recovers ($w^{\#} = w$). Moreover, if $\pi = \pi^{\#} = 0$, then

$$w^{\#} = w \tag{82}$$

as expected.

Analogous to price dispersion, wage dispersion in steady state collapses to unity when setting $\pi = \pi^{\#} = 0$ and $w^{\#} = w = 1$ yields

$$v^w = \frac{(1-\phi_w)\left(\frac{w^{\#}}{w}\right)^{-\epsilon_w(1+\eta)}}{1-\phi_w(1+\pi)^{(1-\zeta_w)(\epsilon_{w,t}(1+\eta))}} \implies v^w = 1. \tag{83}$$

We now solve for the steady-state values of the auxiliary wage-setting variables h_1 and h_2.

$$h_1 = \frac{\psi w^{\epsilon_w(1+\eta)} {N^d}^{1+\eta}}{1-\phi_w\beta(1+\pi)^{\epsilon_w(1+\eta)}(1+\pi)^{-\zeta_w\epsilon_w(1+\eta)}} \tag{84}$$

$$h_2 = \frac{\lambda w^{\epsilon_w} N^d}{1-\phi_w\beta(1+\pi)^{\epsilon_w-1}(1+\pi)^{\zeta_w(1-\epsilon_w)}} \tag{85}$$

The ratio of the auxiliary variables is:

$$\frac{h_1}{h_2} = \underbrace{\psi w^{\epsilon_w\eta}\lambda {N^d}^{\eta}}_{\text{Wage markup}}\underbrace{\frac{1-\phi_w\beta(1+\pi)^{\epsilon_w-1}(1+\pi)^{\zeta_w(1-\epsilon_w)}}{1-\phi_w\beta(1+\pi)^{\epsilon_w(1+\eta)}(1+\pi)^{-\zeta_w\epsilon_w(1+\eta)}}}_{\text{Wage adjustment factor}}$$

If $\pi = \pi^{\#} = 0$, we would drop the wage adjustment factor leaving us with the wage markup term. After plugging this into the first order condition for labour we have:

$$\frac{h_1}{h_2} = \psi w^{\epsilon_w \eta} \lambda N^{d^\eta} \quad \Longrightarrow \quad \left(w^{\#}\right)^{1+\epsilon_w \eta} = \frac{\epsilon_w}{\epsilon_w - 1} \frac{\psi w^{\epsilon_w \eta} \lambda N^{d^\eta}}{(1-\tau_w)} \tag{86}$$

Plug this into the FOC for labour:

$$\left(w^{\#}\right)^{1+\epsilon_w \eta} = \frac{\frac{\epsilon_w}{\epsilon_w - 1} \frac{H_1}{H_2}}{(1-\tau_w)}$$

$$\left(w^{\#}\right)^{1+\epsilon_w \eta} = \frac{\epsilon_w}{\epsilon_w - 1} \frac{\psi w^{\epsilon_w \eta} \lambda N^{d^\eta}}{(1-\tau_w)}$$

Substituting the expression for the optimal reset wage in terms of the steady-state real wage,

$$\left(\frac{1-\phi_w (1+\pi)^{\epsilon_w - 1} (1+\pi)^{\zeta_w (1-\epsilon_w)}}{1-\phi_w} \right)^{\frac{1+\epsilon_w \eta}{1-\epsilon_w}} w^{1+\epsilon_w \eta} = \frac{\epsilon_w}{\epsilon_w - 1} \frac{\psi w^{\epsilon_w \eta} \lambda N^{d^\eta}}{(1-\tau_w)}.$$

After simplifying and rearranging terms we have

$$N^d = \left[\frac{\epsilon_w - 1}{\epsilon_w} \frac{1}{\psi} \frac{1}{\lambda} w \left(\frac{1-\phi_w (1+\pi)^{\epsilon_w - 1} (1+\pi)^{\zeta_w (1-\epsilon_w)}}{1-\phi_w} \right)^{\frac{1+\epsilon_w \eta}{1-\epsilon_w}} \frac{1}{(1-\tau_w)} \right]^{\frac{1}{\eta}},$$

and then using $w = mc$ and plugging in the steady state marginal cost shown earlier, we obtain

$$N^d = \left[\frac{\epsilon_w - 1}{\epsilon_w} \frac{1}{\psi} \frac{1}{\lambda} \frac{\epsilon_p - 1}{\epsilon_p} \left(\frac{1-\phi_w (1+\pi)^{\epsilon_w - 1} (1+\pi)^{\zeta_w (1-\epsilon_w)}}{1-\phi_w} \right)^{\frac{1+\epsilon_w \eta}{1-\epsilon_w}} \frac{1}{(1-\tau_w)} \right]^{\frac{1}{\eta}}$$

Finally, when $\pi = \pi^{\#} = 0$ we get:

$$N^d = \left[\frac{\epsilon_w - 1}{\epsilon_w} \frac{\epsilon_p - 1}{\epsilon_p} \frac{1}{\psi} \frac{1}{\lambda} \frac{1}{(1-\tau_w)} \right]^{\frac{1}{\eta}} \tag{87}$$

3.2 Steady state under positive trend inflation

In models where firms face staggered price-setting, the degree of price dispersion is the key determinant of the inflationary cost. Consequently, when trend inflation is positive, price dispersion becomes a first-order variable shaping the long-run equilibrium, the transitional dynamics, and the welfare implications of the model (Ascari and Sbordone, 2014).

When introducing positive trend inflation, $\bar{\pi}$, in the steady state $\pi_t = \pi_{t-1} = \pi \quad \Longrightarrow \quad \pi = \bar{\pi}$ and $\bar{\pi} > 0$. Hence, with positive trend inflation the usual steady-state properties under no trend inflation no longer hold: price and wage dispersion deviate from unity, and both real marginal cost and the real wage are shifted by the inflation rate.

The aggregate price level—which, under Calvo pricing with trend inflation, is a convex combination of the newly reset price and the lagged aggregate price—becomes:

$$p_i{}^{\#} = \left(\frac{1 - \phi_p \, (1+\bar{\pi})^{(\epsilon_p - 1)(1-\zeta_p)}}{\left(1-\phi_p\right)} \right)^{\frac{1}{1-\epsilon_p}} \tag{88}$$

Steady-state price dispersion no longer collapses to one when trend inflation is positive,

$$v^p = \frac{(1-\phi_p)}{\left(1-\phi_p \, (1+\bar{\pi})^{\epsilon_p (1-\zeta_p)}\right)} (p^{\#})^{-\epsilon_p}. \tag{89}$$

Under positive trend inflation, the household's Euler equation in steady state delivers the familiar Fisher relation:

$$1 + i = \frac{1}{\beta}(1+\bar{\pi}) \tag{90}$$

so that the gross nominal interest rate exceeds the subjective discount rate by exactly the trend inflation factor.

The steady state auxiliary pricing variables are:

$$x_1 = \frac{\lambda mc Y}{1 - \phi_p \beta \, (1+\bar{\pi})^{\epsilon_p (1-\zeta_p)}} \tag{91}$$

$$x_2 = \frac{\lambda Y}{1 - \phi_p \beta (1+\bar{\pi})^{(\epsilon_p - 1)(1-\zeta_p)}} \tag{92}$$

In the steady state, when we take the ratio or dynamic price-adjustment factor we are able to solve for the steady state marginal cost:

$$\frac{x_1}{x_2} = mc \frac{1 - \phi_p \beta (1+\bar{\pi})^{(\epsilon_p - 1)(1-\zeta_p)}}{1 - \phi_p \beta \, (1+\bar{\pi})^{\epsilon_p (1-\zeta_p)}}$$

We substitute the dynamic price adjustment factor back into the reset-price equation:

$$\frac{p_i^{\#}}{mc} = \frac{\epsilon_p}{\epsilon_p - 1} \frac{1 - \phi_p \beta (1+\bar{\pi})^{(\epsilon_p - 1)(1-\zeta_p)}}{1 - \phi_p \beta \, (1+\bar{\pi})^{\epsilon_p (1-\zeta_p)}}$$

When we assume $\zeta_p = 0$, similar to Ascari and Sbordone (2014) we obtain the simple decomposition of the markup:

$$\mu = \frac{1}{mc} = \frac{P}{P_i^{\#}} \frac{p^{\#}}{mc} = \underbrace{\left(\frac{1 - \phi_p \, (1+\bar{\pi})^{(\epsilon_p - 1)}}{\left(1-\phi_p\right)} \right)^{-\frac{1}{1-\epsilon_p}}}_{\text{price adjustment gap}} \underbrace{\left[\frac{\epsilon_p}{\epsilon_p - 1} \frac{1 - \phi_p \beta (1+\bar{\pi})^{(\epsilon_p - 1)}}{1 - \phi_p \beta \, (1+\bar{\pi})^{\epsilon_p}} \right]}_{\text{marginal markup}} \tag{93}$$

Next, the optimal reset wage can be expressed relative to the steady-state real wage as

$$w^{\#} = \left(\frac{1 - \phi_w (1+\bar{\pi})^{(\epsilon_w - 1)(1-\zeta_w)}}{1 - \phi_w} \right)^{\frac{1}{1-\epsilon_w}} w. \tag{94}$$

Wage dispersion in the steady state no longer collapses to unity when assuming positive trend inflation

$$v^w = \frac{(1-\phi_w)\left(\frac{w^\#}{w}\right)^{-\epsilon_w(1+\eta)}}{1-\phi_w(1+\bar{\pi})^{(1-\zeta_w)(\epsilon_w(1+\eta))}} \tag{95}$$

We now solve for the steady-state values of the auxiliary wage-setting variables h_1 and h_2.

$$h_1 = \frac{\psi w^{\epsilon_w(1+\eta)} N^{d^{1+\eta}}}{1-\phi_w\beta(1+\pi)^{\epsilon_w(1+\eta)}(1+\pi)^{-\zeta_w\epsilon_w(1+\eta)}} \tag{96}$$

$$h_2 = \frac{\lambda w^{\epsilon_w} N^d}{1-\phi_w\beta(1+\pi)^{\epsilon_w-1}(1+\pi)^{\zeta_w(1-\epsilon_w)}} \tag{97}$$

Again, with trend inflation the ratio of the auxiliary variables would now maintain the wage adjustment factor.

$$\frac{h_1}{h_2} = \underbrace{\psi w^{\epsilon_w\eta}\lambda N^{d^\eta}}_{\text{Wage markup}} \underbrace{\frac{1-\phi_w\beta(1+\bar{\pi})^{(\epsilon_w-1)(1-\zeta_w)}}{1-\phi_w\beta(1+\bar{\pi})^{\epsilon_w(1+\eta)(1-\zeta_w)}}}_{\text{Wage adjustment factor}}$$

After plugging this into the first order condition for labour we have:

$$\left(w^\#\right)^{1+\epsilon_w\eta} = \frac{\epsilon_w}{\epsilon_w-1}\psi w^{\epsilon_w\eta}\lambda N^{d^\eta}\frac{1-\phi_w\beta(1+\bar{\pi})^{(\epsilon_w-1)(1-\zeta_w)}}{1-\phi_w\beta(1+\bar{\pi})^{\epsilon_w(1+\eta)(1-\zeta_w)}}$$

Following a similar set of steps as in the previous section we show:

$$N^d = \left[\frac{\epsilon_w-1}{\epsilon_w}\frac{1}{\psi}\frac{1}{\lambda}mc\frac{1}{(1-\tau_w)}\left(\frac{1-\phi_w(1+\bar{\pi})^{(\epsilon_w-1)(1-\zeta_w)}}{1-\phi_w}\right)^{\frac{1+\epsilon_w\eta}{1-\epsilon_w}}\frac{1-\phi_w\beta(1+\bar{\pi})^{(\epsilon_w-1)(1-\zeta_w)}}{1-\phi_w\beta(1+\bar{\pi})^{\epsilon_w(1+\eta)(1-\zeta_w)}}\right]^{\frac{1}{\eta}} \tag{98}$$

4 Log-linearisation of Price Dispersion (Uhlig Method)

We start from the nonlinear law of motion for price dispersion under Calvo pricing with indexation:

$$v_t^p = (1+\pi_t)^{\epsilon_p}\left[(1-\phi_p)(1+\pi_t^\#)^{-\epsilon_p} + \phi_p(1+\pi_{t-1})^{-\epsilon_p\zeta_p}v_{t-1}^p\right]. \tag{99}$$

In equilibrium, reset inflation equals actual inflation, i.e. $\pi_t^\# = \pi_t$. The steady-state values are denoted by bars: $\bar{\pi}$ and $\bar{v}^p$. Define the following log-deviation variables:

$$\hat{v}_t^p \equiv \ln v_t^p - \ln \bar{v}^p, \qquad \tilde{\pi}_t \equiv \ln(1+\pi_t) - \ln(1+\bar{\pi}).$$

Let:

$$X_t = (1-\phi_p)(1+\pi_t)^{-\epsilon_p} + \phi_p(1+\pi_{t-1})^{-\epsilon_p\zeta_p}v_{t-1}^p.$$

Then:

$$\ln v_t^p = \epsilon_p \ln(1+\pi_t) + \ln X_t, \tag{100}$$

and the log-linearisation becomes:

$$\hat{v}_t^p = \epsilon_p \tilde{\pi}_t + \widehat{X}_t.$$

To linearise $\widehat{X}_t$, note that $X_t = a_t + b_t$, where:

$$a_t = (1-\phi_p)(1+\pi_t)^{-\epsilon_p}, \qquad b_t = \phi_p (1+\pi_{t-1})^{-\epsilon_p \zeta_p} v_{t-1}^p.$$

Using Uhlig's approximation for $\hat{x} = \widehat{a+b}$:

$$\widehat{X}_t \approx \frac{a}{\bar{v}^p} \hat{a}_t + \frac{b}{\bar{v}^p} \hat{b}_t,$$

where:

$$\hat{a}_t = -\epsilon_p \tilde{\pi}_t, \qquad \hat{b}_t = -\epsilon_p \zeta_p \tilde{\pi}_{t-1} + \hat{v}_{t-1}^p.$$

Substitute back:

$$\begin{aligned} \hat{v}_t^p &= \epsilon_p \tilde{\pi}_t + \frac{a}{\bar{v}^p}(-\epsilon_p \tilde{\pi}_t) + \frac{b}{\bar{v}^p}\left(-\epsilon_p \zeta_p \tilde{\pi}_{t-1} + \hat{v}_{t-1}^p\right) \\ &= \left[\epsilon_p - \epsilon_p \cdot \frac{a}{\bar{v}^p}\right] \tilde{\pi}_t - \epsilon_p \zeta_p \cdot \frac{b}{\bar{v}^p} \tilde{\pi}_{t-1} + \frac{b}{\bar{v}^p} \hat{v}_{t-1}^p. \end{aligned}$$

Using steady-state values:

$$a = (1-\phi_p)(1+\bar{\pi})^{-\epsilon_p}, \qquad b = \phi_p (1+\bar{\pi})^{-\epsilon_p \zeta_p} \bar{v}^p,$$

we get:

$$\hat{v}_t^p = \epsilon_p \left[1 - \frac{(1-\phi_p)(1+\bar{\pi})^{-\epsilon_p}}{\bar{v}^p}\right] \tilde{\pi}_t - \epsilon_p \zeta_p \phi_p (1+\bar{\pi})^{-\epsilon_p \zeta_p} \tilde{\pi}_{t-1} + \phi_p (1+\bar{\pi})^{-\epsilon_p \zeta_p} \hat{v}_{t-1}^p. \tag{101}$$

Simplified dynamic form. Assuming $\tilde{\pi}_{t-1} \approx \tilde{\pi}_t$ (valid under local approximation), we can write:

$$\hat{v}_t^p = A \tilde{\pi}_t + B \hat{v}_{t-1}^p, \tag{102}$$

where:

$$\begin{aligned} A &= \epsilon_p \left[1 - \frac{(1-\phi_p)(1+\bar{\pi})^{-\epsilon_p}}{\bar{v}^p}\right] - \epsilon_p \zeta_p \phi_p (1+\bar{\pi})^{-\epsilon_p \zeta_p}, \\ B &= \phi_p (1+\bar{\pi})^{-\epsilon_p \zeta_p}. \end{aligned}$$

This shows that higher trend inflation $\bar{\pi}$ increases both the contemporaneous inflation effect and the persistence of price dispersion.

5 GNK Phillips curve around trend inflation: literal step–by–step derivation

5.1 Reset price log-linearisation

We set trend (gross) inflation $\Pi \equiv 1+\bar{\pi}$ and define log-deviations around trend as $\hat{z}_t \equiv \log z_t - \log \bar{z}$, so that $\hat{\pi}_t \equiv \log(1+\pi_t) - \log\Pi$. Starting from the reset-price formula

$$p_t^{\#} = \frac{\varepsilon_p}{\varepsilon_p - 1}\frac{x_{1,t}}{x_{2,t}},$$

take logs and subtract the steady state:

$$\begin{aligned}
&\log p_t^{\#} = \log\Big(\tfrac{\varepsilon_p}{\varepsilon_p-1}\Big) + \log x_{1,t} - \log x_{2,t},\\
&\log \bar{p}^{\#} = \log\Big(\tfrac{\varepsilon_p}{\varepsilon_p-1}\Big) + \log \bar{x}_1 - \log \bar{x}_2,\\
\Rightarrow\quad &\hat{p}_t^{\#} = (\log x_{1,t} - \log \bar{x}_1) - (\log x_{2,t} - \log \bar{x}_2) = \hat{x}_{1,t} - \hat{x}_{2,t}.
\end{aligned}$$

$$\boxed{\hat{p}_t^{\#} = \hat{x}_{1,t} - \hat{x}_{2,t}}$$

5.2 Linearise x_1, x_2 recursions and solve forward

From the model,

$$\begin{aligned}
x_{1,t} &= \lambda_t mc_t Y_t + \phi_p \beta (1+\pi_t)^{-\zeta_p\varepsilon_p}(1+\pi_{t+1})^{\varepsilon_p} x_{1,t+1},\\
x_{2,t} &= \lambda_t Y_t + \phi_p \beta (1+\pi_t)^{\zeta_p(1-\varepsilon_p)}(1+\pi_{t+1})^{\varepsilon_p-1} x_{2,t+1}.
\end{aligned}$$

Group inflation powers and evaluate at trend Π:

$$\bar{f}_1 \equiv \phi_p\beta\,\Pi^{\varepsilon_p - \zeta_p\varepsilon_p}, \qquad \bar{f}_2 \equiv \phi_p\beta\,\Pi^{\varepsilon_p - 1 + \zeta_p(1-\varepsilon_p)}.$$

Define $a_t \equiv \lambda_t mc_t Y_t$, $b_t \equiv \lambda_t Y_t$. Then

$$x_{1,t} = a_t + \bar{f}_1\,\mathbb{E}_t[x_{1,t+1}], \qquad x_{2,t} = b_t + \bar{f}_2\,\mathbb{E}_t[x_{2,t+1}]. \tag{A0}$$

Divide by steady states and subtract steady state values $\bar{x}_i = \bar{a}/(1-\bar{f}_1)$ and $\bar{x}_2 = \bar{b}/(1-\bar{f}_2)$:

$$\begin{aligned}
&\frac{x_{1,t}}{\bar{x}_1} = \frac{a_t}{\bar{x}_1} + \bar{f}_1\,\mathbb{E}_t\left[\frac{x_{1,t+1}}{\bar{x}_1}\right], &&\frac{x_{2,t}}{\bar{x}_2} = \frac{b_t}{\bar{x}_2} + \bar{f}_2\,\mathbb{E}_t\left[\frac{x_{2,t+1}}{\bar{x}_2}\right],\\
\Rightarrow\quad &\hat{x}_{1,t} = \frac{a_t}{\bar{x}_1} - \frac{\bar{a}}{\bar{x}_1} + \bar{f}_1\,\mathbb{E}_t[\hat{x}_{1,t+1}], &&\hat{x}_{2,t} = \frac{b_t}{\bar{x}_2} - \frac{\bar{b}}{\bar{x}_2} + \bar{f}_2\,\mathbb{E}_t[\hat{x}_{2,t+1}],\\
\Rightarrow\quad &\hat{x}_{1,t} = (1-\bar{f}_1)(\hat{\lambda}_t + \widehat{mc}_t + \hat{y}_t) + \bar{f}_1\,\mathbb{E}_t[\hat{x}_{1,t+1}],\\
&\hat{x}_{2,t} = (1-\bar{f}_2)(\hat{\lambda}_t + \hat{y}_t) + \bar{f}_2\,\mathbb{E}_t[\hat{x}_{2,t+1}].
\end{aligned}$$

Explicit geometric iteration for $\hat{x}_{1,t}$. Let $u_t \equiv (\hat{\lambda}_t + \hat{mc}_t + \hat{y}_t)$. Then

$$\begin{aligned}
\hat{x}_{1,t} &= (1-\bar{f}_1)u_t + \bar{f}_1\,\mathbb{E}_t[\hat{x}_{1,t+1}] \\
&= (1-\bar{f}_1)u_t + \bar{f}_1\,\mathbb{E}_t\big[(1-\bar{f}_1)u_{t+1} + \bar{f}_1\,\mathbb{E}_{t+1}[\hat{x}_{1,t+2}]\big] \\
&= (1-\bar{f}_1)u_t + (1-\bar{f}_1)\bar{f}_1\,\mathbb{E}_t[u_{t+1}] + \bar{f}_1^2\,\mathbb{E}_t[\hat{x}_{1,t+2}] \\
&= (1-\bar{f}_1)u_t + (1-\bar{f}_1)\bar{f}_1\,\mathbb{E}_t[u_{t+1}] + (1-\bar{f}_1)\bar{f}_1^2\,\mathbb{E}_t[u_{t+2}] + \bar{f}_1^3\,\mathbb{E}_t[\hat{x}_{1,t+3}] \\
&\;\;\vdots \\
&= (1-\bar{f}_1)\sum_{j=0}^{n}\bar{f}_1^{\,j}\,\mathbb{E}_t[u_{t+j}] + \bar{f}_1^{\,n+1}\,\mathbb{E}_t[\hat{x}_{1,t+n+1}].
\end{aligned}$$

Under stability ($\bar{f}_1 \in (0,1)$), letting $n \to \infty$ gives

$$\boxed{\hat{x}_{1,t} = (1-\bar{f}_1)\sum_{j\ge 0}\bar{f}_1^{\,j}\,\mathbb{E}_t[\hat{\lambda}_{t+j} + \hat{mc}_{t+j} + \hat{y}_{t+j}].}$$

Explicit geometric iteration for $\hat{x}_{2,t}$. Let $v_t \equiv (\hat{\lambda}_t + \hat{y}_t)$. The same steps yield

$$\boxed{\hat{x}_{2,t} = (1-\bar{f}_2)\sum_{j\ge 0}\bar{f}_2^{\,j}\,\mathbb{E}_t[\hat{\lambda}_{t+j} + \hat{y}_{t+j}].}$$

Term-by-term cancellation in $\hat{p}_t^{\#} = \hat{x}_{1,t} - \hat{x}_{2,t}$.

$$\begin{aligned}
\hat{p}_t^{\#} &= (1-\bar{f}_1)\sum_{j\ge 0}\bar{f}_1^{\,j}\,\mathbb{E}_t[\hat{\lambda}_{t+j} + \hat{mc}_{t+j} + \hat{y}_{t+j}] - (1-\bar{f}_2)\sum_{j\ge 0}\bar{f}_2^{\,j}\,\mathbb{E}_t[\hat{\lambda}_{t+j} + \hat{y}_{t+j}] \\
&= \underbrace{\Big[(1-\bar{f}_1)\sum_{j\ge 0}\bar{f}_1^{\,j} - (1-\bar{f}_2)\sum_{j\ge 0}\bar{f}_2^{\,j}\Big]}_{=1-1=0}\mathbb{E}_t[\hat{\lambda}_{t+j}] + \underbrace{\Big[(1-\bar{f}_1)\sum_{j\ge 0}\bar{f}_1^{\,j} - (1-\bar{f}_2)\sum_{j\ge 0}\bar{f}_2^{\,j}\Big]}_{=0}\mathbb{E}_t[\hat{y}_{t+j}] \\
&\quad + (1-\bar{f}_1)\sum_{j\ge 0}\bar{f}_1^{\,j}\,\mathbb{E}_t[\hat{mc}_{t+j}] \\
&= (1-\bar{f}_1)\sum_{j\ge 0}\bar{f}_1^{\,j}\,\mathbb{E}_t[\hat{mc}_{t+j}].
\end{aligned}$$

Hence

$$\boxed{\hat{p}_t^{\#} = (1-\bar{f}_1)\sum_{j\ge 0}\bar{f}_1^{\,j}\,\mathbb{E}_t[\hat{mc}_{t+j}].}$$

5.3 Price aggregator linearisation with indexation

Starting from

$$(1+\pi_t)^{1-\varepsilon_p} = (1-\phi_p)(p_t^{\#})^{1-\varepsilon_p} + \phi_p(1+\pi_{t-1})^{\zeta_p(1-\varepsilon_p)},$$

linearise each term around the trend steady state, using $x^\alpha \approx \bar{x}^\alpha\big(1+\alpha\widehat{\log x}\big)$:

$$(1+\pi_t)^{1-\varepsilon_p} - \Pi^{1-\varepsilon_p} \approx \Pi^{1-\varepsilon_p}(1-\varepsilon_p)\,\hat{\pi}_t,$$
$$(p_t^{\#})^{1-\varepsilon_p} - 1 \approx (1-\varepsilon_p)\,\hat{p}_t^{\#},$$
$$(1+\pi_{t-1})^{\zeta_p(1-\varepsilon_p)} - \Pi^{\zeta_p(1-\varepsilon_p)} \approx \Pi^{\zeta_p(1-\varepsilon_p)}\zeta_p(1-\varepsilon_p)\,\hat{\pi}_{t-1}.$$

Subtract the steady state identity $\Pi^{1-\varepsilon_p} = (1-\phi_p)+\phi_p\Pi^{\zeta_p(1-\varepsilon_p)}$ and divide by $(1-\varepsilon_p)$:

$$\Pi^{1-\varepsilon_p}\,\hat{\pi}_t = (1-\phi_p)\,\hat{p}_t^{\#} + \phi_p\Pi^{\zeta_p(1-\varepsilon_p)}\zeta_p\,\hat{\pi}_{t-1}.$$

Divide both sides by $(1-\phi_p)+\phi_p\Pi^{\zeta_p(1-\varepsilon_p)}$ to obtain

$$\boxed{\hat{\pi}_t = s_0\,\hat{p}_t^{\#} + \zeta_p s_1\,\hat{\pi}_{t-1}}, \qquad s_0 = \frac{1-\phi_p}{(1-\phi_p)+\phi_p\Pi^{\zeta_p(1-\varepsilon_p)}}, \quad s_1 = \frac{\phi_p\Pi^{\zeta_p(1-\varepsilon_p)}}{(1-\phi_p)+\phi_p\Pi^{\zeta_p(1-\varepsilon_p)}}.$$

5.4 Define S_t and show the reset-price Euler recursion

Let

$$\theta_1 \equiv \bar{f}_1 = \phi_p\beta\Pi^{\varepsilon_p-\zeta_p\varepsilon_p}, \qquad S_t \equiv \sum_{j=0}^{\infty}\theta_1^j\,\mathbb{E}_t[\hat{mc}_{t+j}].$$

From the boxed expression above,

$$\begin{aligned}
\hat{p}_t^{\#} &= (1-\theta_1)\sum_{j\ge 0}\theta_1^j\,\mathbb{E}_t[\hat{mc}_{t+j}] \\
&= \underbrace{\mathbb{E}_t[\hat{mc}_t]}_{=\hat{mc}_t} + \sum_{j\ge 1}\theta_1^j\,\mathbb{E}_t[\hat{mc}_{t+j}] \\
&= \hat{mc}_t + \theta_1\sum_{k\ge 0}\theta_1^k\,\mathbb{E}_t[\hat{mc}_{t+1+k}] \qquad (k=j-1) \\
&= \hat{mc}_t + \theta_1\,\mathbb{E}_t\left[\sum_{k\ge 0}\theta_1^k\,\hat{mc}_{t+1+k}\right] \\
&= \hat{mc}_t + \theta_1\,\mathbb{E}_t[S_{t+1}].
\end{aligned}$$

Thus

$$\boxed{S_t = \hat{mc}_t + \theta_1\,\mathbb{E}_t[S_{t+1}]}, \qquad \boxed{\hat{p}_t^{\#} = \theta_1\,\mathbb{E}_t[\hat{p}_{t+1}^{\#}] + \hat{mc}_t}$$

(where we have set any normalisation residual L_t aside; it only shifts constants: $\hat{p}_t^{\#} = \theta_1\mathbb{E}_t[\hat{p}_{t+1}^{\#}] + \hat{mc}_t + (L_t - \theta_1\mathbb{E}_t[L_{t+1}])$).

5.5 Substitute through the aggregator; isolate $E_t[\hat{p}_{t+1}^{\#}]$

From the price aggregator shifted one period,

$$\mathbb{E}_t[\hat{\pi}_{t+1}] = s_0\,\mathbb{E}_t[\hat{p}_{t+1}^{\#}] + \zeta_p s_1\,\hat{\pi}_t,$$

so

$$\boxed{\mathbb{E}_t[\hat{p}^{\#}_{t+1}] = \frac{1}{s_0}\,\mathbb{E}_t[\hat{\pi}_{t+1}] - \frac{\zeta_p s_1}{s_0}\,\hat{\pi}_t.}$$

Plug this into the reset-price Euler equation:

$$\hat{p}^{\#}_t = \theta_1\left(\frac{1}{s_0}\,\mathbb{E}_t[\hat{\pi}_{t+1}] - \frac{\zeta_p s_1}{s_0}\,\hat{\pi}_t\right) + \hat{mc}_t,$$
$$s_0\,\hat{p}^{\#}_t = \theta_1\,\mathbb{E}_t[\hat{\pi}_{t+1}] - \theta_1\zeta_p s_1\,\hat{\pi}_t + s_0\,\hat{mc}_t.$$

Now substitute $s_0\,\hat{p}^{\#}_t$ back into the aggregator at t:

$$\begin{aligned}\hat{\pi}_t &= s_0\,\hat{p}^{\#}_t + \zeta_p s_1\,\hat{\pi}_{t-1} \\ &= \left[\theta_1\,\mathbb{E}_t[\hat{\pi}_{t+1}] - \theta_1\zeta_p s_1\,\hat{\pi}_t + s_0\,\hat{mc}_t\right] + \zeta_p s_1\,\hat{\pi}_{t-1}.\end{aligned}$$

Move the $-\theta_1\zeta_p s_1\,\hat{\pi}_t$ term to the left:

$$(1+\theta_1\zeta_p s_1)\,\hat{\pi}_t = \theta_1\,\mathbb{E}_t[\hat{\pi}_{t+1}] + s_0\,\hat{mc}_t + \zeta_p s_1\,\hat{\pi}_{t-1}.$$

$$\boxed{(1+\theta_1\zeta_p s_1)\,\hat{\pi}_t = \theta_1\,\mathbb{E}_t[\hat{\pi}_{t+1}] + s_0\,\hat{mc}_t + \zeta_p s_1\,\hat{\pi}_{t-1}}$$

5.6 Final explicit-coefficient GNK PC (MC form)

Divide through by $(1+\theta_1\zeta_p s_1)$:

$$\hat{\pi}_t = \underbrace{\frac{\theta_1}{1+\theta_1\zeta_p s_1}}_{\tilde{\beta}_\pi(\Pi)}\,\mathbb{E}_t[\hat{\pi}_{t+1}] + \underbrace{\frac{s_0}{1+\theta_1\zeta_p s_1}}_{\kappa_{mc}(\Pi)}\,\hat{mc}_t + \underbrace{\frac{\zeta_p s_1}{1+\theta_1\zeta_p s_1}}_{\gamma(\Pi)}\,\hat{\pi}_{t-1},$$

with

$$\theta_1 = \phi_p\beta\,\Pi^{\varepsilon_p-\zeta_p\varepsilon_p}, \qquad s_0 = \frac{1-\phi_p}{(1-\phi_p)+\phi_p\Pi^{\zeta_p(1-\varepsilon_p)}}, \qquad s_1 = \frac{\phi_p\Pi^{\zeta_p(1-\varepsilon_p)}}{(1-\phi_p)+\phi_p\Pi^{\zeta_p(1-\varepsilon_p)}}.$$

5.7 Output-gap form

We do not construct a flexible–price counterfactual in this paper. Instead we define the activity gap as the log deviation of output from the trend–inflation steady state, $x_t \equiv \widehat{y}_t$.

Define the model-consistent gap mapping $\hat{mc}_t = \Psi(\Pi)\,x_t$. Then the output-gap Phillips curve is

$$\boxed{\hat{\pi}_t = \tilde{\beta}_\pi(\Pi)\,\mathbb{E}_t[\hat{\pi}_{t+1}] + \underbrace{\kappa_{mc}(\Pi)\,\Psi(\Pi)}_{\kappa_y(\Pi)}\,x_t + \gamma(\Pi)\,\hat{\pi}_{t-1}.}$$

When plotting against annualised inflation (pp), multiply model-quarter slopes by 4.

Note on L_t: If one keeps $\hat{p}_t^{\#} = S_t + L_t$, the term $L_t - \theta_1 \mathbb{E}_t[L_{t+1}]$ carries through the two substitutions above as a *constant* that does not multiply $\hat{\pi}_t, \mathbb{E}_t[\hat{\pi}_{t+1}], \hat{\pi}_{t-1}, \hat{mc}_t$; hence it does not affect the reported coefficients.

6 Calibration

We adopt a standard calibration approach[2] for the model parameters, following values commonly used in the New Keynesian literature. Table 1 reports the parameters related to household preferences, price and wage setting, and the monetary policy rule. Fiscal policy parameters and steady-state calibration targets are presented in Table 2. Finally, Table 3 summarises the persistence of the exogenous shock processes affecting the economy. Where possible, parameter values are chosen to match standard empirical estimates; otherwise, they are set to conventional values used in prior studies to ensure comparability and to facilitate interpretation of the results. [3]

Table 1: Model Parameters: Preferences, Price Setting, and Monetary Policy

Parameter	Description	Value
β	Discount Factor	0.9884
b	Habit Formation Parameter	0.65
ω	Non-Ricardian Household Consumption Share	0.1
ω_w	Non-Ricardian Household Welfare Share	0.5
η	Inverse Frisch Elasticity	1
ψ	Labor Disutility Weight	3
ϵ_w	Elasticity of Substitution - Labor	6
ϵ_p	Elasticity of Substitution - Goods	11
ϕ_w	Wage Stickiness (Calvo)	0
ϕ_p	Price Stickiness (Calvo)	0.75
ζ_w	Wage Indexation Parameter	0
ζ_p	Price Indexation Parameter	0.1
ϕ_π	Inflation Coefficient in Taylor Rule	2.5
ϕ_y	Output Gap Coefficient in Taylor Rule	0.25
ρ_i	Interest Rate Smoothing Parameter	0.75
trend_inflation	Annual Trend Inflation (%)	0-10

Notes: Preferences, price and wage setting, and monetary policy calibration.

[3]Our calibration largely follows Garín et al. (2016) and Ascari and Sbordone (2014), while we calibrate where possible according to South African data and estimates from the literature looking at past work, such as Kemp and Hollander (2020); Hollander et al. (2024) and Havemann and Hollander (2024).

Table 2: Model Parameters: Fiscal Policy and Steady-State Targets

Parameter	**Description**	**Value**
γ_{gd}	Government Spending Response to Debt	0.12
γ_{gy}	Government Spending Response to Output	0.05
γ_{trd}	Transfers Response to Debt	0.36
γ_{try}	Transfers Response to Output	0.16
γ_{rp}	Risk Premium Response to Debt	0.001
γ_{wd}	Labour Tax Response to Debt	0.11
γ_{cd}	Consumption Tax Response to Debt	0.21
G^*	Government Spending Target	0.195
Y^*	Output Target	1
D^*/Y^*	Debt-to-Output Ratio Target	1.6
τ_{w^*}	Labour Tax Rate Target	0.191
τ_{C^*}	Consumption Tax Rate Target	0.167
tr^{NR^*}	Transfers to Non-Ricardians Target	0.035
ρ_{tr}	Transfers Shock Persistence	0.85
ρ_w	Labour Tax Rate Persistence	0.42
ρ_c	Consumption Tax Rate Persistence	0.24
ρ_g	Government Spending Persistence	0.82

Notes: Calibrated values from baseline parameterisation.

Table 3: Model Parameters: Shock Processes

Parameter	**Description**	**Value**
ρ_a	Productivity Shock Persistence	0.75
ρ_v	Preference Shock Persistence	0.75
ρ_{ϵ_w}	Wage Markup Shock Persistence	0.75
ρ_{ϵ_p}	Price Markup Shock Persistence	0.75
ρ_{rp}	Risk Premium Shock Persistence	0.75

Notes: Persistence parameters calibrated from baseline specification.

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