The Propagation of Inflation Target Shocks in a HANK Model*

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Abstract

This paper compares the propagation of inflation target shocks to that of transitory interest rate shocks in a baseline Heterogeneous Agent New Keynesian model (HANK). In this model, the Neo-Fisher effect emerges under inflation target shocks, leading to a short-run co-movement between inflation and nominal interest rates. This result corroborates similar findings for New Keynesian models with a representative agent. Movements in disposable labor income (indirect effects) are the main source of consumption responses to both types of monetary shocks, with a secondary role for intertemporal substitution (the direct effect). However, under inflation target shocks, in the short run, indirect effects tend to be much stronger, though an inertial Taylor rule and a fiscal policy that allows for deficit financing considerably attenuate their size.

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1 Introduction

In the representative-agent New Keynesian model, several research papers have pointed out that sufficiently persistent changes in the inflation target induce rising inflation and interest rates in the short run. For instance, Ireland (2007), Garin et al. (2018), and Uribe (2022) supported the emergence of a short-run co-movement between inflation and nominal interest rates due to inflation target shocks that are permanent or very persistent, albeit stationary. This pattern is known as the Neo-Fisher effect.

In New Keynesian models with a representative agent, in response to an inflation target shock (stationary but persistent or permanent), inflation and inflation expectations start increasing immediately. Indeed, firms know that in the long run the price level and nominal wages will increase. They understand that they will confront a higher cost of adjusting their prices if they postpone this decision by keeping outdated prices in face of elevated labor costs. Hence, their optimal strategy is to begin increasing their prices immediately. Nominal interest rates rise quickly but gradually to fight the inflationary surge, but they increase at a slower rate, leading to a decline in ex-ante and ex-post real interest rates. In this context, output and consumption tend to increase in contrast to the outcome of a transitory monetary policy shock.

Uribe (2022) and Garcia-Cicco et al. (2024) showed the empirical relevance of inflation target shocks in explaining the dynamics of inflation. Uribe (2022) presented evidence for the U.S. and Garcia-Cicco et al. (2024) extended the empirical methodology in Uribe (2022) to a more flexible framework, which is applied to a sample of eighty countries. They find support for the Neo-Fisher effect for most countries investigated. Schmitt-Grohé and Uribe (2022) studied the effects of permanent inflation target shocks on exchange rates in a small-open economy model. They showed that these shocks induce a depreciation of the nominal and real exchange rates, in opposition to the outcome of a transitory monetary shock. In a model with imperfect information, in which agents are unable to distinguish between transitory and persistent monetary shocks, Lukmanova and Rabitsch (2023) documented a delayed Neo-Fisher effect, with an initial fall of the interest rate on impact after a shock to the inflation target. Finally, Airaudo (2023) reported a link between the magnitude of the Neo-Fisher effect and wealth effects in households' labor supply decisions. Indeed, weaker wealth effects in labor supply tend to amplify the Neo-Fisher effect.

In the Heterogeneous-Agent New Keynesian (HANK) literature, Kaplan et al. (2018), Kaplan and Violante (2018), and Alves et al. (2021) emphasized the complexity of the transmission mechanism of monetary policy. For instance, aggregate consumption responses to transitory monetary policy shocks, in contrast to the canonical representative agent, relies less on intertemporal substitution (the direct effect) and more on indirect general equilibrium effects, such as movements in wages, employment, dividends, capital gains, taxes, and transfers expenditures.

Kaplan et al. (2018) emphasized the differences between models with a representative agent and HANK for the transmission mechanism of transitory monetary policy shocks and highlighted the smaller role of intertemporal substitution on consumption responses to these disturbances. Alves et al. (2021) explored additional extensions to the basic model in Kaplan et al. (2018) and focus on what extent different building blocks of the model amplify or dampen the response of aggregate consumption to a transitory monetary policy shock. For alternative specifications, independent of their amplification or dampening effects, they attest to the robustness of the prevalent role of indirect effects on the propagation of transitory monetary shocks to aggregate consumption. Kaplan and Violante (2018) compared the transmission mechanism of transitory monetary shocks to the transmission mechanism of other economic shocks, such as technology shocks and government expenditures. They showed that similarities between representative-agent New Keynesian and HANK models depend on the nature of the shock. For instance, demand shocks generate the same aggregate consumption dynamics through very similar economic mechanisms. This is not the case for transitory monetary shocks and fiscal shocks, which entailed very distinct transmission mechanisms.

Despite the growing literature on inflation target and permanent monetary shocks, research on HANK has focused its attention on transitory monetary policy shocks and how their propagation differs compared with representative agent models. In this paper, I concentrate the analysis on comparing two types of monetary shocks: inflation target shocks (stationary, but persistent, or permanent) and transitory interest rate shocks, which are the traditional object of analysis in HANK papers. Though I establish a dialogue with models featuring a representative agent, the focus is in contrasting the two monetary shocks, maintaining a baseline HANK model throughout the paper. This baseline specification is a discrete version of Kaplan et al. (2018) described in section 2.

In the present paper, after inflation target shocks, impulse responses of inflation and nominal interest rates corroborate the presence of the Neo-Fisher effect. In other words, there is short-run positive co-movement between these variables. In addition, output and consumption rises due to declining real interest rates (ex-ante and ex-post). After transitory interest rate shocks, both inflation and output decline, according to the predictions of representative-agent New Keynesian models. Qualitatively, the baseline HANK model behaves in the same way as the monetary model with a representative agent described in Uribe (2022).

Regarding consumption responses decomposition, irrespective of the type of monetary shock, responses are primarily driven by indirect effects, which is the hallmark of HANK models. Indirect effects basically come from movements in disposable labor income due to changes in tax rates. The main finding of this paper is that these indirect effects tend to be much stronger in the short run after inflation target shocks.

Under the benchmark calibration, inflation target shocks, on impact, affect expected inflation because firms anticipate high marginal costs for long horizons since these shocks are persistent or permanent. In line with the Phillips curve, inflation responds strongly and immediately. Ex-ante and ex-post real interest rates both falls, but we see a stronger reduction in ex-post real rates. Consequently, we notice an expressive increase in output and consumption. According to the benchmark fiscal rule, the government must cut tax rates since debt services decreased because of declining ex-post real interest rates and the tax base increased due to the vigorous economic expansion. On the other hand, on impact, since the decline in ex-ante real interest rates is not substantial, there is not a strong enough incentive for intertemporal substitution, which tends to lower the size of the short-run direct effect.

The relative strength of the changes in ex-ante and ex-post real rates also determine the size of prevalent indirect effects under transitory interest rate shocks. But, in this case, the initial decline in inflation is not very significant because expected inflation does not react that much to short-lived shocks, and the increase in ex-post real interest rates is not enough, in the short run, to trigger a massive role for indirect effects. Indeed, changes in tax rates needed to finance an increased debt service in an economic recession are not that sizeable. Still, on impact, indirect effects are stronger than the direct effect, but their magnitudes are smaller compared to the same decomposition under inflation target shocks.

This paper considers some variations in the benchmark calibration. Indeed, in all cases, indirect effects become somewhat weaker under inflation target shocks in the short run, but, in most cases, their magnitudes continue to be sizeable compared to the situation in which the model faces transitory interest rate shocks. However, an inertial Taylor rule and a fiscal strategy allowing for deficit financing substantially increase the amplitude of the direct effect to an amount close to values we observe under transitory interest rate shocks.

The paper proceeds as follows. Section 2 introduces a baseline HANK model. Then, Section 3 presents and discusses the main results concerning impulse responses to monetary shocks and consumption responses decomposition. Finally, I offer concluding remarks and suggest future research on the topic in section 4.

2 A Baseline HANK Model

I present a discrete time version of the model in Kaplan et al. (2018), following the specification described in Auclert et al. (2021, 2023). The model embed a consumption-savings problem with incomplete markets in a standard New Keynesian environment with price and wage stickiness. In addition, firms accumulate capital and face adjustment costs, and households have access to liquid and illiquid accounts. The Taylor rule features both inflation target shocks and transitory interest rate shocks. First, I describe inflation target shocks as stationary but persistent, according to Eo and Lie (2020), and Lukmanova and Rabitsch (2023). Alternatively, I also specify these shocks as permanent, following Ireland (2007) and Uribe (2022).

2.1 Persistent Stationary Inflation Target Shocks

2.1.1 Households

At each time t, households choose consumption (c_{it}) and allocate their savings between liquid (b_{it}) and iliquid assets (a_{it}), subject to a convex portfolio adjustiment cost $\Phi_t(a_{it}, a_{it-1})$. They offer the same number of hours worked (N_t), which is determined by firms' labor demands. The Bellman equation for the household optimization problem is

$$V_t(z_{it}, a_{it-1}, b_{it-1}) = \underset{c_{it}, a_{it}, b_{it}}{Max} \left\{ \frac{c_{it}^{1-\sigma}}{1-\sigma} - \varphi \frac{N_t^{1+v}}{1+v} + \beta E_t \left[V_{t+1}(z_{it+1}, a_{it}, b_{it}) \right] \right\}$$

The borrowing constraints are $a_{it} \geq 0$ and $b_{it} \geq \underline{b}$, where $\underline{b}$ is the borrowing limit in liquid assets.

The variable V_t is the value function, E_t represents the expectation operator, and z_{it} stands for idiosyncratic earnings shocks. Housholds are indexed by their holdings of liquid, illiquid assets, and by their idiosyncratic earnings shock. These variables are jointly distributed according to $\mathbf{D}_t$, which depends upon the solution of the consumer's problem above. The parameters are the discount factor (β), the relative risk aversion coefficient (σ), the inverse of the Frisch elasticity (v), and the disutility of labor coefficient (φ).

The following equations comprise the budget constraint:

$$c_{it} + b_{it} + d_t + \Phi_t(a_{it}, a_{it-1}) = (1-\tau_t) z_{it} w_t N_t + (1 + r_t^b) b_{it-1}$$

$$a_{it} = (1 + r_t^a)a_{it-1} + d_t$$

The gross real returns on liquid and illiquid assets are $(1+r_t^b)$ and $(1+r_t^a)$. Households need to pay a cost $\Phi_t(a_{it}, a_{it-1})$ for depositing into or withdrawing from the illiquid account. The variable d_t denotes the net deposit rate related to the illiquid account. Finally, given real wages w_t, labor earnings taxed at rate τ_t also compose households' income stream.

The portfolio adjustment cost function is

$$\Phi_t(a_{it}, a_{it-1}) = \frac{\chi_1}{\chi_2} \left| \frac{a_{it} - (1 + r_t^a)a_{it-1}}{(1 + r_t^a)a_{it-1} + \chi_0} \right|^{\chi_2} [(1 + r_t^a)a_{it-1} + \chi_0]$$

The parameters χ_0, χ_1, and χ_2 control the shape of the function $\Phi_t(a_{it}, a_{it-1})$, especially its curvature.

2.1.2 Production, Investment, and Price Setting

The production of intermediate goods j (y_{it}) follows a Cobb-Douglas technology $Y_{it} = F(k_{jt-1}, n_{jt}) = \Theta_t k_{jt-1}^{\alpha} n_{jt}^{1-\alpha}$, which combines capital (k_{jt-1}) and labor (n_{jt}). These firms choose their own capital stock, subject to a quadrtic adjustment cost $\zeta(\frac{k_{jt}}{k_{jt-1}})k_{jt-1}$, with the function $\zeta(x)$ specified as $\zeta(x) = x - (1 - \delta) + \frac{1}{2\delta e_I}(x - 1)^2$. The parameter δ is the depreciation rate and e_I controls the shape of $\zeta(x)$.

The expression for investment is $I_{jt} = k_{jt} - (1 - \delta)k_{jt-1} + \zeta(\frac{k_{jt}}{k_{jt-1}})k_{jt-1}$.

These firms operate under monopolistic competition and set prices according to the Rotemberg scheme, in which they face a quadratic price adjustment cost, and are subject to the constraint $Y_{jt} = \left(\frac{P_{jt}}{P_t}\right)^{-\frac{\mu}{\mu-1}} Y_t$, where P_t is the price of the final good and $\frac{\mu}{\mu-1}$ stands for the elasticity of substitution between different intermediate goods in the Dixt-Stiglitz aggregator for the final output (Y_t), which is $Y_t = \left(\int_0^1 Y_{jt}^{\frac{1}{\mu}} \right)^{\mu}$.

The quadratic adjustmente cost function ψ_t is

$$\psi_t = \frac{\mu}{\mu - 1} \left(\frac{1}{2k^p} \right) \left[\log\left(\frac{P_{jt}}{P_{jt-1}} \right) \right]^2 Y_t$$

The parameter k^p controls the degree of price stickiness.

The firm solves the following problem:

$$J_t(P_{jt-1}, k_{jt-1}) = \underset{P_{jt}, k_{jt}, n_{jt}}{Max} \left\{ \begin{array}{c} \frac{P_{jt}}{P_t} F(k_{jt-1}, n_{jt}) - w_t n_{jt} - k_{jt} + (1 - \delta) k_{jt-1} - \\ \zeta(\frac{k_{jt}}{k_{jt-1}}) k_{jt-1} - \psi_t + \frac{1}{1+r_t} J_{t+1}(P_{jt}, k_{jt}) \end{array} \right\}$$

$$\text{subject to } \left[\frac{F(k_{jt-1}, n_{jt})}{y_t} \right]^{\frac{1-\mu}{\mu}} = \frac{P_{jt}}{P_t}$$

As usual, I impose a symmetric equilibrium in which $k_{jt} = K_t$, $n_{jt} = N_t$, $Y_{jt} = Y_t$, and $P_{jt} = P_t$.

The solution of the firm's decision problem engenders the price Phillips curve given by

$$\log(1 + \pi_t) = \frac{1}{1 + r_t} \left(\frac{Y_{t+1}}{Y_t} \right) \log(1 + \pi_{t+1}) + k^p \left(mc_t - \frac{1}{\mu} \right)$$

The variable mc_t is the real marginal cost defined as the ratio between w_t and the derivative $\frac{\partial}{\partial n_t} F(K_{t-1}, N_t)$.

The dividends (div_t) are

$$\text{div}_t = F(K_{t-1}, N_t) - w_r N_t - I_t - \psi_t$$

2.1.3 Unions and Nominal Wage Setting

Labor hours n_{it} are determined by union labor demand. Every worker i belongs to a specific union k. There ara a continuum of unions that aggregate the efficient units of work of its members in a union-specific task N_{kt}. Therefore, $N_{kt} = \int z_{it} n_{ikt} di$. Finally, a competitive labor packer combines these specific tasks into aggregate employment services according to the Dixt-Stiglitz aggregator $N_t = \left(\int_0^1 N_{kt}^{\frac{1}{\mu_w}} \right)^{\mu_w}$. The packer finally sells these services to firms at nominal wage W_t.

There is a quadratic utility cost ψ_t^w of adjusting the nominal wage set by union k (W_{kt}), which is similar to the specification for the price adjustment cost:

$$\psi_t^w = \frac{\mu^w}{\mu^w - 1} \left(\frac{1}{2k^w} \right) \left[\log \left(\frac{W_{kt}}{W_{kt} - 1} \right) \right]^2$$

The parameter k^w governs the degree of wage stickiness.

The cost ψ_t^w is an extra additive disutility term in the household flow of utility. I restrict the analysis to a situation in which, for each of its members, all unions k set a common wage W_{kt} per efficient unit. The union k stipulates the uniform rule $n_{ikt} = N_{kt}$ that regulates how the members should supply hours. Given these restrictions the union sets the common wage W_{kt} to maximize the average utility of its members. In short, all unions choose to set the same nominal wage $W_{kt} = W_t$ and all households work the same number of hours $n_{ikt} = N_{kt} = N_t$.

The following wage Phillips curve emerges from this setup:

$$\log\left(1 + \pi_t^w\right) = \beta \log\left(1 + \pi_{t+1}^w\right) + k^w \left(\varphi N_t^{1+v} - \frac{(1-\tau_t) w_t N_t}{\mu_w} \int z_{it} c_{it}^{-\sigma} di \right)$$

2.1.4 Monetary Authority and the Government

The monetary authority sets the nominal interest rate i_t according to a Taylor rule. I follow the specification in Eo and Lie (2020), and in Lukmanova and Rabitsch (2023). In these papers, inflation target shocks (π_t^*) are stationary but persistent, and interest rate shocks (z_t^m) are transitory. In the model, movements in the inflation target can be interpreted, more broadly, as persistent changes in the systematic behavior of the Central Bank, which cannot be characterized as transitory deviations from a stable policy rule. For instance, new appointed board members may change the dynamics of the monetary policy committee and, therefore, cause systematic fluctuations in monetary policy decisions.

The monetary policy rule is

$$i_t = (1-\gamma_i)\left[r^* + \pi_t^* + \alpha_\pi\left(\pi_t - \pi_t^*\right)\right] + \gamma_i(1+i_{t-1}) + z_t^m$$

The variable r^* is a reference real rate and, in absence of inertia, the term $r^* + \pi_t^*$ corresponds to the nominal rate consistent with inflation π_t kept at its time-varying target π_t^*. The Central Bank reacts to the gap between inflation and its target according to the coefficient α_π. The parameter γ_i controls the degree of interest rate inertia.

The government, the only issuer of liquid assets, faces exogenous expenditures G_t and collects taxes on household labor income. In this paper, I keep G_t constant and focus only on monetary shocks. Government assets are real bonds with one period maturity denoted by B_t^g. The intertemporal budget constraint is $B_t^g = (1+r_t)B_{t-1}^g + \tau_t w_t N_t - G_t$. I adopt a simple specification for the benchmark fiscal policy and consider a government that sets a constant level of bond supply B_t^g. Hence, I keep B_t^g at its steady state, i.e., $B_t^g = B_{t-1}^g = B^g$, and revenues adjust according to $\tau_t w_t N_t = r_t B^g + G_t$. Following Auclert (2020), an alternative fiscal rule considers tax rates that respond to deviations of government debt from its steady state. This rule allows for government deficits. In this case, the budget constraint $B_t^g = (1+r_t)B_{t-1}^g + \tau_t w_t N_t - G_t$ and the rule $\tau_t = \tau_{ss} + \phi_T(B_t^g - B^g)$ describe fiscal policy. The strictly positive parameter ϕ_T controls tax rates reaction and τ_{ss} stands for their level at the steady state.

2.1.5 Financial Intermediary and Market Clearing Conditions

A competitive financial intermediary takes liquid and illiquid deposits from households and invests them in government bonds B_t^g and in firm equity p_t. This intermediary passes on to households the returns on these assets and levies a fee at proportional cost $\omega \int b_{it-1} di$. Expected equity return is $E_t\left[\frac{\text{div}_{t+1} + p_{t+1}}{p_t}\right]$. No arbirage imposes the following restriction:

$$\begin{aligned} E_t(1+r_{t+1}) &= \frac{1+i_t}{E_t\left(1+\pi_{t+1}\right)} = E_t(1+r_{t+1}^a) = E_t\left(\frac{\text{div}_{t+1} + p_{t+1}}{p_t}\right) \\ &= E_t(1+r_{t+1}^b) + \omega \end{aligned}$$

However, the ex-post returns on equity and bonds are subject to capital gains or losses, as well as to surprise inflation or deflation (valuation effects). the ex-post real rate on government bonds is $1+r_t = \frac{1+i_{t-1}}{1+\pi_t}$. By assumption, the net proceeds due to valuation effects flow to the illiquid account. Hence, we have

$$1 + r_t^a = \Theta_p\left(\frac{\text{div}_t + p_t}{p_{t-1}}\right)\left(1-\Theta_p\right)\left(1+r_t\right)$$

The symbol Θ_p denotes the share of equity in the illiquid portfolio.

The aggregate consumption $C_t = \int c_{it} di$, government expenditures G_t, investment I_t, price adjustment costs ψ_t, liquidity transformation costs $\omega \int b_{it-1} di$, and portlofio adjustment costs $\int \Phi_t(a_{it}, a_{it-1}) di$ are measured in units of final goods. Therefore the following restriction must hold:

$$Y_t = C_t + G_t + I_t + \psi_t + \omega \int b_{it-1} di + \int \Phi_t(a_{it}, a_{it-1}) di$$

Total savings by households (liquid and illiquid accounts) correspond to the value of firm equity (p_t) and government bonds (B_t^g). Therefore, we have the equation

$$p_t + B_t^g = \int (a_{it} + b_{it})\, di$$

2.2 Permanent Inflation Target Shocks

To allow for permanent inflation target shocks, one has to change the firm's pricing problem, the union's nominal wage choice, and the Taylor rule specification.

The quadratic adjustmente cost function ψ_t for firms is

$$\psi_t = \frac{\mu}{\mu - 1} \left(\frac{1}{2k^p} \right) \left[\log(\frac{P_{jt}}{P_{jt-1}}) - \log(X_t^m) \right]^2 Y_t$$

The variable X_t^m denotes the inflation target that follows a non-stationaty process, and the parameter k^p controls the degree of price stickiness.

The price Phillips curve becomes

$$\log(\frac{1 + \pi_t}{X_t^m}) = \frac{1}{1 + r_t} \left(\frac{Y_{t+1}}{Y_t} \right) \log(\frac{1 + \pi_{t+1}}{X_{t+1}^m}) + k^p \left(mc_t - \frac{1}{\mu} \right)$$

There is a quadratic utility cost ψ_t^w of adjusting the nominal wage set by union k (W_{kt}), which is similar to the specification for the price adjustment cost:

$$\psi_t^w = \frac{\mu^w}{\mu^w - 1}\left(\frac{1}{2k^w}\right)\left[\log\left(\frac{W_{kt}}{W_{kt}-1}\right) - \log\left(X_t^m\right)\right]^2$$

The variable X_t^m denotes the inflation target, around which one defines the cost of nominal wage changes by union k, and the parameter k^w governs the degree of wage stickiness.

The expression for the wage Phillips curve is:

$$\log\left(\frac{1+\pi_t^w}{X_t^m}\right) = \beta \log\left(\frac{1+\pi_{t+1}^w}{X_{t+1}^m}\right) + k^w\left(\varphi N_t^{1+v} - \frac{(1-\tau_t)w_t N_t}{\mu_w}\int z_{it} c_{it}^{-\sigma} di\right)$$

The monetary authority sets the nominal interest rate i_t according to a Taylor rule. I follow the specification in Uribe (2022), in which permanent and transitory monetary shocks coexist. In levels, the permanent shock is X_t^m and the transitory is Z_t^m.

In level, the monetary policy rule is

$$(1+i_t) = \left[(1+r^*)X_t^m\left(\frac{1+\pi_t}{X_t^m}\right)^{\alpha_\pi}\right]^{1-\gamma_i}(1+i_{t-1})^{\gamma_i} Z_t^m$$

The variable r^* is a reference real rate and, in absence of inertia, the term $(1+r^*)X_t^m$ corresponds to the nominal rate consistent with inflation π_t kept at its time-varying target $\pi_t^* = X_t^m - 1$. The Central Bank reacts to the gap between inflation and its target according to the coefficient α_π. The parameter γ_i controls how inertial is the rule.

In this setup, Z_t^m is stationary, but X_t^m is not. I assume that the growth rate of the inflation target shock, which follows the expression $x_t^m =$

$\log(\frac{X_t^m}{X_{t-1}^m})$, is a stationary process. Hence, auto-regressive processes of order one describe the stochastic variables x_t^m and $z_t^m = \log(Z_t^m)$. We can define detrended nominal interest rates and inflation by the equations $(1+i_t^d) = \frac{1+i_t}{X_t^m}$ and $1+\pi_t^d = \frac{1+\pi_t}{X_t^m}$. After this transformation, the monetary policy rule becomes

$$(1+i_t^d) = \left[(1+r^*)\left(1+\pi_t^d\right)^{\alpha_\pi}\right]^{1-\gamma_i}(1+i_{t-1}^d)^{\gamma_i}\exp(z_t^m - \gamma_i x_t^m)$$

2.3 Solution and Calibration

To solve the household's problem, I discretize the individual state space (z_{it}, a_{it}, b_{it}), using 3, 50, and 70 grid points, respectively. The idiosyncratic shocks z_{it} follow a first-order auto-regressive specification, which I approximate by a discrete Markov chain. I then write the equations describing the equilibrium in the sequence space and represent them as a Directed Acyclic Graph (DAG). After that, I use the Sequence Space Jacobian method (SSJ) proposed by Auclert et al. (2021) to obtain impulse responses to both types of monetary shocks (e.g., interest rate shocks and inflation target shocks). For permanent inflation target shocks, I express the model in terms of stationary nominal variables, by dividing $1+i_t$, $1+\pi_t$, and $1+\pi_t^w$ by the stochastic trend X_t^m.

I show the benchmark calibration for structural parameters in Table 1. In fact, I borrowed most of the calibration concerning households and firms from Auclert et al (2021). Those magnitudes are very standard in the literature. Regarding exogenous monetary shocks, for the model with stationary inflation target shocks, I set the persistence of the first order auto-regressive inflation target process to 0.95 and the one for the transitory interest rate shock to

0.5. Most of the estimation of standard New Keynesian models pointed out to very persistent inflation target shocks. For instance, Lukmanova and Rabitsch (2023) found a posterior range between 0.984 and 0.997, though Uribe (2022) reported estimations with much more uncertainty, but still with a very high posterior mean. In the case of the transitory interest rate shock, the value 0.5 for the auto-regressive coefficient comes from Kaplan et al. (2018) and Alves et. al. (2021).

According to Uribe (2022), for the model with permanent inflation target shocks, I set the auto-regressive coefficient for $x_t^m = \log(\frac{X_t^m}{X_{t-1}^m})$ to 0.3. As usual in HANK models, the benchmark calibration considers a Taylor rule without inertia and no reaction to the output gap. I set the reaction to the inflation gap $\pi_t - \pi_t^*$ to 1.5, which is also a standard parameter value. In all computation of impulse responses, following Kaplan et al. (2018) and Alves et al. (2021), I consider positive shocks with initial size of 0.25% (i.e. 1% annually).

Since results are very similar for the model with permanent inflation target shocks, I only report results for the case of stationary inflation target shocks when I discuss extensions to the basic calibration. First, I also consider an inertial Taylor rule ($\gamma_i = 0.8$) and report the results maintaining the persistence of transitory interest rate shocks[1]. In addition to the inertial Taylor rule, as extensions to the benchmark calibration, I contemplate the following cases: an aggressive response to inflation ($\alpha_\pi = 5$), more flexibility in prices ($k^p = 1.2$), and more flexibility in wages ($k^w = 1.2$). Finally, I consider a fiscal policy rule in which tax rates react linearly to deviations of lagged government debt from its steady state with a coefficient ϕ_T. Following

[1] I also examine an alternative calibration with white noise transitory shocks and an inertial Taylor rule. Indeed, the results are qualitatively and quantitatively very similar for both specifications, so I decide to report results with a persistent specification for transitory shocks.

Auclert (2020), I set $\phi_T = 0.1$. This specification corresponds to a deficit financing strategy.

3 Results

I present impulse responses to the two types of monetary shocks and a decomposition of consumption responses put forth by Kaplan et al. (2018). Impulse responses summarize the propagation of shocks in the economy and are necessary ingredients to perform stochastic simulations in HANK, using the method of Boppart et. al. (2018). Since the presence of idiosyncratic shocks in HANK models alters the nature of the household's problem because we cannot describe consumption dynamics using an aggregate Euler equation, the analysis focuses on how aggregate consumption changes in this case. The decomposition of consumption responses highlights the role of intertemporal substitution vis-a-vis alternative channels, such as shifts in disposable labor income and asset returns, by which monetary shocks affect aggregate consumption.

3.1 Impulse Responses to Inflation Target and Interest Rate Shocks

I present impulse responses for output, consumption, ex-ante real interest rate, inflation, nominal interest rate, and ex-post real interest rate. I consider only the two monetary shocks discussed in section 2.

3.1.1 Benchmark Calibration

For the two types of monetary shocks, Figures 1 and 2 exhibit impulse responses for the benchmark calibration in the two specifications: model with stationary inflation target (IT) shocks and a model with permanent inflation target (IT) shocks.

Inflation Target Shocks

According to the first panel of Figures 1 and 2, in both models, the Neo-Fisher effect emerges as in specifications with a representative agent. In other words, there is a positive short-run co-movement between inflation and nominal interest rates. In addition, output and consumption rises due to declining real interest rates (ex-ante and ex-post). The ex-post real rates show a stronger decline compared to the ex-ante rates. Inflation and nominal interest rates respond strongly to the shock. Indeed, inflation target shocks affect expected inflation because firms anticipate high marginal costs for long horizons since these shocks are very persistent. Expected high marginal costs signal high wages and vigorous economic activity in the future. Hence, firms immediately start increasing their prices and production levels. Phillips curve propagates expected inflation and current economic slack movements to inflation. Finally, the Central Bank reacts to inflation and nominal interest rates rise. In Figure 2, with permanent shocks, the magnitudes of the responses are somewhat weaker because we have low persistence shocks to the growth rate of X_t^m in a model that differs from the one with stationary inflation target shocks. Nevertheless, we see the same transmission mechanism.

Interest Rate Shocks

According to the second panel of Figures 1 and 2, output and consumption drops along with the inflation rate, following the conventional wisdom about the propagation of transitory monetary policy shocks in traditional macroeconomic models. Indeed, the shock has negligible effects on expected inflation due to its transitory nature. Therefore, an exogenous increase in the nominal interest rate leads to an increase in real interest rates (ex-ante and ex-post), which dampens economic activity and consumption. In this context of economic downturn, inflation declines. Both ex-ante and ex-post real rates display similar magnitudes and reach approximately the same maximum response, though with a delay. We can see that the second panel of Figure 1 depicts the same responses reported in the second panel of Figure 2. These responses coincide because the detrended model with permanent shocks if $x_t^m = 0$ is isomorphic to the specification with stationary and persistent inflation target shocks when one keeps π_t^* in its steady state.

3.1.2 Extensions

To save space, I present only results regarding the model with stationary inflation target shocks, since results for the model with permanent shocks are qualitatively similar. I consider the following extensions: an inertial Taylor rule ($\gamma_i = 0.8$), a Taylor rule with an aggressive response to inflation ($\alpha_\pi = 5$) but no inertia, a calibration with more flexibility in prices ($k^p = 1.2$), another one with more flexibility in wages ($k^w = 1.2$), and a different fiscal policy that allows for deficit financing. Qualitatively, impulse responses for these alternative calibrations are very similar to those obtained under benchmark parameters. However, we see some differences in the magnitudes of these responses.

Inflation Target Shock

I compare the responses of alternative calibrations to that of the benchmark parameterization displayed in the first panel of Figure 1.

In the case in which the Taylor rule displays inertia (first panel of Figure 3), persistent interest rates affect expected inflation in a way to mitigate the effects of an increase in the inflation target. People understand that the Central Bank will vigorously fight inflation in the future. Therefore, inflation rises less, and real interest rates decline moderately compared to the results reported in Figure 1. We also see a gradual rise in nominal rates with smaller magnitudes and a slow return to the steady state. On impact, the ex-ante and ex-post real rates decline with close magnitudes compared to the benchmark calibration. Finally, on impact, output and consumption jumps more, amplifying the effects of the initial shift in the inflation target.

If the response to inflation is more aggressive (first panel of Figure 4), inflation and nominal rates rise less compared to Figure 1. People understand that the Central Bank will respond strongly only contemporaneously, and this aggressive response does not mitigate the effect of the shock as much as the case of the inertial monetary policy rule. The ex-post rate declines less than what we see in Figure 1 and the ex-ante real rates behave very close to the responses based on the benchmark calibration.

If one increases the slope of the Phillips curve for prices or wages (first panel of Figures 5 and 6), ex-ante real rates decline more compared to the benchmark calibration, but their magnitudes have still smaller sizes in contrast to those related to ex-post real rates. Overall, impulse responses are very similar to those reported in the first panel of Figure 1.

If the fiscal policy allows for deficit financing, ex-ante real rates drop very much and nominal rates show a substantial degree of inertia and do not jump strongly on impact. With this gradual monetary policy response, inflation rises more. We see a substantial increase in consumption and output due to the strong decline in ex-ante real rates.

Interest Rate Shocks

I compare the responses of alternative calibrations to that of the benchmark parameterization displayed in the second panel of Figure 1.

In the case in which the Taylor rule displays inertia (second panel of

Figure 3), the Central Bank signals a strong future reaction to inflationary pressures. Hence, expected inflation and inflation decline heavily. Consequently, ex-ante real rates increase substantially, causing a significant drop in consumption and output.

If the response to inflation is more aggressive (second panel of Figure 4), the effect on expected smaller inflation is not substantial. Hence, we see a modest rise in ex-ante real interest rates. Inflation drops more contemporaneously, and nominal rates must rise less because of the credible threat to reacting strongly according to the Taylor rule.

Regarding increases in the slope of the Phillips curve for prices or wages (second panel of Figures 5 and 6), we see a more consistent decline in inflation because the Phillips curves are more sensitive to the economic downturn. Again, the effect on expected smaller inflation is not robust, and ex-ante real rates increase less. The Central Bank does not need to react more strongly because the slope of the Phillips curve lead to a strong effect of the recession on inflation. The responses reported in Figures 5 and 6 are somewhat like those related to the benchmark calibration.

If one considers a deficit financing strategy (second panel of Figure 7), the ex-ante and ex-post real rates increase with close magnitudes. Therefore, we see a substantial drop in consumption and output after the shock. Inflation also exhibits a significant decline due to a very weak economic activity. The Central Bank does not need to push the interest rate hard because the recession contributes to inflation stabilization.

3.2 Decomposition of the Effects of Monetary Shocks on Aggregate Consumption

I present a decomposition of impulse responses for aggregate consumption into direct and indirect effects. Following Kaplan et al. (2018), these effects are computed by counterfactuals scenarios. For instance, regarding the direct effect, we let the real liquid rate change according to the trajectory implied by the specific monetary shock, but freeze tax rates, wages, employment, and illiquid real rate, which are arguments of aggregate consumption, at their steady state levels. Indirect effects are computed in a similar way, varying each argument of aggregate consumption at a time, while keeping the remaining arguments at their steady state levels.

3.2.1 Benchmark Calibration

Figures 8 and 9 show consumption responses decomposition after both types of shocks. The first and second rows of Tables 2 and 3 display the normalized size of the direct and indirect effects on the impact of the shock[2]. Indirect effects dominate under both types of monetary shocks, especially on impact. However, under inflation target shocks, in the short run, indirect effects tend to be much stronger.

Inflation Target Shocks

According to the first panel of Figures 8 and 9, movements in tax rates are the main source of indirect effects in both models. Indeed, the government moves tax rates to close its budget according to the benchmark fiscal rule. When ex-post real interest rates decline, the government needs to cut

[2]The size of the direct and indirect effects reported agrees with the range of values suggested in Kaplan et al. (2018) for HANK models, which is less than $\frac{1}{3}$ for the direct effect and more than $\frac{2}{3}$ for indirect effects.

taxes, stimulating consumption and output. According to the first panel of Figures 1 and 2, since movements in ex-post real rates are stronger under inflation target shocks, indirect effects tend to be stronger than those related to transitory monetary shocks. Notice that, in the first panel of Figures 1 and 2, the drop in ex-ante real rates is not sufficient to induce an increase in consumption only due to intertemporal substitution. Indeed, the relative strength of the responses of ex-ante and ex-post real rates determine the prevalence of indirect effects. On impact, inspecting Tables 2 and 3, the first and second rows point to a very small size of the direct effect and substantial indirect effects. In Figure 9, with permanent shocks, the amplitudes of the decomposition differ from those of Figure 8 because, now, we have low persistence shocks to the growth rate of X_t^m in a model that is distinct from the one with stationary inflation target shocks.

Interest Rate Shocks

According to the second panel of Figures 8 and 9, after a transitory interest rate shock, when ex-post real rates rise, the government must increase taxes, cooling down consumption and economic activity. Again, shifts in tax rates are the main factor accounting for consumption responses. However, this indirect effect is smaller compared to the case of inflation target shocks, but still very prominent. We can see that the second panel of Figure 9 depicts the same responses reported in the second panel of Figure 8. This pattern happens because the detrended model with permanent shocks when $x_t^m = 0$ is isomorphic to the specification with stationary and persistent inflation target shocks if one keeps π_t^* in its steady state. In addition, for the same reason, on impact, according to Tables 2 and 3, the decompositions of the two models featuring alternative inflation target specifications are the same.

3.2.2 Extensions

To save space, I present only results regarding the model with stationary inflation target shocks, since results for the model with permanent shocks are qualitatively similar. I consider the following extensions: an inertial Taylor rule ($\gamma_i = 0.8$), a Taylor rule with an aggressive response to inflation ($\alpha_\pi = 5$) but no inertia, a calibration with more flexibility in prices ($k^p = 1.2$), another one with more flexibility in wages ($k^w = 1.2$), and a different fiscal policy that allows for deficit financing.

Inflation Target Shocks

If we inspect Figures 10 to 14, indirect effects are still the dominant force. As in the benchmark calibration, tax rates are key to understand movements in disposable labor income leading to consumption responses. The relative strength of the changes in ex-ante and ex-post real rates, shown in the first panel of Figures 3 to 7, determine the size of indirect effects in the first panel of Figures 10 to 14. According to Tables 2 and 3, an inertial Taylor rule and a fiscal policy rule that allows for deficit financing are cases that display weaker indirect effects on impact. In the first situation, persistent movements in the nominal interest rate affect expected inflation in a way to mitigate the effects of an increase in the inflation target. Hence, inflation does not increase that much and ex-post real interest rates do not plunge vigorously. On the other hand, nominal interest rates do not need to increase that much contemporaneously, leading to a more pronounced reduction in ex-ante real interest rates. The fiscal policy rule attenuates changes in tax rates that come directly from drops in ex-post real interest rates. In any case, ex-ante real interest rates jump almost with the same intensity as ex-post rates, weakening the size of indirect effects on impact. Regarding the role of fiscal policy, this paper corroborates the findings in Alves et al. (2021), which stress that the fiscal reaction to monetary shocks is key to understand how indirect effects shape aggregate consumption responses to that shock.

Interest Rate Shocks

The relative strength of the changes in ex-ante and ex-post real rates still controls the magnitudes of the effects coming from variations in disposable income. After a transitory shock, most often, the initial jumps in ex-post real interest rates are not enough, in the short run, to trigger a role for indirect effects with the same size as the one displayed under inflation target shocks. According to Tables 2 and 3, the direct effect stays between 20% and 30% on impact, irrespective of the extension we consider. Indeed, compared to the first panel of Figures 10 to 14, the second panel shows, in most of the cases, a relatively weaker consumption response due to changes in the tax rates. The Tables also show that indirect effects are stronger than the direct effect, but their magnitudes are smaller compared to the same decomposition under inflation target shocks, exceptions being the extensions that consider an inertial Taylor rule and a fiscal policy that allows for deficit financing. These specifications show direct effects with sizes close to the ones under inflation target shocks. In the first situation, persistent movements in the interest rate signal lower expected inflation and substantially increase ex-ante real interest rates. In the second one, fiscal policy attenuates movements in tax rates that are direct responses to changes in ex-post real interest rates. In any of these cases, the relative strength of the ex-ante real interest rates vi-a-is its ex-post counterpart rises.

4 Conclusion

In this paper, I compared the propagation of inflation target shocks to that of transitory interest rate shocks in a baseline HANK model presented in Kaplan et al. (2018). Inflation target shocks can be stationary, but persistent, or permanent. I showed that, as in the case of representative-agent New Keynesian models, the Neo-Fisher effect emerges under inflation target shocks, leading to a short-run co-movement between inflation and nominal interest rates. In addition, output and consumption increases due to reductions in real interest rates. The responses of macroeconomic variables to transitory interest rate shocks are conventional. After a transitory shock, nominal rates as well as real rates rise, causing inflation and output to decrease in the short run.

Regarding consumption responses decomposition into the direct effect (intertemporal substitution) and indirect effects (changes in households' disposable income), the results corroborate the hallmark of HANK models, which is the prevalence of indirect effects as the key channel by which monetary shocks affect aggregate consumption dynamics. The main contribution of this paper is to show that indirect effects tend to be much stronger under inflation target shocks in the very short run. This pattern is a consequence of the relative strength of ex-post and ex-ante real interest rates after monetary shocks hit the economy. Under inflation target shocks, on impact, inflation changes more than under transitory interest rate shocks due to shifts in expectations, and we see more substantial variations in ex-post real rates, which trigger indirect effects operating primarily through shifts in tax rates.

Under inflation target shocks and according to alternative calibrations, the direct effect becomes somewhat stronger in the short run. Most often, the magnitudes of indirect effects are still of considerable size compared to the situation in which the model faces transitory interest rate shocks. Nevertheless, after a shift in the inflation target, an inertial monetary policy rule and a fiscal policy with potential for deficit financing are consistent with direct effects with sizes close to the ones under transitory interest rate shocks.

For future research, as in Uribe (2022), one should estimate the HANK model to gauge the relative importance of both monetary shocks as drivers of inflation dynamics in a context in which other shocks also matter. This exercise may guide more realistic calibrations of stochastic processes describing monetary shocks. In addition, indexation mechanisms, which are absent from the baseline model, could be extra ingredients influencing the propagation mechanism of monetary shocks and the relative relevance of indirect effects on consumption responses to these shocks.

References

Airaudo, M. (2023). "Wealth effects, price markups, and the neo-Fisherian hypothesis". *European Economic Review*, 157, 104482, 1-24.

Alves, F., Kaplan, G., Moll, B. and Violante, G.L. (2021). " A Further Look at the Propagation of Monetary Policy Shocks in HANK. *Journal of Money, Credit and Banking*, 52(S2), 521-559.

Auclert, A., Rognlie, M., and Straub, L. (2020). "Micro Jumps, Macro Humps: Monetary Policy and Business Cycles in an Estimated HANK Model". NBER Working Papers 26647.

Auclert, A., Rognlie, M. and Straub, L. (2021). "Using the Sequence-Space Jacobian to Solve and Estimate Heterogeneous-Agent Models". *Econometrica*, 89(5), 2375-2408.

Auclert, A., Rognlie, M. and Straub, L. (2023). "The Intertemporal Keynesian Cross". *Journal of Political Economy*, forthcoming.

Boppart, T., Krusell, P. and Mitman, K. (2018). "Exploiting MIT shocks in heterogeneous-agent economies: the impulse response as a numerical derivative". *Journal of Economic Dynamics and Control*, 89 (April), 68-92.

Eo, Y and Lie, D. (2020). "The Role of Inflation Target Adjustment in Stabilization Policy". *Journal of Money, Credit and Banking*, 52(8), 2007-2052.

García-Cicco, J., Goldstein, P. and Sturzenegger (2024). "Permanent and Transitory Monetary Shocks Around the World", Discussion Paper, Universidad San Andrés.

Garín, J., Lester, R. and Sims, E. (2018). "Raise Rates to Raise Inflation? Neo-Fisherianism in the New Keynesian Model". *Journal of Money, Credit and Banking*, 50(1), 243-259.

Ireland, P. (2007). "Changes in the Federal Reserve's Inflation Target: Causes and Consequences". *Journal of Money, Credit and Banking*, 39(8), 1851-1882.

Kaplan, G., Moll, B. and Violante, G.L. (2018). "Monetary Policy According to HANK". *American Economic Review*, 108(3), 697-743.

Kaplan, G. and Violante, G.L. (2018). "Macroeconomic Heterogeneity and Macroeconomic Shocks". *The Journal of Economic Perspective*, 32(3), 167-194.

Lukmanova, E. and Rabitsch, K. (2023). "Evidence on monetary transmission and the role of imperfect information: Interest rates versus inflation target shocks". *European Economic Review*, 157, 104557, 1-19.

Schmitt-Grohé, S. and Uribe, M. (2022). "The effects of permanent monetary shockz on exchange rates and uncovered interest rate differentials". *Journal of International Economics* 135, 103560, 1-21.

Uribe, M. (2022). "The Neo-Fisher Effect: Econometric Evidence from Empirical and Optimizing Models". *American Economic Journal: Macroeconomics* 14(3), 133-162.

TABLES

Table 1. Structural Parameters unde the Benchmark Calibration

β	Discount factor	0.976
σ	Inverse of Intertemporal Elasticity	2
χ_0	Portfolio Adjustment Cost Pivot	0.25
χ_1	Portfolio Adjustment Cost Scale	6.416
χ_2	Portfolio Adjustment Cost curvature	2
$\underline{b}$	Borrowing Constraint	0
ρ_e	Autocorrelation – Idyosincratic Shock	0.966
σ_e	Standard Deviation-Idyosincratic Shock	0.92
φ	Disutility of Labor	2.073
υ	Inverse Frisch elasticity	1
μ_w	Steady State Wage Markup	1.1
κ_w	Slope of Wage Phillips Curve	0.1
Θ	Steady State TFP	0.468 (normalized output equals to 1)
α	Capital Share	0.33
μ_p	Steady State Price Markup	1.015
κ_p	Slope of Price Phillips Curve	0.1
δ	Depreciation Rate	0.02
ω	Liquidity Premium	0.005
τ	Steady State Labor Tax	0.356
G	Government Spending (fixed)	0.2
B^g	Bond Supply (fixed)	2.8
α_π	Taylor Rule Inflation Coefficient	1.5
γ_i	Taylor Rule Inertial Coefficient	0

Table 2. The size of the Direct Effect on impact in %

Model Calibration	Inflation Target Shocks	Transitory Interest Rate Shocks
Stationary IT Benchmark	2.88	28.45
Permanent IT Benchmark	12.70	28.45
Stationary IT Inertial Taylor	20.19	22.85
Stationary IT Aggressive Taylor	11.38	27.55
Stationary IT More Flexible Prices	5.55	20.80
Stationary IT More Flexible Wages	11.78	24.98
Stationary IT Deficit Financing Fiscal Policy	25.49	27.21

Note: Total effect is normalized to 100% % (sum of the same cell positions in Tables 2 and 3)

Table 3. The size of Indirect Effects on impact in %

Model Calibration	Inflation Target Shocks	Transitory Interest Rate Shocks
Stationary IT Benchmark	97.12	71.55
Permanent IT Benchmark	87.30	71.55
Stationary IT Inertial Taylor	79.81	77.15
Stationary IT Aggressive Taylor	88.62	72.55
Stationary IT More Flexible Prices	94.45	79.20
Stationary IT More Flexible Wages	88.22	75.02
Stationary IT Deficit Financing Fiscal Policy	74.51	72.79

Note: Total effect is normalized to 100% (sum of the same cell positions in Tables 2 and 3)

FIGURES

Figure 1: Model with Stationary IT Shocks – Impulse Responses

(Benchmark)

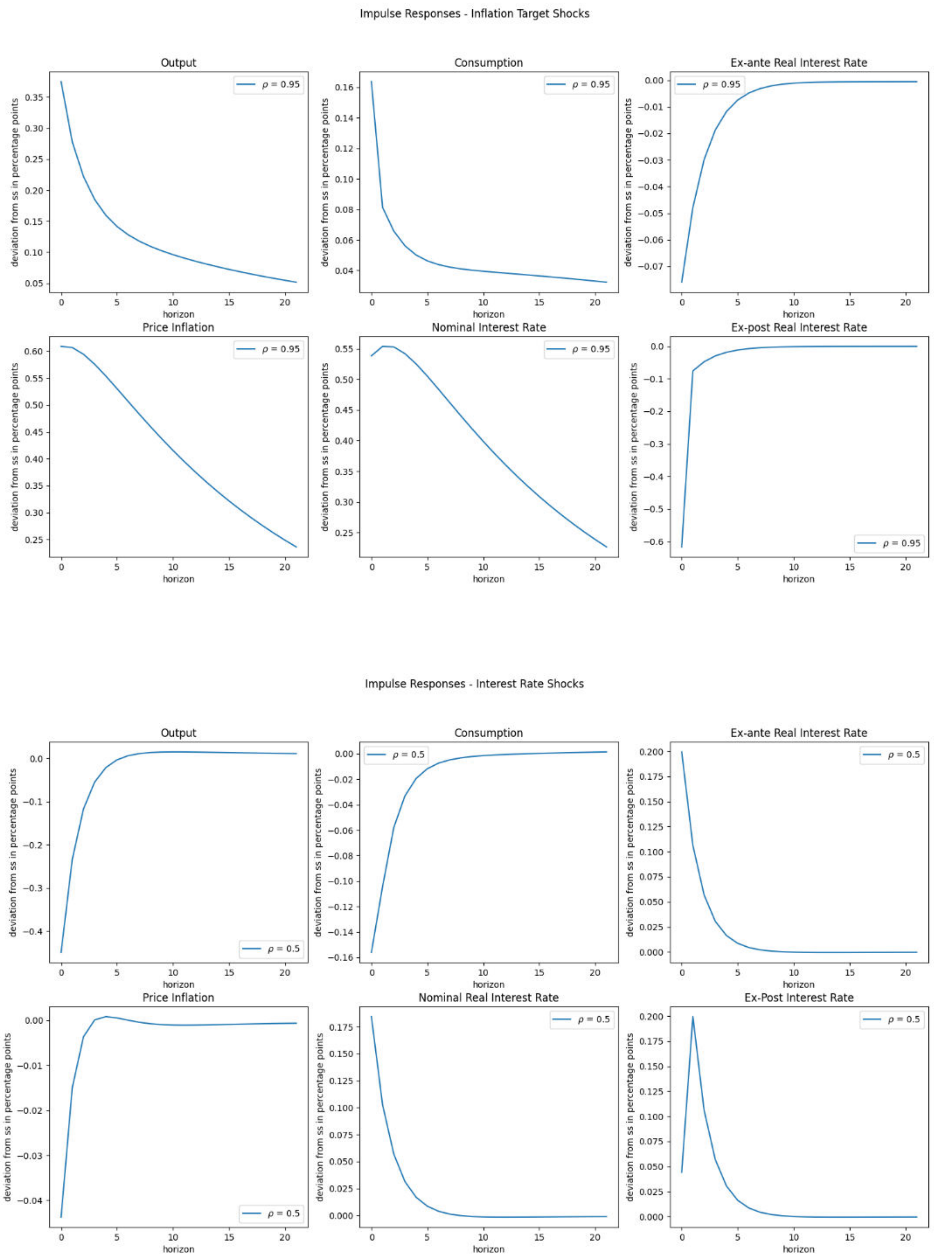
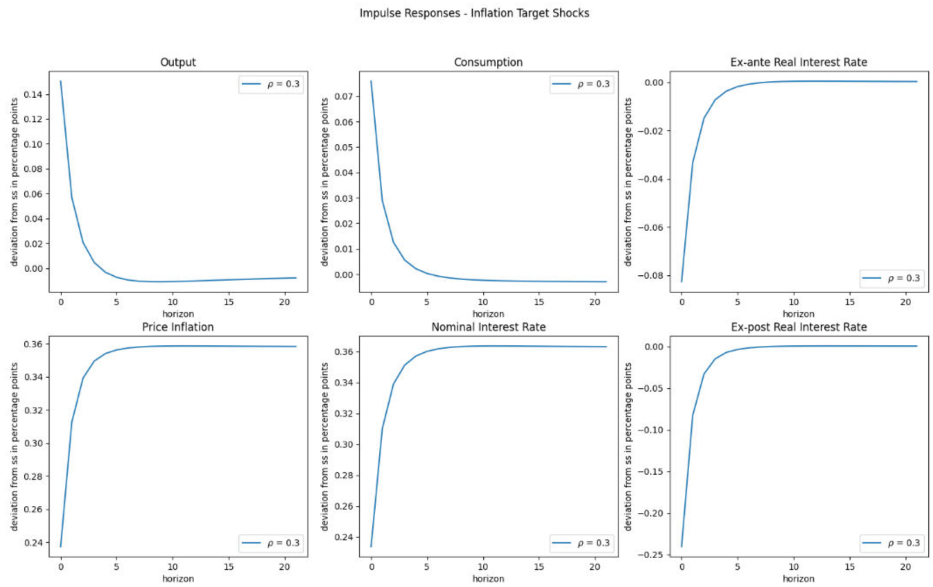


Figure 2: Model with Permanent IT Shocks - Impulses Responses

(Benchmark)



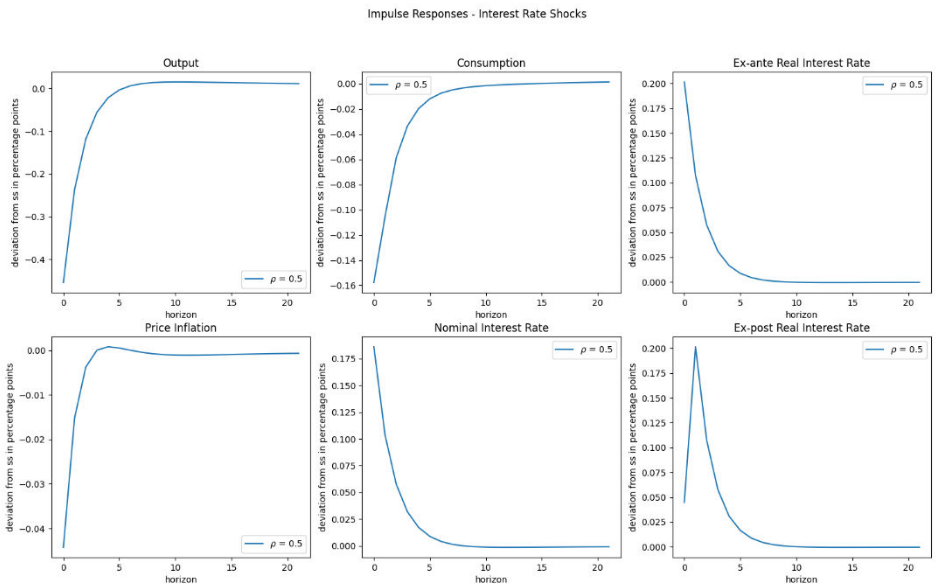


Figure 3: Model with Stationary IT Shocks – Impulse Responses

(Inertial Taylor)

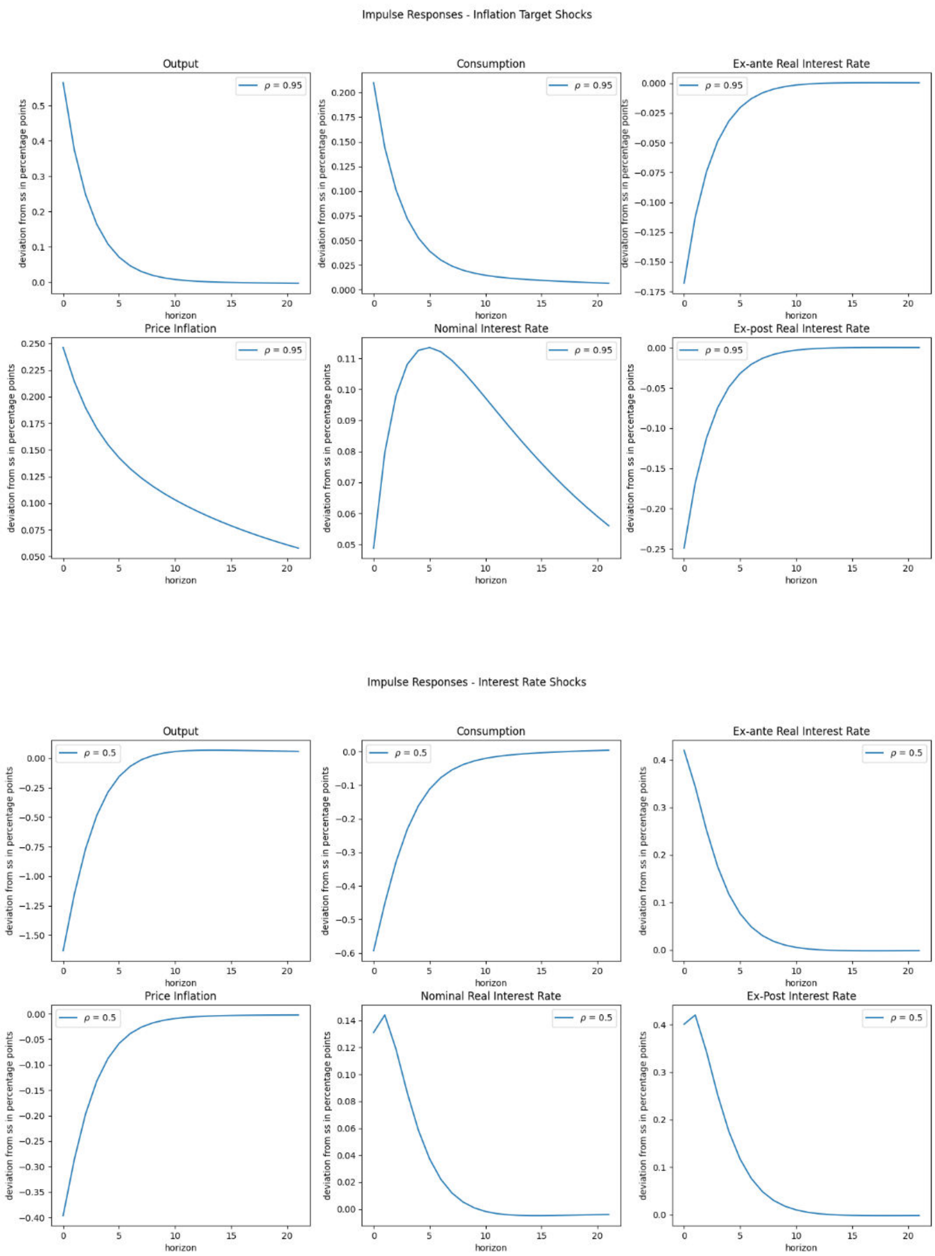
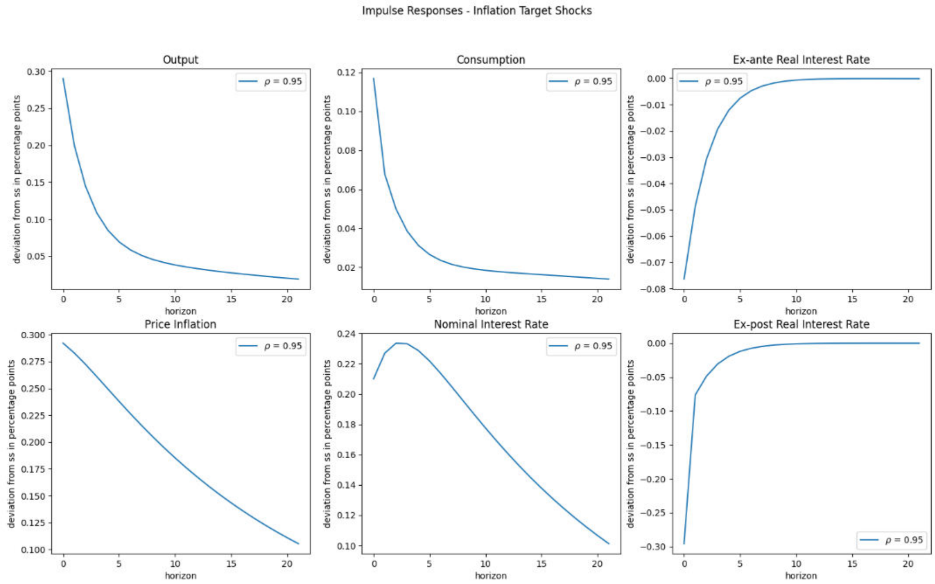


Figure 4: Model with Stationary IT Shocks – Impulse Responses

(Aggressive Taylor)



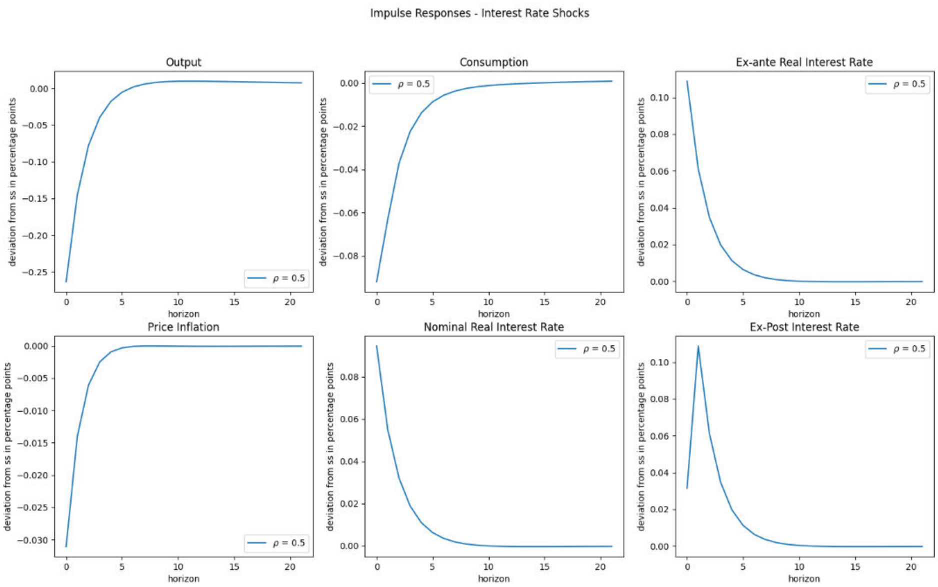
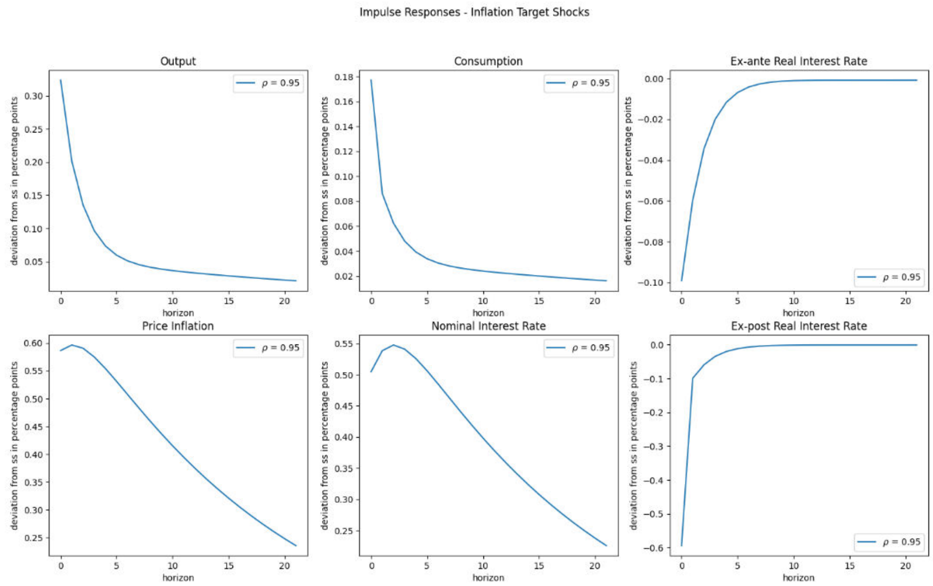


Figure 5: Model with Stationary IT Shocks – Impulse Responses

(More Flexible Prices)



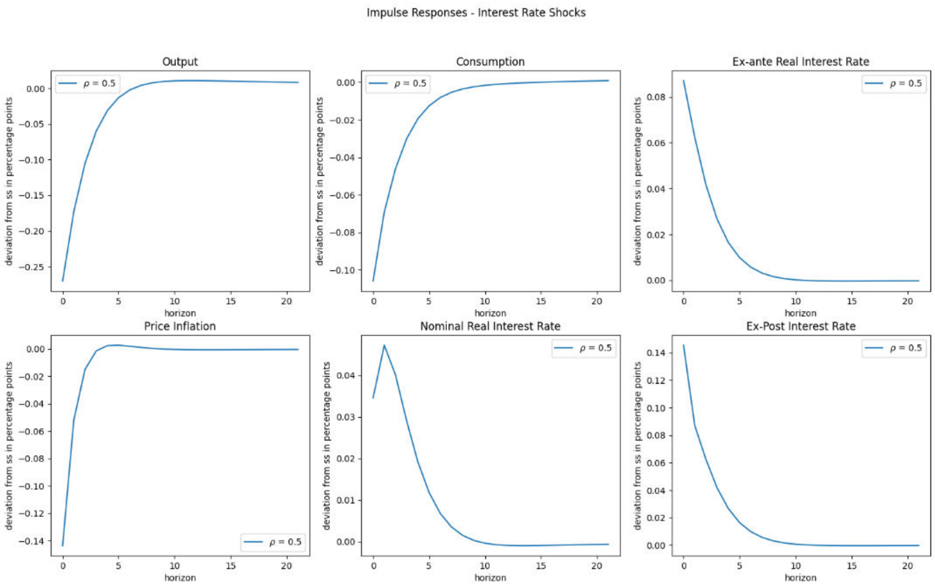
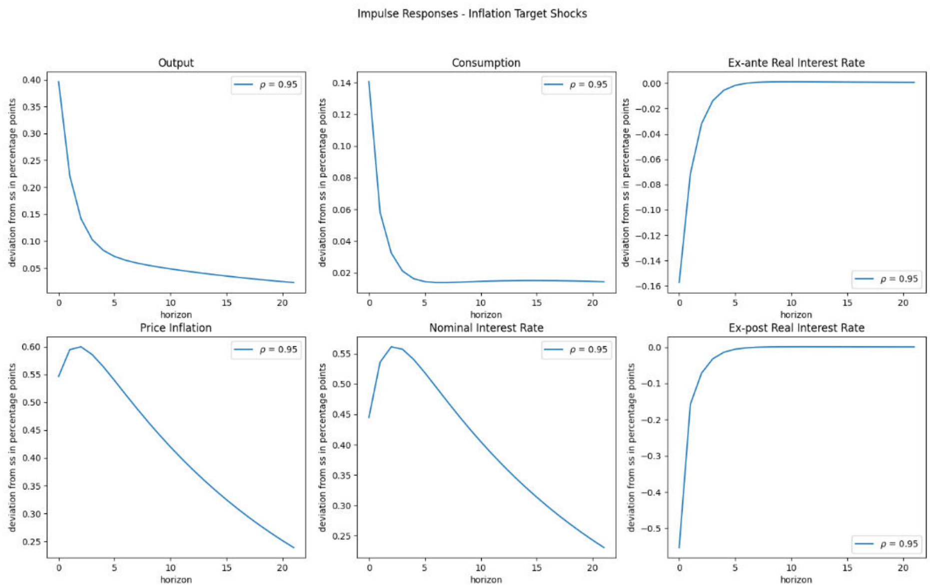


Figure 6: Model with Stationary IT Shocks – Impulse Responses

(More Flexible Wages)



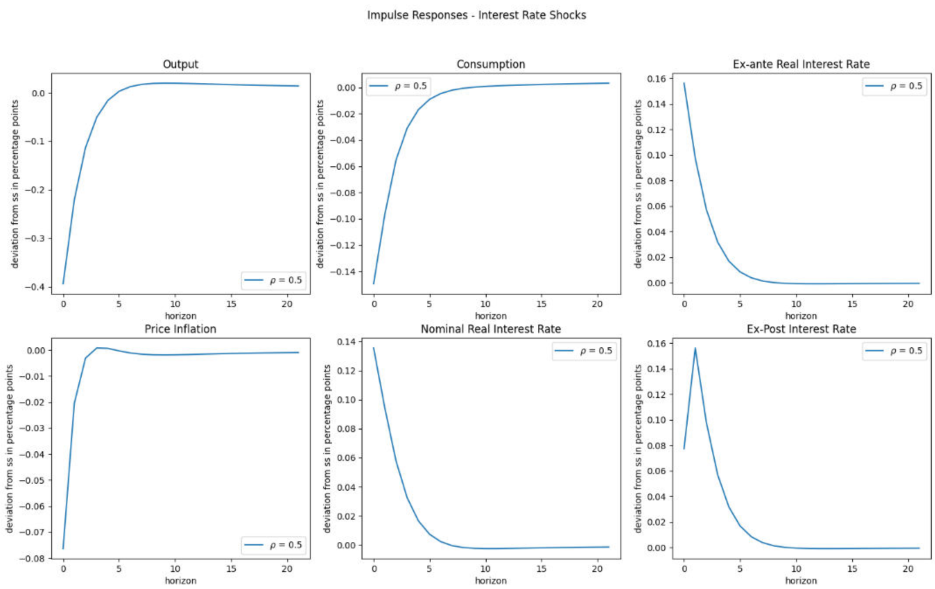
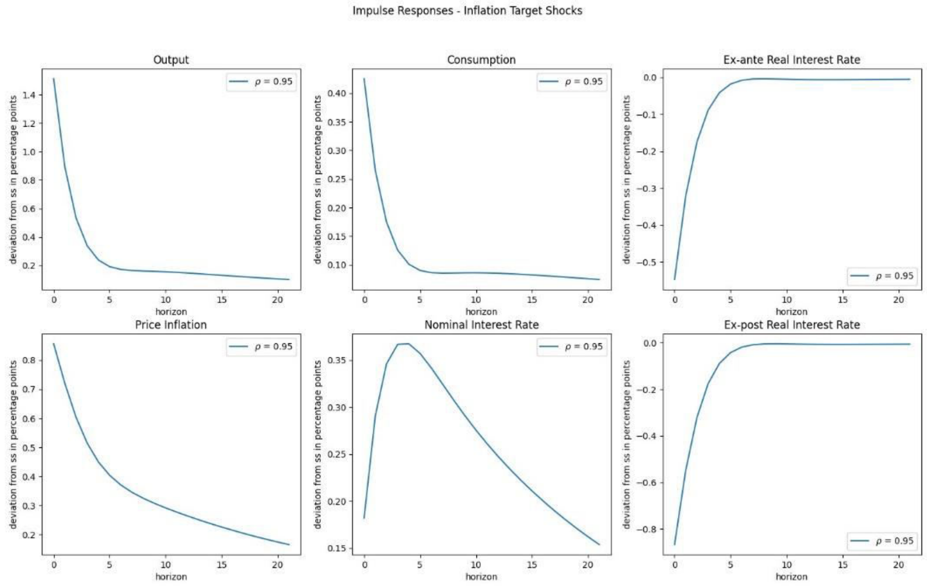


Figure 7: Model with Stationary IT Shocks – Impulse Responses

(Deficit Financing Fiscal Policy)



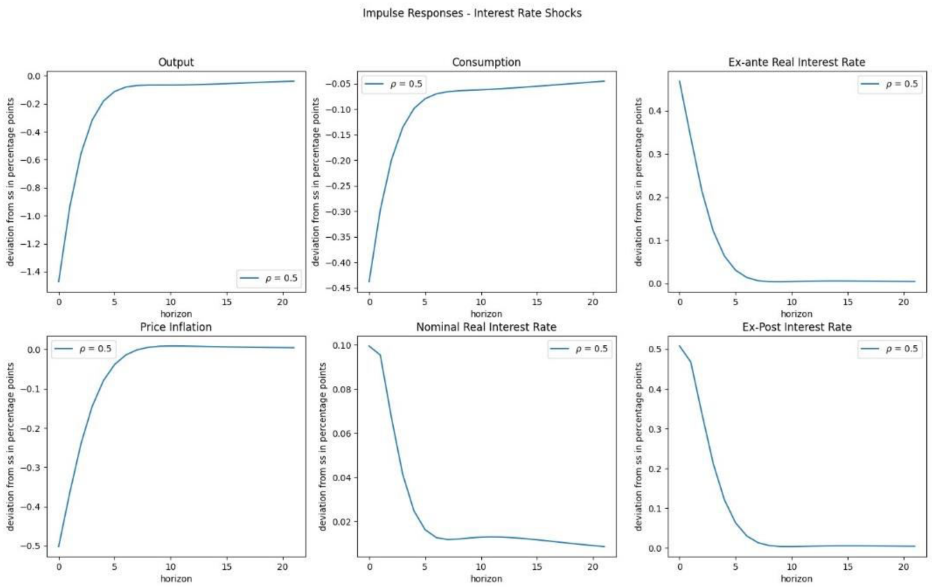


Figure 8: Model with Stationary IT Shocks – Consumption Decomposition (Benchmark)

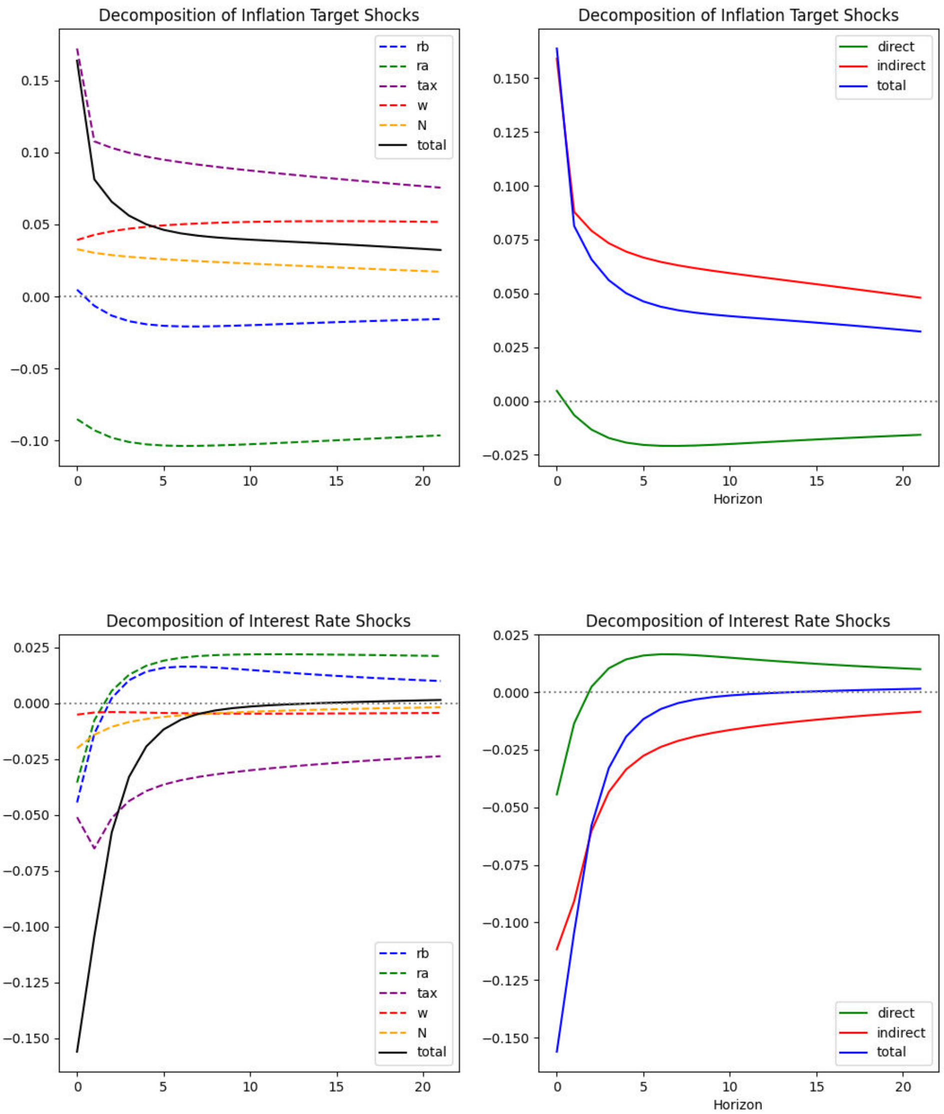


Figure 9: Model with Permanent IT Shocks – Consumption Decomposition (Benchmark)

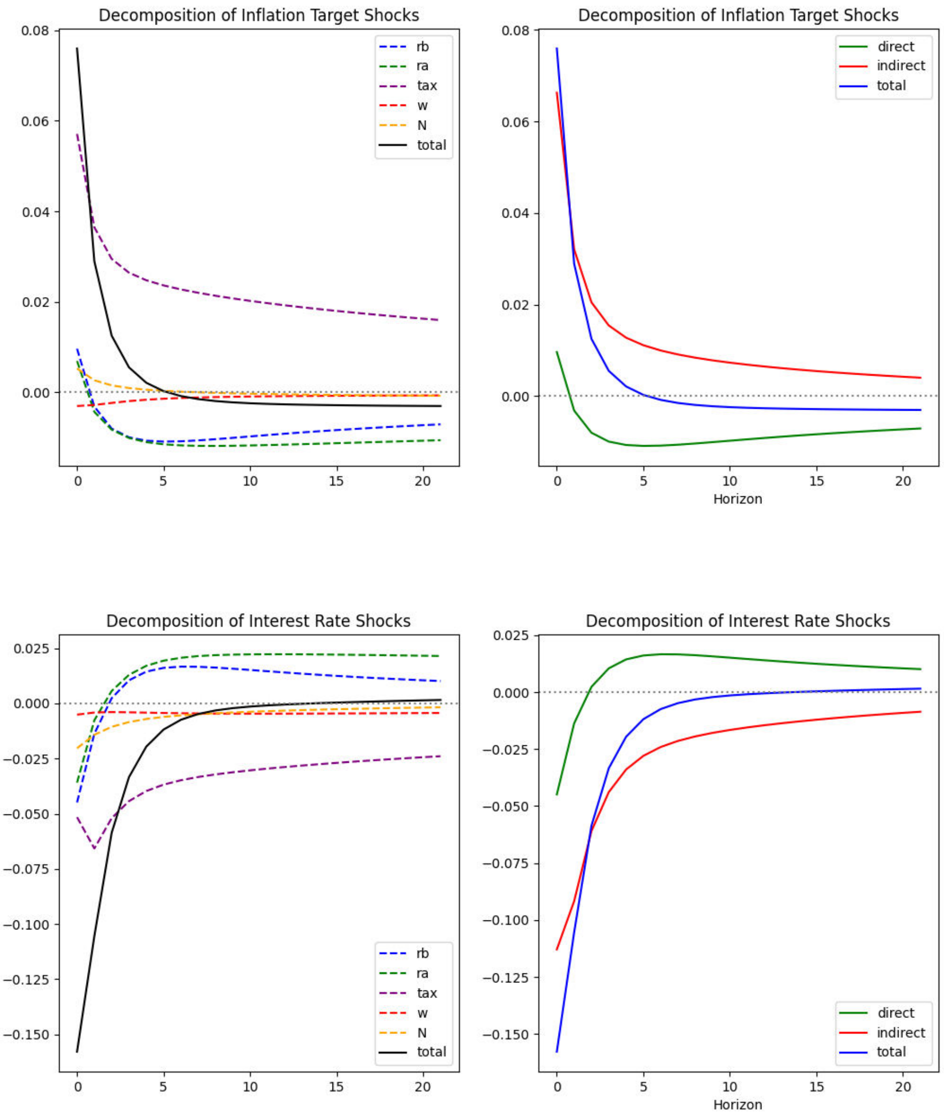


Figure 10: Model with Stationary IT Shocks – Consumption Decomposition (Inertial Taylor)

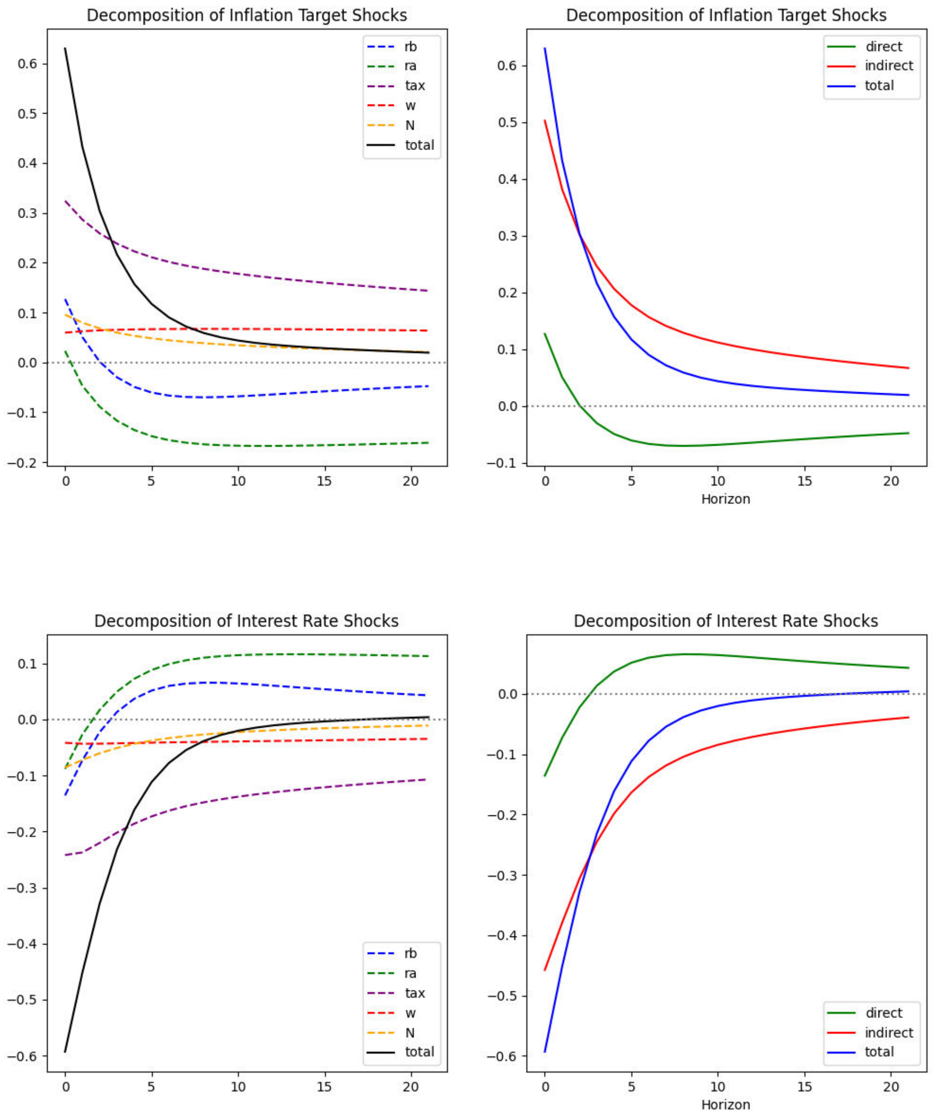


Figure 11: Model with Stationary IT Shocks – Consumption Decomposition (Aggressive Taylor)

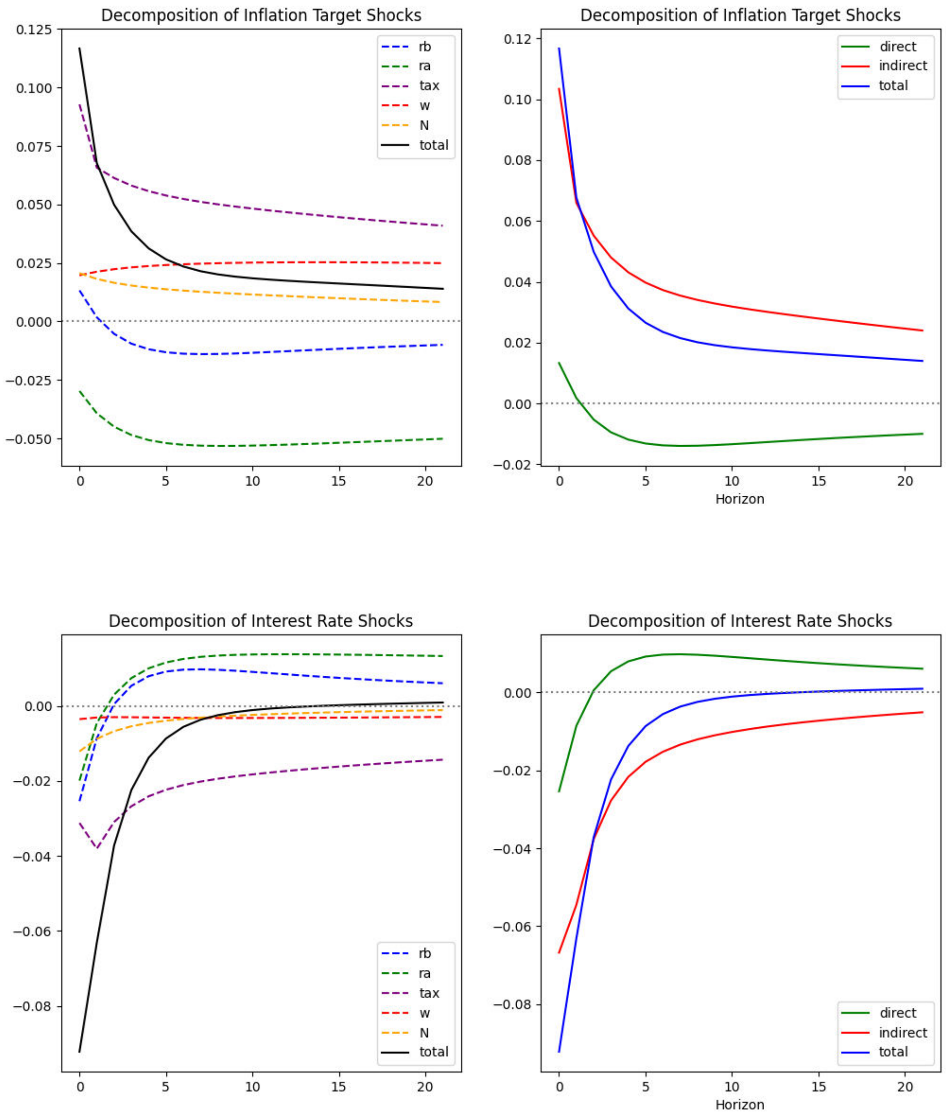


Figure 12: Model with Stationary IT Shocks – Consumption Decomposition (More Flexible Prices)

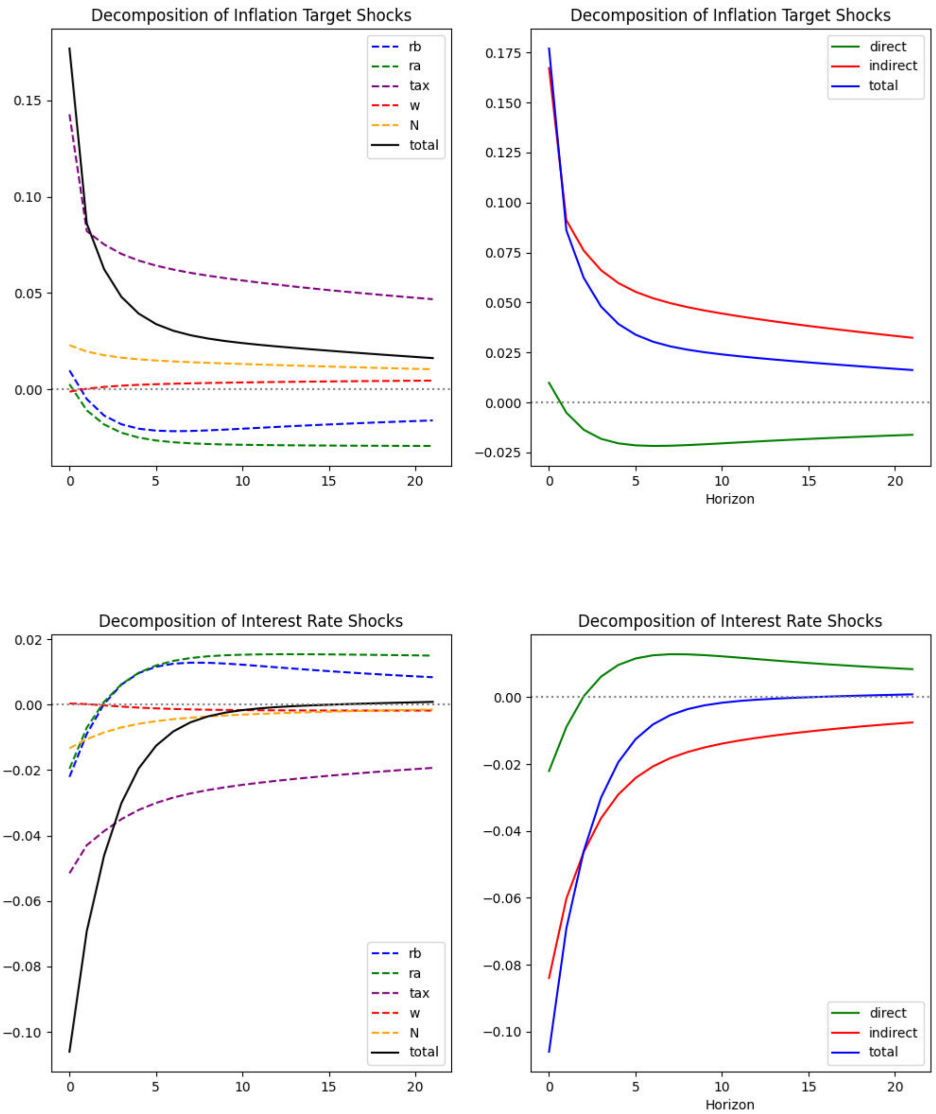


Figure 13: Model with Stationary IT Shocks – Consumption Decomposition (More Flexible Wages)

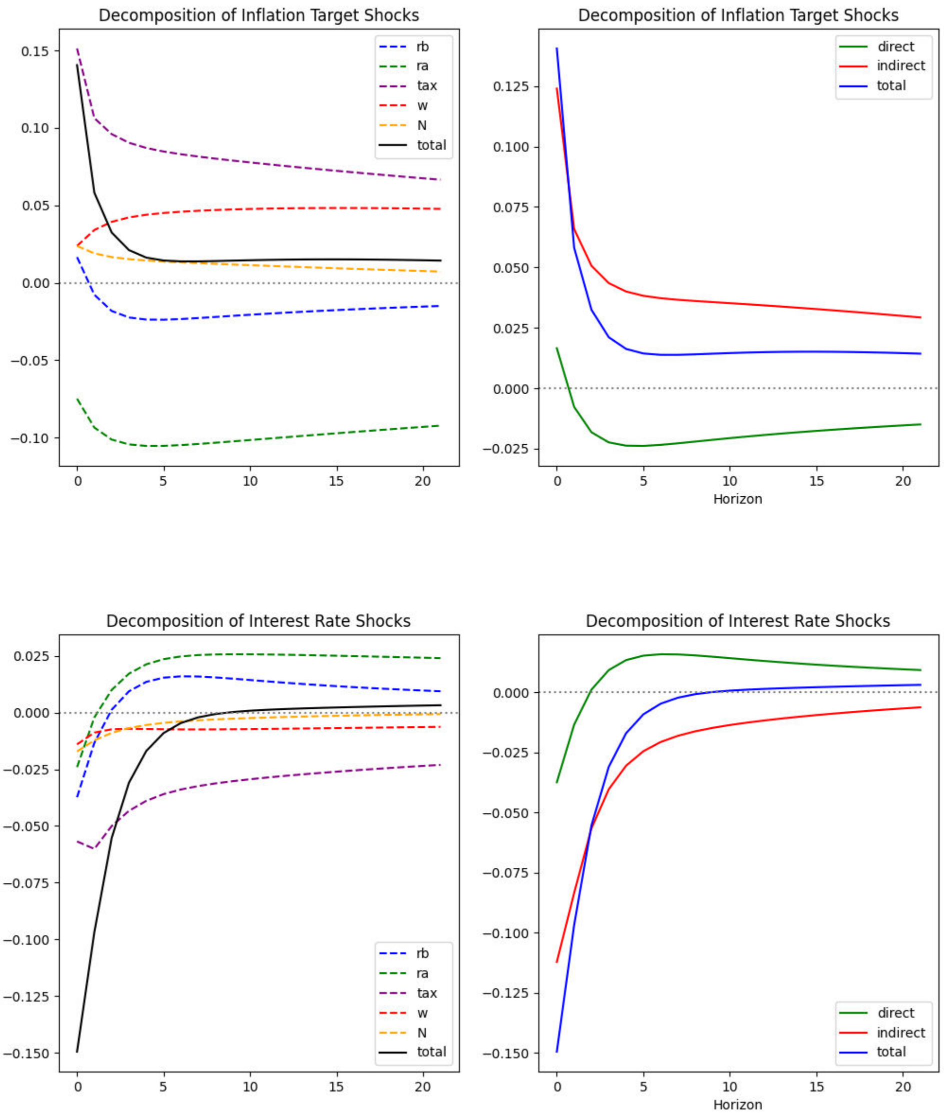


Figure 14: Model with Stationary IT Shocks – Consumption Decomposition

(Deficit Financing Fiscal Policy)