Exchange Rate Policy and Heterogeneity in Small Open Economies*

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Abstract

This paper studies the role of exchange rate regimes in shaping the distributional effects of external monetary shocks. I model a small open economy where agents differ in wealth and in exposure to international trade, producing either tradable or non-tradable goods. The central bank responds to a foreign interest rate hike by a monetary tightening to stabilize the exchange rate or lets the currency depreciate, keeping the interest rate low. I find that exchange rate flexibility distributes consumption gains to the poorer agents. The monetary tightening required to stabilize the currency disproportionately affects their disposable income through interest payments on loans and falling wages. Attempts to fix the exchange rate increase consumption inequality. Flexibility also benefits the non-tradable sector because conditions in this sector are more sensitive to domestic demand and sharply deteriorate when domestic interest rates rise.

Key Words: sudden stops, currency depreciation, worker heterogeneity, redistribution

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1 Introduction

The classical macroeconomic trilemma holds an open capital account, fixed exchange rate, and independent monetary policy as three options that are impossible to pick at the same time. When a country allows free capital flows from abroad, it must either let the exchange rate float or lose control over the interest rates. This trade-off has been studied extensively at the aggregate level, abstracting from heterogeneity in income and wealth. There is rich theoretical literature on the transmission of foreign shocks to domestic variables under different exchange rate arrangements. However, the uneven impact of these shocks in open economies has not been its main focus. This paper offers a study of exchange rate policy from the perspective of inequality.

I compare the dynamics of consumption inequality under different exchange rate regimes in a model economy that faces an external interest rate shock. In particular, I focus on heterogeneity in wealth and exposure to international trade: agents are employed in the production of either tradable or non-tradable goods. Exchange rate policy determines how the shock is transmitted, with potentially very different implications for individual households depending on their wealth and sector of employment. I use a small open economy HANK model that accommodates both types of heterogeneity to compare exchange rate regimes in the distribution of gains and losses they induce and delineate the role of transmission channels in forming this distribution.

More specifically, I concentrate on the interest rate and labor income channels. These are two of the most important channels studied by Kaplan, Moll, and Violante (2018), whose insights I mostly rely on. The exchange rate regime determines whether external shocks propagate mainly through domestic interest rates or currency prices. These variables directly impact consumption and labor supply of the workers through intertemporal substitution and disposable income. Intertemporal substitution is more important in the right tail of the wealth distribution, while current income is dominant in the left tail. Moreover, incomes are affected in different ways across sectors. This creates heterogeneity in individual responses. The heterogeneity then feeds back into aggregates, affecting total consumption and savings since the economy is open and trades goods and assets with the rest of the world. It also affects labor supply through income effects.

To study this heterogeneity, I augment a one-asset version of the HANK model in Kaplan, Moll, and Violante (2018) with international trade and foreign investors in government debt. Rotemberg (1982) adjustment costs prevent jumps in the price level, shutting down the nominal asset revaluation channel commonly present in discrete-time models. Workers do not save or borrow in foreign currency, so the potentially important revaluation channel studied by De Ferra, Mitman, and Romei (2020) is absent as well.[1] As a result, the model is centered around the interest rate and labor income transmission channels, emphasizing their interaction.

[1] Drenik, Pereira, and Perez (2018) show that the rich households in the Latin American and Eastern European data are more likely to hold assets denominated in foreign currency. If they also have a low marginal propensity to consume, the revaluation channel is likely to have a limited contribution to the aggregate dynamics after devaluations.

I calibrate the model to Peru, using estimates for marginal propensity to consume provided by Hong (2023). Production block builds on Devereux and Engel (2007). Retailers sell differentiated non-traded final goods that they assemble from traded and non-traded inputs with a nested structure: foreign and home tradables are more substitutable than tradables and non-tradables. Inputs are made with labor, and all workers are employed either in tradable or non-tradable production. They face idiosyncratic productivity risk. Financial markets are incomplete: workers only hold nominal riskless deposits or take out loans subject to borrowing constraints. Banks aggregate their savings and invest them in the nominal riskless bonds issued by the fiscal authority to pay for government purchases. These bonds are short-term and denominated in the domestic currency.

International investors hold some of these bonds and can adjust their position at any time without cost. A positive shock to the foreign interest rate triggers capital outflows. One way to raise foreign currency returns on government debt and compensate the investors is to raise interest rates, keeping the exchange rate fixed. Another way is to induce an appreciation of the domestic currency. To do this, the monetary authority lets the currency depreciate on impact, which is followed by gradual appreciation.

The latter happens under float. Domestic currency depreciates on impact, which induces an output boom, raises costs, and launches inflation. Wages in tradables rise in response to the exchange rate depreciation that boosts exports and induces substitution from imports to domestic goods. In contrast, wages in non-tradables fall. This is because non-traded goods do not benefit from an export boom, while inflation causes an interest rate hike, with 40% of the shock passing through to the real interest rate in my calibration. This depresses domestic demand, which disproportionately affects non-tradables. The shock, therefore, opens a pro-tradable wage gap.

The total change in consumption inequality is small, but this fact masks two offsetting movements. The gap between the sectors widens, as workers in tradables are initially richer. On the other hand, inequality among workers in tradables falls, because the wage and interest rate channels work in opposite directions. A higher interest rate, which is more important for the rich, depresses consumption. Higher labor income, which is more important for the poor, increases it.

Under peg, consumption inequality increases. The country responds to capital outflows with a sharp monetary tightening, inducing shortfalls in demand and decreasing real wages. The wage and interest rate channels now work in the same direction, both inducing a contraction, but the labor income channel turns out to be quantitatively more important for the left tail than intertemporal substitution is for the right tail. Wealthy workers additionally benefit from a rise in interest income, while borrowers see their budgets negatively affected by rising interest payments.

The two sectors are affected in different ways. Wages in tradables do not fall much, supported by export demand. The non-traded sector does not have this cushion and takes the full weight of the demand shortfall. The resulting pro-tradable wage gap is wider than under float. The reason for aggregate demand falling so much is that the real interest rate under peg overshoots the shock. This is because the nominal interest rate has to match the shock exactly to prevent depreciation, but the real rate increases more since the recession is accompanied by deflation. Total consumption dispersion increases after the shock. The widening gap between sectors contributes around two-thirds of this increase, the rest coming from rising dispersion in non-tradables.

With wages moving in different directions after the shock, inequality dynamics in the two sectors are different under both float and peg. This highlights the importance of the source of labor income in accounting for the heterogeneous effects of external shocks. Cugat (2019) obtains similar results in a model with two types of households working in each sector: those with direct access to international financial markets and those with no access to saving and borrowing at all. Guo, Ottonello, and Perez (2020) incorporate this dimension of heterogeneity as well while focusing on heterogeneity in access to foreign assets.

I next study regimes beyond float and peg to explore the distributional effects of exchange rate policy in more detail. Fully floating and fully fixed exchange rates are the two polar arrangements. In practice, many governments and central banks depart from these corner policies, as documented by Ilzetzki, Reinhart, and Rogoff (2019). I explore policy rules augmented with nominal depreciation that may limit or amplify the pass-through of foreign shocks into the exchange rate, similarly to Cugat (2019). This convexifies the trilemma. Moreover, some rules invert foreign monetary spillovers and may react to a foreign tightening with a domestic easing. This comes at the expense of a larger currency depreciation on impact but potentially supports domestic demand.

In particular, I study Taylor rules with the nominal interest rate determined by a combination of inflation and nominal depreciation. The domestic real interest rate and real depreciation as functions of the shock and inflation are jointly determined from this equation and the modified uncovered interest parity condition. Rules that reduce nominal depreciation relative to pure inflation targeting correspond to "fear of floating" that Calvo and Reinhart (2002) associate with policies partly limiting the exchange rate flexibility. Rules that reduce the real interest on impact at the expense of stronger jump depreciation can be associated with "love of floating".

I find that workers employed in the non-tradable sector are more affected by fear of floating. It might seem counterintuitive since the direct effect of fear of floating is to limit depreciation and hence wage growth in tradables. However, monetary policy in the model operates through aggregate demand. To suppress the real exchange rate, which is one of the prices, it suppresses demand, and wages in non-tradables are more sensitive to this. The reason is that in tradables, expenditure switching and exports act as a stabilization device. When domestic demand falls, the real exchange rate depreciates to shift demand from imports to local traded goods, and exports increase. This supports labor demand in this sector and hence wages. When domestic demand rises, real appreciation diverts part of it abroad, exports fall, and wages grow less.

As a result, when policy moves to less fear of floating, wages jump higher on impact, and the jump in non-tradables starts to catch up with that in tradables. Total consumption dispersion also decreases when policy moves to less fear of floating. Two factors contribute to this. First, the gap between the sectors widens less on impact. Generally, it widens because wages grow more in tradables, but "love of floating" dampens this difference. Second, consumption dispersion within sectors falls more as policy becomes less tight and causes more wage growth.

Finally, I consider the role of elasticity of substitution between different types of goods. Auclert et al. (2021) show that low trade elasticities make exchange rate depreciation contractionary because labor income gains from expenditure switching are not strong enough to compensate the workers for inflation that follows depreciation. I find that wages in non-tradables indeed fall more when elasticities are low. This is because under low elasticities relative prices need to adjust more to cause the same shift in quantities. However, for the same reason, more of the shock is absorbed by movements in the exchange rate, and less of it passes through to the real interest rate. Because of this, aggregate demand actually falls less than under baseline elasticities. Consumption dispersion, however, rises more, since the wage effect, which is more important in the left tail, is more contractionary under low elasticities, while the substitution effect is less contractionary.

1.1 Related Literature

There is a growing literature on the heterogeneous effects of external shocks in small open economies. Recent contributions include De Ferra, Mitman, and Romei (2020), Guo, Ottonello, and Perez (2020), Cugat (2019), Drenik (2015), Anand, Prasad, and Zhang (2015), Iyer (2015), Hong (2020a), Hong (2020b), Zhou (2021) and others. Hong (2020b), in particular, provides estimates of MPC across income deciles in Peruvian population that I use to calibrate my model.

De Ferra, Mitman, and Romei (2020) study the effects of a sudden stop following sustained capital inflows in a small open economy that is levered in foreign currency. They highlight the effect of heterogeneous portfolio composition, pointing out that devaluations are more harmful when poorer households with a high marginal propensity to consume owe more in foreign currency. If the impact changes in wealth are negatively correlated with the marginal propensity to consume, the shock is amplified by larger shortfalls in domestic demand, causing further deterioration of the terms of trade to push undemanded output abroad. This rationalizes fear of floating in the economies with a heavy foreign debt burden on the left tail of the wealth distribution.

Guo, Ottonello, and Perez (2020) explore the distributional consequences of sudden stops in economies with heterogeneity in the sector of employment and in access to international financial markets in addition to wealth heterogeneity. Differential access to international asset markets drives inequality dynamics following a foreign monetary shock in their model because some households directly save in foreign assets, and they are the ones who launch the first round of consumption response. In my model, the households are all in the same domestic financial market, but the uncovered interest parity condition always holds and is crucial to the inequality dynamics.

Cugat (2019) studies, theoretically and empirically, heterogeneous effects of the large devaluation of 1995 in Mexico, when the exchange rate peg was abandoned (with a lag) following a sudden stop. She quantifies the welfare costs of fear of floating and shows the importance of distinct sectors in a model that aims to account for aggregate responses to a large devaluation. Households in her model are also heterogeneously exposed to international trade. My paper is different from Cugat (2019) and Guo, Ottonello, and Perez (2020) in that I focus on quantifying the importance of the wage and the interest rate transmission channels of a simple HANK model centered around the uncovered interest parity condition and analyze the exchange rate policy through their interaction.

Auclert et al. (2021) study the difference between HANK and RANK open economy models in terms of aggregate responses to foreign monetary shock. They show that the substitution elasticity between home and foreign goods and the elasticity of export demand determine whether expenditure switching generates a strong enough production boom that offsets the real incomes being inflated away by depreciation. They derive analytically the equivalence condition between RANK and HANK under a particular interest rate rule in a model with sticky wages. I emphasize the interaction between expenditure switching and domestic interest rate dynamics instead, focusing on the distributional consequences of foreign shocks.

Empirical contributions to the study of inequality in international economics include, among others, Drenik, Pereira, and Perez (2018) and Cravino and Levchenko (2017). More recently, Di Giovanni, Levchenko, and Mejean (2020) study the role of firm heterogeneity in the propagation of foreign shocks. Drenik, Pereira, and Perez (2018) empirically evaluate the effect of devaluations on the distribution of labor income. They find that labor income inequality decreases after devaluations, which is driven by faster wage growth in the left tail. Cravino and Levchenko (2017) find that devaluations adversely affect consumption of the poor through increasing prices of tradable goods because tradables make up a higher share of their consumption basket. I do not incorporate this effect, making the single final good non-tradable and confining international trade to inputs.

My paper is related to a booming HANK literature. The model is a simplified version of Kaplan, Moll, and Violante (2018) augmented with international trade. Alves et al. (2020) is one of the papers that detail the ways in which the non-Ricardian nature of these models affects aggregate dynamics. Acharya and Dogra (2020), Auclert, Rognlie, and Straub (2018), and Ravn and Sterk (2016) provide insights on determinacy in HANK models and how it is related to income sources.

A large literature studies exchange rate arrangements. Clarida, Gali, and Gertler (2001) and Gali and Monacelli (2005) provide the framework for studying optimal policy in New Keynesian models. The international block of my model builds on Devereux and Engel (2007), which explores the trade-off between expenditure switching and price stabilization as competing objectives of monetary policy under different patterns of price stickiness. I contribute to this literature with a positive study of exchange rate arrangements under heterogeneity of workers caused by internal market incompleteness and sector-specific income that cannot be pooled.

Layout. Section 2 presents the model. Section 3 defines equilibrium and describes the calibration. Section 4 compares float and peg, and Section 5 treats alternative policy regimes. Proofs, solution algorithm, and additional figures are in the appendix.

2 Model

Time is continuous and runs forever. There is no aggregate uncertainty. The economy is populated by a measure one of infinitely-lived agents. They have access to nominal deposits and can take out loans subject to a borrowing constraint. There is international trade in goods, and the domestic economy is divided into the tradable and non-tradable sectors. A constant measure ζ of workers are employed in the tradable sector, and the rest, of measure $1-\zeta$, work in the non-tradable sector.

The nominal budget constraint of a worker with nominal assets A_t is

$$\dot{A}_t = i_t A_t + (i_t^\ell - i_t)\min\{A_t, 0\} + (1-\tau)W_t^s z_t l_t - P_t c_t \tag{1}$$

Here i_t is the nominal interest rate paid on deposits, i_t^ℓ is charged on loans. Workers consume a single final good purchased at a price P_t. They supply $z_t l_t$ effective units of labor, where z_t is individual productivity. The nominal wage a worker receives is denoted by W_t^s with $s \in \{T, N\}$ denoting her sector. The labor income tax rate is τ. Workers do not receive any profit income.

Final good is the numeraire. The nominal equation (1) can be rewritten in real terms:

$$\dot{a}_t = r_t a_t + (r_t^\ell - r_t)\min\{a_t, 0\} + (1-\tau) z_t w_t^s l_t - c_t \tag{2}$$

Real interest rates are $r_t = i_t - \pi_t$ and $r_t^\ell = i_t^\ell - \pi_t$, where $\pi_t = \dot{P}_t / P_t$ is inflation.

Workers do not switch sectors. Productivity z_t is stochastic and idiosyncratic. Flow utility is

$$u(c_t, l_t, z_t) = \frac{c_t^{1-\sigma} - 1}{1-\sigma} - z_t \chi(l_t) \tag{3}$$

The individual state variables of a worker are (a, z), real assets, and labor productivity. The problem of a worker from sector s with individual states (a, z) at time t is

$$\max_{\{c_v, l_v, a_v\}_{v\geq t}} \mathbb{E}\left[\int_t^\infty e^{\rho(t-v)} u(c_v, l_v, z_v) dv \Big| a_t = a, z_t = z\right] \tag{4}$$

subject to equation (2) and the borrowing constraint $a_t \geq \bar{a}$ for every t. This generates policy functions $(c_t^s(a,z), l_t^s(a,z))$ and a sequence of distributions $G_t^s(a,z)$ for $s \in \{T, N\}$. The time index summarizes the other variables entering policy functions. The distributions are equilibrium objects characterized by Kolmogorov forward equations which can be found in Appendix A.1.

Production. Firms with linear technology produce intermediate goods. The total quantities of non-traded and domestic traded goods are

$$q_t^N = (1-\zeta) \int z l_t^N(a,z) dG_t^N(a,z) \tag{5}$$

$$q_t^{dom} = \zeta \int z l_t^T(a,z) dG_t^T(a,z) \tag{6}$$

Firms in the two sectors pay nominal wages W_t^T and W_t^N per efficiency unit of labor. Producers of non-tradables sell their output to domestic retailers at a price P_t^N. Traded good producers sell their output to both domestic and foreign retailers:

$$q_t^{dom} = q_t^H + q_t^E \tag{7}$$

Here q_t^H is the quantity sold at home, and q_t^E is exported. The price at home is P_t^H, the export price is P_t^E. The demand for exports $\tilde{q}_t^E$ is

$$\tilde{q}_t^E = \tilde{q} \left(\frac{P_t^E}{\mathcal{E}_t} \right)^{-\theta_e} \tag{8}$$

Here $\mathcal{E}_t$ is the nominal exchange rate showing the domestic currency price of one unit of foreign currency, and θ_e is the constant demand elasticity.

There is no trade cost and traded good producers do not care where they sell their output. This implies that, in equilibrium, if output is sold both at home and abroad the prices must be the same: $P_t^H = P_t^E$. This will be the case because foreign demand is isoelastic, and domestic demand will come from a nested CES system, as specified below. There is perfect competition in both sectors so in equilibrium $P_t^N = W_t^N$ and $P_t^H = P_t^E = W_t^T$. There is no price rigidity at this intermediate level. Intermediate prices being more flexible than those of the final good is consistent with the evidence in Bils and Klenow (2004) and Nakamura and Steinsson (2008). Under perfect competition, this makes pricing currency choice irrelevant.

Retailers. There is a unit continuum of domestic retailers indexed by j. They produce final goods from bundles of traded and non-traded goods, sourcing non-tradables from domestic firms and tradables from both domestic and foreign firms. The output q_{jt} of a retailer j is given by

$$(q_{jt})^{1-\frac{1}{\theta}} = \eta^{\frac{1}{\theta}} (q_{jt}^T)^{1-\frac{1}{\theta}} + (1-\eta)^{\frac{1}{\theta}} (q_{jt}^N)^{1-\frac{1}{\theta}} \tag{9}$$

Here q_{jt}^N is the quantity of non-traded goods and q_{jt}^T is the bundle of traded goods that combines q_{jt}^H sourced at home and q_{jt}^F imported:

$$\left(q_{jt}^T\right)^{1-\frac{1}{\theta_g}} = \alpha^{\frac{1}{\theta_g}} \left(q_{jt}^H\right)^{1-\frac{1}{\theta_g}} + (1-\alpha)^{\frac{1}{\theta_g}} \left(q_{jt}^F\right)^{1-\frac{1}{\theta_g}} \tag{10}$$

The parameter η determines the relative importance of traded and non-traded goods for the final bundle, and α indexes the home bias in traded goods aggregation.

Throughout, I hold the foreign price of imports constant at $\tilde{p}^F$, so the domestic currency nominal price of imports is $P_t^F = \mathcal{E}_t \tilde{p}^F$. Lowercase letters denote the real counterparts of prices: $P_t^N = P_t p_t^N$, $P_t^H = P_t p_t^H$, $P_t^E = P_t p_t^E$, and $\mathcal{E}_t = P_t e_t$. The latter implies $p_t^F = e_t \tilde{p}^F$.

At any point in time, given an opportunity to sell quantity q, the retailers solve a cost minimization problem to use inputs optimally:

$$\min_{q_{jt}^N, q_{jt}^H, q_{jt}^F} p_t^N q_{jt}^N + p_t^H q_{jt}^H + e_t \tilde{p}^F q_{jt}^F \tag{11}$$
$$\text{s.t. } q_{jt} \geq q, \text{ equation (9), and equation (10)}$$

The marginal cost of retailers is given by

$$(m_t)^{1-\theta} = \eta (p_t^T)^{1-\theta} + (1-\eta)(p_t^N)^{1-\theta} \tag{12}$$

The price index for traded goods p_t^T here is given by

$$(p_t^T)^{1-\theta_g} = \alpha (p_t^H)^{1-\theta_g} + (1-\alpha)(e_t \tilde{p}^F)^{1-\theta_g} \tag{13}$$

Besides the workers, retailers sell their final good to the government. Both workers and the government aggregate varieties j with constant substitution elasticity θ_r:

$$(c_t)^{1-\frac{1}{\theta_r}} = \int_0^1 (c_{jt})^{1-\frac{1}{\theta_r}} dj \tag{14}$$
$$(g_t)^{1-\frac{1}{\theta_r}} = \int_0^1 (g_{jt})^{1-\frac{1}{\theta_r}} dj \tag{15}$$

The demand for each retailer j's output is the sum of individual demands:

$$q_{jt} = \left(\frac{P_t}{P_{jt}}\right)^{\theta_r} \left[\zeta \int c_t^T(a,z) dG_t^T(a,z) + (1-\zeta) \int c_t^N(a,z) dG_t^N(a,z) + g_t\right] \tag{16}$$

From now on I will only deal with the symmetric case $q_{jt} = q_t$ and $P_{jt} = P_t$ for all j.

Retailers are the source of price stickiness. They face quadratic costs of price adjustment as in Rotemberg (1982). I detail their objective in Appendix A.1. The Phillips curve is

$$\rho \pi_t = \kappa (m_t - 1) \tag{17}$$

I normalize the steady-state real marginal cost to 1 using a markup-correcting subsidy. Inflation is positive when real marginal costs are high, which pushes retailers to adjust prices upward.

Banks. The banks have no capital. Their assets are loans to workers and government bond holdings A_t^b (these bonds pay the same interest rate i_t). The liabilities are workers' deposits:

$$A_t^b - \zeta \int \min\{P_t a, 0\} dG_t^T(a,z) - (1-\zeta) \int \min\{P_t a, 0\} dG_T^N(a,z)$$
$$= \zeta \int \max\{P_t a, 0\} dG_t^T(a,z) + (1-\zeta) \int \max\{P_t a, 0\} dG_t^N(a,z) \tag{18}$$

Banks do not make any decisions. Their nominal profit flow only consists of an interest rate differential between their liabilities and the loans they extend to consumers:

$$\Pi_t^b = (i_t - i_t^\ell)\left(\zeta \int \min\{P_t a, 0\} dG_t^T(a,z) + (1-\zeta)\int \min\{P_t a, 0\} dG_t^N(a,z)\right) \tag{19}$$

This profit is rebated to the government.

Government. The government purchases g_t and pays subsidies to the retailers. To finance this, it issues riskless bonds and uses taxes from workers and profits of the retailers and the banks. Denote the government's asset position by B_t. Its nominal budget constraint is

$$\dot{B}_t = i_t B_t - P_t g_t + \tau\left(\zeta W_t^T \int z dG_t^T(a,z) + (1-\zeta) W_t^N \int z dG_t^N(a,z)\right) + \Pi_t^b + (P_t - M_t) q_t \tag{20}$$

The last term is net profits from firms (netting the subsidy). Rewriting in real terms,

$$\begin{aligned}\dot{b}_t &= r_t b_t - g_t + \tau\left(\zeta w_t^T \int z dG_t^T(a,z) + (1-\zeta) w_t^N \int z dG_t^N(a,z)\right)\\ &\quad + (r_t - r_t^\ell)\left(\zeta \int \min\{a,0\} dG_t^T(a,z) + (1-\zeta)\int \min\{a,0\} dG_t^N(a,z)\right) + (1-m_t) q_t\end{aligned} \tag{21}$$

Integrating the budget constraint equation (2) over (a,z), adding it to equation (21), using equation (18), and decomposing the cost of inputs $m_t q_t$,

$$\begin{aligned}&\dot{b}_t - r_t b_t + \zeta \int (\dot{a}_t(a,z) - r_t a) dG_t^T(a,z) + (1-\zeta)\int (\dot{a}_t(a,z) - r_t a) dG_t^N(a,z)\\ &\qquad = \zeta \int (z w_t^T l_t^T(a,z) - c_t^T(a,z)) dG_t^T(a,z) + (1-\zeta)\int (z w_t^N l_t^N(a,z) - c_t^N(a,z)) dG_t^N(a,z)\\ &\qquad - g_t + q_t - p_t^N q_t^N - p_t^H q_t^H - p_t^F q_t^F\end{aligned} \tag{22}$$

A part of the government debt denoted by b_t^* is held by foreign investors. The bond market clearing condition is $b_t^* + a_t^b + b_t = 0$. The final good market clearing condition is

$$q_t = g_t + \zeta \int c_t^T(a,z) dG_t^T(a,z) + (1-\zeta)\int c_t^N(a,z) dG_t^N(a,z) \tag{23}$$

This is a rewriting of equation (16) under symmetry across retailers, $P_{jt} = P_t$ for all j. Perfect competition on the intermediate level leads to $w_t^T = w_t^H = p_t^E$ and $w_t^N = p_t^N$. Using this,

$$\dot{b}_t^* = r_t b_t^* - \underbrace{(p_t^E q_t^E - p_t^F q_t^F)}_{\text{net export}} \tag{24}$$

Equation (24) is the balance of payments identity for the economy. The net foreign asset position of the country is equal to $-b_t^*$, the negative of the foreign investors' holding. The government sets $\{b_t, g_t\}_t$,and the tax τ complying with equation (21) and transversality:

$$\lim_{t\to\infty} e^{-\int_0^t r_s ds} b_t = 0 \tag{25}$$

The asset market clearing condition $a_t^b + b_t^* + b_t = 0$ ensures the same transversality condition for the foreign position of the country since the wealth of agents in HANK models is stationary. For this reason, a stationarity-inducing device discussed in Schmitt-Grohé and Uribe (2003) and Lubik (2007) is not required. I describe fiscal policy in Section 3.

Foreign investors. I assume that the demand for government bonds by foreign investors is infinitely elastic at the nominal interest rate $\hat{\imath}_t$ that satisfies

$$\hat{\imath}_t - \frac{\dot{\mathcal{E}}_t}{\mathcal{E}_t} = r^f + \psi_t \tag{26}$$

Here on the left-hand side is the nominal foreign currency return on the government debt. It is equal to the interest payments less depreciation because debt is denominated in the small economy's currency. On the right-hand side is the opportunity cost: r^f is the foreign real interest rate, and ψ_t is a reduced-form shock that hits it. This shock potentially causes a stop in capital flows, as investors want to stop holding the country's debt unless i_t keeps up with $\hat{\imath}_t$ from equation (26).

If the foreign position in the government debt is positive, $i_t = \hat{\imath}_t$ and equation (26) is the uncovered interest parity condition for this economy. With $i_t = r_t + \pi_t$ and $\dot{\mathcal{E}}_t/\mathcal{E}_t = \mu_t + \pi_t$, inflation π_t cancels out, and equation (26) becomes

$$r_t = r^f + \mu_t + \psi_t \tag{27}$$

Here $\mu_t = \dot{e}_t/e_t$ is the real depreciation of the domestic currency against the foreign currency. The shock ψ_t is the driving force of aggregate dynamics: I will study an unanticipated jump in ψ_t followed by a perfect foresight path back to normal.

Monetary policy. The central bank in this economy manages the nominal interest rates and the exchange rate. I assume that the gap $i_t^\ell - i_t$ is simply held constant at Δ. If the exchange rate is not fixed, the nominal interest rate follows a Taylor rule augmented with nominal depreciation:

$$i_t = r^f + \phi_\pi \pi_t + \phi_\varepsilon \frac{\dot{\mathcal{E}}_t}{\mathcal{E}_t} \tag{28}$$

This specification is a continuous time variant of that in Cugat (2019). In real terms,

$$r_t = r^f + (\phi_\pi + \phi_\varepsilon - 1)\pi_t + \phi_\varepsilon \mu_t \tag{29}$$

The part with inflation is standard. The coefficient ϕ_ε captures the central bank's response to variations in the strength of the currency and reflects possible "fear of floating", as termed by

Calvo and Reinhart (2002).

Section 5 shows that the sign of this coefficient may have implications different from those in discrete time. The case of $\phi_\varepsilon = 0$ corresponds to a fully flexible exchange rate. Importantly, rules like equation (28) cannot deal with exchange rate jumps. The fixed exchange rate regime must prevent jumps in $\mathcal{E}_t$ as well as keep $\dot{\mathcal{E}}_t = 0$ at all points where the sample path of $\mathcal{E}_t$ is smooth. The central bank, in this case, has no direct control over the interest rates because of free capital mobility. Instead, monetary policy in nominal terms is

$$\mathcal{E}_t = \text{const} \tag{30}$$

The constant itself is not determined in this economy. In real terms, equation (30) is given by

$$\mu_t + \pi_t = 0,\ e_t \text{ is continuous in } t \tag{31}$$

In the presence of price stickiness, the price level does not jump. If $\mathcal{E}_t$ is constant, this means that the real exchange rate e_t does not jump either.

Discussion. Two assumptions about the consumer's problem are worth noting. The first is that the workers do not receive any profits. With sticky retail prices and flexible intermediate goods prices, retail profits are countercyclical. In addition, in HANK models the distribution of profit income across agents strongly affects the aggregate consumption response, as discussed extensively by Alves et al. (2020), Bilbiie (2020), Broer et al. (2020), and Werning (2015). To isolate the effect of wages and interest rates, I tune the retail subsidy to eliminate profits in the steady state and rebate profits outside the steady state to the government.

The second assumption is that the workers only save in domestic assets. This assumption is not crucial. If workers had access to a riskless foreign bond and could rebalance their portfolio without frictions, the UIP condition in equation (27) would make their equilibrium portfolio indeterminate. No stationarity-inducing device of Schmitt-Grohé and Uribe (2003) would be required because the government manages its debt and fiscal instruments. The only difference in transition dynamics would be the asset revaluation on impact after a jump in the nominal exchange rate.

3 Equilibrium and Calibration

In this section I define the equilibrium and describe the calibration. The shock ψ_t is the exogenous driver of transition dynamics. Its path is given by

$$\psi_t = \begin{cases} 0, & t < 0 \\ \psi_0 e^{-\delta t}, & t \geq 0 \end{cases} \tag{32}$$

At all times $t < 0$, the economy is in the steady state and agents expect $\psi_t = 0$ for each t. The jump at $t = 0$ is unanticipated. After it happens, the agents perfectly foresee the path of all aggregates, and there are no further jumps. For this reason, I look for equilibrium with right-continuous sample paths of all variables. The parameter ψ_0 can be either positive or negative. In the former case, it means a real tightening abroad

The shocks I consider will be small enough so that the foreigners never decrease their holdings of debt to zero. This means that the uncovered interest parity condition in equation (27) always holds, and it is through this equation that ψ_t affects the equilibrium.

Equilibrium. I construct the equilibrium in real terms, with inflation as the only nominal variable.

Definition 1. Given $\{\psi_t\}_t$, the monetary policy regime, and the tax rates τ, an equilibrium is a sequence of inflation $\{\pi_t\}_t$, sequences of prices $\{r_t, r_t^\ell, e_t, p_t^N, p_t^H, p_t^T, p_t^E, w_t^E, w_t^T, m_t\}_t$, quantities $\{q_t, q_t^N, q_t^T, q_t^{dom}, q_t^H, q_t^F, q_t^E\}_t$, government debt and purchases $\{b_t, g_t\}_t$, foreign bond holdings $\{b_t^*\}_t$, policy functions $\{c_t^s(a,z), l_t^s(a,z)\}_t^s$, and distributions $\{G_t^s(a,z)\}_t^s$, such that

- $\{r_t, \pi_t, e_t\}_t$ satisfy the Taylor rule in equation (29) or the peg condition in equation (31)
- the loan-deposit spread is consistent with $r_t^\ell = r_t + \Delta$
- $\{\pi_t, m_t\}_t$ are consistent with the Phillips curve in equation (17)
- $\{p_t^E, e_t, q_t^E\}_t$ satisfy the real version of export demand in equation (8)
- $w_t^N = p_t^N$ and $w_t^T = p_t^H = p_t^E$ because of perfect competition on the intermediate level
- $\{q_t^N, q_t^{dom}, q_t^H, q_t^E, \{l_t^s(a,z)\}^s\}_t$ are consistent with equation (5), equation (6), and equation (7)
- $\{q_t, q_t^N, q_t^T, q_t^F, q_t^H\}_t$ solve the retailer problem in equation (11)
- $\{m_t, p_t^N, p_t^T, p_t^H, e_t\}_t$ satisfy the price index relations equation (12) and equation (13)
- $\{c_t^s(a,z), l_t^s(a,z)\}\}_t^s$ solve the worker's problem in equation (4) for $\{r_t, r_t^\ell, w_t^T, w_t^N\}_t$
- $\{G_t^s(a,z)\}_t^s$ are consistent with the policy functions $\{c_t^s(a,z), l_t^s(a,z)\}_t^s$ and $\{w_t^T, w_t^N, r_t, r_t^\ell\}_t$
- $\{r_t, r_t^\ell, b_t, g_t, q_t, m_t, \{G_t^s(a,z)\}^s\}_t$ satisfy the government budget constraint in equation (21)
- $\{b_t, r_t\}_t$ satisfy the transversality condition equation (25)
- $\{b_t^*\}_t$ and $\{p_t^E, e_t, q_t^E, q_t^F\}_t$ satisfy the balance of payments equation (24)
- $\{\{c_t^s(a,z), G_t^s(a,z)\}^s, g_t, q_t\}_t$ satisfy final good market clearing in equation (23)
- $\{\{G_t^s(a,z)\}^s, b_t^*, b_t\}_t$ satisfy asset market clearing
- $\{r_t, \mu_t, \pi_t\}_t$ satisfy the uncovered interest parity condition in equation (27)

The government sets the sequences $\{b_t, g_t\}_t$. There are multiple ways to set them and hence multiple possible equilibria indexed by fiscal policy. I consider the case with constant real value of debt b_t, where the purchases g_t adjust to satisfy the government budget constraint.

In principle, government's budget could instead be balanced with taxes. The choice of fiscal instruments in non-Ricardian environments is not neutral. After reporting the baseline results, I conduct additional experiments with lump-sum taxes levied from households and show that aggregate dynamics are slightly different quantitatively, although do not change qualitatively.

Steady state and calibration. All aggregate variables are constant in the steady state. Without inflation, the nominal and real interest rates are the same. The exchange rate is constant, so UIP implies a constant interest rate equal to r^f. Trade is not balanced because foreign investors receive interest payments on government debt, which is offset by positive net exports.

All prices are normalized to one. In particular, I make the workers in the traded and non-traded goods sectors receive the same wage per efficiency unit of labor in the steady state. The actual wages are different, because workers are not equally productive in the two sectors. Mano and Castillo (2015) provide estimates of productivity levels in tradables and non-tradables.

I choose Peru as my reference country due to the availability of important empirical moments. Specifically, I take estimates of the MPC from Hong (2023). From aggregate data, I take targets for tradable output, exports, government debt, foreign ownership of government debt, and government fiscal revenue as shares of the total output. The export share, the foreign ownership of government debt, and the productivity differential between sectors allow me to calibrate (ζ, η, α).

I use aggregate series from FRED and World Bank to arrive at the tradable share and export share.[2] Existing data mostly discriminate between goods and services instead of tradables and non-tradables. I impute the tradable share using a simple procedure relying on two assumptions. First, I assume that all goods are tradable. Second, I assume that the same share of goods and tradable services is exported. Under these assumptions, a good proxy for the "exportable share" of tradables is the ratio of goods exports to the total value of goods produced. Dividing the value of services exported by this "exportable share", I arrive at the total value of tradable services. The value of goods and tradable services as a share of GDP is then the tradable share. This calculation yields a tradable share of 54.28%.

International securities issued by the government, on average, represent 8.82% of GDP in my sample. I set the annual interest rate to 5%. Together with the export share of 21.38%, this pins down the home bias coefficient $\alpha = 0.611$ and the tradable share of domestic demand at $\eta = 0.541$, slightly lower than the tradable share of output, reflecting current account surplus balanced out by the interest payments on government debt held abroad. I set the level of productivity in non-tradables to 0.6 of that in tradables, taking the estimate for Latin America from Mano and Castillo

[2]The FRED series for GDP is MKTGDPPEA646NWDB, PERGGRGDP is for general government revenue, IDSGAMRIAOPE is for international debt issued by the government, and DSAMRIAOGGPE is for domestic debt issued by the government. I take data for the GDP share of services and exports of services, and total exports from the World Bank. The data points I use span the period between 2011 and 2019.

(2015).[3] This leads to $\zeta = 0.46$, so more than half of the population works in non-tradables.

The elasticities θ, θ_g, and θ_e do not affect the steady state but determine the dynamic response of relative prices and quantities of intermediates. In the baseline case, following Guo, Ottonello, and Perez (2020), I set $\theta_g = \theta_e = 3$, but make $\theta = 1.5$ so that traded and non-traded goods are less substitutable than goods of different origin. The elasticity at home and abroad is the same, so the demand for exports as sensitive to terms of trade as demand for imports. Auclert et al. (2021) show that these parameters are important for the magnitude of aggregate responses in HANK models. I analyze exchange rate policy under lower and higher elasticity in Section 5.

I choose $\tau = 0.2$ to make government revenues amount to around 20% of GDP. The slope of the Phillips curve in equation (17) is 0.0067, which I set to match the coefficient in Alves (2019). In Appendix B, I present impulse additional responses for other values of κ. The coefficient on inflation in the Taylor rule equation (28) in the baseline specification is equal to 1.5, which is in the middle of commonly used values. I describe alternative specifications is Section 5. Finally, for the foreign interest rate shock, I choose the jump on impact ψ_0 to be 2% annually, and the decay coefficient δ is 0.25 to generate a half-life of approximately one quarter.

Labor income dynamics. I parameterize the labor disutility function to be isoelastic:

$$\chi(l) = \frac{\chi_1 \chi_2}{1+\chi_2} l^{1+\frac{1}{\chi_2}} \tag{33}$$

Following Kaplan, Moll, and Violante (2018), I set $\chi_2 = 0.5$ as the Frisch elasticity. A normalization $\chi_1 = 0.8$ makes workers supply one unit of labor when the wage and marginal utility are one.

Individual productivity z_t takes values in a finite set $Z = \{\hat{z}_k\}$. Its evolution is described by

$$dz_t = \sum_k \mathbb{1}\{z_t = \hat{z}_k\} \Delta \hat{z}_k \cdot dN_{k,t} \tag{34}$$

Here $dN_{k,t}$ is the increment of a Poisson process with intensity λ_k. The variable $\Delta \hat{z}_k$ is drawn upon arrival of the Poisson shock and takes values $\{\hat{z}_j - \hat{z}_k\}_j$ with probabilities p_{kj}. In words, productivity jumps between states in a Poisson fashion, and both jump intensity and the distribution of the new state depend on the current state. These jumps are not correlated across workers.

I specify the transition matrix to look like a job ladder in the spirit of Alves (2019) and Moscarini and Postel-Vinay (2017). It is possible to either go up one step or fall to the lowest step that is a metaphor for unemployment (although the workers still contribute to output and receive their wages at that level of z). This allows me to keep the number of parameters low and the transition matrix sparse while still matching MPC across income deciles relatively well.

Denote the Poisson transition matrix by $\mathbb{A}^z$. The job ladder structure means that only the

[3] Peru appears to be an outlier in their data, but the estimates strongly depend on the composition of sectors that Mano and Castillo (2015) assign as tradable. For this reason, I choose their reported Latin American average and report alternative calibrations after the baseline results.

elements $\mathbb{A}^z_{k,1}$ in the first column, the elements $\mathbb{A}^z_{k,k}$ on the main diagonal, and the elements $\mathbb{A}^z_{k,k+1}$ directly above the main diagonal are non-zero. I use $K = 10$ and make each productivity level equally likely within a sector. Each $\hat{z}_k$ is hence a particular decile in the income distribution within sector. This imposes a restriction $\mathbb{A}^z_{k,k} + \mathbb{A}^z_{k-1,k} = 0$ for all $k > 1$. Together with the restriction $\sum_k \mathbb{A}^z_{i,k} = 0$ for every i, there are only $K - 1$ entries to fill, all of them on the main diagonal. I parameterize them as $\mathbb{A}^z_{k,k} = -\lambda + (k-1) \cdot \Delta\lambda$ for $k > 1$.

I set up the grid $\{z_k\}$ such that every z_k is in the middle of k−th decile of a log-normal distribution with mean Z in tradables and $0.6Z$ in non-tradables. The variance of log productivity is 0.485, matching the variance of residual income reported in Hong (2023). I define a notion of persistence as

$$\frac{\mathbb{C}[\ln(z_t), \ln(z_{t+6})]}{\mathbb{C}[\ln(z_t), \ln(z_{t+3})]} \tag{35}$$

and target the value of 0.963 to match persistence of the permanent component of the residual income in Hong (2023).[4]

The calibration procedure searches over $\{\lambda, \Delta\lambda, Z, \rho, \sigma, r^\ell\}$ to approximate persistence and MPC estimates from Hong (2023). I compute quarterly MPC following the procedure described in Achdou et al. (2017). Panel (c) in Figure 1 shows MPC fit across income deciles.

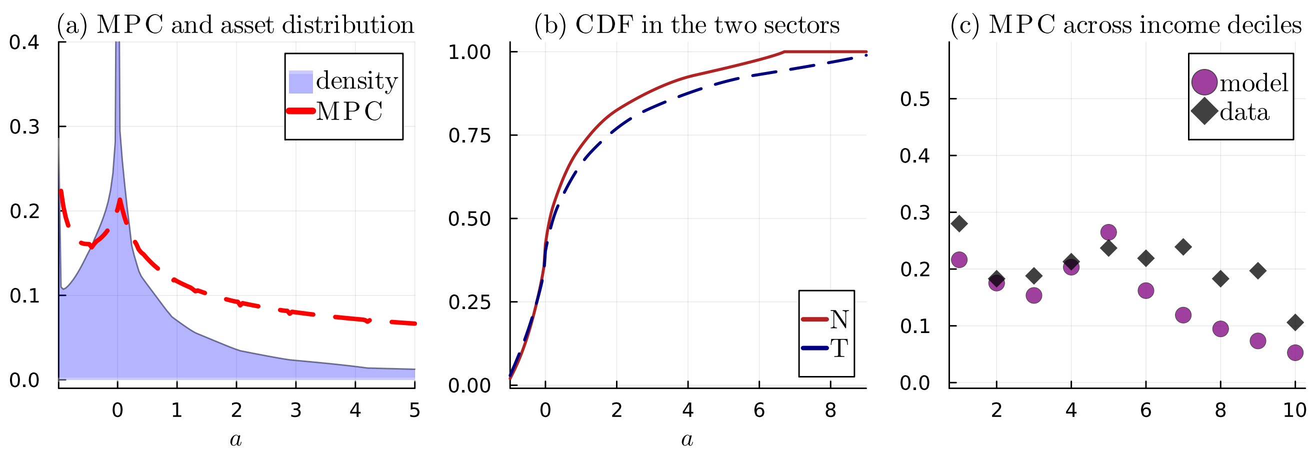

Figure 1: Panel (a): steady-state asset distribution. Panel (b): asset CDF in the two sectors (non-traded sector dashed). Panel (c): quarterly MPC in the model and in Hong (2023).

Wealth distribution. The wealth heterogeneity in my model is standard. The distribution has two mass points: one at the borrowing limit $a = \bar{a} < 0$ and one at $a = 0$. The latter is generated by a discontinuity in the interest rate at zero. Agents close to these two points have a high marginal propensity to consume out of unexpected transitory money windfalls. With just one asset, it is hard to match a high average MPC and a high asset-to-output ratio together, so the model

[4]Hong (2023) models residual income as a combination of and AR(1) process and *iid* innovations. In his baseline, the persistent component is not stationary, with the distribution varying by age. However, variances appear to be flat over ages, so I treat the process as stationary to arrive at targets of $(0.485, 0.963)$ for variance and persistence.

Parameter	Value	Meaning
		Externally calibrated
χ_2	0.5	Frisch elasticity
ϕ_π	1.5	coefficient on inflation in the Taylor rule (for float)
θ	1.5	substitution elasticity between tradables and non-tradables
θ_g	3	substitution elasticity between home and foreign tradables
θ_e	3	elasticity of export demand
κ	0.0067	slope of the Phillips curve
		Internally calibrated
σ	1.075	elasticity of intertemporal substitution
η	0.541	weight on tradable goods in domestic demand
α	0.611	weight on home goods in domestic demand for tradables
$\tilde{q}$	0.041	magnitude of export demand
ζ	0.460	share of workers in tradables
τ	0.2	labor income tax rate
ρ	0.139/12	discount rate
χ_1	0.8	magnitude of labor disutility
r^ℓ	0.221/12	domestic real interest rate on loans
λ	0.297	monthly switch intensity for $k = 1$ and $k = 2$
$\Delta\lambda$	0.035	switch intensity step
Z	0.095	mean productivity in tradables
$\sigma^2(\ln(z))$	0.485	variance of log productivity
—	0.6	relative productivity in non-tradables
		Shock parameters
ψ_0	0.02/12	magnitude of the foreign interest rate jump
δ	1.15/12	persistence of the foreign interest rate jump

Table 1: Model parameters for baseline exercises

produces low net wealth: the workers hold 10.86% of the annual output worth of assets. This maps well into the stock of domestically issued government securities, which averages to 8.68%.

Panel (a) in Figure 1 graphs the steady-state density and the quarterly MPC as a function of asset holdings. The horizontal axis is normalized by mean assets. The mass point at $a = 0$ is of the size around 6.5%, that at $a = \bar{a}$ is around 3%, and the share of borrowers is around one third. As expected, MPC peaks at the borrowing constraints and decreases with wealth.

Panel (b) compares wealth distributions across sectors. The wealth gap starts to accumulate at positive levels of wealth and becomes visible in the right tail. This reflects that the workers in non-tradables are poorer because their productivity is only 60% of that in tradables.

4 Foreign Interest Rate Shock

This section describes the effects of a shock to the foreign interest rate ψ_t for the two baseline monetary regimes. I first report aggregate responses and then detail the distributional effects.

Aggregate effects of the shock. When the foreign interest shock ψ_t hits, it affects the foreign investors' appetite for holding the small economy's bonds. Consider equation (27):

$$(r_t - r^f) - \mu_t = \psi_t$$

If ψ_t is positive, foreign investors need to be compensated with a higher real rate on bonds ($r_t > r^f$) or a real appreciation of the domestic currency ($-\mu_t > 0$). Monetary policy and aggregate demand determine the exact combination of the two in equilibrium.

The jump in the shock is 2% annually, which corresponds to $\psi_0 = 0.02/12$, and the decay rate is $\delta = 1.15/12$, generating a half-life of approximately half a year. The policy rules are

$$r_t = r^f + (\phi_\pi - 1)\pi_t \quad \text{(float)}$$

$$\mu_t + \pi_t = 0, \; e_0 = 1 \quad \text{(peg)}$$

The equation $e_0 = 1$ means that the real exchange rate does not jump on impact and stays at the steady-state level, which is normalized to one. It does not jump because the price level does not jump, and the nominal exchange rate is fixed.

The way to make the domestic currency appreciate in transition under float is to let it depreciate on impact and then let the real exchange rate appreciate back to its long-run value. Under peg, the nominal exchange rate does not move, and $i_t - r^f$ exactly follows the trajectory of the shock ψ_t. The real exchange rate does move because a zero nominal depreciation implies $-\mu_t = \pi_t$. The real interest rate is determined residually from the uncovered interest parity condition.

Figure 2 plots responses of aggregate variables under float (top panels) and peg (bottom panels). The nominal variables, the price level and the nominal exchange rate, are on panels (a) and (e). Real interest rate r_t and real depreciation μ_t are on panels (b) and (f), and the responses of wages and consumption in both sectors are on panels (c), (d), (g), and (h).

Float. Following a tightening abroad, foreign investors demand higher returns on government debt. This triggers a jump depreciation of the domestic currency followed by a real appreciation that increases the returns on the debt (as measured in foreign currency). The size of the jump depreciation in the first quarter is 0.95%.

The foreign currency price of exports falls with depreciation, triggering a jump in export demand, which boosts wages in the tradable sector. In response to higher costs, retail prices start to adjust. This creates inflation and a tightening by the central bank in response. The tightening and the subsequent real appreciation together provide foreign investors with higher returns on debt.

The size of the real interest rate hike is 67*bp* in the first quarter, while the shock is 170*bp*. It

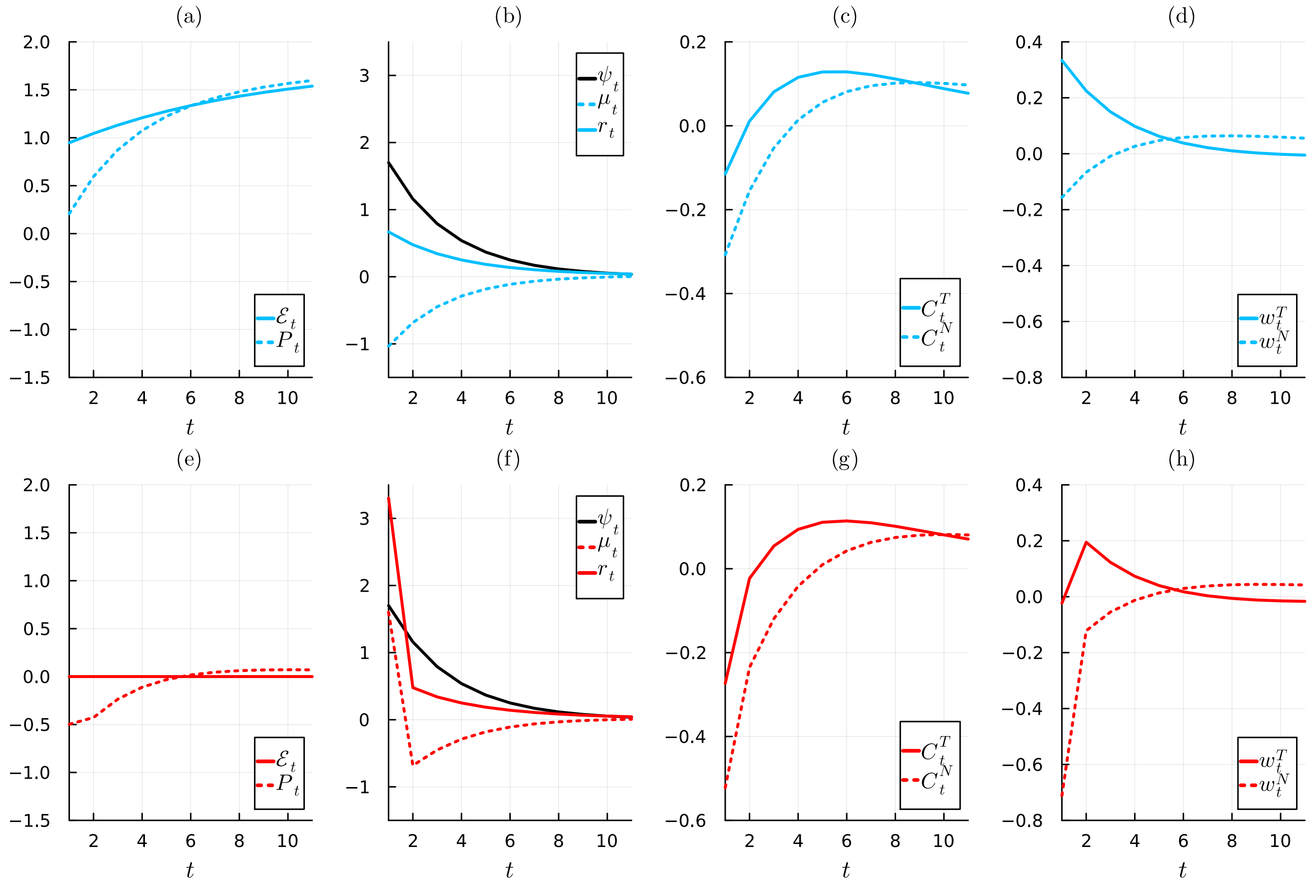

Figure 2: Top panels: response of aggregate variables under float. Bottom panels: responses under peg. Units are percent changes (percentage points in case of r_t and μ_t). Time is measured in quarters. Additional impulse responses can be found on Figure A.1 in Appendix B.

means that there is a 40% pass-through of the foreign tightening to the domestic real interest rate, even though the central bank does not try to keep the exchange rate down.

Peg. When the nominal exchange rate is constant, the real interest rate rises much higher than under float. This induces a contraction in aggregate demand and reduces wages in non-tradables. Tradable sector wages decrease too, but by less, because their decline triggers substitution from imports to local goods and boosts exports. The non-tradable sector is affected by the falling aggregate demand more strongly because substitution between tradables and non-tradables is harder and because there is no additional source of demand coming from abroad.

Aggregate demand falls so sharply that there is deflation in the first quarter. The nominal price of foreign currency cannot change, so its real price starts increasing instead. It is the same real exchange rate depreciation as under float, but now it cannot happen on impact and has to be gradual. Another consequence of deflation is that the real interest rate overshoots the nominal rate and hence ψ_t: it jumps by $330bp$ in the first quarter, overshooting ψ_t by two times.

Distributional effects. The dimensions of heterogeneity I discuss are across the sector of employment and wealth. On average, workers in non-tradables decrease their consumption by more

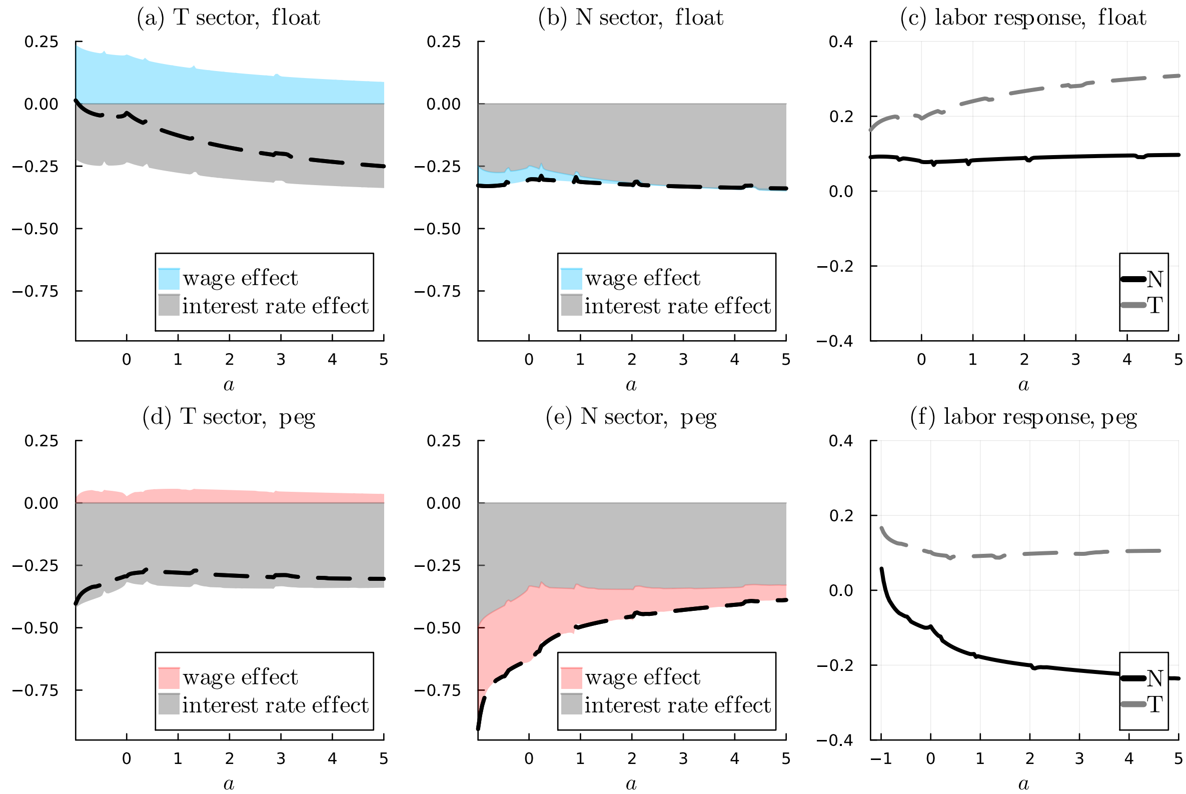

Figure 3: Panels (a), (b), (d), (e): first quarter consumption response (in percent) as a function of initial asset holdings normalized by mean wealth. Darker areas represent the response to the interest rate, lighter areas the response to the wages. Dashed lines plot the overall responses. Panels (c) and (f): response of labor supply (in percent). Non-tradables in solid, tradables dashed.

under both regimes. Under float, the decrease in the first quarter is 0.31%, as opposed to 0.11% in tradables. Under peg, the decrease is 0.52% in non-tradables and 0.27% in tradables.

To capture the differences across wealth levels, I use the first quarter consumption response as a function of the worker's asset position at $t = 0$. Consumption response is driven by the changes in the interest rate and wages. I evaluate both channels, solving for the paths of consumption under counterfactual input sequences $\{r_t, \overline{w}^g, \overline{w}^s\}_t$ and $\{\overline{r}, w_t^g, w_t^s\}_t$, where $\overline{w}^g$, $\overline{w}^s$, and $\overline{r}$ are the steady-state values. Figure 3 plots these components of the first-quarter consumption response.

The response to the interest rate hike is negative under both regimes. Substitution effect makes workers consume less. It is stronger far from constraints, pushing richer agents to cut their consumption by more. Income effect from interest payments depends on the sign of asset position: borrowers consume less because disposable income falls, and it is the opposite for savers. Substitution dominates under float: the response profile shows a stronger impact in the right tail. Under peg, income effect dominates, and poorer households are affected the most. The ones affected the least are those close to zero wealth.

The response to wages is stronger in the left tail, close to the constraints. Under float, wages boost incomes in tradables, which is why the overall consumption response is unambiguously less negative for poorer households: wages and interest rate skew it in the same direction. Under peg, on the contrary, the large fall in wages in non-tradables reinforces the response to interest rate, making the overall drop in consumption unambiguously stronger in the left tail.

Right panels of Figure 3 plot the response of labor supply. Under float, agents start to work more in both sectors. In non-tradables, this is driven by a fall in consumption that raises marginal utility. This increase in labor supply is matched by an increase in demand due to expenditure switching. In tradables, on top of the fall in marginal utility there is a jump in wages, and the labor supply response is stronger. It is matched by booming export demand.

Under peg, labor supply in non-tradables must fall because of decreasing domestic demand. The impact of falling wages on labor supply is stronger than the impact of rising marginal utility. In tradables, labor supply increases mostly due to lower consumption.

To quantify the inequality of the impact of the shock, I compute the changes in the dispersion of log quarterly consumption. Denote the average (over z) steady-state quarterly consumption of workers that start the quarter with wealth a by $C^T(a)$ and $C^N(a)$. The total consumption $C(a)$ is a mixture of $C^T(a)$ and $C^N(a)$ with weights ζ and $1-\zeta$. Let the cumulative consumption over the first quarter after the shock be $C_1^T(a)$ and $C_1^N(a)$, with the mixture $C_1(a)$. Denote by $\Delta_1^T(a) = \ln\left(C_1^T(a)/C^T(a)\right)$ and $\Delta_1^N(a) = \ln\left(C_1^N(a)/C^N(a)\right)$ consumption responses.

Proposition 1. The change in consumption dispersion $\Delta\mathbb{V} = \mathbb{V}[\ln(C_1)] - \mathbb{V}[\ln(C)]$ is

$$\Delta\mathbb{V} = \underbrace{\zeta\mathbb{V}\left[\Delta_1^T\right]}_{\text{response } T} + \underbrace{(1-\zeta)\mathbb{V}\left[\Delta_1^N\right]}_{\text{response } N} + \underbrace{2\zeta\mathbb{C}\left[\ln\left(C^T\right), \Delta_1^T\right]}_{\text{wealth bias } T} + \underbrace{2(1-\zeta)\mathbb{C}\left[\ln\left(C^N\right), \Delta_1^N\right]}_{\text{wealth bias } N}$$
$$+ \underbrace{\zeta(1-\zeta)\left(\mathbb{E}\left[\ln(C_1^N) - \ln(C_1^T)\right]^2 - \mathbb{E}\left[\ln(C^N) - \ln(C^T)\right]^2\right)}_{\text{sector gap}} \tag{36}$$

The increase or decrease in the variance of log consumption is determined by the variance of the response (the first two terms), by how the response is aligned with initial wealth (the third and fourth terms), and by how the distance between the sectors changes (the last term). Table 2 compares this decomposition under float and peg.

Regime	$\Delta\mathbb{V}/\mathbb{V}[\ln(C)]$	response dispersion		wealth bias		sector gap
		tradable	non-tradable	tradable	non-tradable	
Float	0.0010	$\sim 0\%$	$\sim 0\%$	-296%	-64%	460%
Peg	0.0084	$\sim 0\%$	$\sim 0\%$	-4%	35%	69%

Table 2: The change in variance relative to the steady and the contribution of the terms in equation (36) to $\mathbb{V}\left[\ln(C_1)\right] - \mathbb{V}\left[\ln(C)\right]$.

The change in dispersion is almost fully driven by the gap between the sectors and the correlation of consumption response with the initial level of consumption. Under float, overall dispersion moves little in the first quarter, but this masks larger offsetting movements in the three terms. The distance between the sectors increases, because workers in tradables are initially richer and enjoy a boost in wages. Wealth bias is pro-poor in both sectors and distinctly larger in tradables.

Under peg, the total dispersion rises more. The widening gap between the sectors is responsible for two-thirds of the increase. A sizeable fall in the non-traded sector wages also creates an anti-poor bias in consumption response. In tradables, wealth bias is actually slightly pro-poor, because consumption is least affected around zero assets: these agents are not exposed to interest payments and do not engage in intertemporal substitution, being close to a borrowing constraint.

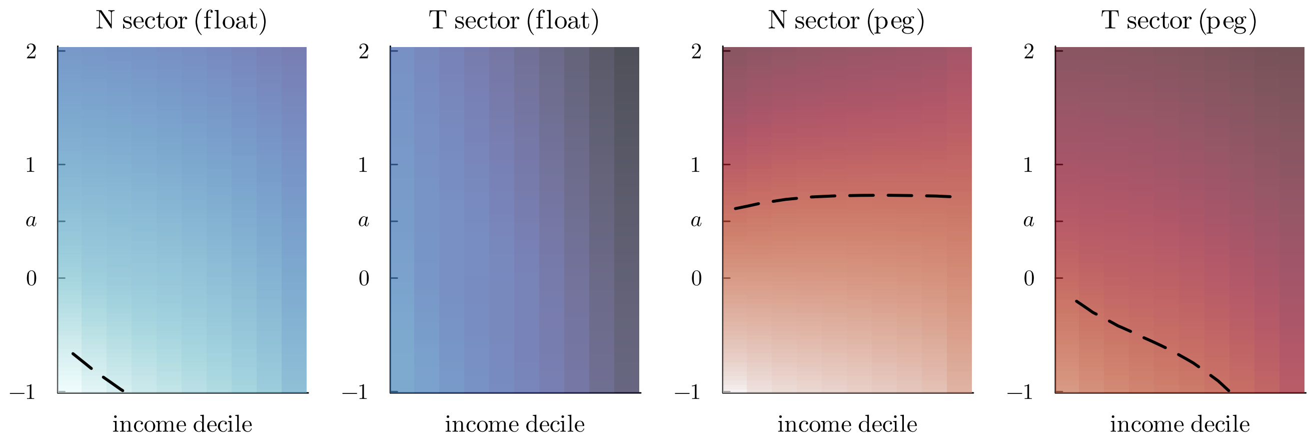

Figure 4: Value gains relative to the steady-state value (in levels). The dashed line shows agents with zeros gains, lighter areas represent agents whose value decreases right after the shock, and darker areas represent agents whose value increases. Assets normalized by mean wealth on the vertical axis, labor income decile on the horizontal axis.

Figure 4 shows welfare gains on the asset-productivity plane. I compute them by subtracting the steady-state value of agents from their value functions at $t = 0$ right after the shock. Under float, value generally increases, as agents anticipate consumption above the steady-state levels after the initial slump. One exception is the poorest workers in non-tradables: their wages fall more than in tradables, and their effective horizon is short because of high marginal utility, so the initial fall in consumption to them is more important. Under peg, the poorest workers in tradables lose in value along with most of those in non-tradables because the fall in wages is more substantial.

The role of fiscal policy. Government expenditures account for 20% of aggregate demand in this economy. After the shock, they decrease due to a fall in government revenues and a rise in debt servicing costs. The magnitude of the response on impact is just above 1% of the steady-state value under float and around 2.5% under peg.

There are three sources of government revenue: payroll taxes $\tau_t = \tau(w_t^T q_t^{dom} + w_t^N q_t^N)$, retail profits net of subsidies $(1-m_t)q_t$, and arbitrage profits of the banks $\xi_t = (r_t - r_t^\ell) \int \min\{a, 0\} dG_t(a)$. The government makes interest payments on debt $r_t b$. The real value of debt outstanding is constant in equilibrium, so the budget constraint given by equation (21) is

$$g_t = \tau_t + \xi_t + (1 - m_t)q_t - r_t b \tag{37}$$

The four terms on the right are the net income sources. Figure A.11 in Appendix B shows the responses of these components (except for the arbitrage profit, which is very low).

Under float, payroll taxes increase because of the boom in production following currency depreciation. Interest payments slightly increase because of a hike in the real rate that reacts to inflation. Retail profits decrease because of rising real costs. Under peg, the interest payment burden increases much more. Payroll taxes decline because of a fall in economic activity, and retail profits rise due to falling real prices and slow adjustment of the price of the final good.

The government's budget could instead be balanced with taxes. When government purchases adjust, increases in debt servicing costs and decreases in taxes are mechanically passed to aggregate demand one-to-one. When lump-sum taxes adjust, the deficit is presented to the taxpayers to cover, so the pass-through to aggregate demand depends on the size and the distribution of tax incidence.

To compare the responses with these two instruments, I solve the model with a constant path of g_t and lump-sum taxes adjusting instead, distributing them equally and in proportion to labor income. This proportional rule is akin to a reduction in wages that workers do not factor in their labor supply decision. It is neutral in the distributional sense.

Figure A.5 and Figure A.6 in Appendix B show the impulse responses under the two fiscal policy regimes. The responses are not exactly the same but close. Consumption response, as expected, is stronger than in the baseline. But since there is no contraction of government purchases, the total aggregate demand response is closer to baseline. This is plotted on panels (a) and (c) of Figure A.11 in Appendix B. The jump in the exchange rate, inflation, and interest rate turns out to be roughly the same across all three fiscal regimes.

The role of elasticities. Substitution elasticities determine the strength of expenditure switching. Parameters θ_g and θ_e govern the substitution between domestic and foreign tradable goods at home and abroad, respectively, while θ governs the spillovers to non-tradables. Auclert et al. (2021) demonstrate in a model with sticky wages and without non-tradables that currency depreciation induced by foreign monetary shocks is contractionary when θ_g and θ_e are low. This is because expenditure switching is weak, and the decrease in real incomes caused by nominal depreciation is not offset by a boom in demand for domestic goods. High elasticities instead make currency depreciation expansionary. The value of these parameters is important for the magnitude as well as the sign of the demand response.

To assess the role of elasticities, I set these parameters to lower and higher levels and compute transitional dynamics. In the baseline model, $(\theta, \theta_g, \theta_e) = (1.5, 3, 3)$. The "low $\{\theta\}$" experiment sets them at $(\theta, \theta_g, \theta_e) = (0.75, 1.5, 1.5)$. The "high $\{\theta\}$" experiment doubles them, $(\theta, \theta_g, \theta_e) = (3, 6, 6)$.

Figure 5 shows impulse response of wages and real interest rate. Upper panels treat the float

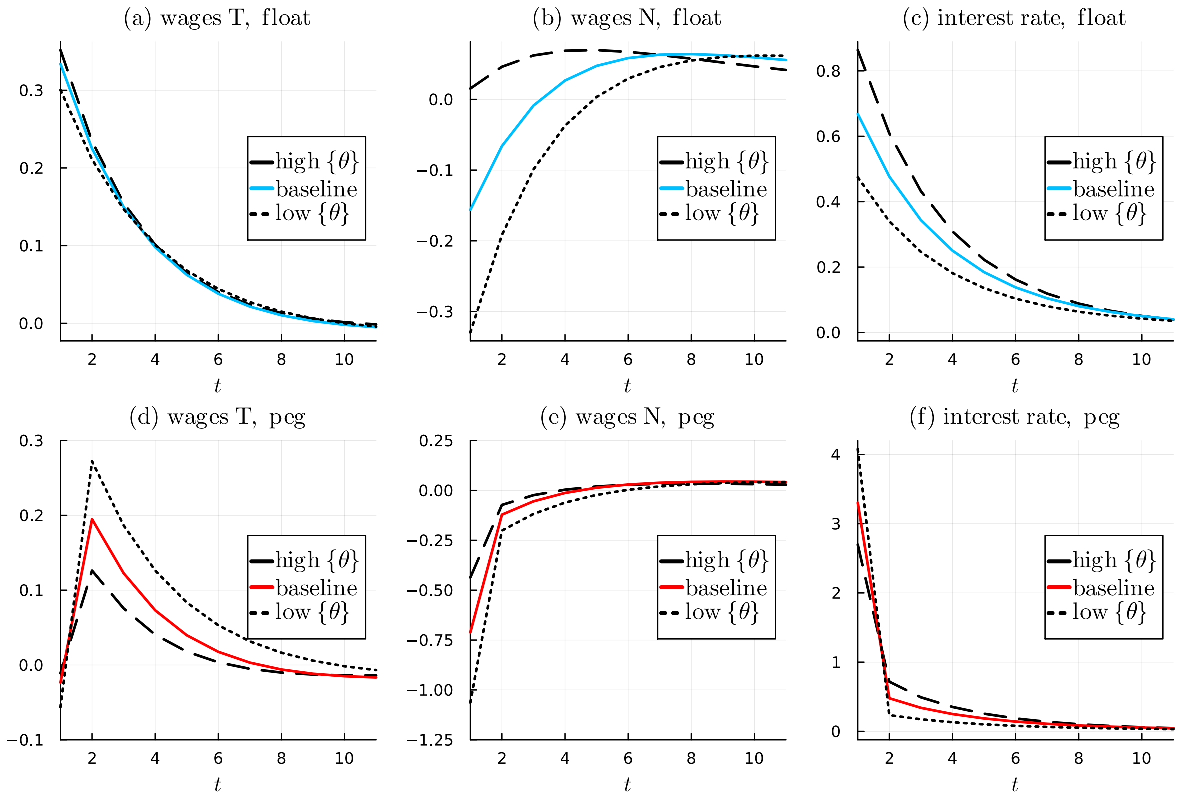

Figure 5: Impulse responses of wages (in percent) and real interest rate (in percentage points) under three sets of elasticities. Solid lines for the baseline, high $\{\theta\}$ dashed, low $\{\theta\}$ dotted.

case. With low $\{\theta\}$, quantities are less responsive to prices. Relative price adjustments have to be larger to induce the same expenditure switching. For this reason, a bigger portion of the shock is absorbed by the jump in the exchange rate, and less of it passes through to the interest rate. However, for the same reason, wages in non-tradables fall more.

These two factors impact consumption response in non-tradables in opposite directions. In my calibration, they turn out to balance each other: consumption in non-tradables falls in the first quarter almost by the same amount regardless of elasticities. In tradables, the wage does not move much with $\{\theta\}$, so consumption response of agents employed in this sector depends on how $\{\theta\}$ determines the real interest rate dynamics. Since high $\{\theta\}$ make the real interest rate jump more, consumption falls the most in this experiment.

Under peg, exchange rate cannot jump on impact, and real depreciation has to happen gradually in the subsequent quarters. With high $\{\theta\}$, relative price adjustment is limited, so wages in tradables do not increase as much along the way as they do in the baseline. As workers in tradables do not anticipate high wages in the future, their consumption response falls relative to the baseline. Conversely, under low $\{\theta\}$, their consumption response is less negative.

In non-tradables, the wage decreases substantially in the first quarter, but relatively quickly reverts after that, as prices adjust. The difference across $\{\theta\}$ is that the relative price adjustment is slower with high $\{\theta\}$, so real exchange rate depreciation takes longer. This implies a more persistent rise in the real interest rate than in the baseline. For this reason, consumption responses in both sectors under high $\{\theta\}$ are more negative.

The role of heterogeneity. There are two types of heterogeneity that affect aggregate responses: wealth heterogeneity within the sectors and the wealth gap between the sectors. The gap between the sectors stems from differences in productivity: in non-tradables it is only 60% of that in tradables. Workers in tradables are richer on average, as shown on panel (b) of Figure 1. To assess the sensitivity of aggregate dynamics to this factor, I compute two other steady states and transition dynamics starting from them. In one experiment, productivities are equal, and in the other experiment, workers in tradables are 60% as productive as those in non-tradables. Impulse responses are on Figure A.2 and Figure A.3 in Appendix B.

The difference in responses is slightly more pronounced under float, because under float wages drive most of consumption dynamics, and the real interest rate moves relatively little. That said, responses are quantitatively close to the baseline under both alternative calibrations. The reason is that the differences in sectoral asset distributions are more pronounced in the right tail, as seen in Figure 1, while left tails are similar.

The second type of heterogeneity is that over initial wealth within sectors. It results from market incompleteness and borrowing constraints. To compare impulse responses to the ones that a model without these properties would produce, I compute transition dynamics in a two-sector RANK model. I remove idiosyncratic productivity shocks and borrowing constraints, leaving a representative agent in each sector. These representative agents follow standard Euler equations $\dot{c}_t = c_t(r_t - \rho)/\sigma$. The only other difference is that I impose a stationarity-inducing device following Schmitt-Grohé and Uribe (2003) that makes the NFA eventually converge back to the steady-state value.[5] Figure A.4 in Appendix B shows impulse responses.

An important difference is that consumption in the two sectors is affected in the same way in the RANK model since it only reacts to the interest rate. The initial rate hike causes a larger fall in aggregate demand than in HANK, and the wage in non-tradables falls more. Under peg, this conditions faster deflation in the first quarter, and hence more real exchange rate depreciation, which calls for a higher interest rate through UIP. Under float, this slows down inflation and causes a slightly lower initial rate hike. Overall, other differences are small.

5 Fear and Love of Floating

This section describes the effects of the shock under alternative policy rules. I consider mixed monetary policy regimes that target a combination of inflation and currency depreciation.

[5]Specifically, I make the effective interest rate depend on the value of assets without internalization. Agents receive less interest income when their assets are higher than in steady state. They interpret these payments as lump-sum tax and take them as given. This way parameters of the device do not affect consumption rules.

There are two main takeaways from this section. First, attempts to limit exchange rate depreciation affect non-tradable sector employees more, even though the exchange rate only directly applies to traded goods. This is because monetary policy limits depreciation by suppressing aggregate demand, and non-tradables are more sensitive to domestic demand since they do not have a close foreign substitute. Second, lowering substitution elasticities has two effects on consumption responses that work in opposite directions. It makes wages in non-tradables fall more, because under low elasticities relative prices are more sensitive. It also makes the interest rate rise less on impact because the exchange rate absorbs more of the shock. I find that the second effect dominates, and low elasticities make aggregate demand fall less on impact.

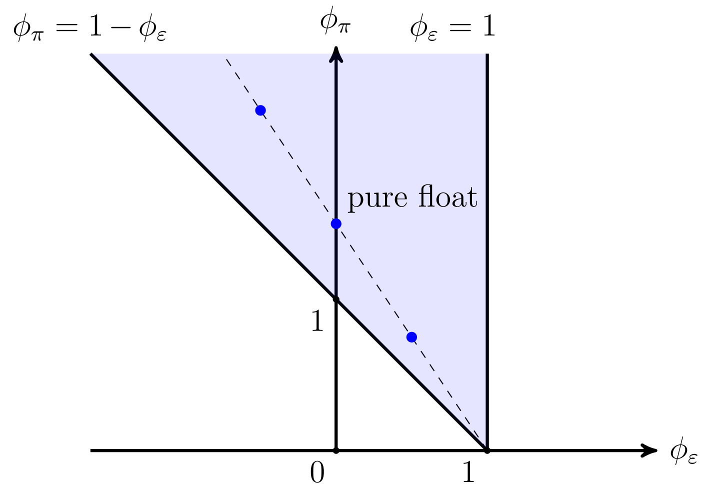

Figure 6: Pairs $(\phi_\varepsilon, \phi_\pi)$ for which the coefficient on inflation in equation (39) is positive (shaded area). Dots represent some of the monetary rules used in numerical exercises.

Aggregate and distributional responses. I consider Taylor rules given by equation (28):

$$i_t = r^f + \phi_\pi \pi_t + \phi_\varepsilon \frac{\dot{\mathcal{E}}_t}{\mathcal{E}_t} \tag{38}$$

for positive coefficients on inflation $\phi_\pi > 0$. Under free capital mobility, these rules form a dynamical system together with the uncovered interest parity condition in equation (27).

This system can be rewritten to show how $\{\phi_\pi, \phi_\varepsilon\}$ determine how much of the shock is channeled to real depreciation and to the real interest rate:

$$r_t - r^f = \underbrace{\left(\frac{\phi_\pi}{1-\phi_\varepsilon} - 1\right)\pi_t}_{\text{indirect}} - \underbrace{\frac{\phi_\varepsilon}{1-\phi_\varepsilon}\psi_t}_{\text{direct}} \tag{39}$$

$$\mu_t = \left(\frac{\phi_\pi}{1-\phi_\varepsilon} - 1\right)\pi_t - \frac{1}{1-\phi_\varepsilon}\psi_t \tag{40}$$

The shock ψ_t enters equation (39) and equation (40) explicitly, so it has a direct effect of $r_t - r^f$

and μ_t. These two variables then determine the real marginal costs of retailers and aggregate demand through relative prices and wages, which impacts inflation. The inflation feedback in equation (39) and equation (40) is the indirect effect of the shock.

Importantly, fear of floating corresponds to *low* values of ϕ_ε. To see why one can compute the nominal exchange rate at time t after the shock:

PROPOSITION 2. *If the economy converges to the steady state after the shock and $\int_0^\infty \psi_t dt$ and $\int_0^\infty \pi_t dt$ both exist, the nominal exchange rate $\mathcal{E}_t$ at any $t \geq 0$ satisfies*

$$\int_t^\infty \psi_s ds = (1-\phi_\varepsilon)[\ln(\mathcal{E}_t) - \ln(P_t)] + (\phi_\pi - 1 + \phi_\varepsilon)\int_t^\infty \pi_s ds \tag{41}$$

This proposition shows that the cumulated future shock at any $t \geq 0$ can be decomposed into the real exchange rate at t and future cumulated inflation. Intuitively, the real exchange rate $\ln(\mathcal{E}_t) - \ln(P_t)$ shows how much of the shock has already been absorbed by real depreciation, and the future cumulated inflation shows how much of the shock is yet to be absorbed.

A useful special case is $t = 0$. As the price level is still at the steady-state value of 1,

$$(1-\phi_\varepsilon)\ln(\mathcal{E}_0) + (\phi_\pi - 1 + \phi_\varepsilon)\int_0^\infty \pi_t dt = \int_0^\infty \psi_t dt \tag{42}$$

This equation shows how much of the shock is instantly absorbed by the jump in the exchange rate $\mathcal{E}_0$ (recall that the value before the shock is normalized to 1).

The sum of the coefficients is ϕ_π, so intuitively, this parameter determines how much exchange rate depreciation on impact and inflation in the future there will be in total. The coefficient ϕ_ε determines the allocation of the shock between the two. Low ϕ_ε puts a high weight on $\ln(\mathcal{E}_0)$, which limits depreciation on impact and hence corresponds to fear of floating. High ϕ_ε allows for a sizeable depreciation on impact and hence corresponds to love of floating.

Policy regimes. I compute transition dynamics after the shock for a set of values $\{\phi_\pi, \phi_\varepsilon\}$. Varying these parameters, I keep the strength of the indirect effects of the shock the same. This amounts to keeping the coefficients on inflation in equation (39) and equation (40) constant. To nest the floating exchange rate regime from Section 4, I set them to 1.5, which leads to $\phi_\pi = 1.5\cdot(1-\phi_\varepsilon)$. I use $\phi_\varepsilon = \{0.75, 0.50, 0.25, 0, -0.25, -0.50, -0.75\}$. Figure 6 illustrates some of these rules.

Figure 7 plots various first-quarter responses as a function of ϕ_ε. From left to right, ϕ_ε increases, and ϕ_π decreases, which corresponds to going from tighter to easier monetary policy. Panel (a) shows that the low values of ϕ_ε lead to larger increases in the real interest rate. According to the UIP condition, it means that less of the additional returns on domestic currency have to come from future real appreciation. This implies a lower initial jump depreciation, shown on panel (b).

High ϕ_ε also corresponds to low ϕ_π, which allows for sustained inflation and further depreciation

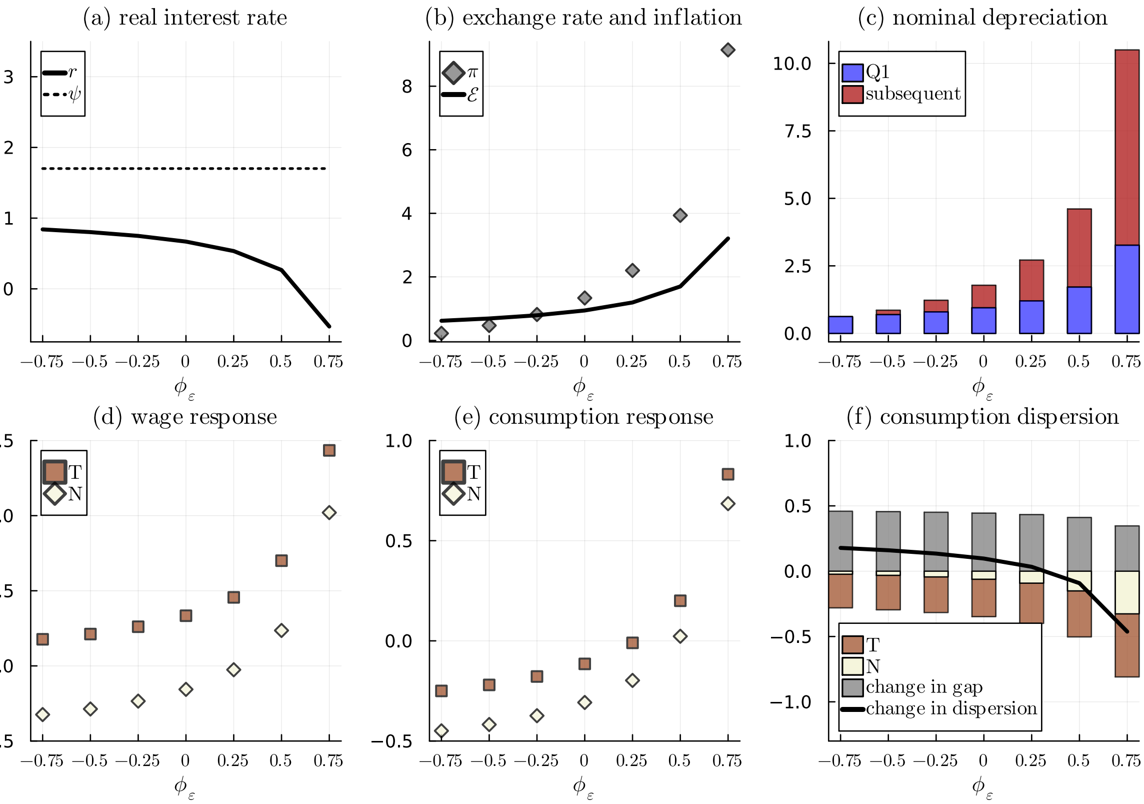

Figure 7: Panel (a): response of the real interest rate in Q1 and the shock. Panel (b): response of inflation (percentage points) and the nominal exchange rate (in percent) in Q1. Panel (c): nominal exchange rate depreciation in Q1 and after Q1 while the economy converges to the new steady state. Panel (d): response of wages in tradables and non-tradables in Q1. Panel (e): response of consumption of agents employed in tradables and non-tradables in Q1. Panel (f): change in consumption dispersion in Q1 (in percent of steady-state variance) with contributions of wealth bias and sector gap terms from equation (36).

after the initial jump. Panel (c) shows that under high ϕ_ε more than half of nominal depreciation happens after the first quarter. Pure float is the middle case, with about 1% jump depreciation and additional 1% nominal depreciation after that.

Another way to see how low ϕ_ε limits initial depreciation is through the goods market. By raising the real interest rate under low ϕ_ε, the central bank depresses aggregate demand. To generate the corresponding decline in output, the wage in non-tradables falls, driving down prices of other goods, including imports. The exchange rate adjustment is hence muted. High ϕ_ε, on the contrary, boosts aggregate demand. Wages go up to support the increase in output, as shown on panel (d). This allows the real price of imports, and hence the exchange rate, to adjust more.

Panels (d) and (e) show that jumps in wages in the tradable sector and consumption of agents employed there are consistently higher than those in non-tradables. This happens for two reasons. One is that expenditure switching from imports to domestic tradable goods is stronger than to non-tradables. The other is that exchange rate depreciation increases demand for exports.

The same factors make wages and consumption in non-tradables more sensitive to policy. In this sector, it is not possible to import foreign demand to make up for domestic demand shortfalls when the real interest rate goes up. At the same time, the rise in domestic demand under high ϕ_ε does not spill over abroad as it does in the tradable sector. As a result, the pro-tradable gap in wages, and hence in consumption responses, is wider when policy is tight.

The change in consumption dispersion, plotted on panel (f) of Figure 7, shows that the pro-poor wealth bias in non-tradables catches up with that in tradables as policy eases. This is a result of stronger wage growth under high ϕ_ε. The same force drives down the increase in the sector gap as policy eases. The overall change in dispersion even turns negative when ϕ_ε is positive.

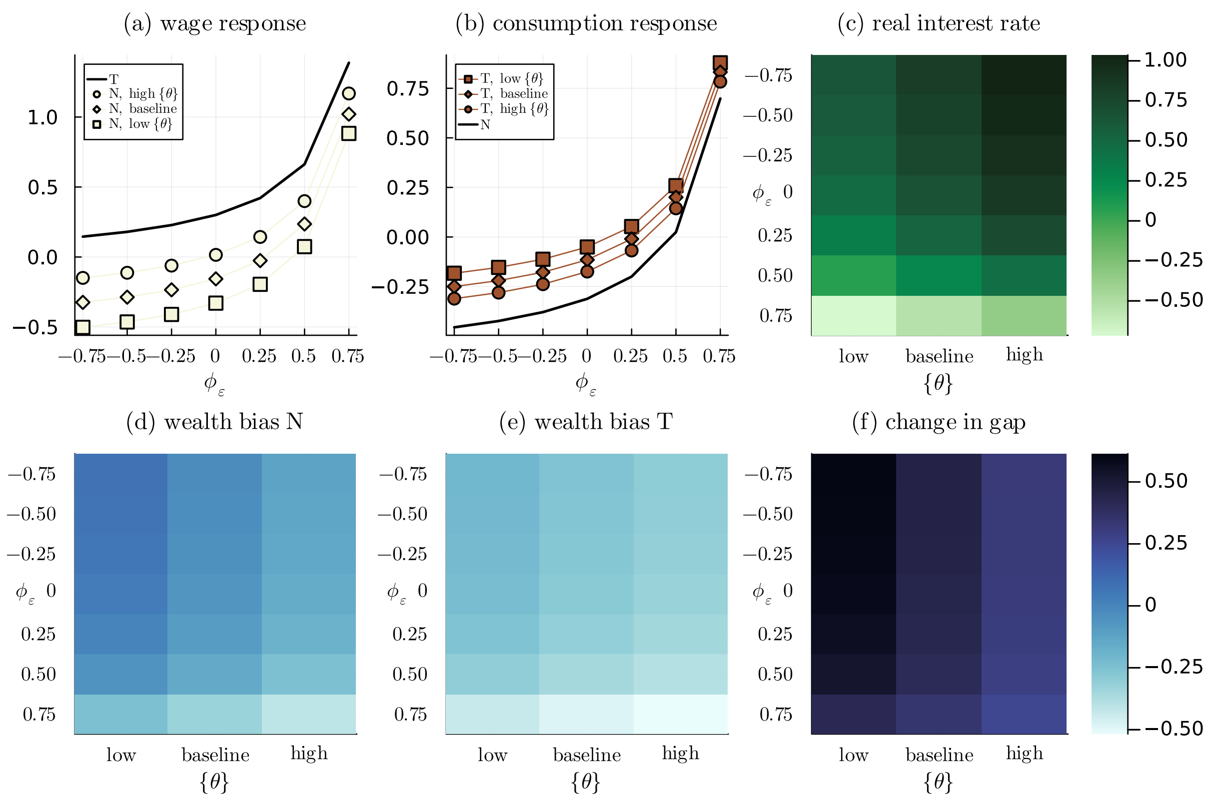

Figure 8: Panel (a): wage responses in both sectors for three sets of $\{\theta\}$ (in percent). Responses in tradables shown as one line because they are very close. Panel (b): consumption responses in both sectors for three sets of $\{\theta\}$ (in percent). Responses in non-tradables shown as one line because they are very close. Panel (c): first quarter responses of real interest rate. Panels (d), (e), and (f): the terms representing wealth bias and the gap between the sectors in equation (36) (in percent of steady-state total variance of log consumption).

The role of elasticities. I next examine how the elasticity of substitution affects the same responses depending on the policy regime. To this end, I consider three sets of parameters. In the baseline, the elasticity of substitution between traded and non-traded goods is $\theta = 1.5$, while the elasticity of substitution between domestic and imported tradables and the export demand elasticities are $\theta_g = \theta_e = 3$. The high elasticity experiment, which I call "high $\{\theta\}$" doubles all of these. The low $\{\theta\}$ experiment halves them.

Panel (a) in Figure 8 shows the first quarter response of wages in the two sectors. The coefficient ϕ_ε is on the horizontal axis, moving from tighter policy on the left to easier on the right. The wage in tradables has roughly identical response profiles under the three parameterizations, so I show them as one line. The wage in non-tradables falls much more in the low $\{\theta\}$ experiment. This is because relative price adjustments have to be more substantial to induce the same expenditure switching when quantities are less sensitive to prices.

Panel (c) shows that the real interest rate jumps less under low $\{\theta\}$. Since prices have to move more to induce the same movement in quantities, a bigger portion of the shock is absorbed by exchange rate revaluation on impact, and a smaller portion passes through to the real interest rate. These two factors, a deeper fall in wages and a weaker interest rate hike under low $\{\theta\}$, offset each other in the non-tradable sector's consumption response. Consumption profile of non-tradables on panel (b) is almost the same for all experiments, so I show it as one line. In tradables, consumption is higher under low $\{\theta\}$ because the interest rate jumps by less while there is no difference in wage responses.

The lower panels show three components of the change in consumption dispersion. Wealth bias in the two sectors is negative for almost all parameter combinations, meaning that the change in consumption is negatively correlated with the initial level. One exception is non-tradables in tight policy regions (low ϕ_ε) with low $\{\theta\}$. Wages fall so much that consumption dispersion within this sector actually increases on impact. The same region of the parameter space delivers the largest increases in the gap between the sectors, as shown on panel (f).

6 Conclusion

With the labor income and interest rate channels at play, the model shows that fixing the exchange rate induces losses in the left tail. This happens due to the interest rate hike that replicates the foreign shock and induces a recession that depresses wages. Under float with inflation targeting, there is still an interest rate hike, and wages in non-tradables fall. However, the tightening is less severe, and the gap between the wages in tradables and non-tradables under float is narrower.

This perhaps counterintuitive result on the wage gap generalizes to other exchange rate regimes. Limiting the exchange rate depreciation requires aggregate demand to fall, which disproportionately affects non-tradables, and the wage gap widens. Amplifying the depreciation with a real interest rate cut suppresses the wage gap.

This differential sensitivity of the two sectors to domestic demand is a common artifact of open economies. However, assumptions on pricing matter. For example, if exports were invoiced in foreign currency, exchange rate depreciation alone would not cause a spike in export demand, although there would still be domestic expenditure switching as imports become more expensive.

Price stickiness is important in the model. A model with sticky wages instead could produce different results, especially if it cannot replicate the dynamics of unemployment in economies where nominal wages are fixed by union contracts and overvalued exchange rate causes massive unemployment, as in Drenik (2015). My sticky-price model does produce an increase in labor incomes after depreciation, even though it happens due to expenditure switching and export boom rather than through the unemployment margin. However, a jump in the price level that would instantly reduce real wages is explicitly ruled out.

Other ingredients that are potentially important in the small open economy context are borrowing constraints and foreign currency debt. I eliminate them to better focus on the labor and interest rate channels, but they would be useful additions in the next steps in this line of research.

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A Model Solution and Proofs

This appendix describes the solution of the problem of the final good producers, the worker's problem, and contains proofs of the propositions in the text.

A.1 Details of the retailer and worker problems

Retailers. The solution to the problem in equation (11) is a standard set of factor demands:

$$q_{jt}^N = (1-\eta) q_{jt} \left(\frac{m_{jt}}{p_t^N} \right)^{\theta} \tag{43}$$

$$q_{jt}^T = \eta q_{jt} \left(\frac{m_{jt}}{p_t^T} \right)^{\theta} \tag{44}$$

$$q_{jt}^F = (1-\alpha) q_{jt}^T \left(\frac{p_t^T}{e_t \tilde{p}^F} \right)^{\theta_g} \tag{45}$$

$$q_{jt}^H = \alpha q_{jt}^T \left(\frac{p_t^T}{p_t^H} \right)^{\theta_g} \tag{46}$$

The real marginal cost m_{jt} of a retailer j is given by

$$m_{jt} q_{jt} = p_t^N q_{jt}^N + p_t^H q_{jt}^H + e_t \tilde{p}^F q_{jt}^F \tag{47}$$

After optimization, it satisfies equation (12) and hence is the same for all retailers, $m_{jt} = m_t$.

Retailers sell their final bundles to workers and the government. The elasticity of substitution between retailers is θ_r. The bundle that each worker or the government demands is a CES aggregate of her demand $\{c_{jt}\}_j$ or $\{g_{jt}\}_j$ for each variety j:

$$(c_t)^{1-\frac{1}{\theta_r}} = \int_0^1 (c_{jt})^{1-\frac{1}{\theta_r}} dj \tag{48}$$

$$(g_t)^{1-\frac{1}{\theta_r}} = \int_0^1 (g_{jt})^{1-\frac{1}{\theta_r}} dj \tag{49}$$

This leads to standard demand functions:

$$c_{jt} = c_t \left(\frac{P_t}{P_{jt}} \right)^{\theta_r} \tag{50}$$

$$g_{jt} = g_t \left(\frac{P_t}{P_{jt}} \right)^{\theta_r} \tag{51}$$

Aggregating this leads to equation (16).

I next describe the dynamic problem of the retailer. A retailer j has quadratic adjustment cost that is proportional to the total sales of the final bundles $P_t q_t$:

$$C_t(\pi_{jt}) = \frac{\hat{\phi} P_t q_t}{2} (\pi_{jt})^2 \tag{52}$$

where the individual inflation is $\pi_{jt} = \dot{P}_{jt} / P_{jt}$. I assume these costs are virtual and do not enter the resource constraint of the economy. Retailers receive a revenue subsidy $\hat{\tau}$ setting the steady-state markup to one. The physical profits are rebated to the government. The value of a retailer j at time t is

$$J(P_{jt}, t) = \max_{\pi_{js}} \int_t^\infty e^{-\hat{\rho}(s-t)} \left[\frac{(1+\hat{\tau})P_{js} - M_s}{P_s} q_{js} - \frac{\hat{\phi} q_s}{2} (\pi_{js})^2 \right] ds \tag{53}$$

subject to equation (16) and $\dot{P}_{jt} = \pi_{jt} P_{jt}$ for all t. They maximize the present discounted value of the stream of real profits net of adjustment cost.

To make the time horizon of the retail managers infinitely short, I impose $\hat{\phi} = \phi\Delta$ and $\hat{\rho} = \rho/\Delta$, where Δ is small. I first solve the problem for finite Δ and then take the limit $\Delta \to 0$.

The HJB equation for this problem is

$$\hat{\rho} J(P_{jt}, t) - \partial_t J(P_{jt}, t) = \frac{(1+\hat{\tau})P_{jt} - M_t}{P_t} q_{jt} + \max_\pi \left(-\frac{\hat{\phi} q_t}{2} \pi^2 + \pi P_{jt} \partial_p J(P_{jt}, t) \right) \tag{54}$$

The first-order condition and the envelope theorem lead to

$$P_{jt} \partial_p J(P_{jt}, t) = \pi_{jt} \hat{\phi} q_t \tag{55}$$

$$\hat{\rho} \partial_p J(P_{jt}, t) - \partial^2_{tp} J(P_{jt}, t) = \theta_r \frac{q_{jt}}{P_t} \left(\frac{M_t}{P_{jt}} - (1+\hat{\tau}) \frac{\theta_r - 1}{\theta_r} \right) + \pi_{jt} (\partial_p J(P_{jt}, t) + P_{jt} \partial^2_{pp} J(P_{jt}, t)) \tag{56}$$

Taking the time derivative of equation (55) and plugging into equation (56),

$$\hat{\rho} \hat{\phi} \pi_{jt} q_t = \theta_r q_{jt} \frac{P_{jt}}{P_t} \left(\frac{M_t}{P_{jt}} - (1+\hat{\tau}) \frac{\theta_r - 1}{\theta_r} \right) + \hat{\phi} (\dot{\pi}_{jt} q_t + \pi_{jt} \dot{q}_t) \tag{57}$$

Invoking symmetry across j,

$$\hat{\rho} \hat{\phi} \pi_t = \theta_r (m_t - \bar{m}) + \hat{\phi} \left(\dot{\pi}_t + \frac{\dot{q}_t}{q_t} \right) \tag{58}$$

Here $\bar{m} = (1+\hat{\tau})(\theta_r - 1)/\theta_r$ is the real marginal cost in the static optimum and hence in the steady state. With the subsidy set at $\hat{\tau} = 1/(\theta_r - 1)$, it is equal to 1.

I now take the limit $\Delta \to 0$, so $\hat{\rho} \to \infty$, $\hat{\phi} \to 0$, and $\hat{\rho}\hat{\phi} \to \rho\phi$. In this limit, the managers of the retail firms have extremely short horizon but the cost of price adjustment is very low, so they still have incentives to change prices. In effect, they trade off adjustment costs against losses from suboptimal pricing in the next instant. The Phillips curve takes the following form:

$$\rho \pi_t = \kappa (m_t - 1) \tag{59}$$

with $\kappa = \theta_r/\phi$. Compared to the Phillips curves in Kaplan, Moll, and Violante (2018) and Alves (2019), this Phillips curve is missing the forward-looking term $\dot{\pi}_t$, making it a first-degree differential equation, which improves stability properties of the solution algorithm.

Workers. The solution of worker's problem in equation (4) generates a value function $v_t(a, z)$ and a distribution of agents $g_t(a, z)$ that satisfy Kolmogorov equations. Asset holdings a and labor productivity z are two individual state variables, and all aggregate states are suppressed in the subindex t. The aggregate sequences that the workers have to know are the after-tax wage and the interest rate $\{w_t, r_t(a)\}_t$. Here the dependence of $r_t(a)$ on a reflects that the interest on deposits is not the same as that on loans. The control variables that they choose are consumption $c_t(a,z)$ and labor supply $l_t(a,z)$, which also maps into a choice of the saving rate $s_t(a,z)$. The following lemma characterizes the value function, the distribution of agents, and the choice of control variables. Define the functions $h(\cdot)$ and $\xi(\cdot)$ by $h(\cdot)^{-1} = u'(\cdot)$ and $\xi(\cdot)^{-1} = \chi'(\cdot)$. Denote the switching intensity of the labor productivity by λ_z and the transition probabilities by $p_{zz'}$.

LEMMA 1. The labor supply and consumption of the workers satisfy

$$l_t(a,z) = \xi(w_t \cdot \partial_a v_t(a,z)) \tag{60}$$
$$c_t(a,z) = h(\partial_a v_t(a,z)) \tag{61}$$

The value function $v_t(a,z)$ solves the following Kolmogorov backward equation on $(\bar{a},\infty) \times Z$ on the time scale $(0,\infty)$:

$$\begin{aligned}\rho v_t(a,z) - \dot{v}_t(a,z) = {} & u(h(\partial_a v_t(a,z))) - z\chi(\xi(w_t \cdot \partial_a v_t(a,z))) \\ & + \partial_a v_t(a,z) \cdot (r_t(a)a + zw_t\xi(w_t \cdot \partial_a v_t(a,z)) - h(\partial_a v_t(a,z))) \\ & + \lambda_z \sum_{z'} p_{zz'}(v_t(a,z') - v_t(a,z))\end{aligned} \tag{62}$$

The density $g_t(a,z)$ solves the following Kolmogorov forward equation on $((\bar{a},0) \cup (0,\infty)) \times Z$ on the time scale $(0,\infty)$:

$$\dot{g}_t(a,z) = -\partial_a[g_t(a,z) \cdot (r_t(a)a + zw_t\xi(w_t \cdot \partial_a v_t(a,z)) - h(\partial_a v_t(a,z)))] \tag{63}$$
$$+ \sum_{z'} \lambda_{z'} p_{z'z} g_t(a,z') - \lambda_z g_t(a,z) \tag{64}$$

Proof. (of Lemma 1) The HJB equation for the problem in equation (4) is

$$\begin{aligned}\rho v_t(a,z) - \dot{v}_t(a,z) = {} & \max_{c,l}\Big\{u(c) - z\chi(l) + \partial_a v_t(a,z) \cdot (r_t(a)a + zw_t l - c_t)\Big\} \\ & + \lambda_z \sum_{z'} p_{zz'}(v_t(a,z') - v_t(a,z))\end{aligned} \tag{65}$$

The first order conditions for the control variables c and l are

$$u'(c) = \partial_a v_t(a,z) \tag{66}$$
$$z\chi'(l) = zw_t u'(c) \tag{67}$$

They immediately imply $\chi'(l) = w_t u'(c)$, which translates into $l_t(a,z) = \xi(w_t u'(c_t(z,a)))$. The first one can be rewritten as $c_t(z,a) = h(\partial_a v_t(a,z))$. Plugging this into equation (65) leads to the differential equation (62). The Kolmogorov forward equation for the problem in equation (4) is

$$\dot{g}_t(a,z) + \partial_a[g_t(a,z) \cdot (r_t(a)a + zw_t l_t(a,z) - c_t(a,z))] = \sum_{z'} \lambda_{z'} p_{z'z} g_t(a,z') - \lambda_z g_t(a,z) \tag{68}$$

Plugging the expressions for the optimal $c_t(a,z)$ and $l_t(a,z)$ leads to equation (64). □

Proof. (of Proposition 1) Consider the change in variance of log consumption:

$$\mathbb{V}\left[\ln\left(C_1\right)\right]-\mathbb{V}\left[\ln\left(C\right)\right]=\mathbb{V}\left[\ln\left(C\right)+\Delta_1\right]-\mathbb{V}\left[\ln\left(C\right)\right]=\mathbb{V}\left[\Delta_1\right]+2\mathbb{C}\left[\ln\left(C\right),\Delta_1\right] \tag{69}$$

The first term can be decomposed as

$$\begin{aligned}\mathbb{V}[\Delta_1]&=\mathbb{E}[\Delta_1^2]-\mathbb{E}[\Delta_1]^2=\zeta\mathbb{E}[(\Delta_1^T)^2]+(1-\zeta)\mathbb{E}[(\Delta_1^N)^2]-(\zeta\mathbb{E}[\Delta_1^T]+(1-\zeta)\mathbb{E}[\Delta_1^N])^2\\&=\zeta\mathbb{V}[\Delta_1^T]+(1-\zeta)\mathbb{V}[\Delta_1^N]+\zeta(1-\zeta)(\mathbb{E}[\Delta_1^T]-\mathbb{E}[\Delta_1^N])^2\end{aligned} \tag{70}$$

The second term can be decomposed as

$$\begin{aligned}2\mathbb{C}[\ln(C),\Delta_1]&=2\mathbb{E}[\ln(C)\Delta_1]-2\mathbb{E}[\ln(C)]\mathbb{E}[\Delta_1]=2\zeta\mathbb{E}[\ln(C^T)\Delta_1^T]+2(1-\zeta)\mathbb{E}[\ln(C^N)\Delta_1^N]\\&-2(\zeta\mathbb{E}[\ln(C^T)]+(1-\zeta)\mathbb{E}[\ln(C^N)])(\zeta\mathbb{E}[\Delta_1^T]+(1-\zeta)\mathbb{E}[\Delta_1^N])\\&=2\zeta\mathbb{C}[\ln(C_1^T),\Delta_1^T]+2(1-\zeta)\mathbb{C}[\ln(C_1^N),\Delta_1^N]\\&+2\zeta(1-\zeta)(\mathbb{E}[\ln(C^T)]-\mathbb{E}[\ln(C^N)])(\mathbb{E}[\Delta_1^T]-\mathbb{E}[\Delta_1^N])\end{aligned} \tag{71}$$

Adding everything up,

$$\begin{aligned}\mathbb{V}[\Delta_1]+2\mathbb{C}[\ln(C),\Delta_1]&=\zeta\mathbb{V}[\Delta_1^T]+(1-\zeta)\mathbb{V}[\Delta_1^N]+2\zeta\mathbb{C}[\ln(C_1^T),\Delta_1^T]+2(1-\zeta)\mathbb{C}[\ln(C_1^N),\Delta_1^N]\\&+\zeta(1-\zeta)(\mathbb{E}[\Delta_1^T-\Delta_1^N]^2+2\mathbb{E}[\ln(C^T)-\ln(C^N)]\mathbb{E}[\Delta_1^T-\Delta_1^N])\\&=\zeta\mathbb{V}[\Delta_1^T]+(1-\zeta)\mathbb{V}[\Delta_1^N]+2\zeta\mathbb{C}[\ln(C_1^T),\Delta_1^T]+2(1-\zeta)\mathbb{C}[\ln(C_1^N),\Delta_1^N]\\&+\zeta(1-\zeta)(\mathbb{E}[\Delta_1^T+\ln(C^T)-\Delta_1^N-\ln(C^N)]^2-\mathbb{E}[\ln(C^T)-\ln(C^N)]^2)\\&=\zeta\mathbb{V}[\Delta_1^T]+(1-\zeta)\mathbb{V}[\Delta_1^N]+2\zeta\mathbb{C}[\ln(C_1^T),\Delta_1^T]+2(1-\zeta)\mathbb{C}[\ln(C_1^N),\Delta_1^N]\\&+\zeta(1-\zeta)(\mathbb{E}[\ln(C_1^T)-\ln(C_1^N)]^2-\mathbb{E}[\ln(C^T)-\ln(C^N)]^2)\end{aligned} \tag{72}$$

This completes the proof. □

Proof. (of Proposition 2) Integrating, equation (40) from t to infinity,

$$\ln(e_t)-\lim_{s\to\infty}\ln(e_s)=\frac{1}{1-\phi_\varepsilon}\int_t^\infty\psi_s ds-\frac{\phi_\pi+1-\phi_\varepsilon}{1-\phi_\varepsilon}\int_t^\infty\pi_s ds$$

Since the economy converges to the steady state at infinity, the limit of the real exchange rate is one.

$$\ln(e_t)=\ln\left(\mathcal{E}_t\right)-\ln(P_t)=\frac{1}{1-\phi_\varepsilon}\int_t^\infty\psi_s ds-\frac{\phi_\pi+1-\phi_\varepsilon}{1-\phi_\varepsilon}\int_t^\infty\pi_s ds$$

This leads to equation (41). □.

B Additional Figures

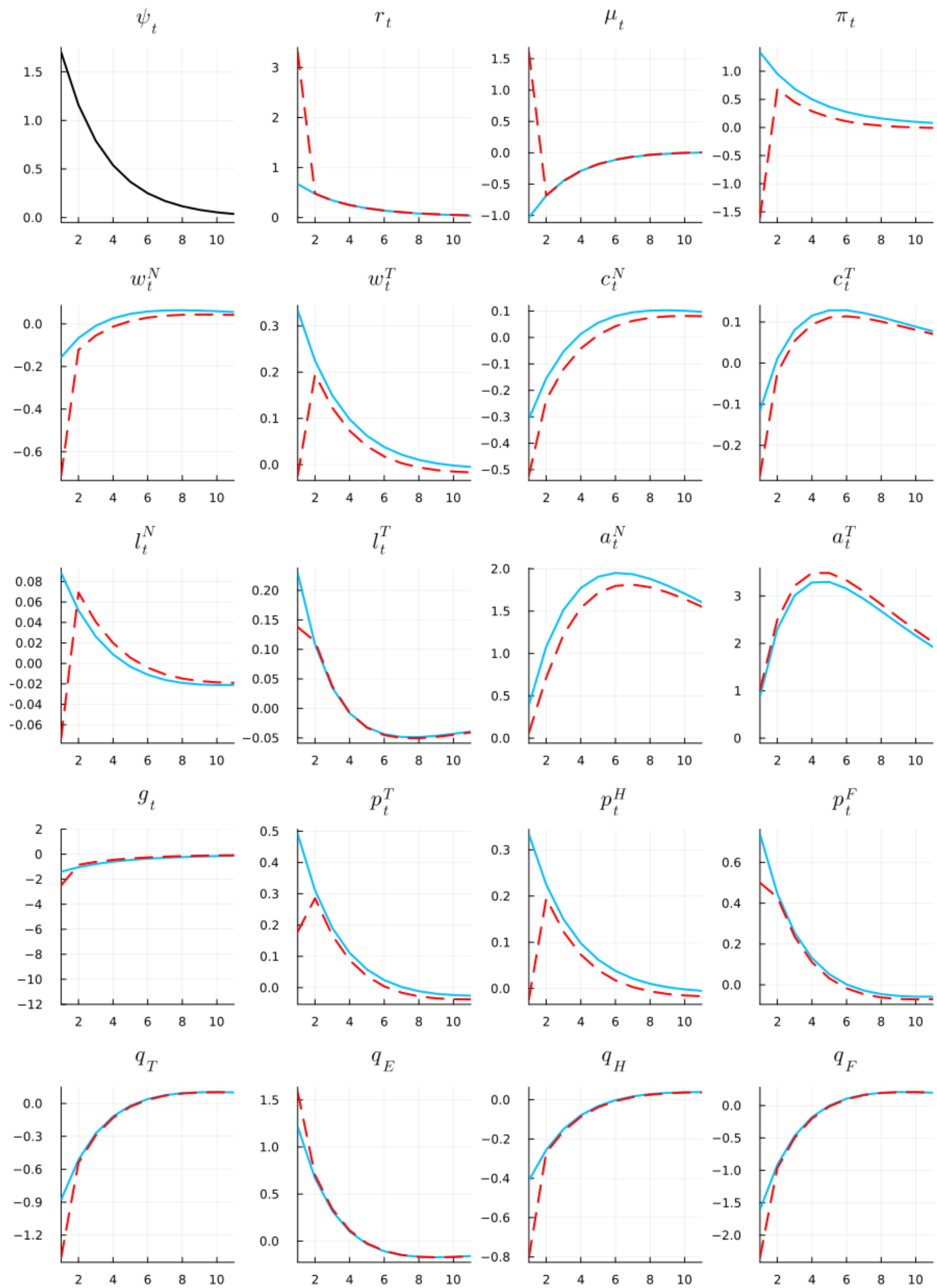

Figure A.1: Impulse responses under float and peg. Units: percentage points and percent.

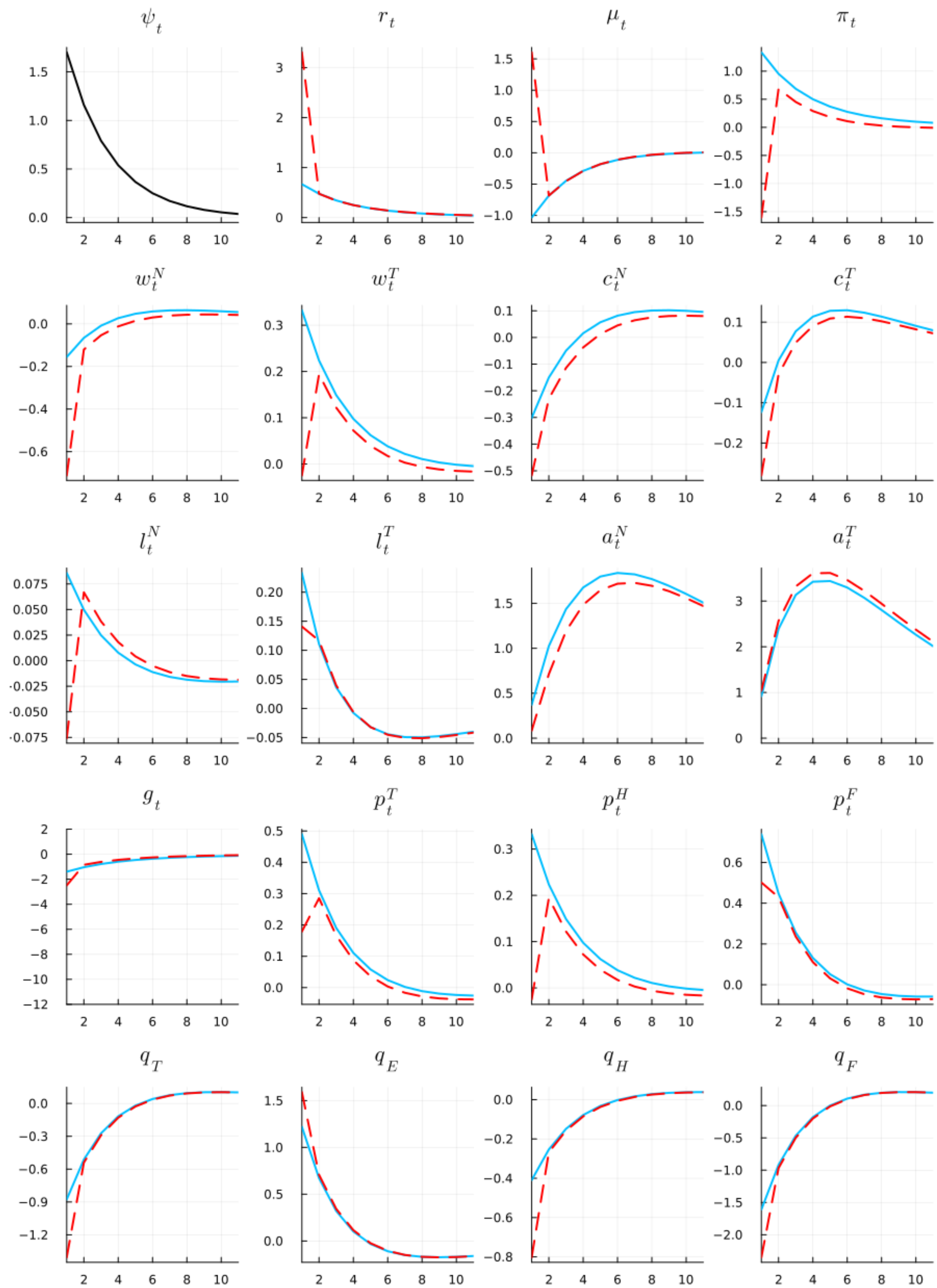

Figure A.2: Impulse responses with the same productivity in the two sectors. Units: percentage points and percent.

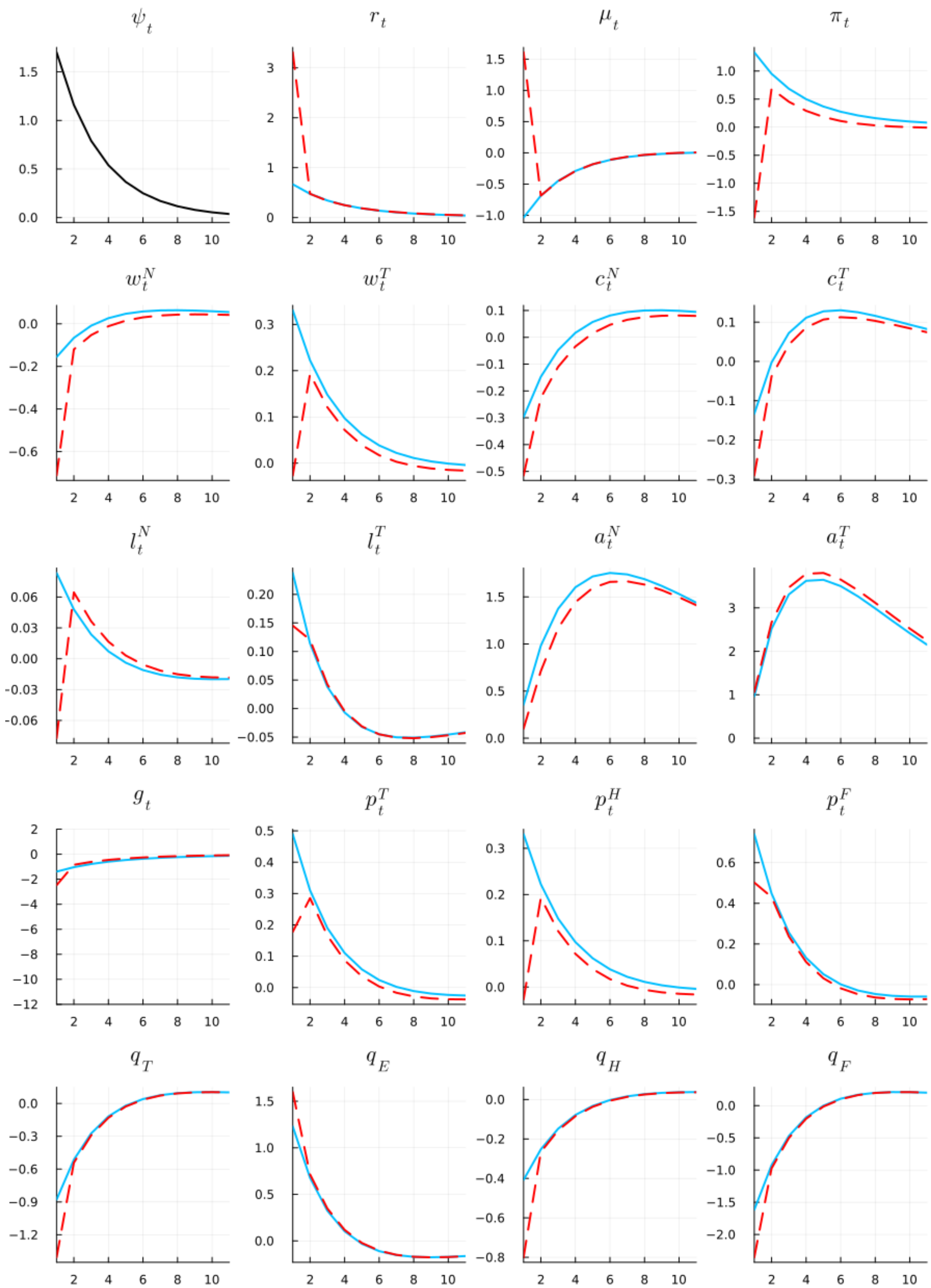

Figure A.3: Impulse responses with workers in tradables less productive. Units: percentage points and percent.

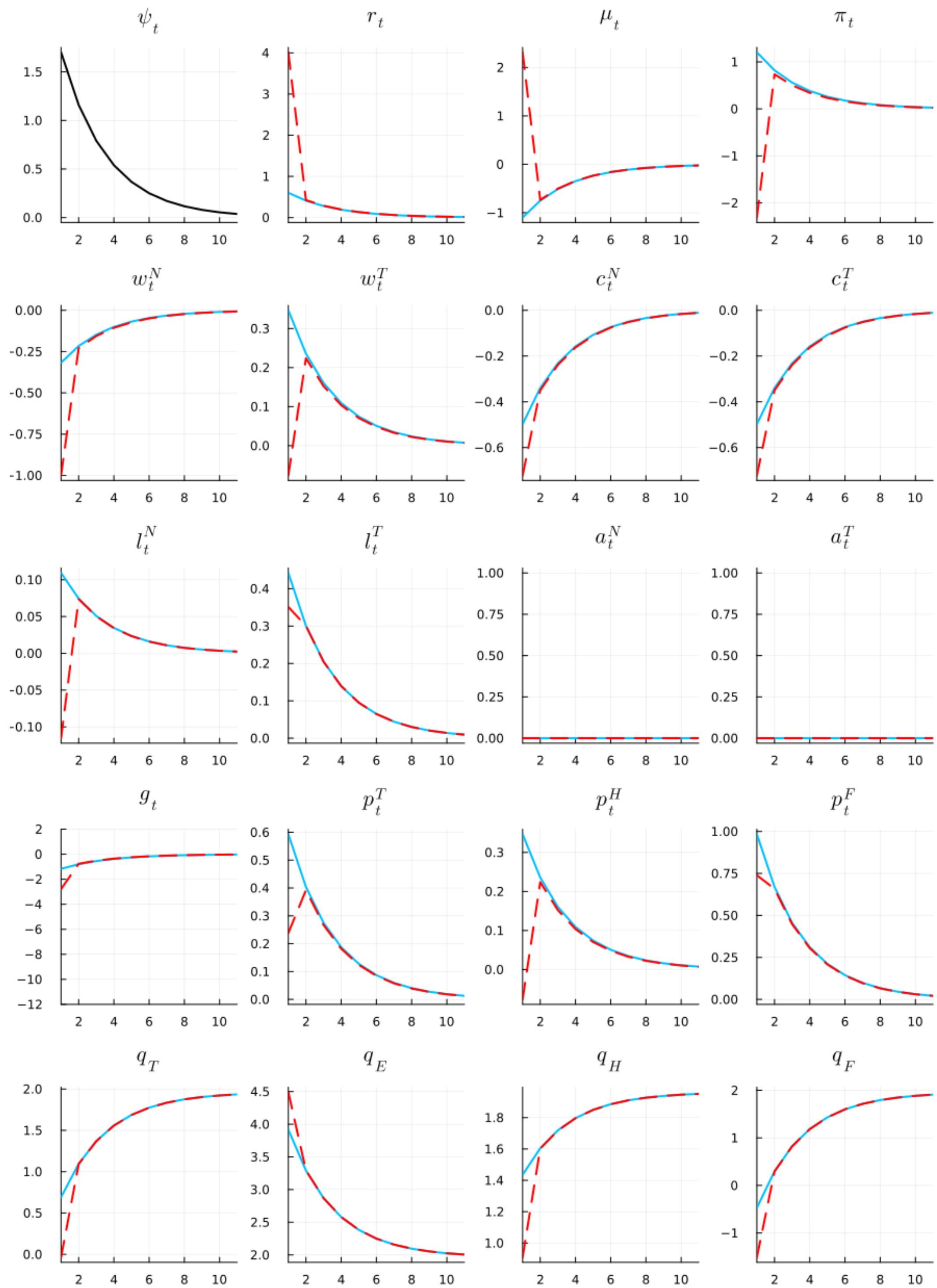

Figure A.4: Impulse responses in a two-sector RANK model. Inflation in percentage points, everything else in percent.

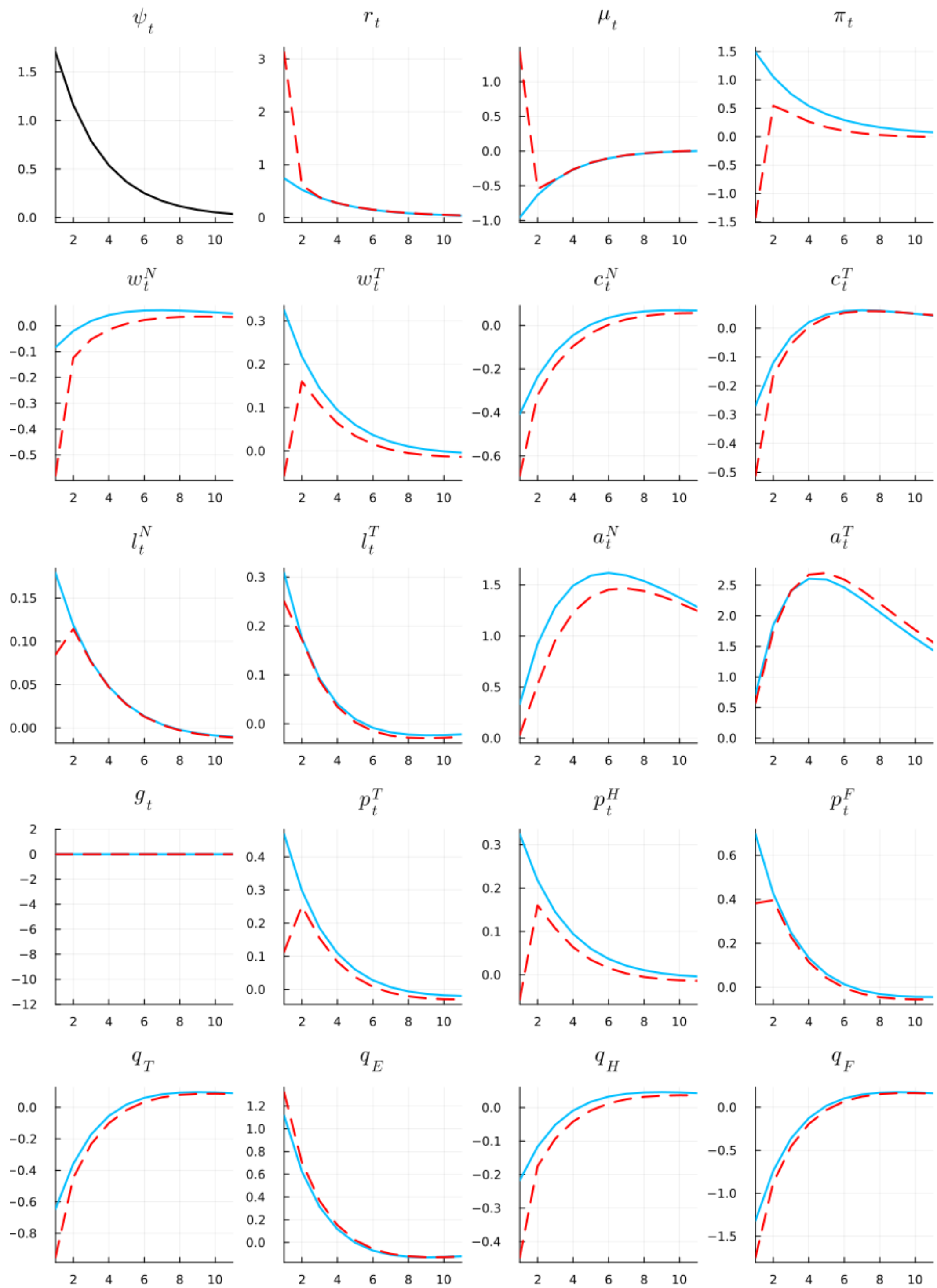

Figure A.5: Impulse responses under proportional taxes. Units: percentage points and percent.

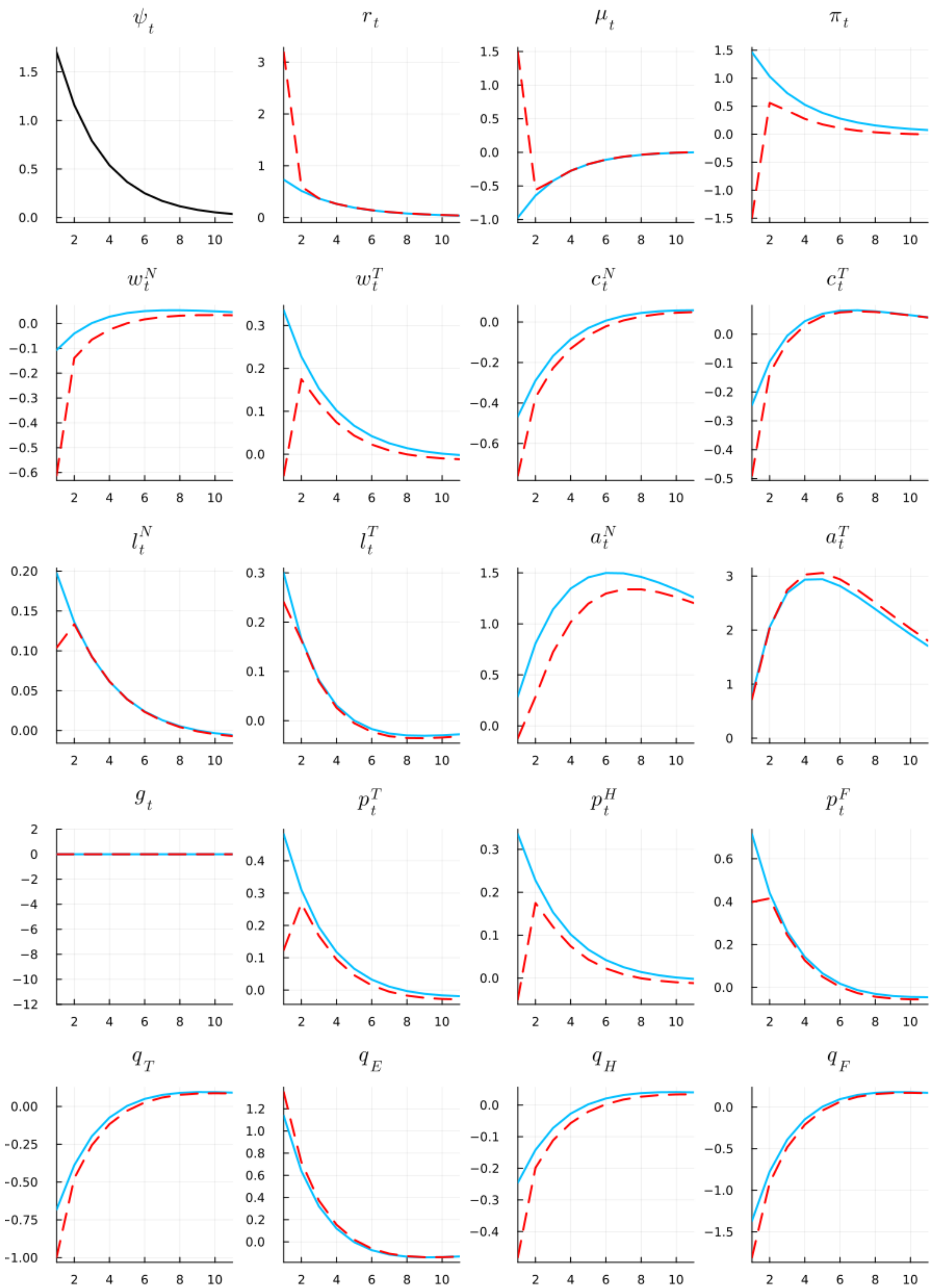

Figure A.6: Impulse responses under flat taxes. Units: percentage points and percent.

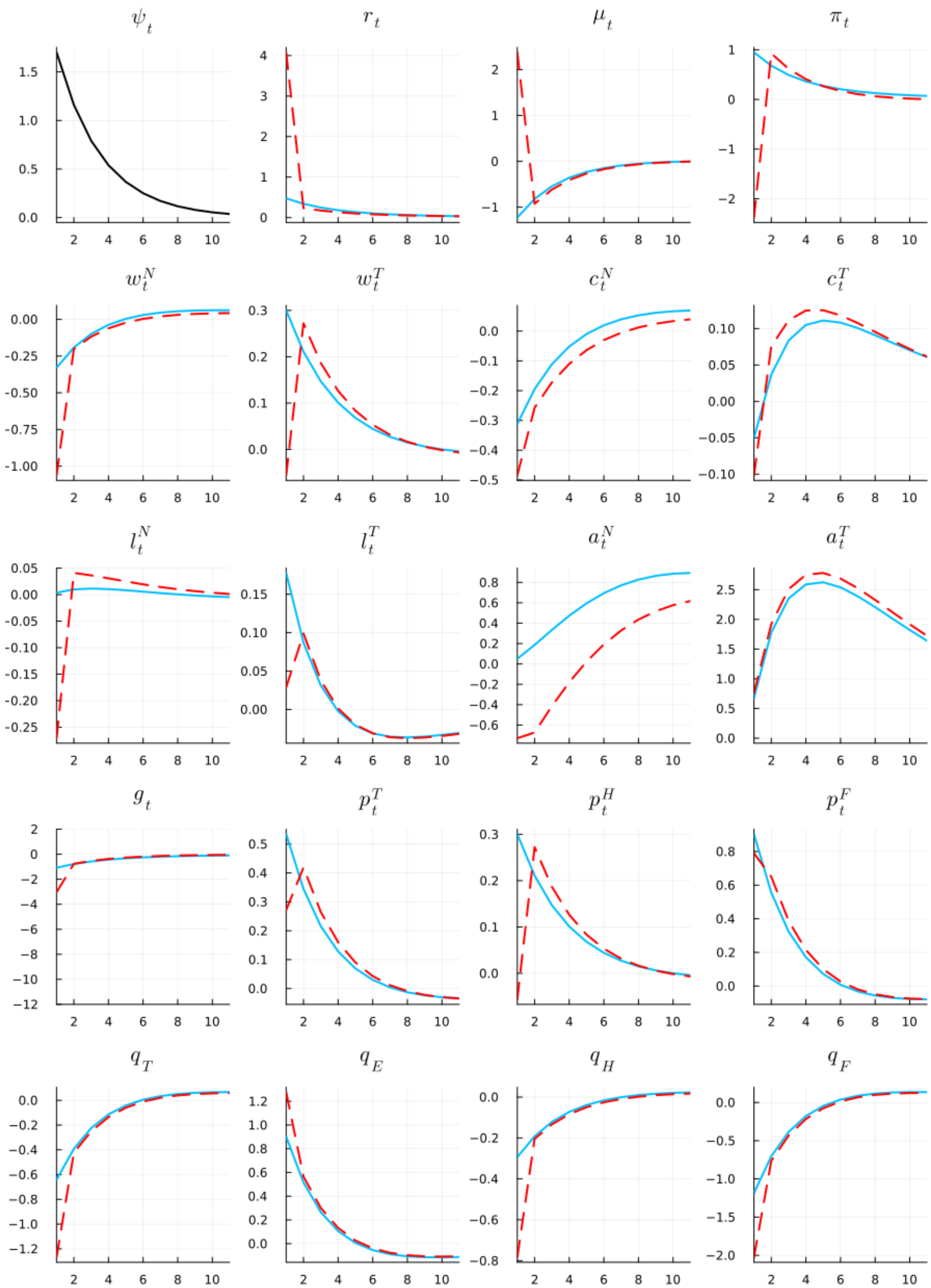

Figure A.7: Impulse responses with $(\theta, \theta_g, \theta_e) = (0.75, 1.5, 1.5)$. Units: percentage points and percent.

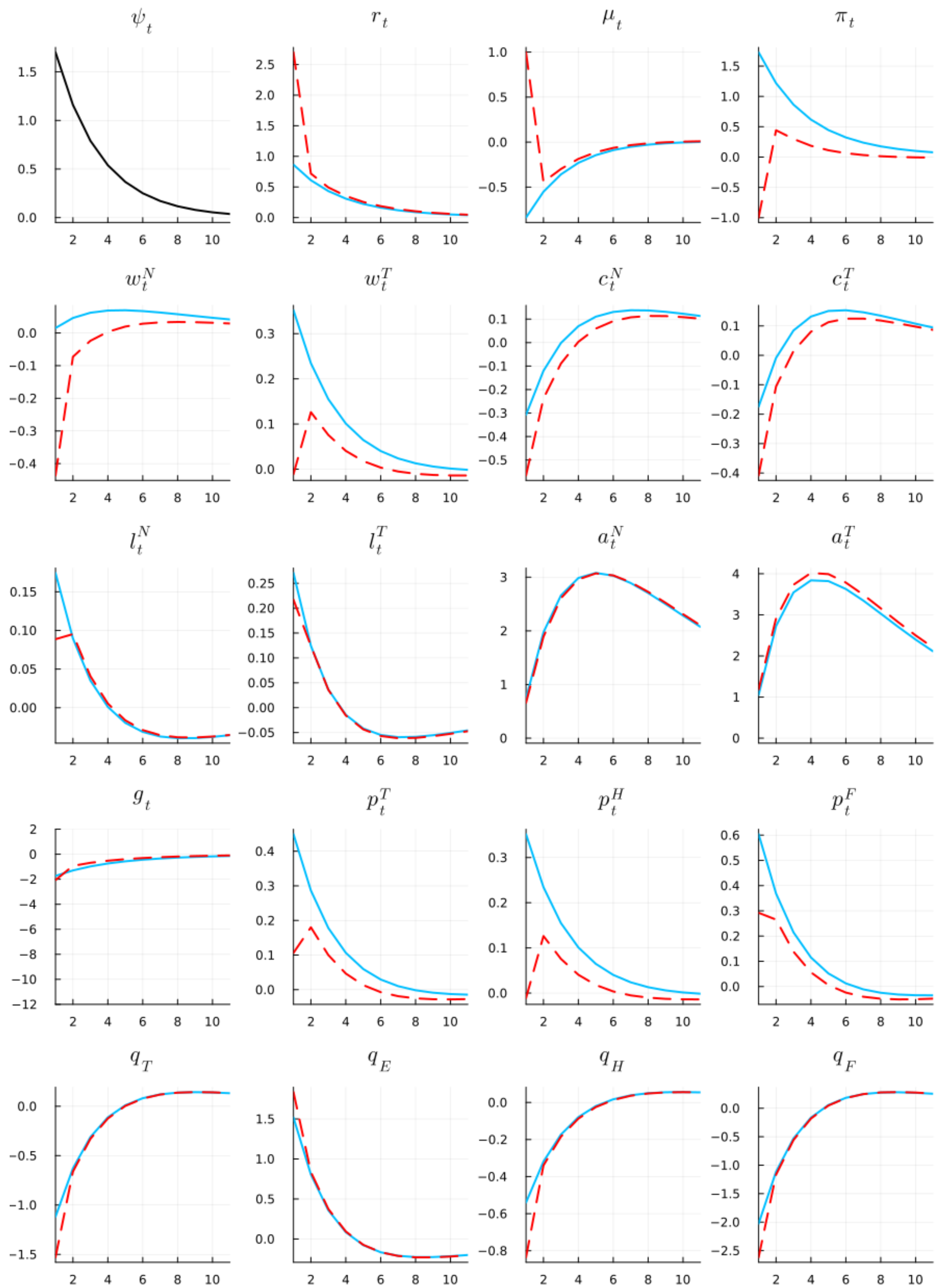

Figure A.8: Impulse responses with $(\theta, \theta_g, \theta_e) = (3, 6, 6)$. Inflation in percentage points, everything else in percent.

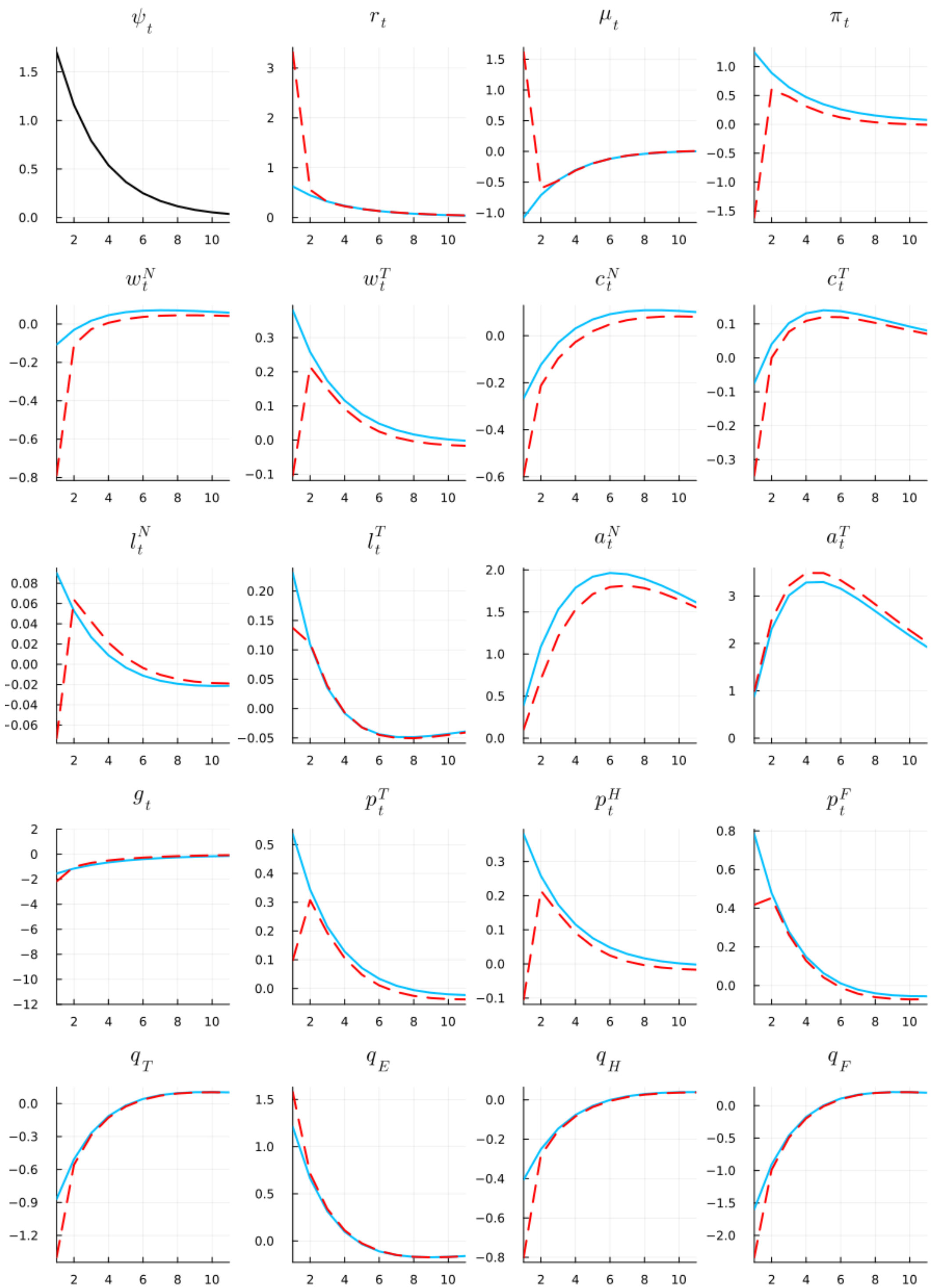

Figure A.9: Impulse responses with $\kappa = 0.005$. Inflation in percentage points, everything else in percent.

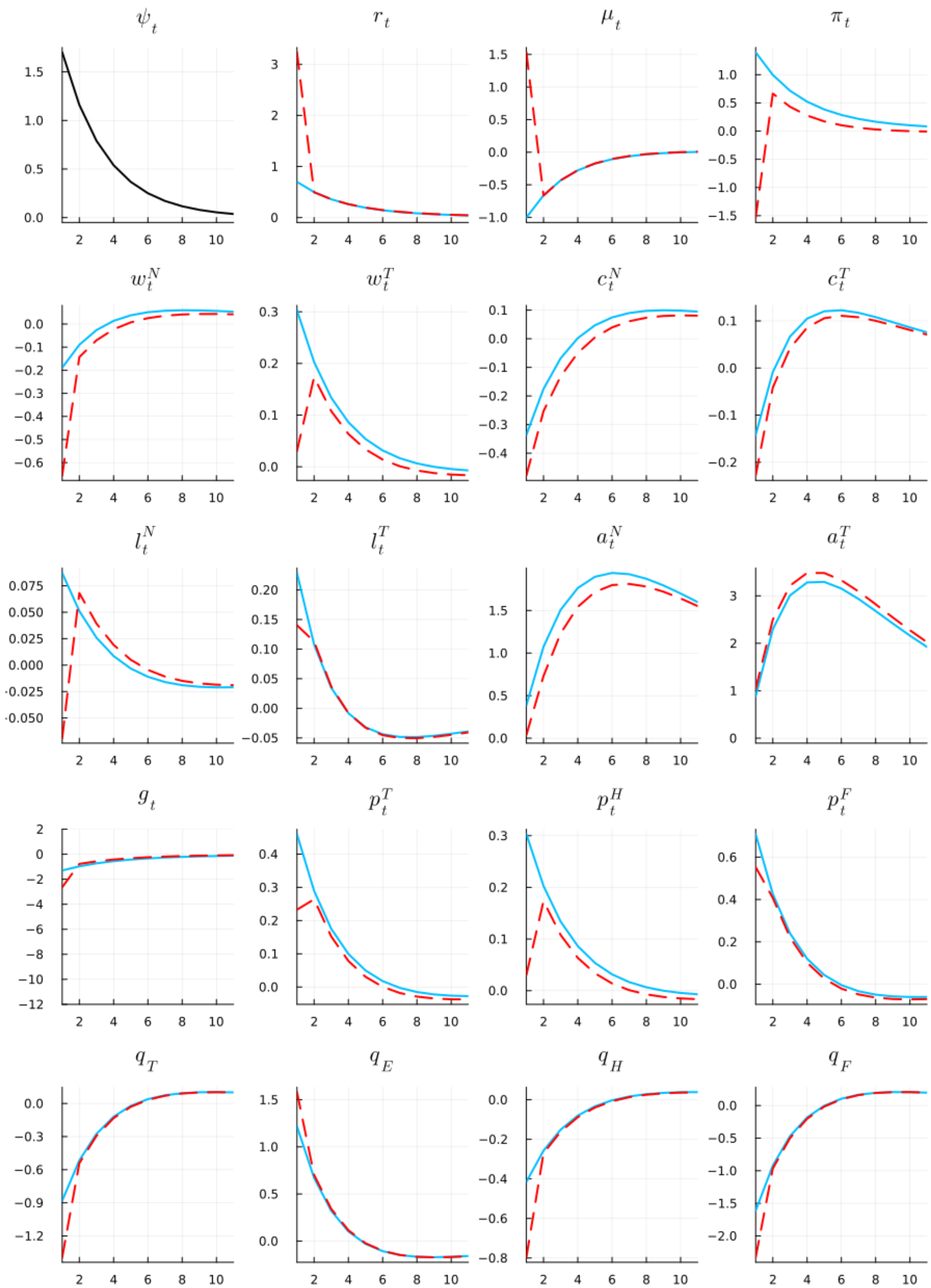

Figure A.10: Impulse responses with $\kappa = 0.0084$. Inflation in percentage points, everything else in percent.

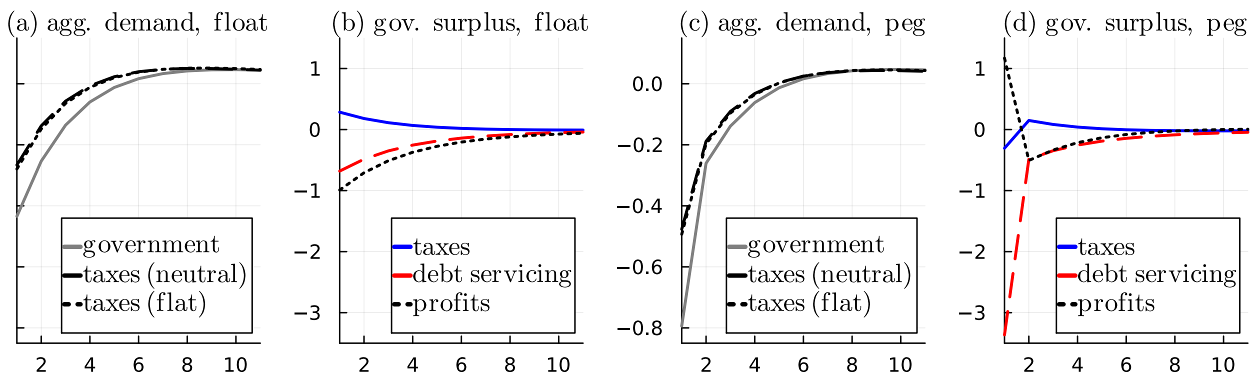

Figure A.11: Responses of aggregate demand under the three fiscal regimes (panels (a) and (c) for float and peg). Responses of components of government expenditures in percent of their steady state value (panels (b) and (d) for float and peg).