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UNDERSTANDING HANK: THE MECHANISMS BEHIND CONTRACTIONARY MONETARY POLICY

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Abstract

This paper investigates how wealthy hand-to-mouth (W-HtM) agents affect the responses of output to a monetary tightening. Accordingly, a one- and two-asset HANK model are calibrated to respectively match the percentage of poor hand-to-mouth (P-HtM), and the percentage of both P-HtM and W-HtM. Findings suggest that moving to a two-asset HANK, a framework that better reflects the empirical composition of household portfolios, lessens the impact of monetary policy. Importantly, the percentage of W-HtM households is critical to explain the cross-country heterogeneity in the magnitude differences between model specifications.

Keywords: Monetary Policy, HANK, Liquidity Constraints, Hand-to-Mouth Agents

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1 Introduction

As the year of 2022 entered its fourth quarter, the European Central Bank's (ECB) President Christine Lagarde announced what many long thought inevitable: the hike of the key ECB interest rates by 75 basis points. In terms of magnitude, this decision has materialised into the biggest increase in the deposit facility rate since the Euro's inception in 1999. In light of such events, and for the first time since the sovereign debt crisis, monetary policy is now back to the forefront of public debate. To better exploit the sudden spotlight, it is fundamental that the ECB utilises this momentum to review its policy strategy and deepen its understanding on how the specific dynamics of member countries are changing the condition under which monetary policy operates. In fact, and since professionals like Cœuré (2019) recognize that heterogeneity has always been at the core of ECB's activity, grasping the country-specific mechanisms behind an asymmetric transmission of monetary policy, seems of utmost relevance at this point in time. Moreover, evaluating such topic under a theoretical setup that allows for the proper modelling of empirically-relevant characteristics, could translate into unprecedented conclusions for policy making at the euro-area level.

This paper focuses on analysing whether increasing the percentage of constrained agents in an economy, influences the response of output to a tightening of monetary policy. Such experience is performed by comparing impact multipliers[2] through the lens of a one- and two-asset Heterogeneous Agents New Keynesian (HANK) model, as per Auclert et al. (2018). The reasoning behind the comparison is the following: working under the one-asset HANK specification, in which the household's wealth accumulation procedure does not distinguish assets according to their liquidity, would imply a loss of important dynamics and mechanisms. As such, and in order to generate a distribution of assets that resembles the composition of household portfolios found in data, the two-asset HANK model is calibrated.

In order to conduct this analysis, the households of five members of the European Monetary Union - Austria, Germany, France, Portugal and Slovakia - are disaggregated in terms of the liquidity

[2]If one looks at the word *monetary multiplier* from a Keynesian perspective, such terminology could sound incorrect. Thus, and also with language simplicity considerations in mind, this paper uses *impact multiplier* as a measure of how an endogenous variable (output) changes in response to a change in an exogenous variable (the optimal interest rate).

of their portfolio. In the spirit of Kaplan et al. (2014), agents are split into (i) wealthy hand-to-mouth households (W-HtM), who despite holding little to no liquid wealth, own positive amounts of illiquid wealth; (ii) poor hand-to-mouth (P-HtM), who hold little liquid wealth, but zero to negative illiquid wealth and (iii) non hand-to-mouth or Ricardian households (N-HtM), who choose consumption according to an Euler Equation.

This paper generates three main findings: Firstly, regardless of the country or model specification, output responds negatively to a rise in the policy interest rate. Secondly, when looking at the same country, the negative impact that tightening monetary policy has on output is overestimated in the one-asset specification, i.e., the impact multipliers of the one-asset model are consistently higher (in absolute terms) than the multipliers in the two-asset specification. Thirdly, the percentage of wealthy hand-to-mouth households is theoretically relevant in explaining the cross-country heterogeneity in the magnitude of the differences between model specifications.

The remainder of the paper is organised as follows. Section 2 lays out existing related literature. Section 3 describes the one- and two-asset HANK models. Section 4 discusses the parameterization of both specifications. Section 5 contains the main results, tracing out the effects of monetary policy in a one- and two-asset HANK model, as well as on the heterogeneity of responses for individual member countries. Section 6 concludes.

2 Literature Review

2.1 How Monetary Policy Shocks affect Output

Grasping whether monetary policy can pose as a relevant tool to stimulate output has been the focus of a substantial branch of monetary economics. In fact, because of its relevance for policy conduction, the real effects of monetary shocks are one of the most studied topics in all of macroeconomics. While the case may seem simple if one considers specific historical episodes like the *Volcker recessions*[3] one should not be deceived by what may seem to be causal relationships. Hence-

[3]The Volcker recessions were an episode of US history that took place in the 1980s, in which every FED increase of the federal funds rate was perceived to generate drops in US output.

forth, to better grasp the causal effects of monetary policy on macroeconomic variables like output, Bernanke (1990) and Sims (1992) pioneered the handling of standard vector autoregression (VAR) models. Early influential studies include findings by Bernanke and Mihov (1998) and Christiano et al. (1999). The former found that after an expansionary monetary policy shock that decreases the funds rate by 25 basis points, output increases relatively fast. Christiano et al. (1999) added a relevant layer to those findings, by showing that regardless of the monetary authority instrument, contractionary monetary policy shocks had significant negative effects on output.

Literature on the effects of monetary policy in euro-area countries is as early as Peersman and Smets (2001). The authors used an identified VAR methodology to assess how output in euro countries is affected by an unexpected monetary policy tightening i.e., a rise in the short-term interest rate. Their findings pointed to a consequent fall in output, which is robust to testing over different sample periods. To fight information problems associated with models like the VAR, Bernanke et al. (2005) introduced the application of the factor-augmented vector autoregressive (FAVAR) methodology in monetary policy analysis for the US. Because of their innovative approach, the authors were able to successfully eliminate the commonly observed price puzzle[4]. A decade later, Soares (2013) applied the approach pioneered by Bernanke et al. (2005) to study euro-area countries. The author concluded that by using a FAVAR, instead of a standard VAR, long-run money neutrality was ensured.

When talking about monetary policy conduction in the euro-area, there is yet another fundamental layer that should not be overlooked: because of country-specific characteristics, countries can respond asymmetrically to a selfsame shock. Through a VAR approach, Peersman and Smets (2005) were the first to find meaningful evidence on this topic, by showing that despite the negative effect that an interest rate hike generates on output, there is considerable country heterogeneity in responses. Rafiq and Mallick (2008) examined this question for Germany, France and Italy by applying a VAR procedure with sign restriction. The authors showed that firstly, responses are not homogeneous, and secondly, that except for Germany, a rise in interest rates does not necessary lead

[4]This counter-intuitive phenomena is characterized by an increase in the price level following a contractionary monetary shock, and is often observed in structural VARs.

to a fall in output. By using a Bayesian vector autoregressive (BVAR) model, Mandler et al. (2022) confirmed that indeed, real output responds more strongly to monetary policy in Germany than in the other euro-area peers.

It is important to note, however, as both Uhlig (2005) and Soares (2013) addressed trough their findings, that methodologies like vector autoregression (VAR) are commonly pointed out as being a priori forcing or narrowing results. Consequently, VAR-based approaches have the potential to be detrimentally restrictive, by inevitably being unable to grasp all the components of monetary policy, thus weakening the strength of the generated conclusions. The need to include transmission channels that cannot explicitly be modelled with empirical methodologies then becomes clear, paving the way to using structural models such as the one employed in this paper, and described in Section 3.

2.2 How Micro-Level Heterogeneity Impacts Monetary Policy Transmission

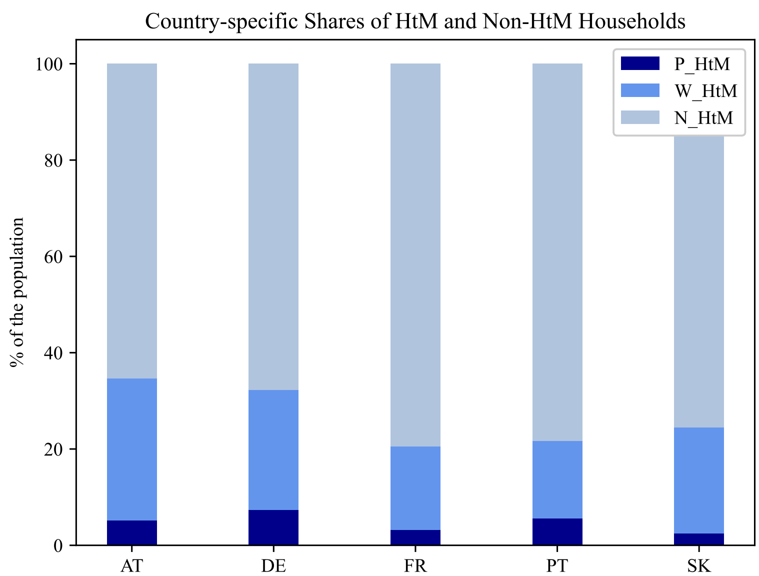
Towards the end of the twentieth century, many attempts on identifying microeconomic heterogeneity in household data were made: Zeldes (1989) defined constrained agents as the ones possessing total wealth lower than two months worth of labour income, whereas Jappelli (1990), opted to use the 1983 Survey of Consumer Finances to assess the percentage of households that had had their credit refused. Interestingly enough, household heterogeneity was not always considered relevant to describe the dynamics of aggregate variables in response to shocks - Krusell and Smith (1998).

In fact, it was not until the early 2000's that the idea that micro factors indeed affect the macroeconomy started becoming widespread. Early literature on this topic pivoted in the analysis of the interactions between heterogeneity and fiscal policy. Galí et al. (2007) and Bilbiie (2008) provided early theoretical contributions to Two-Agent New Keynesian (TANK) literature, by showing that policy effectiveness depends on the share of households without access to financial markets. Barrell et al. (2013) found that the income elasticity of consumption was amongst the main forces explaining cross-country heterogeneity in fiscal multipliers. Importantly, Brinca et al. (2016) later uncovers that the share of liquidity-constrained agents is relevant to explain the magnitude difference of fiscal multipliers.

Kaplan et al. (2014) were amongst the ones that pioneered the examination of how household heterogeneity impacts the transmission mechanisms of monetary policy, laying the foundation for this new and exciting field in macroeconomics. The authors argued that overlooking the distribution of liquid assets across agents can lead to inaccurate conclusions about the effects of monetary policy shocks - thus suggesting the aggregation of households into (i) poor hand-to-mouth households (P-HtM), (ii) wealthy hand-to-mouth households (W-HtM) and (iii) non hand-to-mouth households (N-HtM). Kaplan et al. (2018) later become the benchmark for Heterogeneous Agent New Keynesian (HANK) models by showing why micro-level heterogeneity is widely considered to be a prime driver of policy transmission - thereby contradicting the contributions made 20 years prior by Krusell and Smith (1998). The authors showed how the aggregation that they had earlier suggested can generate stronger and closer-to-reality marginal propensity to consume (MPCs): both the P-HtM and W-HtM respond strongly to shocks (in terms of consumption), since they are at their borrowing constraint. Regarding monetary policy transmission in a framework with heterogenous agents, Corsetti et al. (2018) confirmed what many authors have previously proven theoretically: household heterogeneity, namely differences in the share of (wealthy) hand-to-mouth agents, seems to be driving the asymmetric responses of output to monetary shocks in euro-area countries. In addition, Almgren et al. (2022) showed that monetary policy shocks have heterogeneous effects on output across countries, because the fraction of households that are liquidity constrained varies. More importantly, they argued that countries with a larger fraction of liquidity constrained households, present a larger elasticity of output to monetary policy shocks. The findings of Guo et al. (2023) are consistent with those of Corsetti et al. (2018), in the sense that output responses to expansionary monetary shocks are larger in countries with larger HtM ratios – specifically, countries with a higher share of wealthy-HtM.

If one takes into account the findings from literature, it then becomes logical that, to fully grasp the mechanisms of monetary policy transmission, the employed model must include some degree of micro-economic heterogeneity. More importantly, it must incorporate hand-to-mouth households, especially the wealthy fraction. Additionally, by going beyond literature and considering the data depicted in Figure 1, it is understood that wealthy HtM households represent a considerable share of the population of the five countries under analysis - around 20 to 30 %. Such considerations, deriving from all available evidence, stress, once again, the importance of including this segment of the population in the chosen model. The proper encompassing of wealthy hand-to-mouth agents in this experiment, is behind the decision to measure the differences that arise when moving from a one- to a two-asset model, i.e., from a specification that only includes poor HtM, to one that also includes the wealthy HtM. Further details on the employed model can be found in the next Section.

Figure 1: Country-specific Shares of HtM (P-HtM and W-HtM) and Non-HtM Households. **Notes:** P-HtM stands for poor hand-to-mouth agents, W-HtM for wealthy hand-to-mouth agents and N-HtM for non hand-to-mouth agents. These agents are aggregated according to their asset holdings, as described in 4.1. These shares were estimated using the First Wave of the Households Finance and Consumption Survey (HFCS). More information on this, can be found in Section 4.1.



3 Methodology

In this section, the main building blocks of the models under analysis are depicted. For both the one- and two-asset Heterogeneous Agent New Keynesian (HANK) specifications, the methodology proposed by Auclert et al. (2018) is followed. In both models, agents live infinitely and face uninsurable idiosyncratic income risk.

The crucial distinction between the two models is the wealth accumulation procedure undertaken by households. While in the two-asset model, agents can partially insure against risk by choosing either low-return liquid or high-return illiquid assets, in the one-asset model agents only decide the amount of aggregate wealth in their portfolio - meaning they only make decisions regarding one asset. Assets in the two-asset model carry a portfolio adjustment cost in which one must incur to transform illiquid wealth into liquid (*and vice versa*). This cost is of extreme importance in a setup like the one employed in this experiment, where the economy is hit by a shock and households need to rely on their liquidity to smooth consumption. Each period, households make their decision regarding how much to consume and save, deriving utility from their consumption choices and disutility from hours worked.

The model features sticky wages and the number of hours worked, n, is not defined directly by households, but instead by an union labor demand that takes the household's consumption-savings decision as given. Finally, monetary policy follows a standard Taylor Rule, and the government budget is balanced.

3.1 Households

This economy is populated by a set of heterogeneous agents that face idiosyncratic uncertainty. In this model, agents' productivity is stochastic and non insurable, and follows an AR(1) process: $e_t = \rho_z e_{t-1} + z_t$, $z \sim N(0, \sigma_z^2)$, where ρ_z is the correlation of earnings and σ_z is the variance of earnings. When in state s, the household has a fixed transition matrix Π, and the set of households in state s is equal to π_s, such that $\sum_s \pi_s e(s) = 1$. After being allocated to a state, each household makes its consumption-saving decision. Importantly, the saving decision is different for the one- and two-asset model, which implies distinct household problems. Sub-sections 3.1.2 and 3.1.1, provide a more detailed description.

The number of hours worked by each household is the same, with n being determined by union labor demand. Households receive an individual after-tax wage of $y_t \equiv Y_t e(s)$, where $Y_t \equiv (1 - \tau_t)\omega_t N_t$ stands for household disposable income after paying a proportional tax on labor earnings, τ_t. Households' utility function is a standard CRRA, so that a balanced growth path can be produced. Utility is affected by both consumption, c, and working time, n, and is given by:

$$U(c,N) = \frac{c_{it}^{1-\sigma}}{1-\sigma} - \varphi \frac{N_t^{1+\eta}}{1+\eta}$$

where σ stands for the inverse of the income elasticity of substitution, φ regulates the disutility of working, and η denotes the Frisch elasticity of labor supply.

3.1.1 Household Problem in the Two-Asset Model

In the two-asset specification, the saving process can occur through two different assets: (i) a liquid asset, b_t; and (ii) an illiquid asset, a_t. Because of the liquidity differences between both, the return of the liquid asset b_t is lower than the return of the illiquid asset a_t, yielding $r_t^b < r_t^a$.

To re-allocate between the two assets, households are subject to a convex portfolio adjustment cost of $\Phi_t(a_{it}, a_{it-1})$, where χ_0 is the portfolio adjustment cost pivot, χ_1 is the portfolio adjustment cost scale and χ_2 is the portfolio adjustment curvature:

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

with $\chi_0 > 0$, $\chi_1 > 0$ and $\chi_2 > 1$.

Taking into account all the specifications above, the household problem in the two-asset model can be summarized as follows, where $\underline{b}$ is the borrowing limit for the liquid asset b_t:

$$V_t\left(e_{it}, b_{it-1}, a_{it-1}\right) = \max_{c_{it}, b_{it}, a_{it}} \left\{U(c,N) + \beta \mathbb{E}_t V_{t+1}\left(e_{it+1}, b_{it}, a_{it}\right)\right\}$$

s.t.

$$c_{it} + a_{it} + b_{it} = \left(1 - \tau_t\right) w_t N_t e_{it} + \left(1 + r_t^a\right) a_{it-1} + \left(1 + r_t^b\right) b_{it-1} - \Phi_t\left(a_{it} a_{it-1}\right) \tag{2}$$

$$a_{it} \geq 0, \quad b_{it} \geq \underline{b}$$

3.1.2 Household Problem in the One-Asset Model

In this specification, the wealth accumulation process occurs through an aggregate portfolio choice, where households hold one single asset, h_t. The liquidity and risk of h_t is not specified, which implies that in the one-asset model, households do not face portfolio adjustment costs. Therefore, the household problem in the one-asset model is equivalent to the one in the two-asset specification, if one abstracts from the differences in asset types and excludes adjustment costs:

$$V_t\left(e_{it}, h_{it-1}\right) = \max_{c_{it}, h\prime_{it}} \left\{U(c, N) + \beta \mathbb{E}t V t + 1\left(e_{it+1}, h_{it}\right)\right\}$$

s.t.

$$c_{it} + h_{it} = \left(1 - \tau_t\right) w_t N_t e_{it} + \left(1 + r_t^h\right) h_{it-1} \tag{3}$$

$$h_{it} \geq 0$$

3.2 Financial intermediary

The responsibility of issuing assets (liquid and illiquid) lies within a financial intermediary. Its role can be split into two main avenues: a *banking activity*, where it collects liquid short-term deposits and transforms them, by investing in government debt, B_t, and a *fund activity*, where it collects illiquid assets and invests them into either government bonds, B_t^g, or firm equity, p_t. The liquidity transformation in which the financial intermediary incurs is associated with a cost of $\omega \int b_{it} di$.

This agent seeks to maximize the expected return on illiquid liabilities, $\mathbb{E}_t\left[1 + r_{t+1}^a\right]$, which requires a non-arbitrage condition between the returns of the two assets to hold. This implies that, in equilibrium, the ex-ante return, $\mathbb{E}_t\left[1 + r_{t+1}\right]$, must equal the expected returns on nominal government bonds and equity. Taking into account the intermediation costs, the returns pass onto households as:

$$\mathbb{E}_t\left[1 + r_{t+1}\right] = \frac{1 + i_t}{\mathbb{E}_t\left[1 + \pi_{t+1}\right]} = \frac{\mathbb{E}_t\left[d_{t+1} + p_{t+1}\right]}{p_t} = \mathbb{E}_t\left[1 + r_{t+1}^a\right] = \mathbb{E}_t\left[1 + r_{t+1}^b\right] + \omega \tag{4}$$

The ex-post returns r_t, r_t^a and r_t^b are subject to inflation and capital gains. As in Auclert et al. (2021), it is assumed that capital gains accrue to the illiquid account. Consequently, the Fisher Equation is reached:

$$1 + r_t = \frac{1 + i_{t-1}}{1 + \pi_{t-1}} = 1 + r_{t-1}^b + \omega \tag{5}$$

and

$$1 + r_t^a = \Theta_p \left(\frac{d_t + p_t}{p_{t-1}} \right) + \left(1 - \Theta_p\right) (1 + r_t) \tag{6}$$

where Θ_p denotes the share of equity in the illiquid portfolio. Equation (6) discloses that the return on the illiquid asset is an average of both firm equity and dividends, and the return on capital.

3.3 Firms

Firms in the economy are divided into two segments: a competitive final goods firm, to which the monopolistically competitive firms sell intermediate goods, j, to. Intermediate goods are produced according to a standard Cobb Douglas production function:

$$Y_{jt} = AK_{jt}^{\alpha} N_{jt}^{1-\alpha} \tag{7}$$

where Y denotes output, K the capital stock and α the capital share.

Firms seek to maximize profits by choosing their capital stock, subject to a quadratic adjustment cost $\zeta\left(\frac{K_{jt}}{K_{jt-1}}\right) K_{jt-1}$, where $\zeta(x) \equiv x - (1-\delta) + \frac{1}{2\delta\epsilon_I}(x-1)^2$. Each firm sets its product's price, p_{jt}, subject to an adjustment cost of:

$$\psi_t^p \left(p_{jt}, p_{jt-1}\right) = \left(\frac{\mu_p}{\mu_p - 1}\right)\left(\frac{1}{2\kappa_p}\right) \left[\log \left(p_{jt}/p_{jt-1}\right)\right]^2 Y_t$$

Notably, a fraction of firms fails to adjust their price index to the previous period inflation, hence prices become:

$$P_{jt} = \Pi_{t-1} P_{j,t-1} \tag{8}$$

with $\Pi_{t-1} \equiv \frac{P_{t-1}}{P_t}$. Consequently, an indexed Phillips curve is generated by the optimal price-setting of firms:

$$\log(1 + \pi_t) = \kappa_p \left(\frac{w_t}{F_N'(K_{t-1}, N_t)} - \frac{1}{\mu_p} \right) + \frac{1}{1 + r_{t+1}} \frac{Y_{t+1}}{Y_t} \log(1 + \pi_{t+1}) \tag{9}$$

where $w_t/F_N'(K_{t-1}, N_t)$ denotes the marginal cost. The slope of the Phillips curve, κ_p, is given by $\kappa_p = \frac{(1-\beta\lambda_p)(1-\lambda_p)}{\lambda_p}$, where λ_p denotes the Calvo price parameter. If prices were to be fully flexible, i.e., $\lambda_p = 0$, and all firms were to set the same price, a constant mark-up over marginal costs $\frac{\mu_p}{\mu_p - 1}$ would arise.

Considering that aggregate investment can be summarized as $I_t = K_t - (1-\delta)K_{t-1} + \zeta\left(\frac{K_{jt}}{K_{jt-1}}\right)K_{jt-1}$ and dividends as $d_t = Y_t - \omega_t N_t - I_t - \psi_t$, the capital stock accumulation equation can be attained:

$$(1+r_{t+1})\,Q_t = \alpha\frac{Y_{t+1}}{K_t}mc_{t+1} - \left[\frac{K_{t+1}}{K_t} - (1-\delta) + \frac{1}{2\delta\epsilon_I}\left(\frac{K_{t+1}-K_t}{K_t}\right)^2\right] + \frac{K_{t+1}}{K_t}Q_{t+1} \tag{10}$$

where Q_t stands for the Tobin's Q ratio, $Q_t = 1 + \frac{1}{\delta\epsilon_I}\frac{K_t - K_{t-1}}{K_{t-1}}$.

3.4 Labor Unions

As in any standard New Keynesian model with sticky-wages, household working hours, n_{it}, are set by the union labor demand. In this economy, a continuum of unions exists, k, with wages for each labor type being settled by a different labor union.

The process of wage setting unfolds as follows: taking as given the consumption-saving decision by households, each union asks its members to supply working hours according to $n_{ikt} = N_{ikt}$, while setting wages that seek to maximize each household's average utility. Similarly to what happens with the price adjustment cost incurred by firms, by setting nominal wages, W_{kt}, the union sustains a quadratic adjustment cost:

$$\psi_t^w\left(W_{kt}, W_{kt-1}\right) = \left(\frac{\mu_w}{\mu_w - 1}\right)\left(\frac{1}{2\kappa_w}\right)\left[\log\left(W_{kt}/W_{kt-1}\right)\right]^2$$

As a consequence of the union maximization problem, a Phillips curve for wage inflation emerges:

$$\log\left(1+\pi_t^w\right) = \kappa_w\left(\varphi N_t^{1+v} - \frac{(1-\tau_t)\,w_t N_t}{\mu_w}\int e_{it}c_{it}^{-\sigma}di\right) + \beta\log\left(1+\pi_{t+1}^w\right) \tag{11}$$

where, $\kappa_w = \frac{(1-\beta\lambda_w)(1-\lambda_w)}{\lambda_w}$ stands for the slope of the wage Phillips curve and λ_w is the Calvo wage parameter. If wages were to be fully flexible, i.e., $\lambda_w = 0$, all unions would set the inverse wage markup to $\frac{\mu_w - 1}{\mu_w}$.

3.5 Monetary and Fiscal Policies

The monetary authority adjusts the nominal interest rate, i_t, according to a standard Taylor rule:

$$i_t = r_t^* + \phi_\pi\pi_t + \phi_y(Y_t - Y_{ss}) \tag{12}$$

where r_t^* is the optimal real interest rate, π_t is the inflation rate and $Y_t - Y_{ss}$ is the output gap. ϕ_π stands for the Taylor rule coefficient on inflation while ϕ_y stands for the Taylor rule coefficient on output.

The government issues bonds B^g, spends on goods and services G_t and collects a proportional tax on labor income $\tau_t w_t N_t$. Every period, the government's budget constraint is balanced:

$$\tau_t w_t N_t = r_t B^g + G_t \tag{13}$$

3.6 Equilibrium

Considering a given distribution of agents, the competitive equilibrium is summarized as follows:

1. Taking factor prices and initial conditions as given, households solve their maximization problem using the value function $V_t(e_{it}, b_{it-1}, a_{it-1})$[5] and the respective policy functions, $c(e_{it}, b_{it-1}, a_{it-1})$, $b(e_{it}, b_{it-1}, a_{it-1})$ and $a(e_{it}, b_{it-1}, a_{it-1})$.

2. The financial intermediary, firms and labor unions optimize.

3. Monetary and fiscal authorities follow their set of rules.

4. Asset markets clear, implying that total households' savings equals both the value of firm equity and government bonds:

$$p_t + B^g = \int a_{it} di + \int b_{it} di$$

5. Goods market clears, with the final good being used for private and public consumption, investment, price and wage adjustment costs, liquidity transformation and portfolio adjustment costs:

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

[5]For visual simplicity, the competitive equilibrium for the one-asset specification is not described. As stated previously, it will resemble that of the two-asset, if one abstracts from the distinction between assets and from portfolio adjustment costs.

4 Calibration

The one- and two-asset specifications of the model are calibrated for five European Monetary Union (EMU) economies: Austria (AT), Germany (DE), France (FR), Portugal (PT) and Slovakia (SK). The undertaken analysis thus concerns a sample of countries that accounts for 54,2% of the Euro-Area's size, in terms of GDP[6].

Computationally, for the model to be able to (i) generate empirically relevant country-specific characteristics and (ii) yield parameters that are consistent with the standards found in literature, some other variables must be unconstrained. To solve such problem, the computational strategy of Auclert et al. (2021) is employed. All details regarding the calibration strategy can be found in Section A of the Appendix.

4.1 Calibration Targets

Calibrations targets are the set of parameters that are empirically estimated for each of the economies under analysis. These include the share of hand-to-mouth agents (P-HtM and W-HtM), the liquid and illiquid wealth to GDP ratios, and the capital-to-output ratio. Detailed information on the value of the mentioned targets can be found in Tables 4 and 5 in the Appendix.

The estimated shares for hand-to-mouth agents (P-HtM and W-HtM) are retrieved from Sá (2022), which were in turn obtained by applying the methodology followed by Kaplan et al. (2014). The disaggregation of asset holdings into two saving instruments can be achieved by partitioning households into three different categories: (i) wealthy hand-to-mouth households (W-HtM), who despite holding little to no liquid wealth, own positive amounts of illiquid wealth (possibly large levels); (ii) poor hand-to-mouth (P-HtM) are the ones, who hold little liquid wealth, but zero to negative illiquid wealth and (iii) non hand-to-mouth or Ricardian households (N-HtM), who choose consumption according to an Euler Equation.

The data used by Sá (2022) was retrieved from the first wave of the Household Consumption and Finance Survey (HCFS), which was carried out between late 2008 and mid-2011 (mostly in 2010) and included more than 62,000 households. This survey is conducted jointly by the euro-area

[6]Data retrieved from World Bank national accounts data, and OECD national accounts data files.

central banks and some national statistical agencies, and aims to provide relevant micro data, such as information on the composition of household balance sheets across countries.

The value for liquid and illiquid assets in each country are estimated by following the methodology of Sierminska and Medgyesi (2013). The authors define liquid wealth as financial assets (comprising deposit accounts, stocks, bonds, mutual funds and life insurance) less liabilities; and illiquid wealth as housing (principal residence and investment real estate) less mortgages and other home-secured debt, plus self-employment business.

Instead of working with the monetary value of wealth, and having consistency considerations in mind, the decision was to transform the variables into wealth to GDP ratios. To perform such transformation, data on GDP at constant prices was required. Given that the raw values were obtained by using the results of the HCFS, and knowing that these surveys were mostly conducted during 2010, data for that same year was collected. Data for the wealth distribution and GDP at constant prices was drawn from the World Bank.

Importantly, in the one-asset model specification, the constrained hand-to-mouth agents are all P-HTM. In this specification, households can only hold one indistinguishable asset in their portfolio, which does not allow for the modeling or identification of the W-HTM fraction of the economy. Moreover, and due to the reason mentioned above, there is also no distinction between liquid and illiquid wealth. This means that the one-asset model is calibrated for total wealth, which stands for the aggregate of those values.

The Penn World Table 8.0 (PWT 8.0), using the average from 1990 to 2011, was used to retrieve the capital-to-output ratios.

4.2 Parameters held constant

Resorting to literature, specifically Auclert et al. (2021) and Auclert et al. (2018), a set of parameters are held constant across specifications and countries. These parameters comprise the inverse of the income elasticity of substitution, σ, the inverse of the Frisch elasticity, η, the portfolio adjustment cost curvature, χ_2, the borrowing limit, $\underline{b}$, the autocorrelation of earnings, ρ_z , the share of equity in the illiquid portfolio, Θ_p, the depreciation rate, δ, the slope of the price Phillips curve, κ_p, the slope of the wage Phillips curve, κ_p, the steady-sate wage markup, μ_w, the government spending ratio, G, the Taylor Rule coefficient on inflation, ϕ_π and on output, ϕ_y. Detailed information on the value of the mentioned parameters can be found in Table 8 in the Appendix.

4.3 Parameters Endogenously Calibrated

In order to computationally reach the target moments for each country, a simulated method of moments is used. This set of parameters does not have a strong empirical counterpart, and thus will be endogenously calibrated for each economy. Detailed information on the values of the mentioned parameters can be found in Tables 6 and 7 in the Appendix.

For both the one- and two-asset model specifications, these unconstrained parameters encompass the discount factor, β, and the variance of earnings, σ_z. For the two-asset model specification, three extra parameters are calibrated endogenously: the portfolio adjustment cost pivot, χ_0, the portfolio adjustment cost scale, χ_1, and the liquidity premium, ω.

4.4 Computational Strategy

The methodology proposed by Auclert et al. (2021), and followed in this experiment, is called sequence-space jacobian and can be used to solve the model presented in Section 3. The idea behind the employed mechanism is that the equilibrium can be written as a system of linear equations, in the space of perfect-foresight sequences. Importantly, and given that Heterogenous Agent New Keynesian (HANK) models imply dealing with stochasticity and rich micro-heterogeneity, there are real gains in using the sequence-space to reach a solution: the size of the system of equations is independent of the state-space size. In fact, if instead the equilibrium was written as in Reiter (2009), the process would be much more lengthy.

This approach relies on the calculation of sequence-space jacobians, which consist of derivatives of equilibrium mappings between aggregate sequences around the steady state. By computing all relevant space jacobians, all pertinent model aspects are accounted for, and the general equilibrium can be found. From there on, these derivatives can be composed, inverted and later transformed to obtain the impulse response functions plotted in the Appendix.

Computationally, for the algorithm to find an equilibrium solution that makes sense for the chosen set of calibration targets, guesses for the endogenously calibrated parameters have to be made. Naturally, the closer this guesses are from the range of parameters that can close the model, the faster the algorithm is. Moreover, a higher number of both calibration targets and endogenously calibrated parameters will of course increase the waiting game: meaning that the process of reaching an equilibrium solution that suits the targets in the two-asset model, requires a more complex and frequent updating of guesses. Regardless of being a highly innovative and efficient method for solving heterogeneous-agent models with policy shocks, the handling of this algorithm requires a complete understanding of its intrinsic dynamics.

5 Results

This section concerns the analysis of the response of the several economies and model specifications to a one-time unexpected contractionary monetary shock. The underlying intention is to i) describe the monetary policy experiments being conducted, ii) grasp the mechanisms behind the negative response of output to an interest rate rise, iii) compare the results obtained for the one- and the two-asset specifications, iv) assess seemingly relevant mechanisms, to rationalise cross-country differences in responses and v) with robustness considerations in mind, gauge if using a Taylor Rule that also reacts to output, changes any of the conclusions reached.

5.1 Monetary Policy Experiments and Transition Dynamics

It is assumed that the economy is initially at its steady-state level and that the Taylor Rule only responds to prices. At time $t = 0$, the optimal real interest rate, r_t^*, increases by 75 basis points, which temporarily drives the economy out of equilibrium. The economy will return to its initial steady-state level in a given number of periods, depending on the degree of persistence of the monetary shock, $\rho_{r_t^*}$. The chosen degree of persistence for this experiment is $\rho_{r_t^*} = 0.5$, which is consistent with VAR-based empirical evidence and is also the value chosen by Kaplan et al. (2018) and Alves et al. (2020). A second experience is performed to evaluate the impact that having a Taylor Rule that also responds to output has on the conclusions reached for the baseline case.

To examine the economy's response to this shock, the analysis relies on the impulse response functions (IRFs) and the corresponding impact multipliers. The latter is defined as follows:

$$\text{Impact Multiplier} = \frac{\Delta Y_0}{\Delta r_0^*}$$

where ΔY_0 is the change in output from period 0 to period 1, and Δr_0^* the change in the optimal real interest rate from period 0 to period 1. The values for both ΔY_0 and Δr_0^* come from the impulse response functions at impact that can be found in the Appendix. For the baseline Taylor Rule case, please refer to Section B and for the extended Taylor Rule case refer to Section C.

5.2 Understanding the Mechanisms

Tables 1 and 2 display the baseline-case impact multipliers for the two specifications of the model and the impact responses of relevant aggregates, for all countries under analysis. The correspondent IRFs are reported in Section B of the Appendix.

Table 1: Impact Multiplier for the One-Asset HANK Model and correspondent Impact Responses of relevant aggregates

Country	M1	Output	Consumption	Prices	Wages	Hours Worked
AT	**-1.23**	-0.92	-0.21	-0.25	-0.52	-1.23
DE	**-1.04**	-0.78	-0.21	-0.30	-0.59	-1.00
FR	**-1.41**	-1.06	-0.23	-0.18	-0.42	-1.41
PT	**-0.91**	-0.68	-0.15	-0.35	-0.70	-0.90
SK	**-1.52**	-1.14	-0.22	-0.19	-0.42	-1.58

Note: M1 stands for the Impact Multipliers of the One-Asset HANK Model

Table 2: Impact Multiplier for the Two-Asset HANK Model and correspondent Impact Responses of relevant aggregates

Country	M2	Output	Consumption	Prices	Wages	Hours Worked
AT	**-0.30**	-0.23	-0.26	-0.71	-1.41	-0.30
DE	**-0.13**	-0.10	-0.27	-0.82	-1.65	-0.13
FR	**-1.18**	-0.88	-0.30	-0.29	-0.60	-1.18
PT	**-0.82**	-0.61	-0.36	-0.45	-0.82	-0.81
SK	**-1.39**	-1.04	-0.26	-0.24	-0.50	-1.44

Note: M2 stands for the Impact Multipliers of the Two-Asset HANK Model

Regardless of the country or model specification, and as literature seems to suggest, one can confirm that output responds negatively to a rise in the policy interest rate. The mechanism unfolds as follows: by increasing the real interest rate, the monetary authority induces a rise in the nominal interest rate. This increase is translated into increased returns on both liquid and illiquid assets, which enter the household budget constraint. This effect will thus influence the household saving-consumption decision, as it incentivises increased savings and shrinks consumption levels, i.e., intertemporal substitution effect. The reduced consumption levels translate into a decreased aggregate demand, thus inducing firms to damp both prices and labor demand. As a consequence, the labor market moves to an equilibrium where the offered wages are lower. When faced with lower wages, labor unions can either make households (i) supply less labor because each unit of work supplied is now less rewarded, i.e., substitution effect or, (ii) in an effort to keep the level of consumption before the shock, supply more labor, i.e., income effect. When analysing Tables 1 and 2, it becomes clear that households work less hours after being hit by the shock, implying that there is a dominance of the substitution effect in this experiment. As consumption and number of worked hours decrease, output follows.

5.3 Inspecting the Magnitude Differences between Model Specifications

Interestingly, the impact multipliers generated by the one-asset model are higher (in absolute terms) than the multipliers in the two-asset specification, for every country under analysis. This implies that output in the one-asset model consistently reacts more strongly to the monetary shock, *vis-a-vis* the two-asset model (Tables 1 and 2). These findings suggest that, ignoring the real distribution of assets in a country's portfolio, i.e., working under the one-asset specification, can lead to an overestimation of the negative impact that tightening monetary policy can have on output.

Let us then dive into the one- and two-asset models, to better understand what are the mechanisms behind such conclusions. As thoroughly explained in Section 5.2, the intertemporal substitution effect shrinks consumption and the dominance of the substitution effect causes worked hours to fall in both model specifications. However, besides these common standard effects, the two-asset model encompasses an additional layer of mechanisms because of the inclusion of wealthy hand-to-mouth agents. Such addition, that implies the disaggregation of wealth into liquid and illiquid assets and the inclusion of even more constrained agents in the model, justifies the change of the magnitude of the responses of both consumption and hours worked.

As Kaplan et al. (2018) put forward, moving from a one- to a two-asset model, unveils an extra channel through which households may accommodate a monetary policy shock: the rebalancing of their portfolio between liquid and illiquid assets. Such phenomena allows households to shift between assets, which may prevent harsh decreases in variables such as hours worked or consumption. In the scope of this experiment, their findings imply that the degree of disruption generated from the shock is expected to be lower in the two-asset model, consequently leading to reduced observed multipliers.

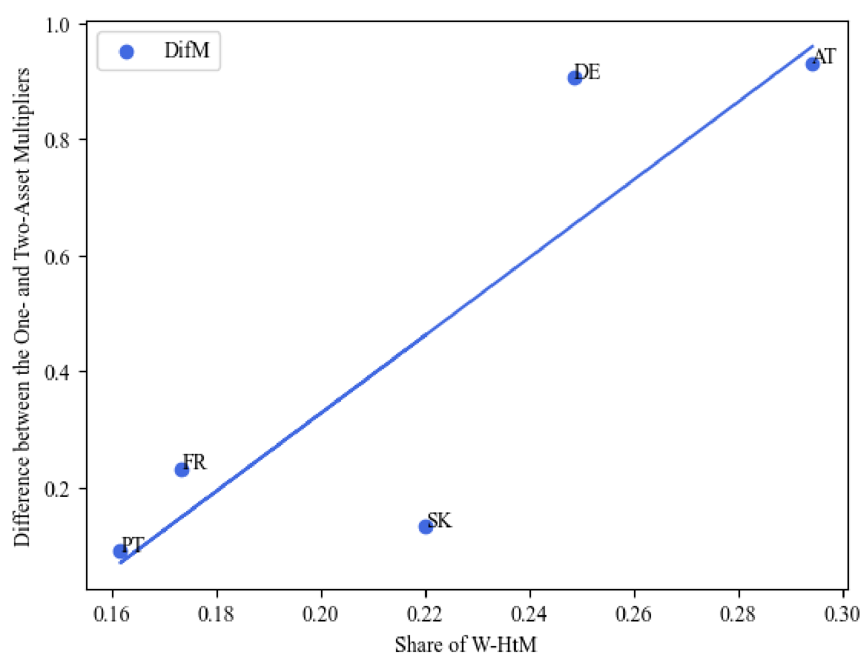
Following the monetary shock, both liquid and illiquid returns are driven upwards, increasing the opportunity cost of not holding these saving instruments. The gap between illiquid and liquid returns is such, that households are induced to move towards illiquid asset holdings. To accommodate this increase, an additional fall in consumption unfolds. Henceforth, the magnitude of the drop in consumption in the two-asset model surpasses that of the one-asset model (Tables 1 and 2). Such a result is in line with what is shown by Kaplan et al. (2014) and Brinca et al. (2016): when faced with temporary changes in income, the consumption response of agents with higher MPCs (as is the case for wealthy hand-to-mouth agents) is quite powerful. In other words, by including these agents in the two-asset model, it was expected that consumption would react more vigorously. In the scope of this paper, and even if aligned with what was expected, the consumption response can come across as puzzling: if the mechanism behind the stronger reaction of consumption under the two-asset model was just rationalised, how can the multiplier be smaller in magnitude? Undeniably consumption cannot be the variable driving the response of output. In fact, if one refers again to Tables 1 and 2, it is clear that hours worked react more strongly than consumption in both models, implying that this is the key variable behind the obtained results.

So, what is the mechanism behind the more moderate response of hours worked in the two-asset model? The option of portfolio rebalancing is associated with adjustment costs from liquidity transformation, inducing households to feel poorer, and consequently unveiling an income effect that was not relevant in the one-asset specification. Because wealthy hand-to-mouth agents do not hold liquid asset positions, they do not have interest from bonds to cancel these costs. As such, to absorb this extra "burden", households in the two-asset model will adjust hours worked less strongly. This implies that the dominance of the substitution effect over the income effect that was reported in Section 5.2, is dampened in the two-asset specification, thus contributing for the two-asset multipliers to be lower than those in the one-asset model.

5.4 Factors Driving Cross-Country Differences in Multipliers

Thus far, it has become evident that all countries' output responds negatively to a tightening of monetary policy. Nevertheless, in some countries the one-asset multiplier is closer to the two-asset multiplier than in others. Hence, implying that the magnitude of the differences between model specifications is heterogeneous across countries. As evidence in Section 5.3 seems to suggest, these magnitude differences between multipliers arise via portfolio rebalancing channel, that amplifies the income effect in the two-asset model. Moreover, since this rebalancing is conducted only by households holding a positive amount of liquid wealth, the amount of wealthy hand-to-mouth households can pose as an important factor in explaining this cross-country heterogeneity. Indeed, Figure 2 reveals that the percentage of wealthy hand-to-mouth households is extremely relevant in explaining the cross-country differences between model specifications.

Figure 2: Absolute Difference between the One- and Two-Asset Impact Multiplier (Baseline Taylor Rule) against the Share of W-HtM Households, for each country under analysis. **Notes:** The Pearson correlation coefficient is 0.865229.



The rationale behind Figure 2 is the following: the more W-HtM there is, the higher is the magnitude of the income effect mentioned in Section 5.3. Of course, the higher the income effect, the lower in absolute terms will be the drop in hours worked in the two-asset specification. Since labor supply drives the differences between model specifications, if N_t does not decrease so violently, it is expected that output also follows a more moderate fall. As such, the higher the percentage of W-HtM, the higher the difference separating the two-asset multiplier from that of the one-asset tends to be. This relationship can be verified by the the positively slopped line depicted.

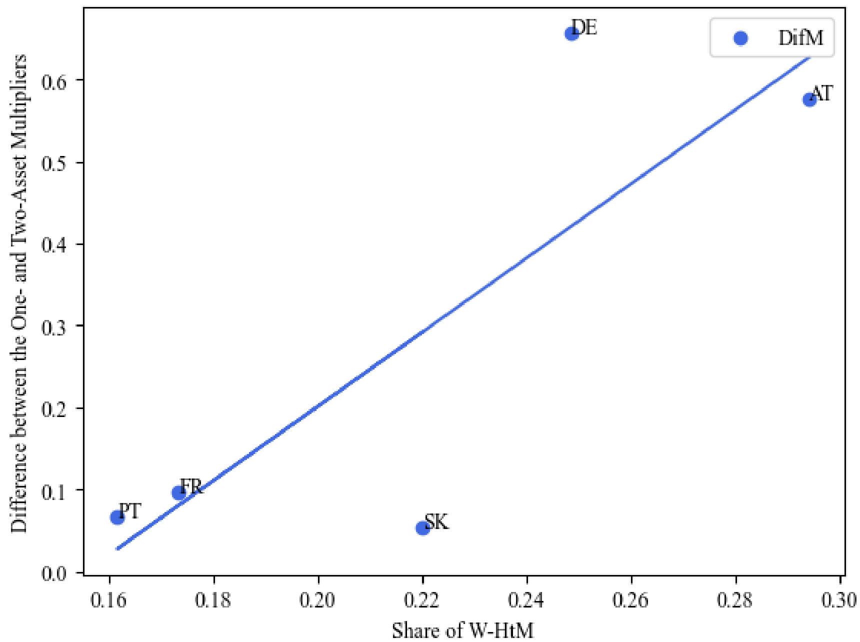
5.5 Robustness Exercises: Changing the Taylor Rule

Regardless of the fact that all countries under analysis are members of the European Monetary Union, ignoring that the European Central Bank can also react to output fluctuations could make the reached conclusions limited. In fact, Gross and Zahner (2021) discuss that (despite decreasing) the role of economic activity in driving monetary policy decisions in the euro-area should be accounted for. For that reason, the baseline specification is extended, and the Taylor rule is adapted so it reacts to both prices and output deviations from the steady-state. Table 3 reveals that under this extended Taylor Rule, one-asset multipliers are still larger than two-asset multipliers for all countries under analysis. Moreover, under this setup, output is not allowed to fluctuate as strongly as before, expectedly inducing the magnitude of the multipliers in both models to be significantly lower. Figure 3 shows that, as for the importance of W-HtM agents, all mechanisms described in Section 5.4 still hold. Section C of the Appendix reports the correspondent IRFs.

Table 3: Impact Multipliers for the One- and Two-Asset Models, for Different Taylor Rule specifications.

	One-Asset Multiplier		Two-Asset Multiplier	
Country	**TR only prices**	**TR prices and output**	**TR only prices**	**TR prices and output**
AT	-1.23	-0.76	-0.30	-0.18
DE	-1.04	-0.68	-0.13	-0.02
FR	-1.41	-0.82	-1.18	-0.73
PT	-0.91	-0.60	-0.82	-0.54
SK	-1.52	-0.86	-1.39	-0.81

Figure 3: Absolute Difference between the One- and Two-Asset Impact Multiplier (Taylor Rule Extension) against the Share of W-HtM Households, for each country under analysis. **Notes:** The Pearson correlation coefficient is 0.821681.



6 Conclusion

For this study, the households of five members of the European Monetary Union - Austria, Germany, France, Portugal and Slovakia - where disaggregated in terms of the liquidity of their portfolio, as proposed by Kaplan et al. (2014). Doing so, allowed for the separation of the effects produced by those who hold no illiquid wealth, the poor hand-to-mouth households (P-HtM), from the effects of those who hold large amounts of it, the wealthy hand-to-mouth households (W-HtM). This paper focused on analysing whether increasing the percentage of constrained agents in an economy, influenced the response of output to a tightening of monetary policy. This analysis is done by comparing impact multipliers through the lens of a one- and two-asset Heterogeneous Agents New Keynesian (HANK) model, as per Auclert et al. (2018). The reason behind this comparison relies on the fact that the one-asset HANK specification only considers P-HtM agents, and is thus ignoring that 20-30 % of the population of the countries under analysis is characterised as W-HtM. As such, to grasp the effects generated by the households that hold illiquid wealth, the two-asset HANK model is calibrated.

This paper contributes to literature by investigating how moving to a theoretical framework that includes assets with different degrees of liquidity - and thus, better reflects the composition of household portfolios found in data - affects the response of output to monetary policy shocks. The results obtained are first that, regardless of the country or model specification, output responds negatively to a rise in the policy interest rate. Secondly, it is found that the impact multipliers of the one-asset model are consistently higher (in absolute terms) than the multipliers in the two-asset specification, for all countries. Such magnitude difference arises because of the introduction of the portfolio rebalancing channel in the two-asset model. Finally, it is shown that the percentage of wealthy hand-to-mouth households is theoretically relevant in explaining the cross-country heterogeneity in the magnitude of the differences between model specifications. Importantly, all this conclusions are robust to different specifications of the Taylor Rule followed by the monetary authority.

These findings unveil important policy implications for the conduction of monetary policy. If central banks were to ignore the real distribution of assets in a country's portfolio, i.e., if their policy analysis' model resembles that of the one-asset model specification employed in this paper, the negative impact that tightening monetary policy can have on output might be overestimated. Moreover, if household heterogeneity, here proxied by differences in wealth distribution, is proved to affect cross-country heterogeneity in responses to monetary policy, it is hugely advisable that central banks work under a framework that parallels the two-asset HANK model. In fact, this recommendation aligns with those made by Darracq Paries et al. (2021) on the latest *Review of Macroeconomic Modelling in the Eurosystem*.

A shortcoming of the employed model is that the portfolio rebalancing costs are endogenously calibrated, meaning that there is no empirical counterpart for its values in literature. Given their relevance in explaining the transmission mechanisms that justify the obtained results, an obvious next step would be to empirically estimate such parameters for all countries under analysis. Further research could also focus on understanding what are the consequences of allowing the adjustment of different types of fiscal instruments following the monetary shock, as in this paper neither debt nor government expenses are allowed to fluctuate. Another interesting exercise would be to measure how changing both the size and degree of persistence of the monetary shock, translates into different welfare costs for households, as these size-persistence considerations could unveil important insights for policy-making at the euro-area level.

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Appendix

A Model Calibration

This Section presents all the relevant parameters in what regards the calibration of the two model specifications, as thoroughly explained in Section 4. Calibration Targets for the One- and Two-Asset Models are depicted in Tables 4 and 5, respectively. Endogenously Calibrated Parameters are shown in Tables 6 and 7. Constant Parameters across countries are depicted in Table 8.

Table 4: Calibration Targets for the One-Asset HANK Model.

Country	% P-HTM	Total Wealth (twealth)	K/Y
AT	0.052	6.116	3.359
DE	0.073	5.169	3.013
FR	0.032	6.549	3.392
PT	0.055	7.774	3.229
SK	0.025	5.484	3.799

Table 5: Calibration Targets for the Two-Asset HANK Model.

Country	% P-HTM	% W-HTM	Liquid Wealth	Illiquid Wealth	K/Y
AT	0.052	0.294	1.003	5.101	3.359
DE	0.073	0.248	1.160	4.008	3.013
FR	0.032	0.173	1.230	5.318	3.392
PT	0.055	0.161	1.008	6.765	3.229
SK	0.025	0.219	0.433	5.050	3.799

Table 6: Endogenously Calibrated Parameters, for which calibration values change between model specifications.

	β		σ_z	
Country	**One-Asset**	**Two-Asset**	**One-Asset**	**Two-Asset**
AT	0.98572	0.294	0.97987	0.29787
DE	0.98413	0.248	0.97888	0.29151
FR	0.98676	0.173	0.98508	0.15932
PT	0.98218	0.161	0.98328	0.16903
SK	0.98749	0.219	0.98646	0.11292

Table 7: Endogenously Calibrated Parameters, for which calibration values are constant regardless of the model specification.

Country	χ_0	χ_1	ω
AT	0.145	5.272	0.003
DE	0.117	3.165	0.002
FR	0.512	12.283	0.001
PT	3.229	29.850	0.003
SK	3.799	9.164	0.001

Table 8: Constant Parameters across countries.

Parameter	**One-Asset**	**Two-Asset**
Households		
σ	2	2
η	1	1
χ_2	nd.	2
$\underline{b}$	0	0
ρ_z	0.95	0.91-0.95
Financial Intermediary		
Θ_p	0.85	0.85
Firms		
δ	0.06	0.06
κ_p	0.1	0.1
Labor Unions		
κ_w	0.1	0.1
μ_w	1.1	1.1
Policy		
G	0.2	0.2
ϕ_π	1.5	1.5
ϕ_y	0 or 0.5	0 or 0.5

B Impulse Response Functions for the Baseline Case

This Section presents the impulse response functions of the two specifications of the models, for the baseline case where the Taylor Rule only responds to prices. For each country and each model specification, the IRFs of output, Y_t, consumption, C_t, hours worked, N_t, wages, w_t, prices, p_i, will be plotted. For the One-Asset HANK, Figures 4, 5, 6, 7 and 8 are plotted. For the Two-Asset HANK, Figures 9, 10, 11, 12 and 13 are plotted.

B.1 Impulse Response Functions for the One-Asset HANK

Figure 4: One-Asset IRFs for Austria, for the baseline Taylor Rule.

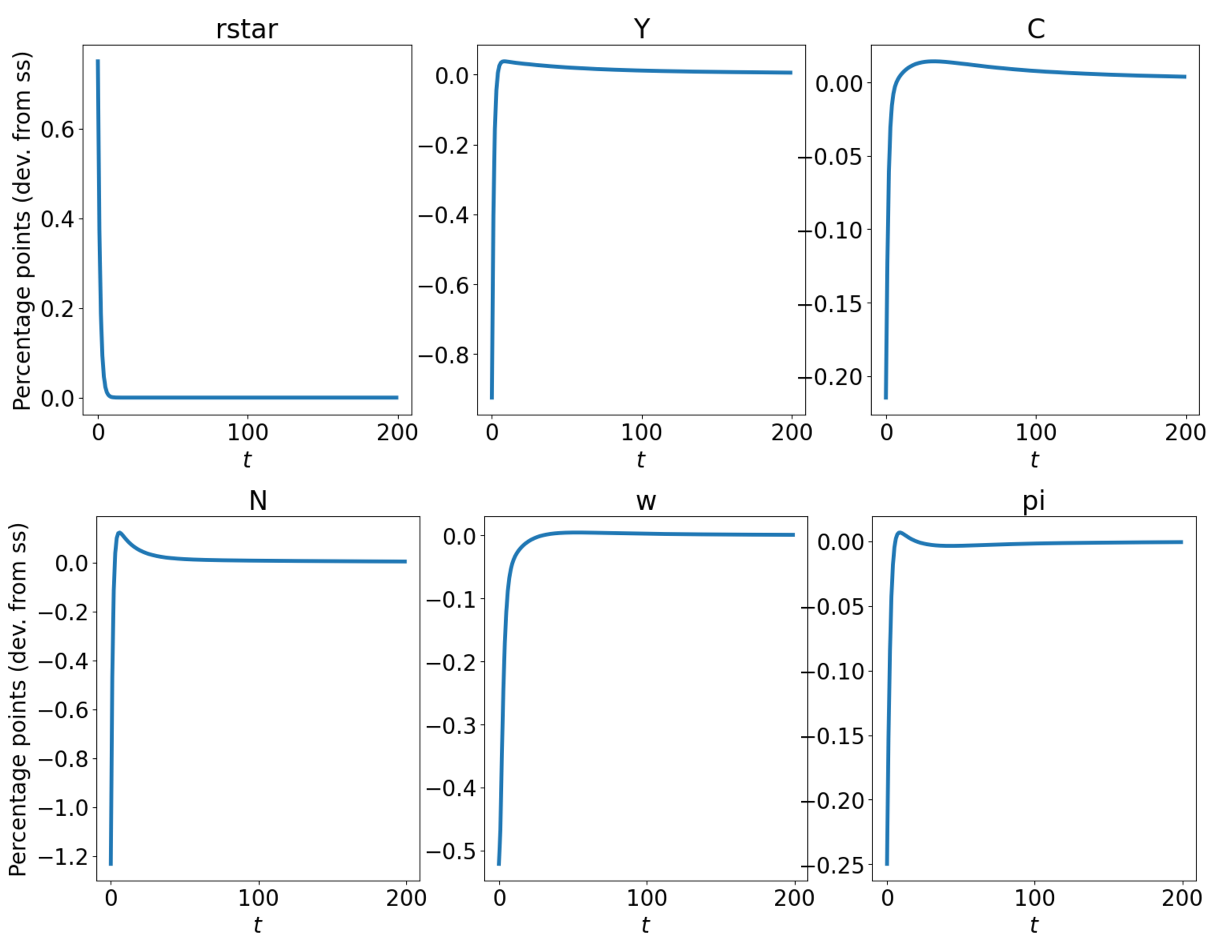


Figure 5: One-Asset IRFs for Germany, for the baseline Taylor Rule.

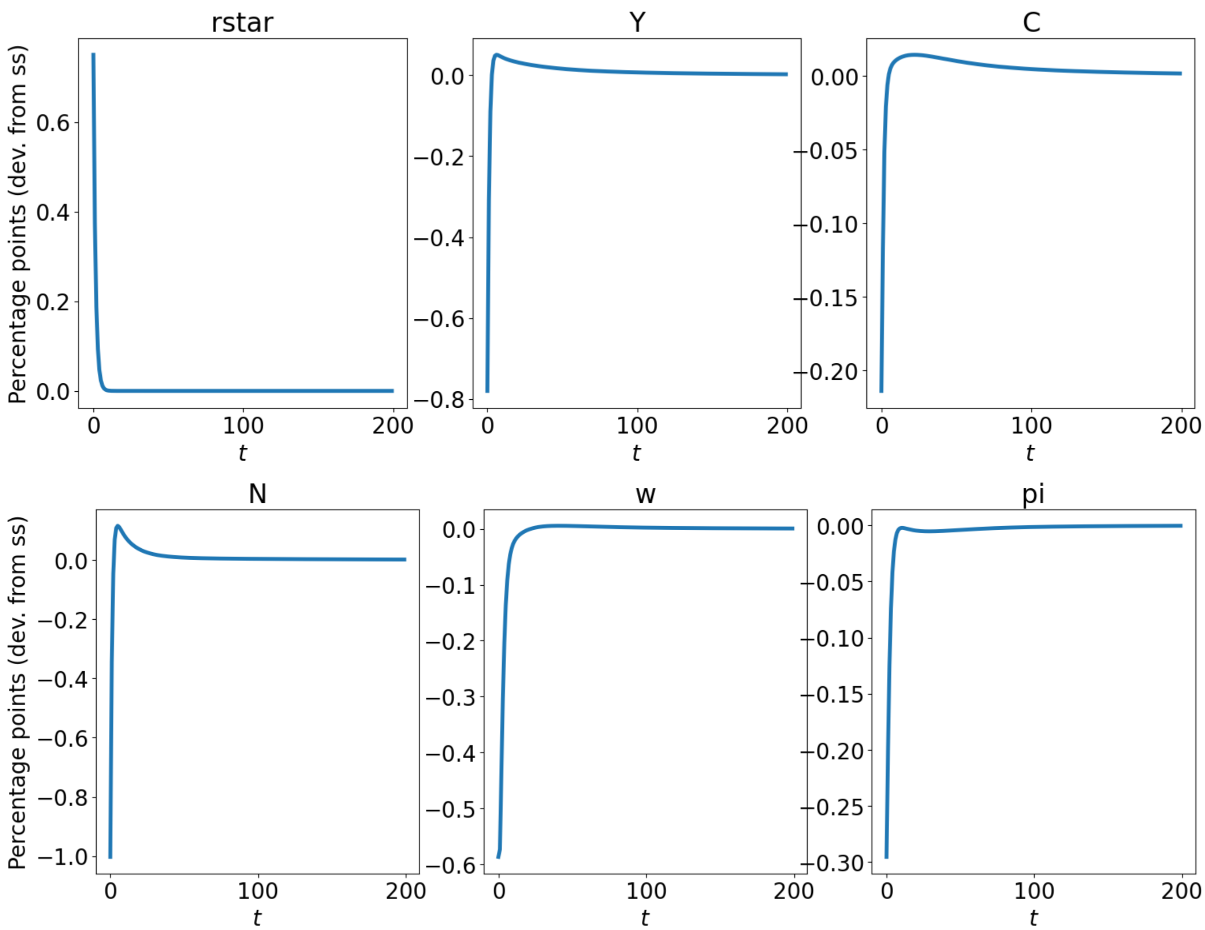


Figure 6: One-Asset IRFs for France, for the baseline Taylor Rule.

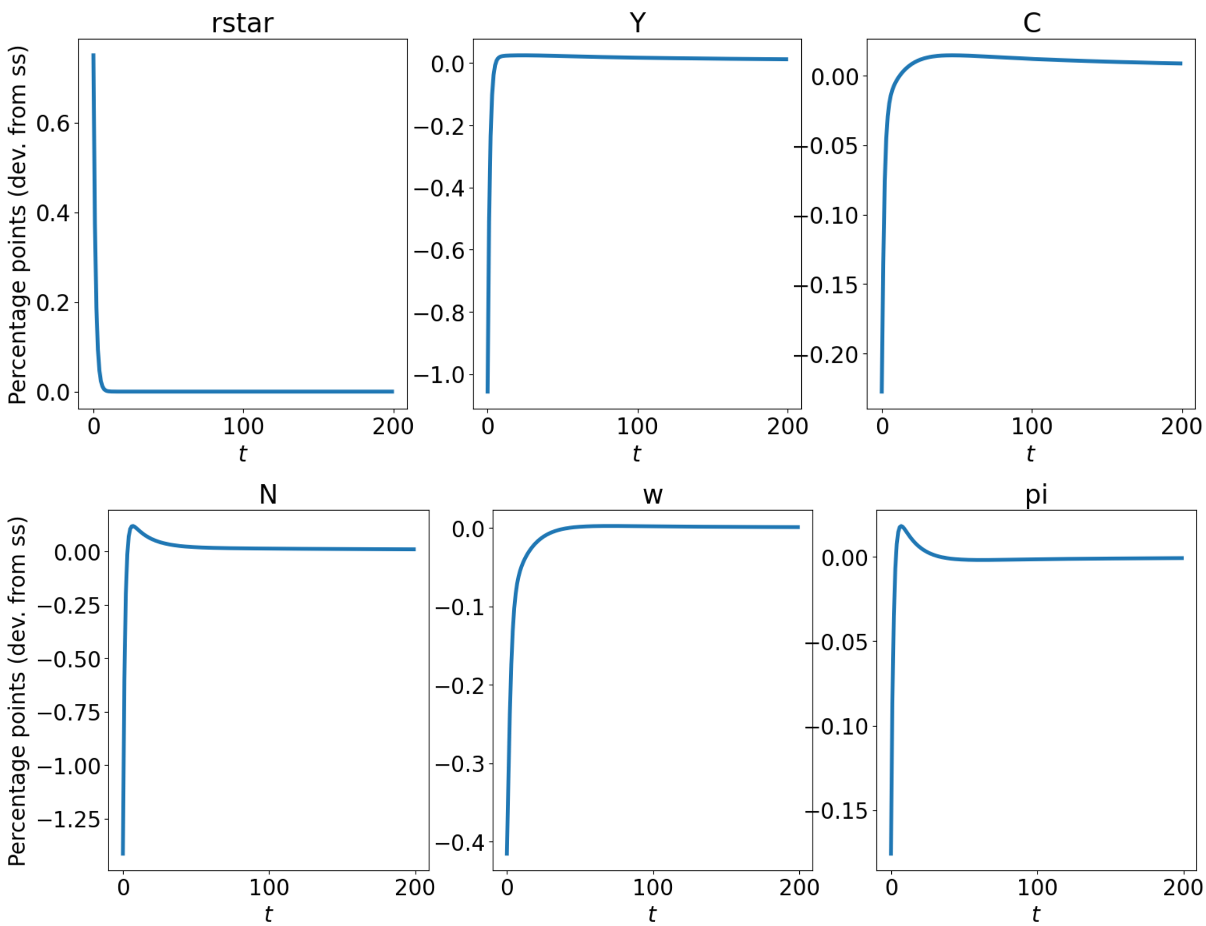


Figure 7: One-Asset IRFs for Portugal, for the baseline Taylor Rule.

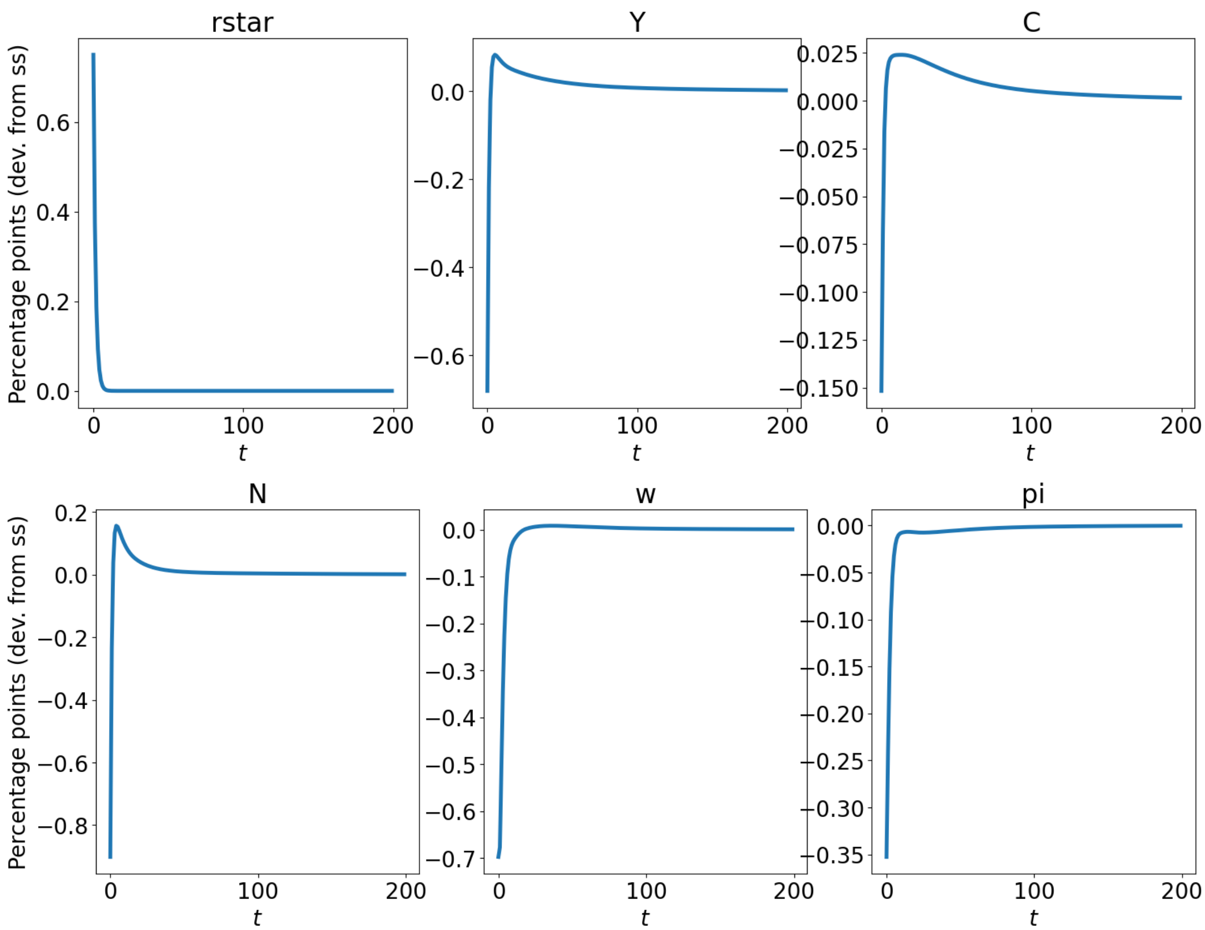
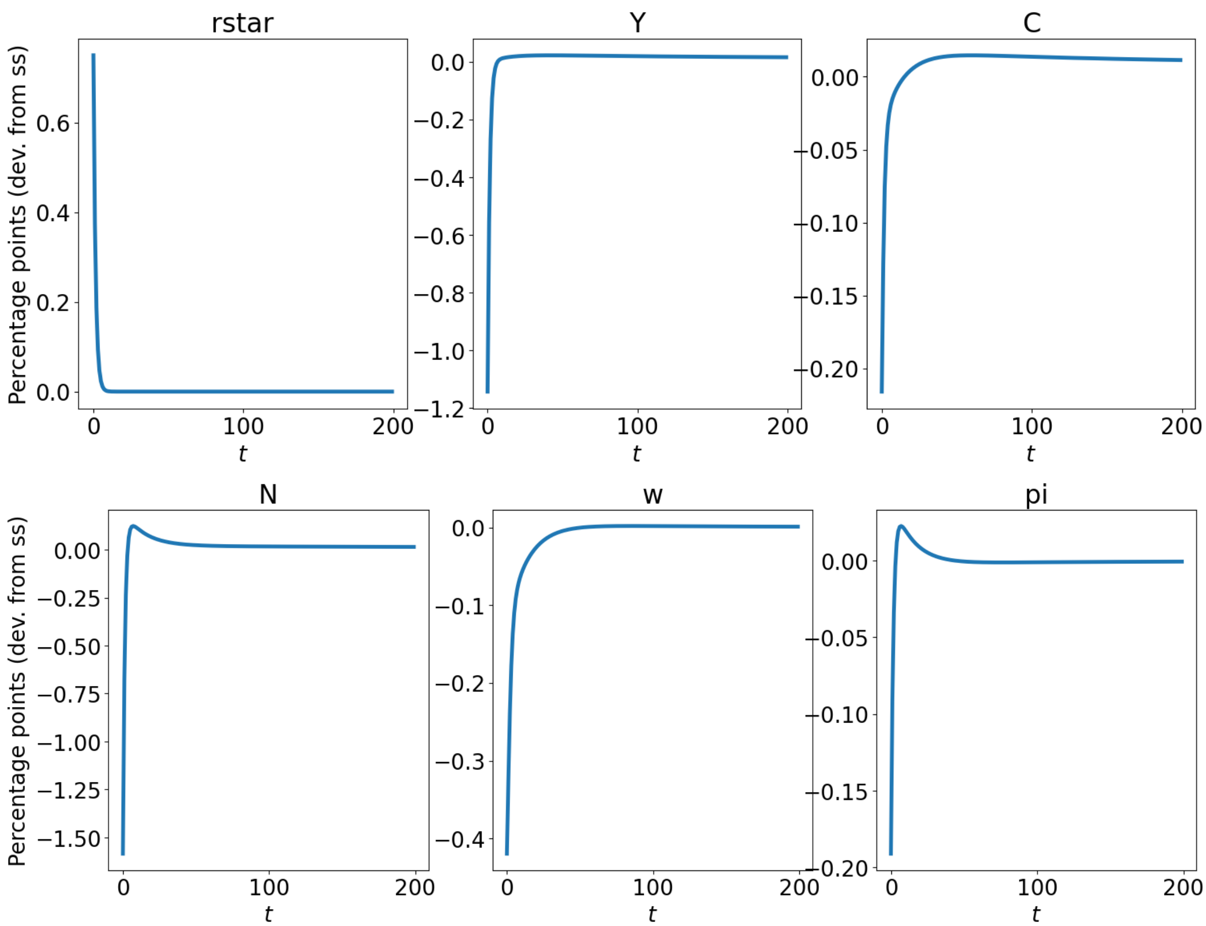


Figure 8: One-Asset IRFs for Slovakia, for the baseline Taylor Rule.



B.2 Impulse Response Functions for the Two-Asset HANK

Figure 9: Two-Asset IRFs for Austria, for the baseline Taylor Rule.

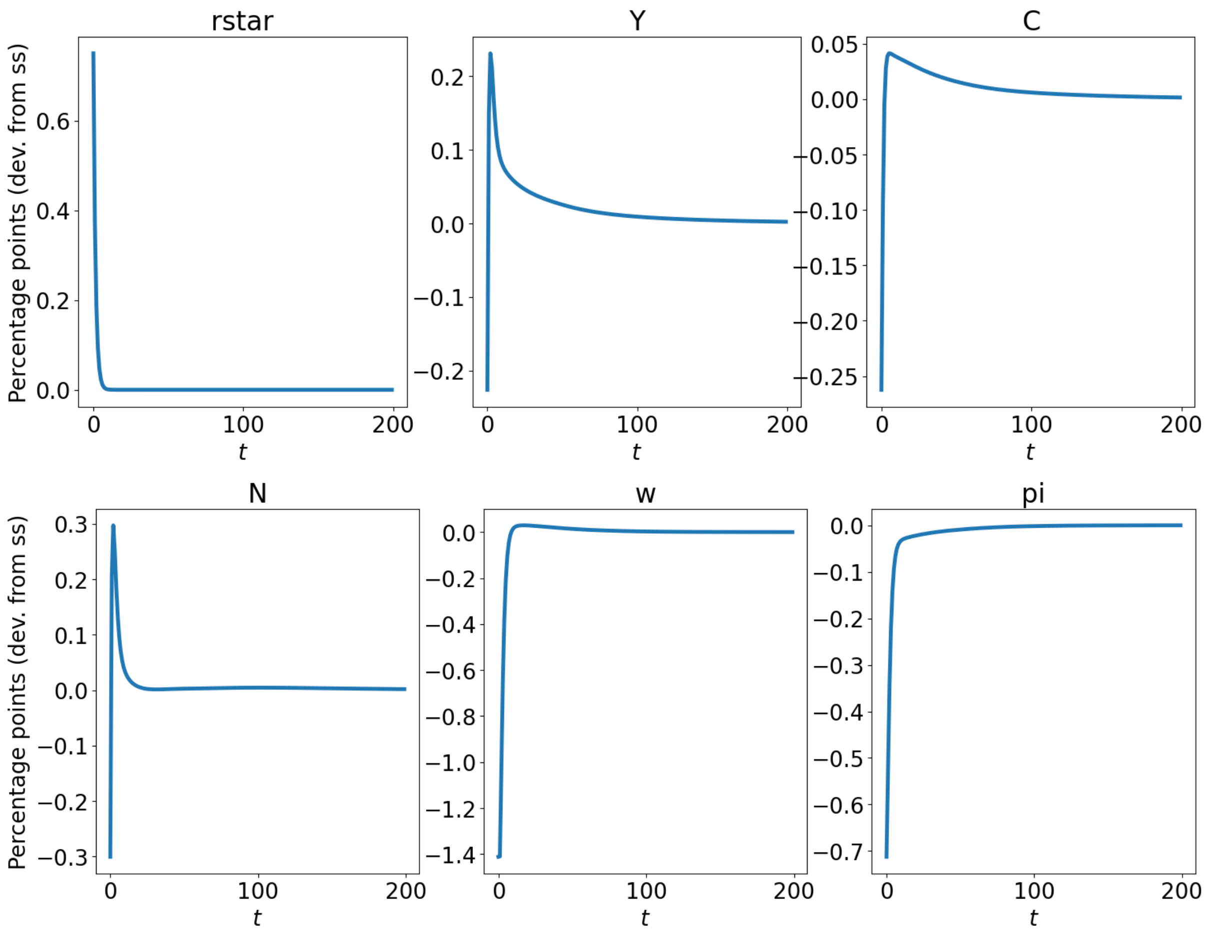


Figure 10: Two-Asset IRFs for Germany, for the baseline Taylor Rule.

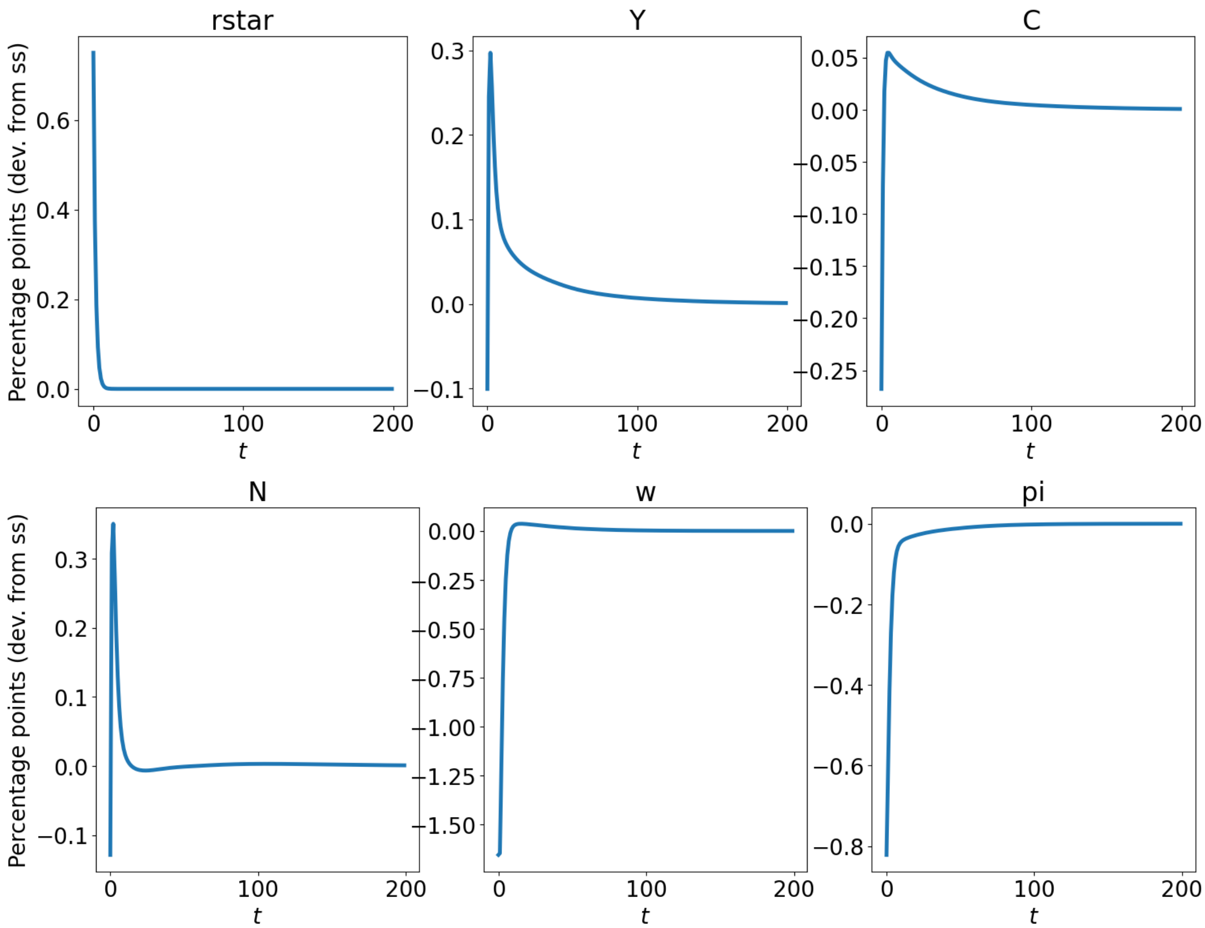


Figure 11: Two-Asset IRFs for France, for the baseline Taylor Rule.

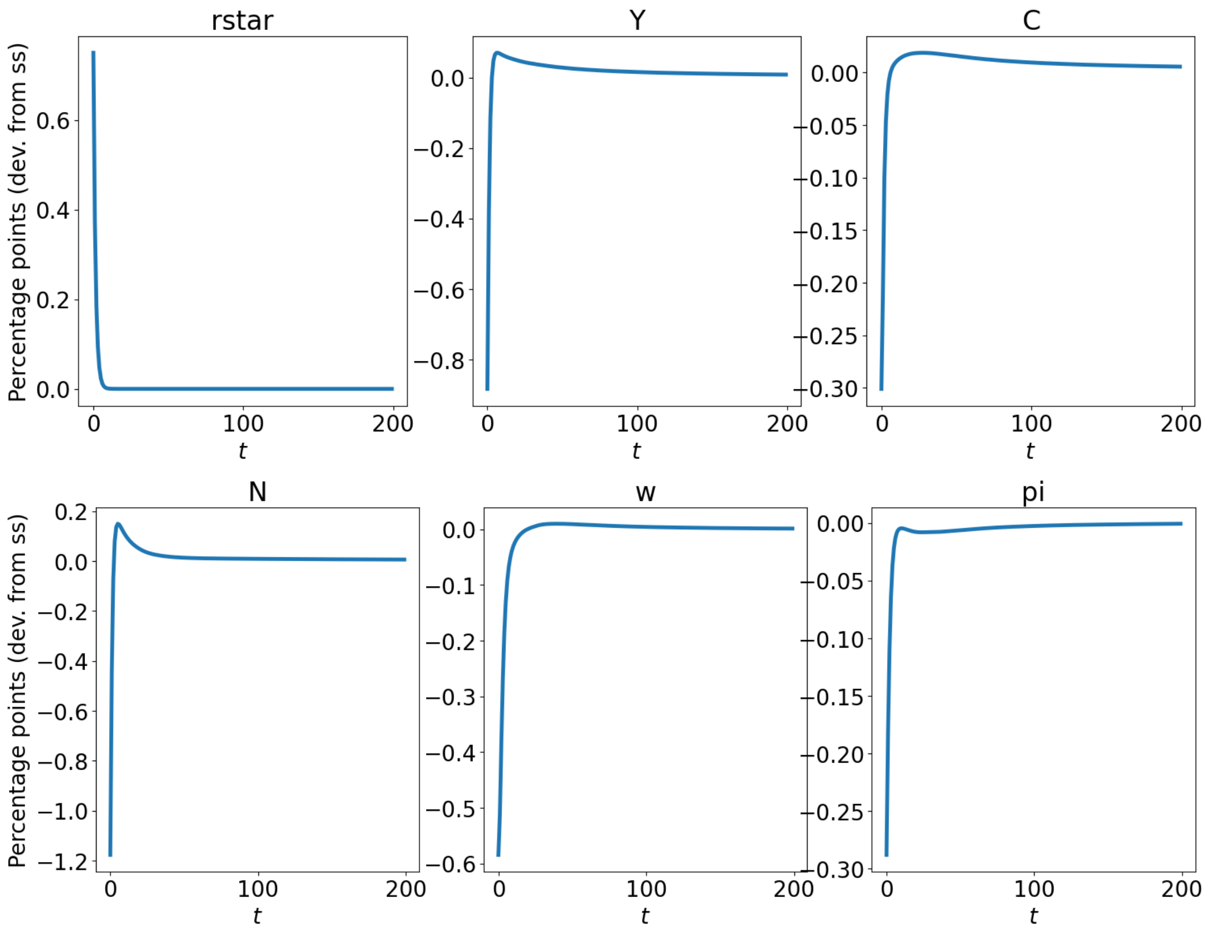


Figure 12: Two-Asset IRFs for Portugal, for the baseline Taylor Rule.

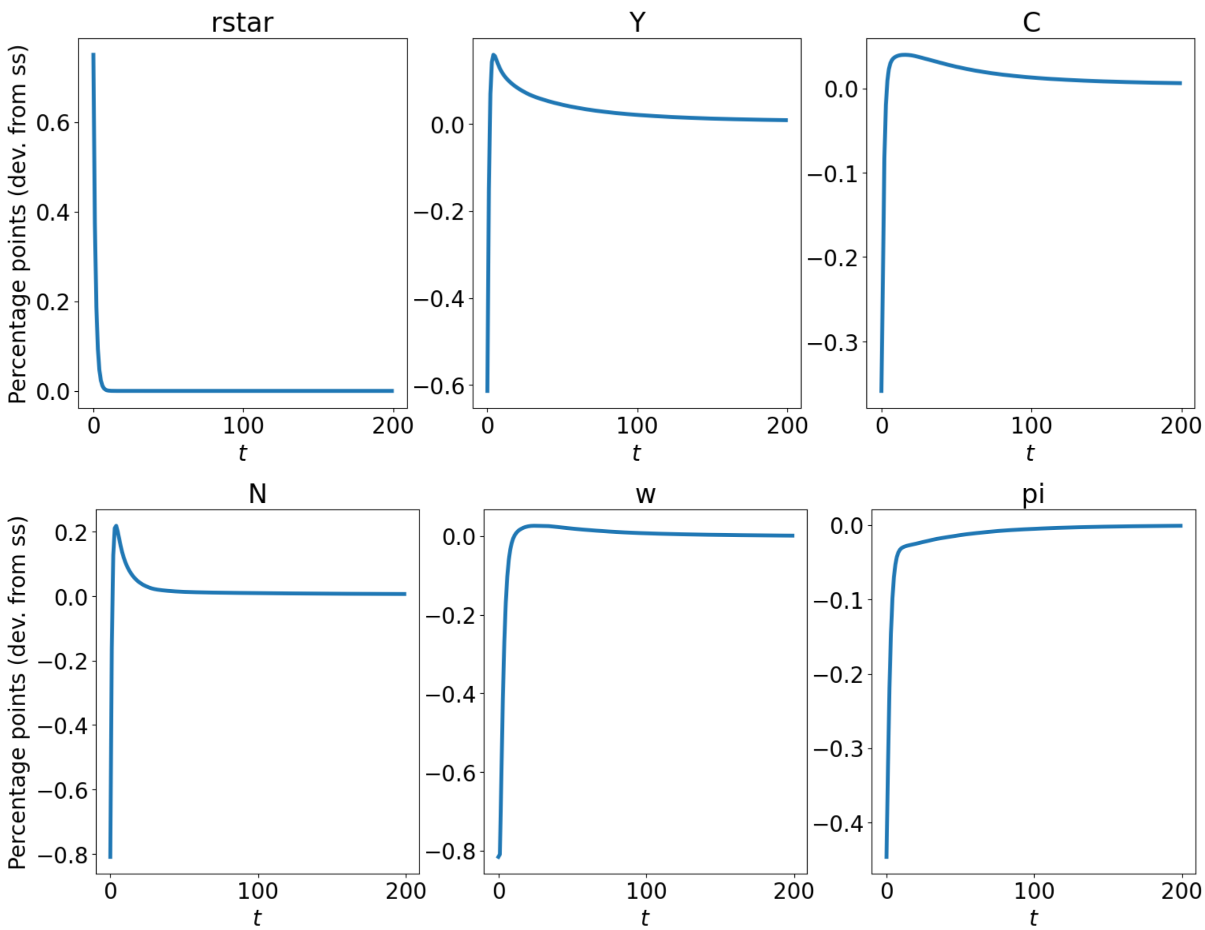
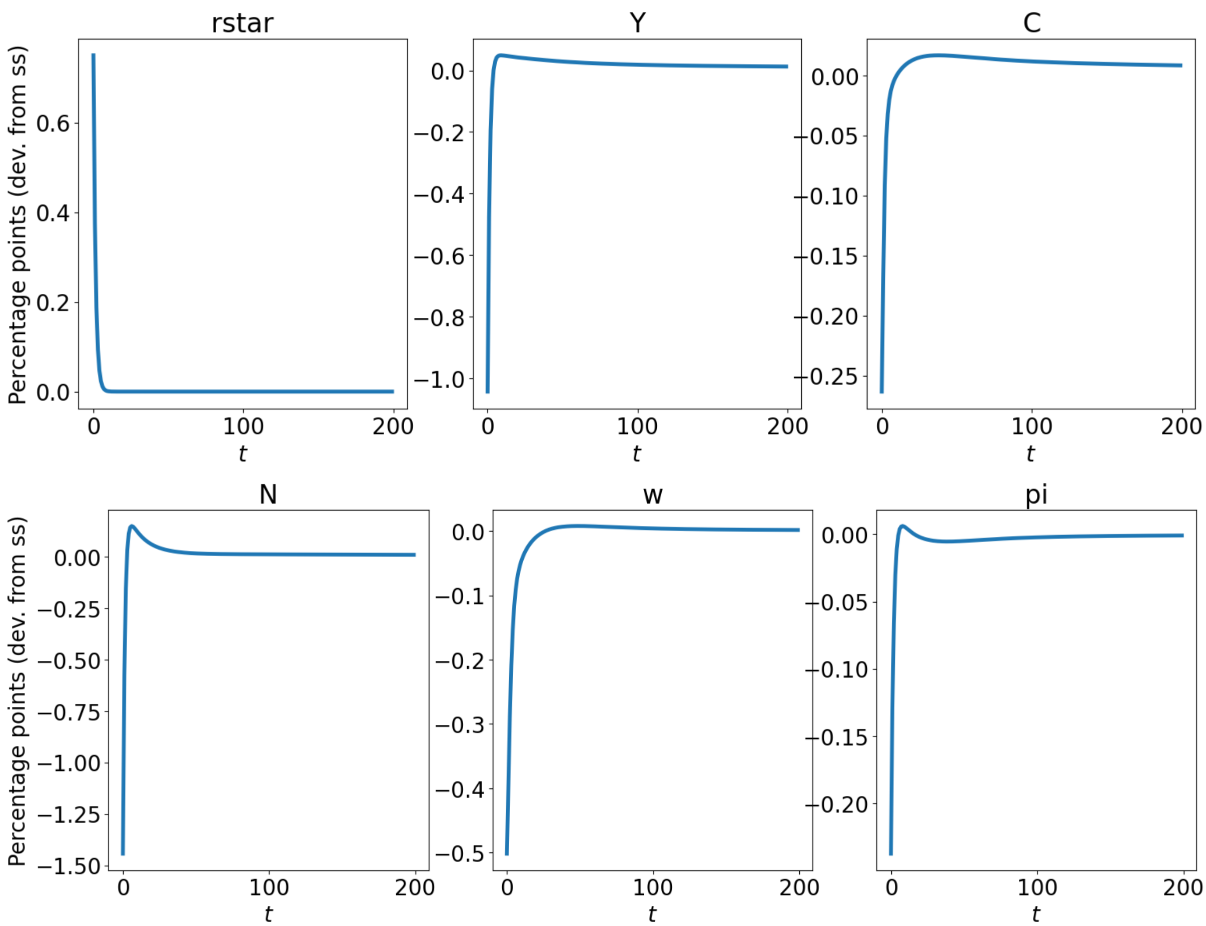


Figure 13: Two-Asset IRFs for Slovakia, for the baseline Taylor Rule.



C Impulse Response Functions for the Taylor Rule Extension Case

This Section presents the impulse response functions of the two specifications of the models, for the extended case where the Taylor Rule responds to prices and output. For each country and each model specification, the IRFs of output, Y_t, consumption, C_t, hours worked, N_t, wages, w_t, prices, p_i, will be plotted. For the One-Asset HANK, Figures 14, 15, 16, 17 and 18 are plotted. For the Two-Asset HANK, Figures 19, 20, 21, 22 and 23 are plotted.

C.1 Impulse Response Functions for the One-Asset HANK

Figure 14: One-Asset IRFs for Austria, for the extended Taylor Rule.

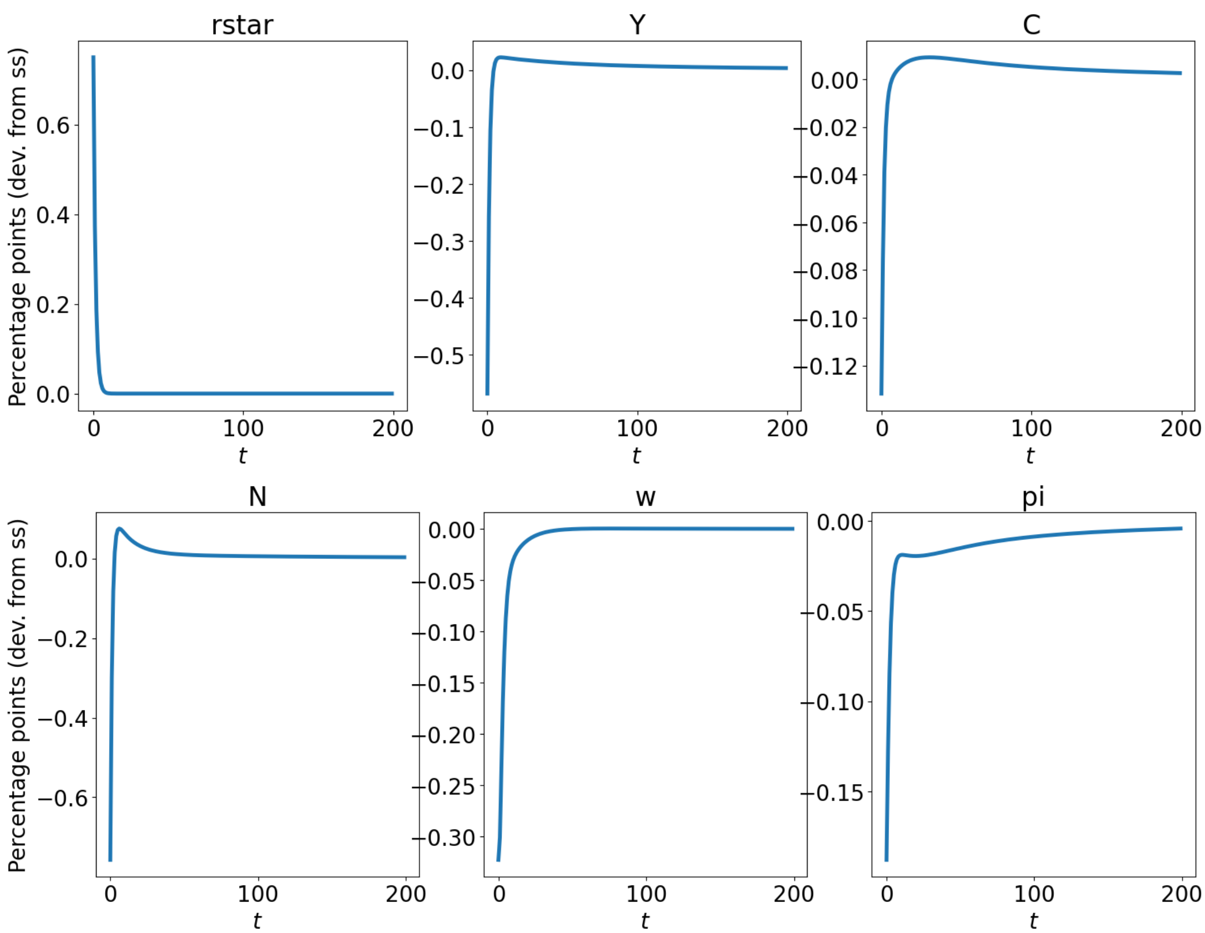


Figure 15: One-Asset IRFs for Germany, for the extended Taylor Rule.

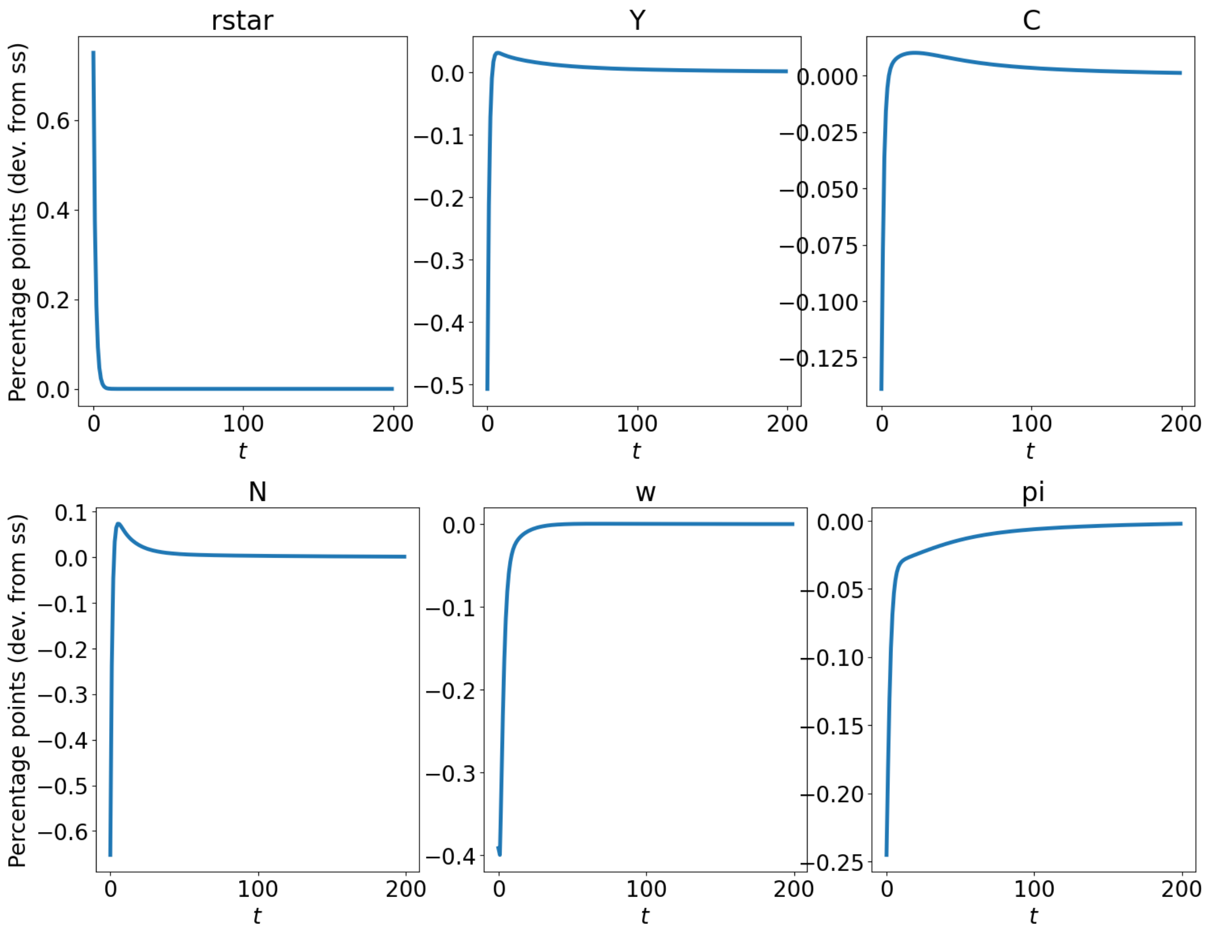


Figure 16: One-Asset IRFs for France, for the extended Taylor Rule.

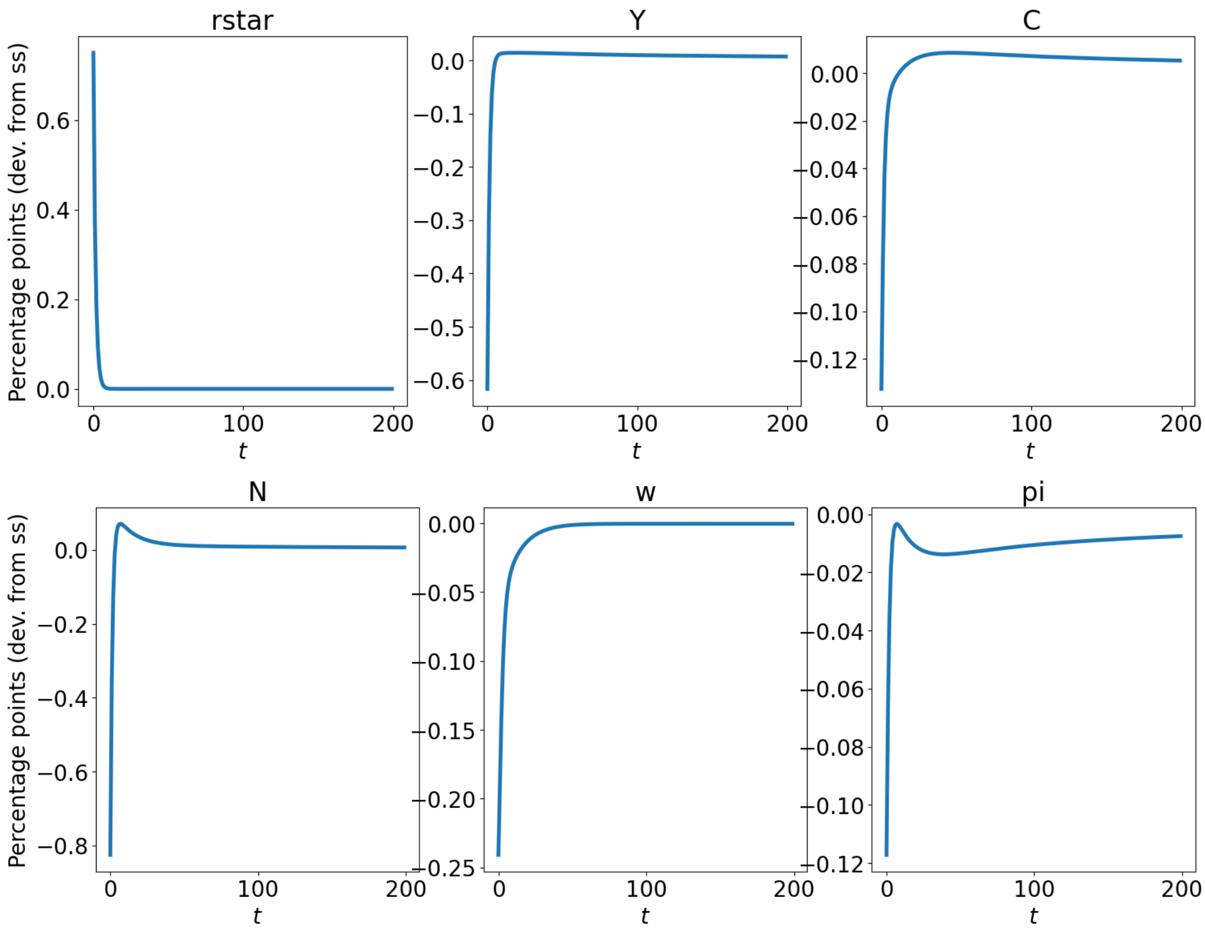


Figure 17: One-Asset IRFs for Portugal, for the extended Taylor Rule.

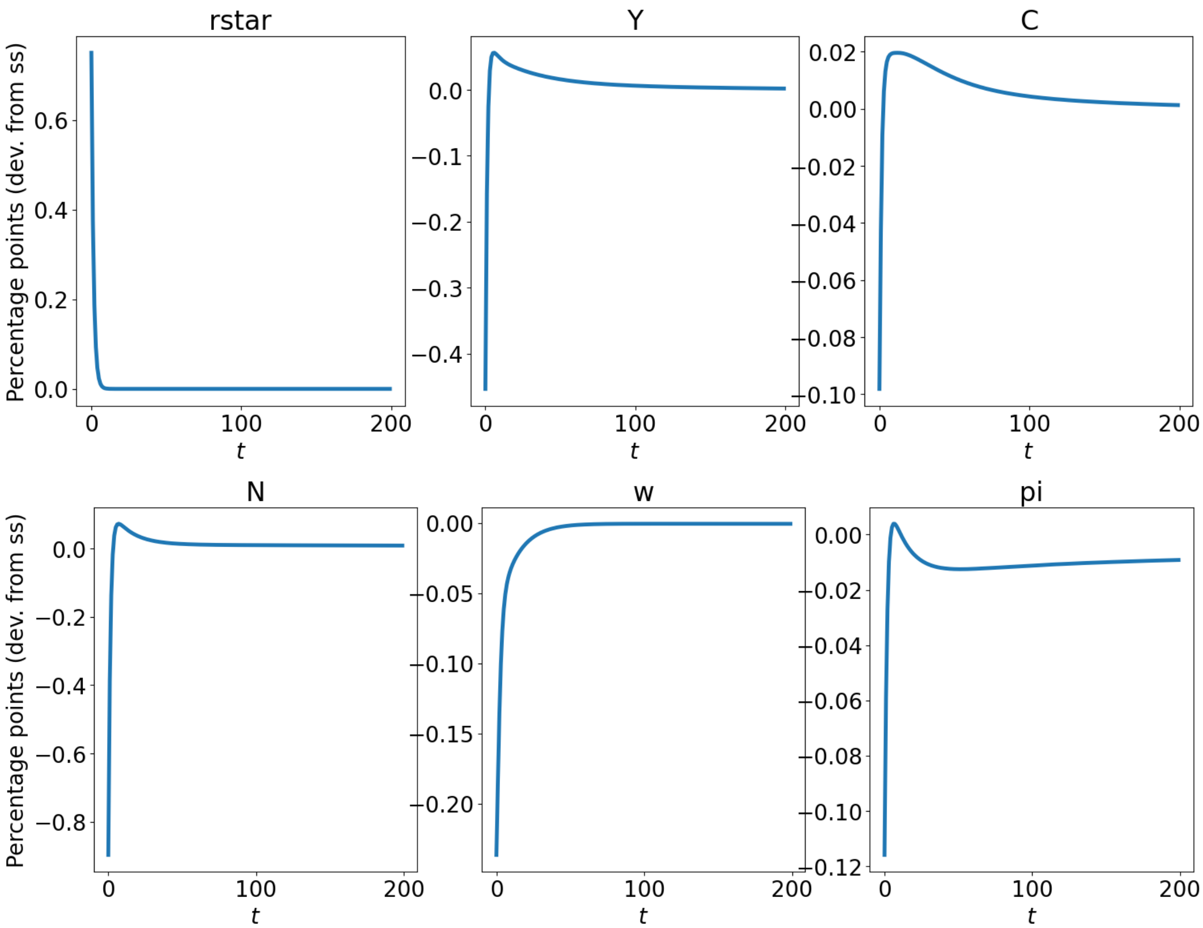
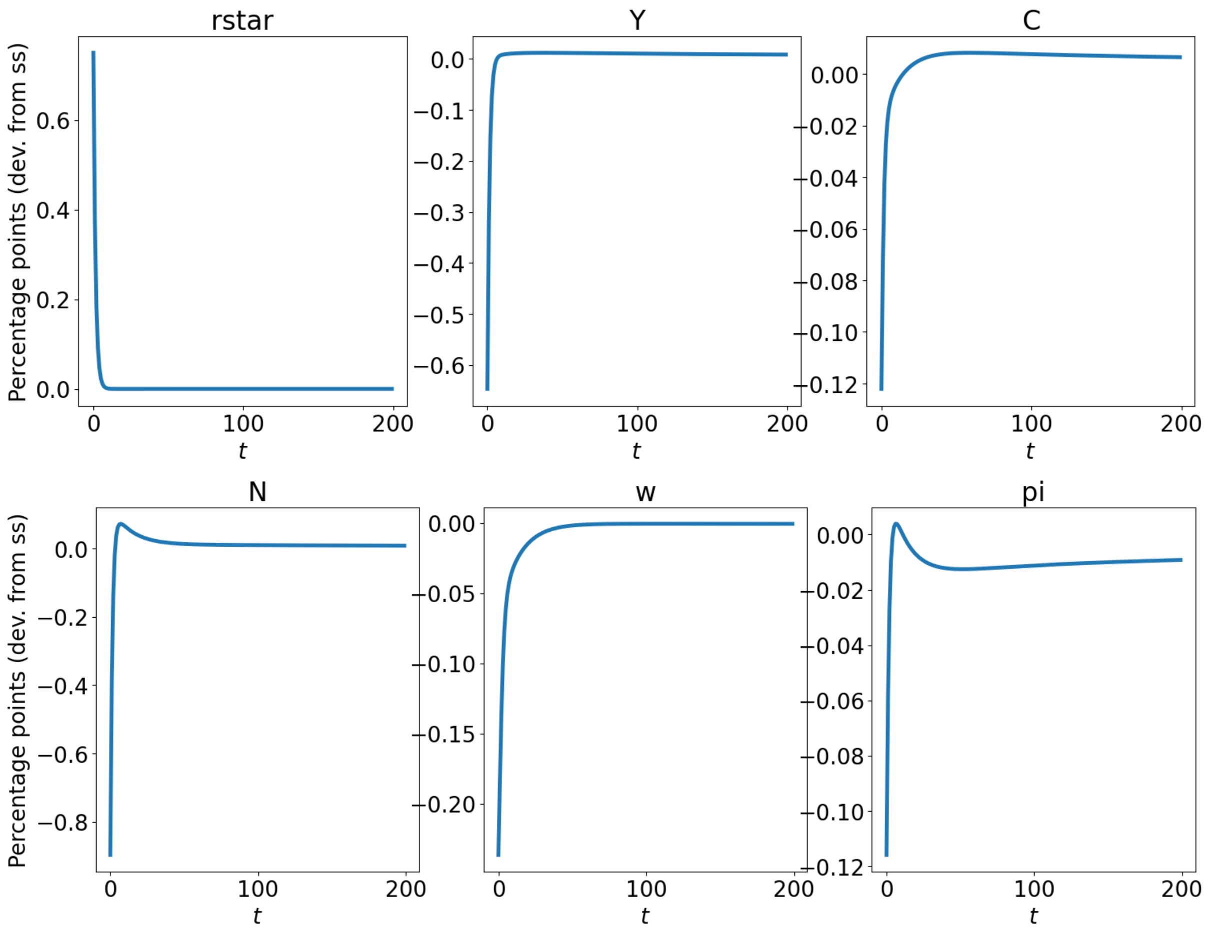


Figure 18: One-Asset IRFs for Slovakia, for the extended Taylor Rule.



C.2 Impulse Response Functions for the Two-Asset HANK

Figure 19: Two-Asset IRFs for Austria, for the extended Taylor Rule.

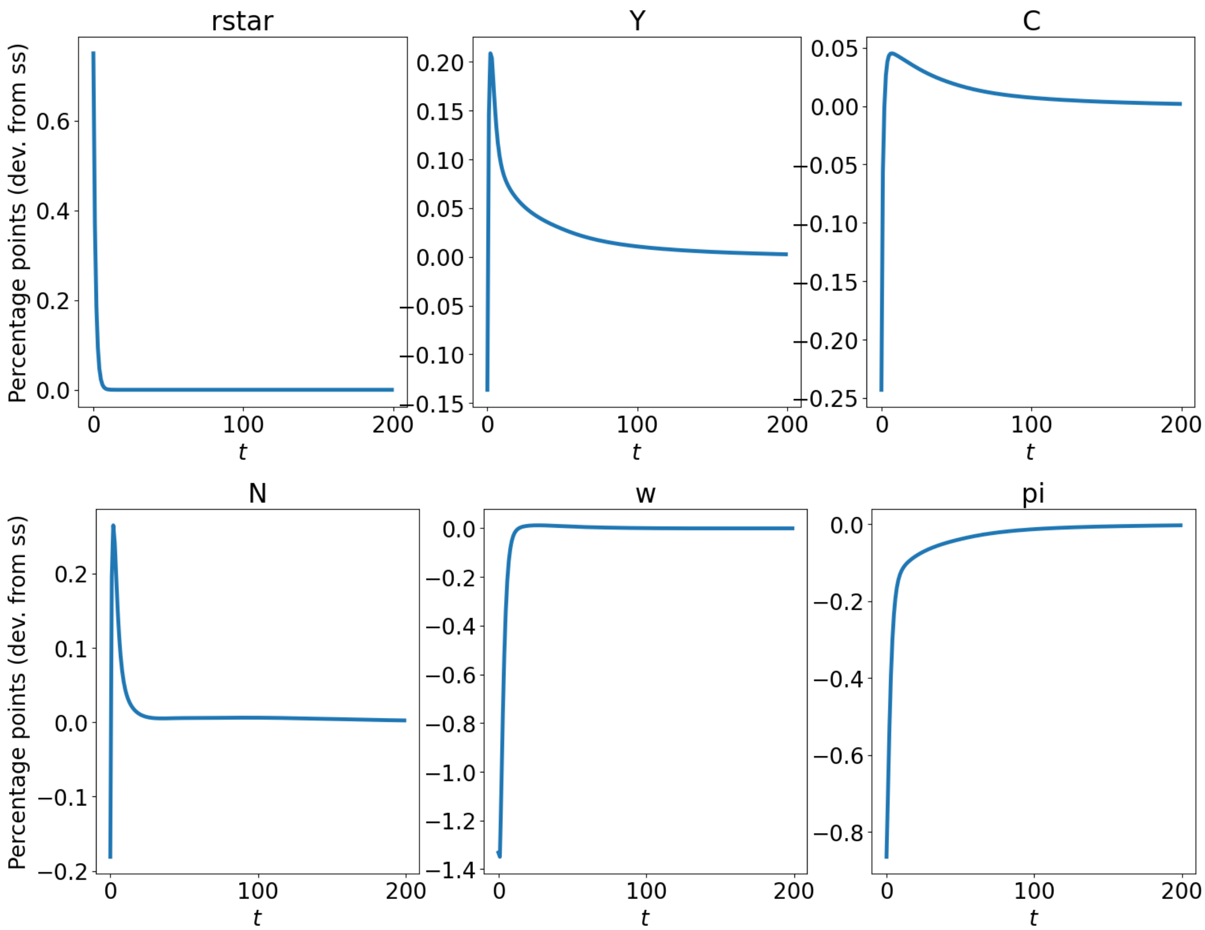


Figure 20: Two-Asset IRFs for Germany, for the extended Taylor Rule.

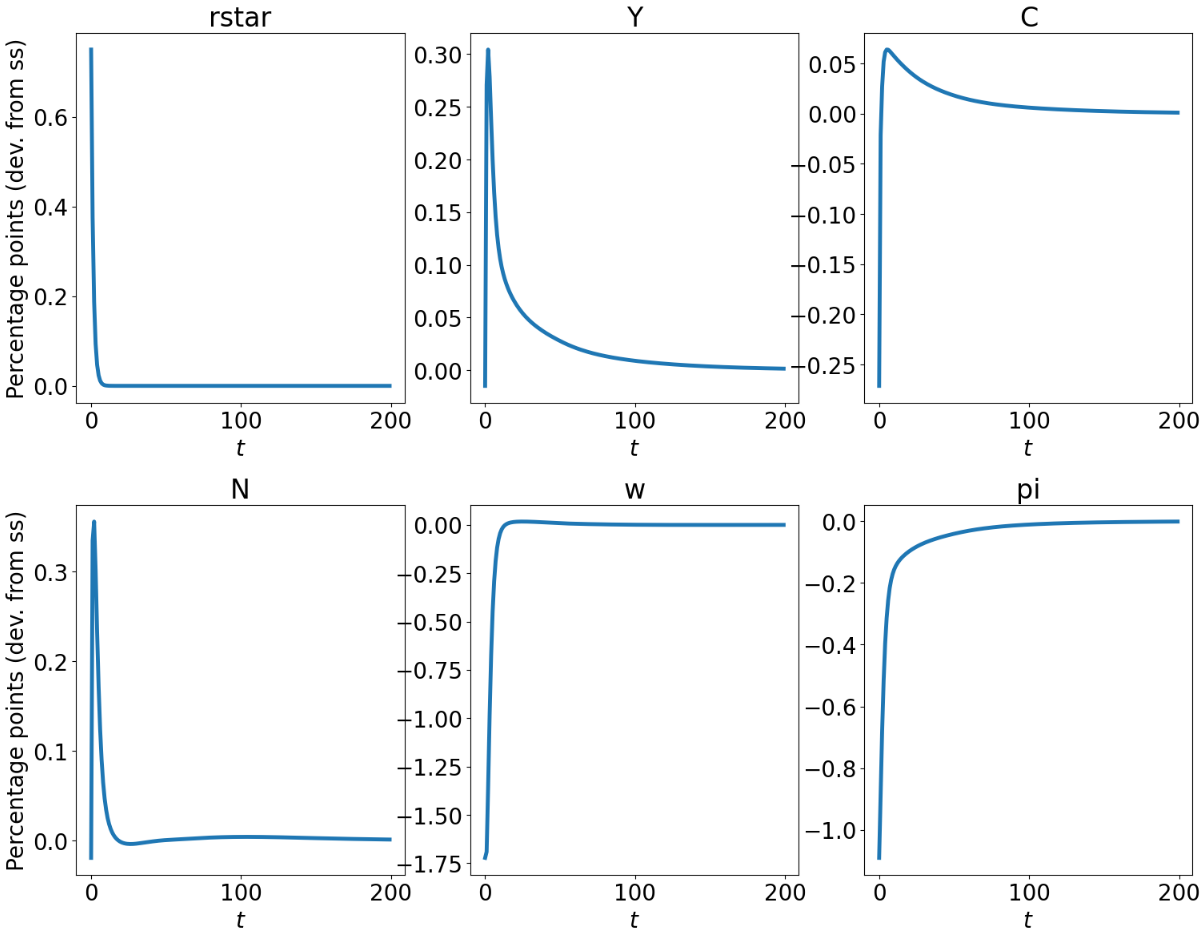


Figure 21: Two-Asset IRFs for France, for the extended Taylor Rule.

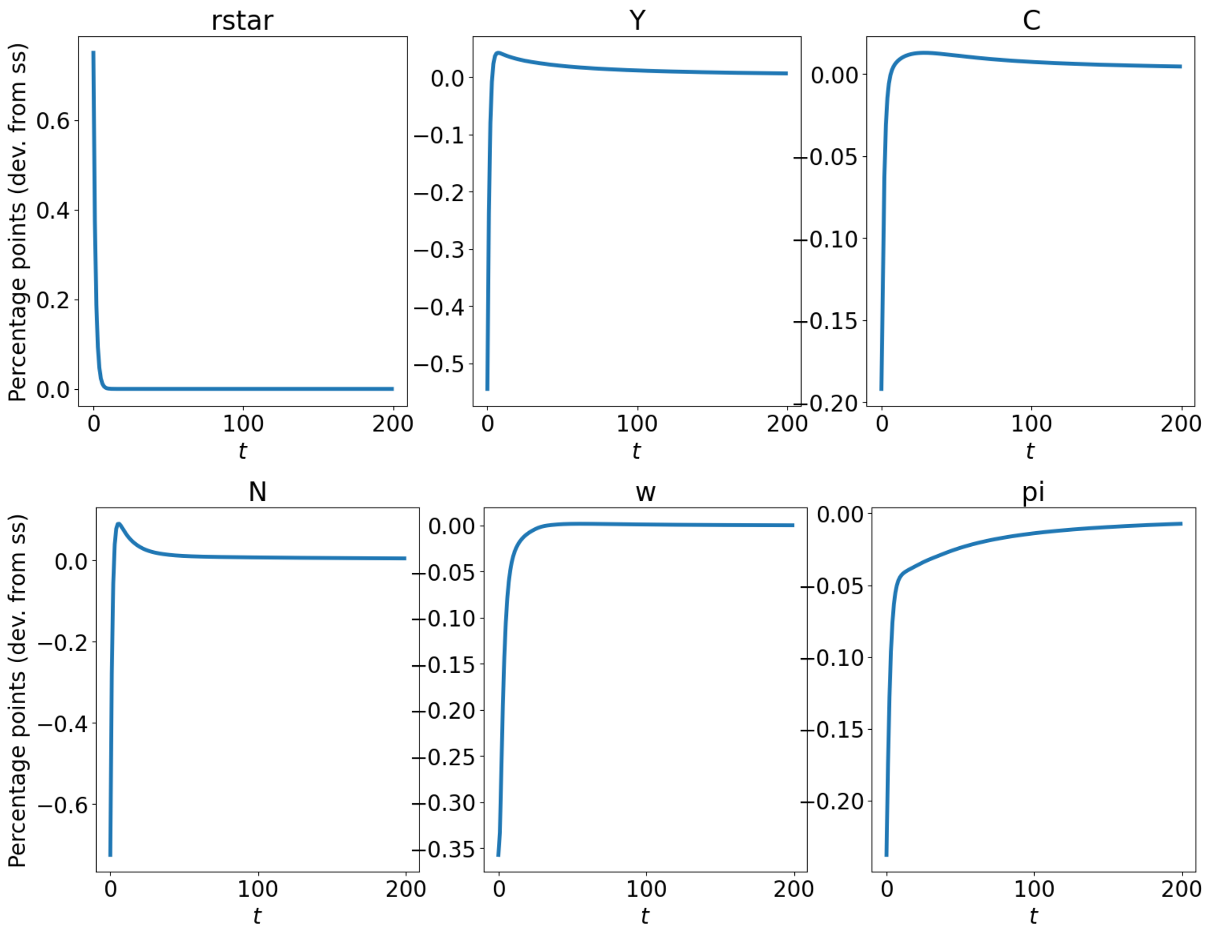


Figure 22: Two-Asset IRFs for Portugal, for the extended Taylor Rule.

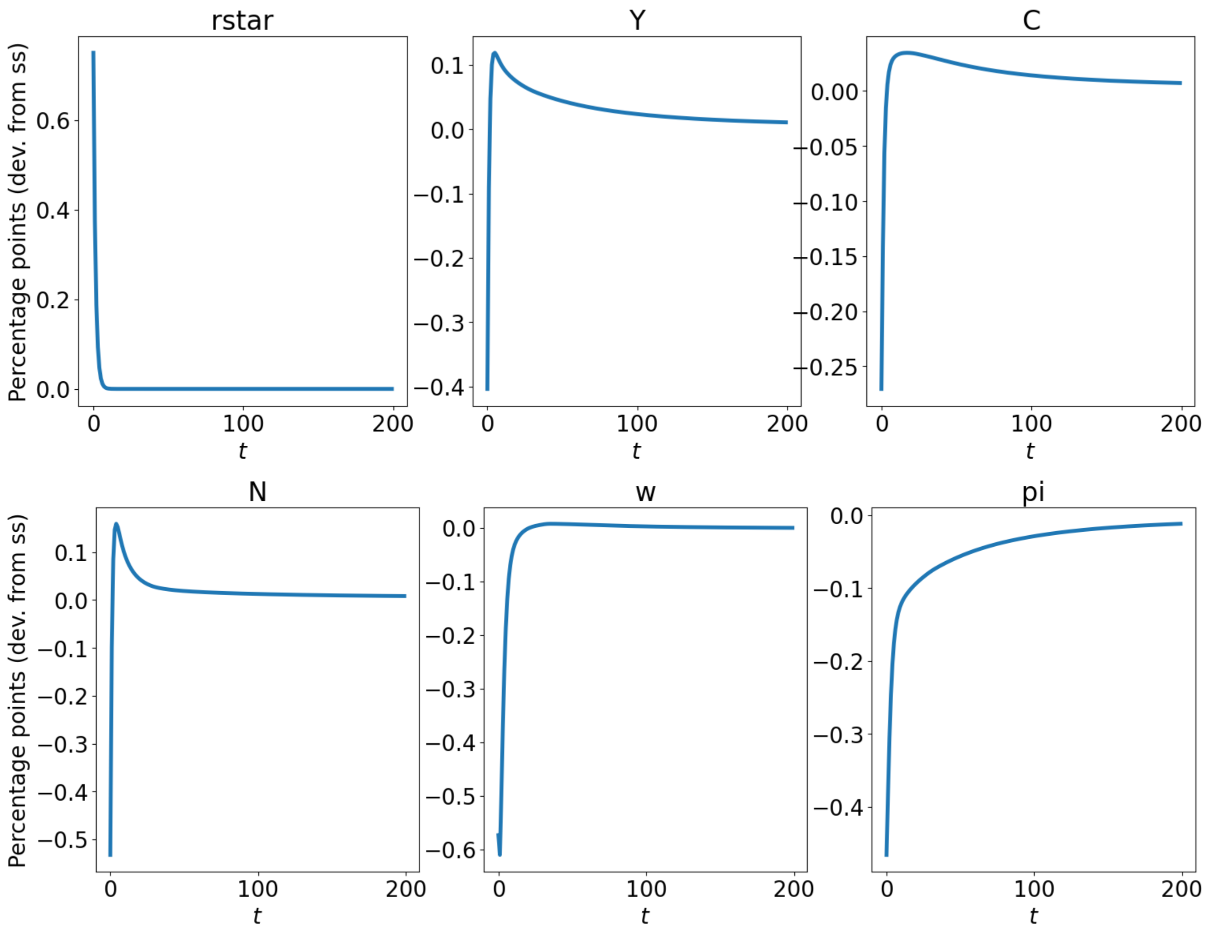


Figure 23: Two-Asset IRFs for Slovakia, for the extended Taylor Rule.