A Monetary Policy Framework for Developing Countries*

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Abstract

We present an Open Economy HANK model tailored to capture key characteristics of Low-Income Countries (LICs): (i) poor households with no access to markets (hand-to-mouth) and (ii) a subsistence level of consumption for tradable goods. With the model calibrated for a representative LIC, and motivated by recent macroeconomic developments, we illustrate our framework investigating the consequences of a shock to external prices. We analyze its effects on macroeconomic variables, inequality and poverty. The shock triggers a consumption-led recession, an increase in inflation and a drop in real wages. Consumption inequality increases: poor households can't insure against the shock, while richer households exploit their wealth to shield their consumption. Households at the bottom and at the top of the income distribution are the

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most negatively affected by the shock: the former suffer from lower wages and consumption; the latter from negative revaluations of their assets. Monetary policy has limited ability to improve the welfare of poorer households due to its offsetting effects on real wages and labor demand, a finding consistent across the alternative monetary policy specifications analyzed. In contrast, fiscal transfers are shown to be effective in cushioning the welfare losses among poorer households.
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1 Introduction

A significant proportion of low-income households in developing countries rely heavily on imported food items. The COVID pandemic and the Russian invasion of Ukraine caused a terms of trade shock that has driven up food prices, presenting central banks in these countries with challenging trade-offs. One such critical trade-off is balancing inflation stabilization, on the one hand, with supporting household employment that enables income generation for purchasing essential subsistence goods, on the other hand. Thus, in countries with substantial income disparities, monetary authorities must carefully assess the trade off between deviations in inflation from target and output stabilization due to distributional concerns. Well intended aggressive monetary policy stances to tame inflation might have pervasive employment effects, and hurt the exact households that they are trying to protect in the first place. The trade off will become more stark as the global economy fragments, increasing the frequency and intensity of shocks battering developing countries.

An extensive literature on Monetary Policy has developed frameworks to understand optimal responses to terms of trade and potential other shocks. However, most do not account for rich heterogeneity in income and wealth, which is pervasive in Low-income countries (LICs), and is key to understand whether more aggressive monetary policy stances or alternative monetary policy rules can improve the welfare of households at the lower end of the income distribution. The main goal of our paper is to build such a general framework to analyze alternative monetary policy responses considering rich household-level heterogeneity, and we illustrate its use with a trade shock, as motivated above. We find that trade shocks affect agents in the left tail of the income distribution disproportionately. Our main contribution is to show that most monetary policy rules are not able to improve the welfare of these agents by much. Even though we focus on the impact of external shocks to a small open economy, our model can accommodate other shocks, such as to risk premium, capital flows and productivity.

We begin our paper by building a model of a small open economy, in which consumers cannot perfectly insure income shocks, in the spirit of Kaplan et al. (2018) and Gali et al. (2004). Domestic producers combine capital and labor to produce intermediate and final goods. A competitive investment firm operates the technology that converts home goods into capital. Households supply labor, and building on Auclert et al. (2021a), there is a nominal rigidity, with nominal wage set by a continuum of labor unions. The hours supplied by each of the households are incorporated via a CES aggregator. The union sets the wage to maximize the utility of its members subject to a penalization on changing wages a la Rotemberg (1982). Consumers have access to foreign and domestic goods. The small open economy takes as given the international risk-free rate and price of imported goods. Because we are interested in distributional issues, our households are heterogeneous in terms of productivity.

Our model has two key features that we believe are important for low-income countries: limited financial market participation and subsistence preferences. First, a fraction of consumers do not participate in the financial market. Hence, consumers are either financially included or excluded, on top of their productivity differences. Financially included consumers invest in a risk-free bond, and own shares in the investment fund, whereas financially excluded do not have any means to smooth consumption. Although a stark assumption, limited financial inclusion is pervasive in LICs, and captures the evidence of a persistent higher share of 'hand-to-mouth' consumers in these countries, regardless of a history of shocks (see, for example, Demirguc-Kunt et al., 2022; Demirgüç-Kunt and Klapper, 2012).[1] Second, we focus on the case with a subsistence level of consumption for imported goods. LICs feature a large level of staple consumption (see for example, Unsal et al., 2022). The equilibrium response that subsistence preferences imply is that households in different points of the income distribution consume distinct baskets, and in addition, that these baskets change continuously with income levels, which is consistent with the evidence for emerging markets on non-homothetic preferences (see, for example,

[1] Dabla-Norris et al. (2021) shows the relevance of different financial constraints for credit with a heterogeneous agents setting. For some LICs, entry costs are significant.

Cravino and Levchenko, 2017). In addition, Portillo et al. (2016) shows that the effects of subsistence go beyond changes in consumption baskets, meaning less substitutability in response to food shocks.

Using this rich framework of a standard HANK model reshaped to incorporate key idiosyncrasies in LICs, we then proceed to the quantitative implementation by calibrating it to match key features of LICs. The model is solved by using highly efficient solutions methods proposed by Auclert et al. (2021a), in which the algorithm for transitional dynamics updates guesses following a Newton's method, using sequence-space Jacobians. The advantage of this methodology is that does not rely on techniques to approximate the equilibrium distribution or value functions and still allows us to capture the richness of non-linearities from idiosyncratic shocks to heterogeneous agents in the presence of aggregate shocks.

Regarding the *positive implications* of the shock to food prices, the model produces intuitive responses in terms of aggregates. As a result of the shock, inflation and the nominal interest rate increase, the latter coming from the central bank's reaction via a Taylor rule. The uncovered interest rate parity implies that the nominal exchange rate appreciates, leading to a real exchange rate appreciation. The government increases taxes to pay higher interest rates on debt. Consumers can only cut consumption of foreign goods within subsistence levels, which means they need to adjust their purchases of the domestic good. Due to the appreciation of the exchange rate, exports also fall. As a result of lower consumption and exports, the home country suffers a recession. In addition, because of low activity and high inflation, the real wage drops.

The food price shock also leads to significant distributional impacts, with an immediate increase in consumption inequality. Lower productivity households are disproportionately affected due to a drop in real wages, which compresses their labor income. This is a result that permeates all of our exercises. In contrast, financially included, higher productivity households can use their accumulated assets to smooth out the impact, resulting in less suffering compared to financially excluded households. Analyzing the distribution of agents based on their cash-on-hand (COH) levels reveals an increase in the mass of agents with below steady-state COH and a decrease in those with above steady-state COH immediately after the shock. As the shock fades, the distributions gradually return to their steady-state values.

We then shift to a *normative analysis*, evaluating the welfare effects of the shock. The welfare criterion measures the loss in steady-state income that would yield the same utility as the shock to agents. Households with lower initial cash-on-hand (COH) levels experience larger welfare drops, primarily due to the decrease in real wages. Financially excluded (FE) agents, who rely solely on labor income, are adversely affected, especially those with low productivity levels and COH positions. Similarly, financially included (FI) households with lower COH levels and productivity suffer the most. Interestingly, top quantile households experience slightly more negative effects than middle and high quantiles, as their income mainly comes from returns on assets. The shock's impact on output causes a negative revaluation of their investment firm equity, which they are sensitive to. In a counterfactual scenario where FI households' assets are not negatively revalued, the welfare effect would be less severe for households with lower initial COH positions.

What are the effects of less aggressive interest rate rules? We examine different monetary policy reactions by comparing the baseline scenario with an alternative one in which the monetary authority is less aggressive against inflation. It leads to higher inflation, a smaller GDP drop, and a greater decrease in real wages due to the presence of sticky nominal wages. While households at the bottom of the Cash-on-Hand (COH) distribution experience a slightly smaller welfare drop, those with higher COH positions face a more significant negative impact. There are two opposing effects at work here: a larger drop in real wages due to higher inflation, and a smaller reduction in hours worked because of the less significant output decrease. The two almost offset each other, resulting in very small welfare gains to low-income households from lower reduction of worked hours due to the milder recession. Therefore, the Central Bank seems mostly unable to engineer an outcome that is unambiguously favourable for low-income households.

This is confirmed by looking at other alternative rules. When the Central Bank adjusts interest rates gradually in response to changes in inflation (interest rate smoothing), inflation increases more than in the baseline scenario but decreases quicker. This slower response shifts the timing of the movements in aggregate demand, and the welfare effects of the shock with interest rate-smoothing show that all agents are slightly better off under this rule in comparison to the baseline. Alternatively, when the central bank targets the price of imports (the source of the shock in the baseline), there is a much larger increase in the real rate, a larger decrease in domestic demand and output, and inflation spikes less. The drop in labor demand is particularly harmful to low cash-on-hand (COH) households. Except for high COH households, the shock is more costly in this scenario. As expected, when the central bank targets only domestic prices, as "seeing through" the shock and reacting only to contamination of "core" prices, rates react less to inflation. The recession is slightly less pronounced, but much longer. All quantiles seem to benefit in terms of welfare, with more improvement for those in the top. Using an alternative shock to UIP premium (calibrated to generate the same monetary policy reaction) shows similar dynamics, with the exchange rate benefiting activity, which leads to a smaller compression in consumption. Nonetheless, in distributional terms, the lower quantiles are once again hit harder.

Given the result that monetary policy is to a certain extent unable to improve distributional outcomes following a shock, we also present a specification in which bottom quantiles receive transfers that translate into higher taxes to other quantiles. The effects on macro variables are small in comparison to the baseline scenario, but the policy is able to offset to a great extent the welfare loss of bottom quantiles.

Literature review. Our paper is closely related to a recent stream of literature that studies the transmission of external shocks in small open economies with rich heterogeneity at the micro level. This stream has been successful in exploring classic topics of international macroeconomics such as contractionary devaluations (Auclert et al., 2021b), the impact of financial and real integration for the conduct of monetary policy (Guo et al., 2020), the response to capital flow shocks when there is liability dollarization (Zhou, 2022; De Ferra et al., 2020), exchange rate policy (Oskolkov, 2023) and fear of floating (De Ferra et al., 2020).[2] The literature focused mostly on developed markets and emerging economies. As in most of these papers, we study an open economy model with limited insurance of income shocks, and nominal rigidities, building on the closed economy lessons of Kaplan et al. (2018) and on the open economy framework of Gali et al. (2004). Differently from the previous literature, our focus is to understand monetary policy in LICs.

The environment in our paper is closely related to the ones of Auclert et al. (2021b), Auclert et al. (2021a), and De Ferra et al. (2020). We adopt the solution method developed in Auclert et al. (2021a), and focus on sticky wages as the nominal rigidity. As in Auclert et al. (2021b), the real income channel plays an important role in the transmission of the

[2] Closely related to this agenda is Cugat et al. (2019), which focuses on a Two Agent New Keynesian model, building on the work of Debortoli and Galí (2017).

external shock. Differently from Auclert et al. (2021b), we study an economy with capital accumulation and, following the evidence for Low-Income countries, non-financially included households and non-homothetic preferences. In addition, we study a terms of trade shock, and the impact of alternative interest rules over welfare, whereas Auclert et al. (2021b) studies a depreciation shock, and the focus is on aggregates and the positive implications. As in De Ferra et al. (2020), we study an open economy heterogeneous agent model with capital accumulation. Among others, there are two main differences with this paper: non-homothethic preferences and limited asset market participation, which are both characteristic features of LICs. Non homothetic preferences are key to our contractionary response of aggregates and distributions to the food price shock. In addition, we also focus on shocks to the terms of trade whereas De Ferra et al. (2020) studies a shock to capital flows.

Our paper is part of large literature that studies terms of trade shocks in Emerging and Low-Income countries. The initial contributions tried to understand whether terms of trade shocks could drive the business cycle (see for example, Mendoza, 1995; Kose, 2002; Kehoe and Ruhl, 2008; Corsetti et al., 2007), while more recent work casts doubt on the ability of terms of trade shocks in driving fluctuations (see, for example, Schmitt-Grohé and Uribe, 2018). Most of this literature focuses on representative agent models, while our work focuses on the distributional impact. A recent exception closely related to our work is Auclert et al. (2023), which studies the implications of a shock to the oil prices, and Aggarwal et al. (2022), which looks at the evolution of the world's balance of payment after the Covid-19 pandemic. Our contribution to the literature of terms of trade shocks is to highlight how a preference for the left tail of the distribution could lead a central bank to allow for higher inflation than the target as a response to the shock.

Finally, our paper relates to a large literature that studies monetary and fiscal policies transmission mechanisms in low-income and low middle-Income countries. This body of work emphasizes that the transmission mechanism of monetary policy in LICs is weak, as emphasized by, for example, Mishra et al. (2012), Mishra and Montiel (2013) and Acharya (2017), and that the channel by which monetary policy affects the real economy is through the banking sector. Mishra et al. (2014) finds that LICs exhibit a weaker transmission of monetary policy into bank lending rates than developed and emerging markets. Although this view is somehow disputed (for example, by Berg et al., 2013),[3] by limiting

[3]Li et al. (2016) offers a methodological explanation for differences in findings, especially those from

consumption sensitivity to real rates and allowing for financial exclusion for part of the population, our paper captures this limited pass-through, for other reasons. As explained above, When comparing our baseline results with those of using a less aggressive monetary policy in a model calibrated for LICs, we find relevant effects for macro variables and distribution, meaning that monetary policy is being transmitted.

On the theoretical side, Portillo et al. (2016) studies how subsistence requirements in food consumption affect the design of monetary policy in a RANK model. The main conclusion is that optimal policy calls in most cases for the stabilization of sticky prices non-food inflation, roughly correspondent to core inflation, even in the presence of subsistence. We find similar results in a HANK framework when using a monetary policy rule that focuses on domestic prices, which correspond to core inflation in our setting. By combining heterogeneous agents with an open economy, our paper highlights other mechanisms affecting the outcome of monetary policy, such as the effects of the response of agents that are able to smooth consumption.[4] A recent modelling contribution focusing on the case of Zambia is Baldini et al. (2015), which develops a monetary policy model with lack of financial inclusion, transmission of monetary policy through the banking sector, specific modelling of monetary aggregates, and lack of secondary markets for assets. Peralta-Alva et al. (2023) studies the welfare impact of alternative measures for fiscal consolidation in a model with heterogeneous agents, segmented labour markets and sectors of different productivity levels calibrated for Ethiopia. We also find that the the fiscal response to monetary policy is a determinant of the monetary transmission mechanism in LICs, a result that aligns with and expands the findings of Caramp and Silva (2022), which uses a standard calibration for a RANK model.

The next section presents the model, followed by the quantitative analysis and a brief conclusion.

VAR-based inference. Lack of transparent communication may also play a role. See Adam et al. (2018) for a summary of the discussion in the 2010s. Clarification on monetary policy transmission power in LICs might come from increasingly use of micro-data for research.

[4] Portillo et al. (2016) includes an extension with financial exclusion, but the agents with access to financial instruments are not able to smooth consumption in a closed economy with zero net supply of assets.

2 Model

We build on the setup of Auclert et al. (2021b) and De Ferra et al. (2020) and study a one asset, heterogeneous agents, open economy model, with wage rigidity and capital accumulation. There are two key features in our environment. First, a fraction of the households are poor and have no access to the financial market. This fact is in line with the evidence from developing economies as documented in Demirguc-Kunt et al. (2022).[5] Second, there is a subsistence level of consumption for tradable goods, which we introduce via Stone Geary preferences. These preferences imply that the poor spend relatively more on tradable goods, which is in line with the evidence of Cravino and Levchenko (2017) for the 1994 Mexican devaluation.[6] These preferences also introduce an externality between rich and poor households, because rich households do not internalize that their consumption decisions affect the prices that poor households face. As a result, perfect home good price stabilization might not be a desirable outcome, as shown in Fanelli and Straub (2020), which differs from Gali and Monacelli (2005).

Households. Time is discrete and there are no aggregate shocks to the economy. Households are subject to idiosyncratic shocks to their labor productivity. These shocks are indexed by the variable $e_{i,t}$, which follows a Markov chain on the space $\{e^1, \dots, e^S\}$. Households belong to one of two groups: *Financially excluded* (*FE*) and *Financially included* (*FI*). *FE* households are of size $\lambda \in [0, 1]$ and do not participate in financial markets. On the contrary, *FI* households can save in real government bonds and in the equity of an investment firm.

Preferences. Households have preferences that can be represented by the following sepa-

[5] There is also large evidence of limited asset market participation in developed markets. See for example Mankiw and Zeldes (1991), Vissing-Jørgensen (2002), Parker and Vissing-Jorgensen (2009), and Guvenen (2009), among many others studies.

[6] For recent studies documenting the impact on different groups of consumers of price changes see Argente and Lee (2021) and Jaravel (2019).

rable utility function:

$$\mathbb{E}_0\left[\sum_{t=0}^{\infty}\beta^t U(c,n)\right], \tag{1}$$

$$U(c,n) = u(c) - v(n) = \frac{c^{1-\sigma}}{1-\sigma} - \psi\frac{n^{1+\phi}}{1+\phi}, \tag{2}$$

$$c = \left[(\chi)^{\frac{1}{\eta}}(c_H)^{\frac{\eta-1}{\eta}} + (1-\chi)^{\frac{1}{\eta}}(c_F-\bar{c})^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}}. \tag{3}$$

In the equations, c is the consumption basket, defined in equation (3), n are hours worked, c_H is consumption of the home good, c_F is consumption of the foreign good, σ is the elasticity of intertemporal substitution, ϕ is the Frisch elasticity of labor supply, χ is weight of the home good in the consumption basket, and η is the elasticity of substitution between domestic and foreign goods. Importantly, the consumption basket in (3) is a non-homothethic CES aggregator, where non-homotheticity arises due to the presence of a subsistence level for the consumption of the foreign good, $\bar{c}$. As we document in appendix B, the inclusion of $\bar{c}$ allows us to better capture specific features of LICs. Before moving to the description of the problems faced by the different households, note that we can re-write the consumption basket in equation (3) with an appropriate re-labelling of foreign consumption:

$$\begin{aligned}
\tilde{c_F} &:= c_F - \bar{c}, \\
\tilde{c} &:= \left[(\chi)^{\frac{1}{\eta}}(c_H)^{\frac{\eta-1}{\eta}} + (1-\chi)^{\frac{1}{\eta}}(\tilde{c_F})^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}}.
\end{aligned} \tag{4}$$

Moreover, the price index P_t associated with the consumption aggregator in equation (4) is given by:

$$P_t = \left[\chi P_{H,t}^{1-\eta} + (1-\chi)P_{F,t}^{1-\eta}\right]^{\frac{1}{1-\eta}}, \tag{5}$$

where $P_{F,t}$ and $P_{H,t}$ are, respectively, the foreign and domestic good prices.

Financially excluded households (FE). FE households are hand-to-mouth agents that solve the following programming problem:

$$\begin{aligned}
V_t^{FE}(e_t) \quad &= \quad \max_{\{c_{H,t},c_{F,t}\}} u(c_t) - v(n_t) + \beta\mathbb{E}_t[V_{t+1}(e_{t+1})], \\
\text{s.t.} \quad & \frac{P_{H,t}}{P_t}c_{H,t} + \frac{P_{F,t}}{P_t}c_{F,t} = z_t, \\
& z_t = w_t e_t n_t - \frac{P_{H,t}}{P_t}Tax_t,
\end{aligned}$$

where w_t is the real wage, expressed in terms of the economy's price index (i.e., $w_t = \frac{W_t}{P_t}$), and Tax_t are lump sum taxes.[7] Households choose consumption of the domestic and foreign good, which are given by the tuple $c_{H,t}, c_{F,t}$. As it is standard in models with sticky wages, hours worked, n_t, are chosen by a labor union, so that households don't optimize over such variable. Following the re-labelling of equation (4), the problem of *FE* households can be re-written as:

$$
\begin{aligned}
V_t^{FE}(e_t) \quad &= \quad \max_{\{\tilde{c}_t\}} u(\tilde{c}_t) - v(n_t) + \beta \mathbb{E}_t[V_{t+1}(e_{t+1})], \\
\text{s.t.} \quad & \tilde{c}_t = z_t - \frac{P_{F,t}}{P_t}\bar{c}, \\
& z_t = w_t e_t n_t - \frac{P_{H,t}}{P_t} Tax_t.
\end{aligned}
$$

Given our CES structure, it follows that optimal consumption choices will be given by:

$$
c_{H,t} = \chi \left(\frac{P_{H,t}}{P_t} \right)^{-\eta} \tilde{c}_t, \tag{6}
$$

$$
c_{F,t} = (1-\chi) \left(\frac{P_{F,t}}{P_t} \right)^{-\eta} \tilde{c}_t + \bar{c}. \tag{7}
$$

Equation (7) highlights the implications of introducing a subsistence level of consumption in imported goods. In particular, relative to a scenario with a subsistence level equal to zero, $\bar{c} = 0$, the demand for foreign goods is less elastic. This is consequence of the fact that, regardless of the relative price of foreign goods, domestic households will need to consume at least $\bar{c}$ units of the imported good. In other words, the demand of foreign goods is non-homothethic, and as prices of foreign goods increase, consumers will devote a large fraction of total expenditure to these goods.

Financially included households (FI). FI households do participate in financial markets. Accordingly, following the re-labelling of equation (4), their programming problem can be written as:

$$
\begin{aligned}
V_t^{FI}(a_t, e_t) \quad &= \quad \max_{\{\tilde{c}_t, a_{t+1}\}} u(\tilde{c}_t) - v(n_t) + \beta \mathbb{E}_t[V_{t+1}(a_{t+1}, e_{t+1})], \\
\text{s.t.} \quad & \tilde{c}_t + a_{t+1} = (1+r_t)a_t + z_t - \frac{P_{F,t}}{P_t}\bar{c}, \qquad (8) \\
& z_t = w_t e_t n_t - \frac{P_{H,t}}{P_t} Tax_t, \\
& a_{t+1} \geq \underline{a},
\end{aligned}
$$

[7] In our benchmark calibration, taxes are allocated proportionally to the household's productivity level, e_t, so that more productive households pay more taxes to the government.

where a_t captures the value of household assets, $\underline{a}$ is the borrowing constraint, and r_t is the real interest rate on assets. The solution to this programming problem defines $\tilde{c}_t$, which is then allocated to foreign and domestic goods also according to equations (6) and (7).

Labor unions. We introduce sticky wages into our setting following Auclert et al. (2018). Each household i is assumed to provide their hours of work, n_i, to a continuum of unions indexed by k. Each union k aggregates hours into a union-specific task, $N_{k,t} = \int e_{i,t} n_{i,k,t}$, where $n_{i,k,t}$ are the hours that household i provides to union k. Union-specific tasks are then aggregated into employment services, N_t through a CES aggregator with elasticity of substitution ϵ:

$$N_t = \left(\int_k N_{k,t}^{\frac{\epsilon-1}{\epsilon}} \right)^{\frac{\epsilon}{\epsilon-1}}. \tag{9}$$

Employment services are then sold to firms at the nominal wage W_t. The union sets the wage as to maximize the average utility of its members subject to an extra additive quadratic disutility term: $\frac{\xi}{2} \int_\kappa \left(\frac{W_{\kappa,t}}{W_{\kappa,t-1}} - 1 \right)^2$. We assume that the union allocates hours demanded by firms equally across its members, so that all households end up working the same amount of hours. As shown in Auclert et al. (2018), this setting implies the following Wage New Keynesian Phillips Curve:

$$\pi_t^W = \kappa \left(\frac{v'(N_t)}{\frac{\epsilon}{\epsilon-1} w_t (\lambda u'(C_t^{FE}) + (1-\lambda) u'(C_t^{FI}))} - 1 \right) + \beta \pi_{t+1}^W, \tag{10}$$

where $\pi_t^W = \frac{W_t}{W_{t-1}} - 1$ and $\kappa = \frac{\epsilon}{\xi}$.

Firms. Firms produce consumption goods using labor and capital according to a Cobb-Douglas production function: $Y_t = K_t^\alpha L_t^{1-\alpha}$, where K_t is capital used in production, and L_t is labor in effective units.[8] The firm's maximization implies:

$$w_t = \frac{P_{H,t}}{P_t} (1-\alpha) Y_t / L_t, \tag{11}$$

$$r_t^k = \alpha Y_t / K_t, \tag{12}$$

where r_t^k denotes the marginal product of capital. Equation (11) implies the following relation between π_t^W and $\pi_t^H = \frac{P_{H,t}}{P_{H,t-1}} - 1$:

$$1 + \pi_t^H = (1 + \pi_t^W) \frac{N_t / Y_t}{N_{t-1} / Y_{t-1}}. \tag{13}$$

[8] Raw hours worked times the idiosyncratic productivity of the household providing the hours worked.

Foreign demand. Foreign demand for domestic goods is computed assuming that foreign households face a problem analogous to the one faced by domestic consumers. As a consequence, the optimal demand of domestic goods by foreign households, $C^*_{H,t}$ is given by:

$$C^*_{H,t} = (1-\chi^*)\left(\frac{P^*_{H,t}}{P^*_t}\right)^{-\eta^*} C^*, \tag{14}$$

where $P^*_{H,t}$ is the price of the domestic good expressed in foreign currency, P^*_t is the foreign price index, χ^* is the weight of the foreign good in the foreign consumption basket, η^* is the elasticity of foreign and domestic goods in the foreign consumption basket, and C^* is foreign aggregate demand.

Real exchange rate. We assume that the foreign central bank keeps foreign inflation constant, and normalize $P^*_t = P^* = 1$. Together with the assumption of dealing with a small open economy, it follows that $P^*_{F,t} = P^*_t = 1$. Additionally, given the nominal exchange rate $\mathcal{E}_t$, the law of one price holds:

$$P_{H,t} = \mathcal{E}_t P^*_{H,t}, \tag{15}$$

$$P_{F,t} = \mathcal{E}_t P^*_{F,t} = \mathcal{E}_t. \tag{16}$$

Let us define the real exchange rate as:

$$\mathcal{Q}_t = \frac{\mathcal{E}_t P^*_t}{P_t} = \frac{\mathcal{E}_t}{P_t}. \tag{17}$$

Combining equations (5), (15), (16) and (17), we can define three important objects:

$$\frac{P_{H,t}}{P_t} = \left(\frac{1-(1-\chi)\mathcal{Q}_t^{1-\eta}}{\chi}\right)^{\frac{1}{1-\eta}}, \tag{18}$$

$$P^*_{H,t} = \left(\frac{\mathcal{Q}_t^{\eta-1}-(1-\chi)}{1-\chi}\right)^{\frac{1}{1-\eta}}, \tag{19}$$

$$\frac{P_{F,t}}{P_t} = \mathcal{Q}_t. \tag{20}$$

These equations create a mapping between the real exchange rate, $\mathcal{Q}_t$, and the relevant price ratios that are necessary to solve the programming problems of domestic households, as well as define foreign demand for domestic goods.

Investment. A competitive investment firm operates a technology that converts home goods into investment goods, facing quadratic adjustment costs $\Xi_t = \frac{\zeta}{2}(\frac{K_{t+1}}{K_t} - 1)^2 K_t$. The law of motion of capital is given by: $K_{t+1} = (1-\delta)K_t + I_t$, where δ is the depreciation rate. The investment firm's profits are given by:

$$\Pi_t^{Inv} = \frac{P_{H,t}}{P_t}\left(r_t^k K_t - I_t - \Xi_t\right). \tag{21}$$

Optimization by the firm implies:[9]

$$q_t = \frac{P_{H,t}}{P_t}\left[1 + \zeta\left(\frac{K_{t+1}}{K_t} - 1\right)\right], \tag{22}$$

$$q_t = \frac{\frac{P_{H,t+1}}{P_{t+1}}}{(1+r_{t+1})}\left[\left(r_{t+1}^k - \frac{d\Xi_{t+1}(K_{t+1}, I_{t+1})}{dK_t}\right)\right] + \frac{q_{t+1}(1-\delta)}{(1+r_t)}, \tag{23}$$

where q_t captures the constraint's shadow value.

Assets market. Three types of assets are available in this economy: domestic government bonds, B_t, foreign government bonds, B_t^*, and equity shares of the investment firm. Domestic bonds have a return equal to $(1+r_t)$, while foreign bonds a have return equal to $(1+i_t^*)\frac{\mathcal{Q}_{t+1}}{\mathcal{Q}_t}$. The return on the equity of the investment firm is given by $\frac{\mathbb{E}_t[p_{t+1}+\Pi_{t+1}^I]}{p_t}$, where p_t is the price of a share of the investment firm. No-arbitrage implies the uncovered interest parity condition (UIP):

$$(1+r_t) = (1+i_t^*)\frac{\mathcal{Q}_{t+1}}{\mathcal{Q}_t}, \tag{24}$$

and that:

$$(1+r_t) = (1+i_t^*)\frac{\mathcal{Q}_{t+1}}{\mathcal{Q}_t} = \frac{\mathbb{E}_t[p_{t+1} + \Pi_{t+1}^{Inv}]}{p_t}. \tag{25}$$

[9] The programming problem of the firm is given by

$$V(K_t) = \max_{I_t, K_{t+1}} \left(r_t^k K_t - I_t - \Xi_t\right)\frac{P_{H,t}}{P_t} + \frac{1}{1+r_t}V(K_{t+1})$$
$$K_{t+1} = (1-\delta)K_t + I_t$$

where we also define $q_t K_t := V(K_t)$. Note that this follows because $V(\lambda K_t) = \lambda V(K_t)$. Appendix A.3 shows how to derive the investment firm's optimality conditions.

Government. The government faces a standard budget constraint:

$$B_t = (1 + r_{t-1})B_{t-1} + \frac{P_{H,t}}{P_t}G_t - \frac{P_{H,t}}{P_t}T_t \tag{26}$$

where G_t is government expenditure, and T_t are tax revenues. We assume that the government keeps its debt constant by adjusting tax revenues. This gives us a rule for total tax revenues at each point in time:

$$\frac{P_{H,t}}{P_t}T_t = r_{t-1}B_{t-1} + \frac{P_{H,t}}{P_t}G_t \tag{27}$$

Monetary policy. We assume monetary policy to follow a standard Taylor rule that targets price-index inflation:

$$i_t = r^* + \phi_\pi \pi_t \tag{28}$$

where r^* denotes the zero-inflation real rate and $\pi_t = \frac{P_t}{P_{t-1}} - 1$. Combining equation (28) with the Fisher equation, we can see that in this economy the real rate will be equal to:

$$(1 + r_t) = \frac{(1 + r^* + \phi_\pi \pi_t)}{(1 + \mathbb{E}_t \pi_{t+1})}. \tag{29}$$

Current Account. The current account identity is defined as:

$$\begin{aligned} CA_t &= nfa_t - nfa_{t-1} = TB_t + r_{t-1}nfa_{t-1}, \\ TB_t &= \frac{P_{H,t}}{P_t}C^*_{H,t} - \frac{P_{F,t}}{P_t}[(1-\alpha)C^R_{F,t} + \alpha C^P_{F,t}] = EX_t - IM_t \end{aligned} \tag{30}$$

When all other markets clear, the current account identity will also hold via Walras Law. 10

Equilibrium Definition. Given sequences of foreign prices $\{i^*_t, P^*_t\}$, a monetary policy rule given by $i_t = r^* + \phi_\pi \pi_t$, an initial wealth distribution $\mathcal{D}_0(a, e)$, and an initial capital level K_0, a competitive equilibrium is a path of policies for households

$$\left\{c^i_{H,t}(a,e), c^i_{F,t}(a,e), c^i_t(a,e), a^i_{t+1}(a,e)\right\}_{i \in FI,FE}$$

[10]See Appendix A.2 shows the derivation of the identity.

distributions $\mathcal{D}_t(a,e)$, prices $\{\mathcal{E}_t, \mathcal{Q}_t, P_t, P_{H,t}, P_{F,t}, W_t, p_t, i_t, r_t, r_t^k\}$ and aggregate quantities $\{C_t, C_{H,t}, C_{F,t}, CA_t, TB_t, K_t, I_t, Y_t, A_t, \text{nfa}_t\}$, such that all agents optimize, firms optimize, and the domestic goods, labor, and asset market clear:

$$\textit{Goods} \quad Y_t = C_{H,t} + C_{H,t}^* + G_t + I_t + \Xi_t, \tag{31}$$

$$\textit{Labor} \quad N_t = \int n_{i,t} e_{i,t} di = L_t, \tag{32}$$

$$\textit{Assets} \quad A_t = \int_{i \in Rich} a_{i,t} di = B_t + p_t + nfa_t = B_t + q_t K_{t+1} + nfa_t, \tag{33}$$

where $C_{Ht} \equiv \sum_e \pi_e \int c_{H,t}(a,e)\mathcal{D}_t(a,e)$ denotes aggregate consumption of home goods, and C_t, C_{Ft}, A_t are defined similarly. We focus on equilibria in which the long-run exchange rate returns to its steady state level, $\mathcal{Q}_\infty = \mathcal{Q}_{ss}$.

3 Quantitative Analysis

3.1 Calibration

Table 1 summarizes the parameters that we use to calibrate our model, whose goal is to be representative of a typical LIC. The time period is a quarter. β, the discount factor, is chosen to be consistent with a yearly interest rate of 6%, much higher than what is usually used for the calibration of advanced economies.[11] σ and ϕ, the coefficients capturing the inverse of the elasticity of intertemporal substitution and of the Frisch elasticity, respectively, are set to 2, standard values in the literature. The coefficient that accounts for labor disutility, ψ, is set to 7.04 to normalize quarterly output to be equal to 1. In order to model idiosyncratic productivity risk, we follow the literature by assuming that the household's labor productivity, e, behaves accordingly to the following AR(1) process: $\log e_t = \rho_l \log e_t + \varepsilon_t$, with $\sigma_l = std(\varepsilon_t)$. Estimates of the persistence and variance of the income process are usually based on the empirical findings for the US economy of Floden and Lindé (2001) (e.g., Guerrieri and Lorenzoni, 2017). Since we intend to represent a

[11] The real rate is obtained as the difference between the Ghanaian average nominal interest rate on domestic bonds and inflation between 2009 and 2018. The series, taken from the IMF IFS Statistics, are: Monetary and Financial Accounts, Interest Rates, Securities Markets, Government Debt Securities, Government Bonds, Percent per Annum; Prices, Consumer Price Index, All items, Percentage change, Corresponding period previous year, Percent.

typical LIC, instead of using these estimates we produced our own using data from the ECG-ISSER Ghana Socioeconomic Panel Survey (GSPS),[12] as explained in appendix C. For the domestic and foreign elasticities of substitution across goods we rely on the estimates by Feenstra et al. (2018), and set $\eta = \eta^* = 1.01$. χ, the coefficient that captures the weight given to the domestically-produced good in the CES aggregator is set to 0.484, consistent with a share of imports to GDP of 30%, which is in line with the values reported by Melina and Portillo (2018) for low-income countries.

In order to calibrate $\bar{c}$, the parameter that introduces a subsistence level of foreign consumption, we take into consideration that the subsistence level of consumption of imported goods accounts, on average, for 10% of the overall households' consumption basket in LICs. This figure is reached after calculating what staple foods are more important at country level to avoid under-nourishing and countries' dependence on imports of these food items, as explained in appendix B, using data from the Food and Agricultural Organization of the United Nations' (FAO's) Food Balances database and the World Bank's Consumption database.[13] The parameter λ, which captures the fraction of financially excluded households, was obtained from the ECG-ISSER Ghana Socioeconomic Panel Survey GSPS.[14] The borrowing constraint $\underline{a}$ is set to zero, implying that financially included households are unable to lend among themselves.

The parameters that relate to the firms in the model are standard ones used in the literature. α, accounting for the capital share, is set to 0.33, while ϵ, set to 11, implies a 10% steady-state markup. As standard in the literature, the slope of the Phillips curve, κ, is set to 0.1. ζ, the coefficient accounting for the adjusment cost of capital, is set to 17, following De Ferra et al. (2020). In order to match the average annual MPC of 0.632, which has been recently estimated using data for Peru in Hong (2022),[15] we set the capital to output ratio to 47%.[16]

[12] The survey is administered by the Economic Growth Center at Yale University, the Global Poverty Research Lab at Northwestern University, and the Institute of Statistical, Social, and Economic Research at the University of Ghana.

[13] In line with the evidence provided by Cravino and Levchenko (2017), our calibration implies a decreasing relation between the share of imported goods in the consumption basket and household's income.

[14] We computed our estimate by looking at the fraction of households that declare to have only saved at home (i.e., not at financial institution).

[15] Given the limited availability of studies estimating the average MPC in LICs, we decided to use this figure instead of the more commonly used estimates for advanced economies.

[16] Despite the overall capital to output ratio is generally greater than 47% in LICs, we decide to use this

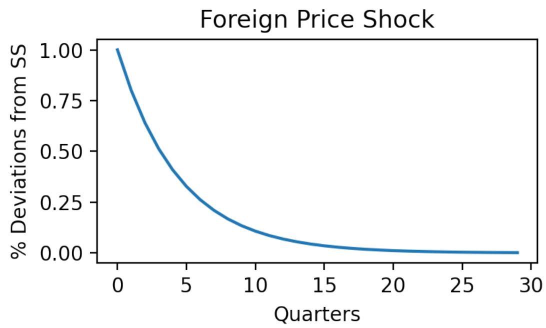
Table 1: Parameter Values

Parameter	Explanation	Value	Target/Source
Households			
β	Discount factor	0.955	Interest rate r = 6%
σ	Inverse EIS	2	Standard value
ϕ	Inverse Frisch	2	Standard value
ψ	Labor disutility coefficient	7.04	$Y = 1$
ρ_l	Persistence, labour productivity	0.97	Own calc. (see appendix C)
σ_l	St. deviation, labour productivity	0.14	Own calc. (see appendix C)
η	Elasticity of substitution across goods	1.01	Feenstra et al. (2018)
χ	Weight of home good in consumption	0.484	Melina and Portillo (2018)
$\bar{c}$	Subsistence foreign consumption	0.058	Own calc. (see appendix B)
λ	Financially excluded	33%	Ghanaian survey
$\underline{a}$	Borrowing constraint	0	Standard value
Foreign			
η^*	Elasticity of substitution across goods	1.01	Feenstra et al. (2018)
$(1-\chi^*)C^*$	Foreign demand shifter	0.32	Terms of trade = 1
Firms			
α	Capital share	0.33	Standard value
ϵ	Steady-state markup	11	De Ferra et al. (2020)
κ	Slope of Phillips curve	0.1	Standard value
ζ	Capital adjustment cost coefficient	17	De Ferra et al. (2020)
Government			
ϕ_π	Taylor rule coefficient	1.5	Standard value
G/Y	Government spending (% GDP)	15%	Melina and Portillo (2018)
Aggregates			
B/Y	Domestic debt (% GDP)	20%	Melina et al. (2016)
K/Y	Domestic capital (% GDP)	47%	Mean annual MPC = 0.632
nfa/Y	Net Foreign Asset Position (% GDP)	-35%	WEO and IFS databases (last year available)

Notes: See text for a discussion on the targets.

value as it allows us to match the MPC estimated in the literature, given the importance of such a statistic for HANK models.

Figure 1: Exogenous increase in import prices.



Notes: The figure depicts the evolution of the shock to import prices ε_t, which follows a first order auto-regressive process with persistence 0.8. The shock enters the model through $P_t^* = \mathcal{E}_t P_t^*(1+\varepsilon_t)$. We calibrate the initial value of ε_t such that, if the nominal exchange rate were kept constant, there would be a one percent deviation from the steady state value of the foreign prices P_t^* on impact.

The Taylor rule coefficient is set to $\phi_\pi = 1.5$ in our benchmark framework. Nonetheless, we experiment with different levels of this parameter to evaluate the consequences of more or less stringent monetary policy reactions to inflation. The government expenditure to output ratio is set to 15%, in line with evidence in Melina and Portillo (2018). The ratio of debt to GDP is 20%, the same value used by Melina et al. (2016) in calibrating a model for low-income countries. The ratio between NFA and output is set to −35%, consistent with the values reported for low-income countries in the IMF's WEO and IFS databases.

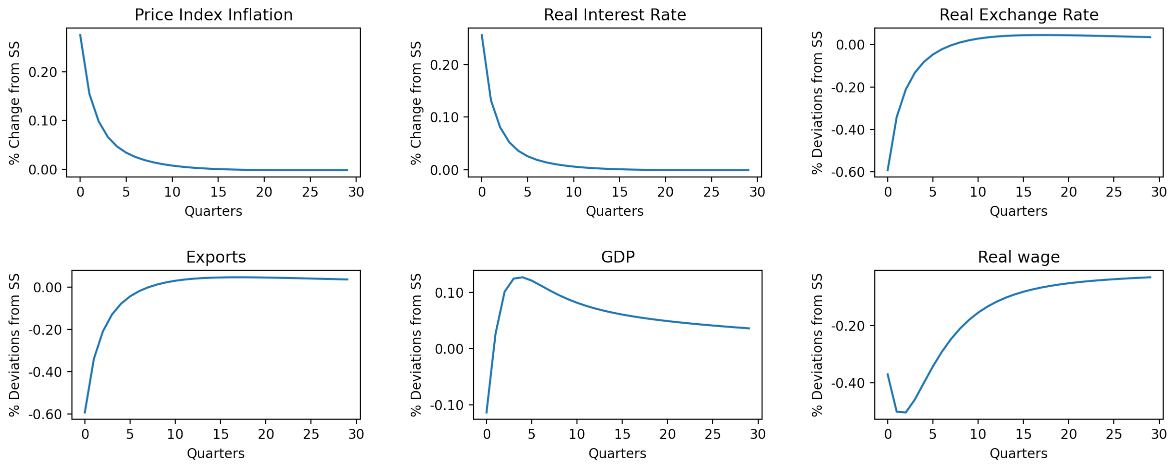
3.2 Positive Implications

A shock to import prices. We are interested in understanding how the increase in the price of staple foods, which has taken place in the global economy since the beginning of the Russian invasion of Ukraine, is expected to affect LICs. In order to capture this phenomenon, we shock our economy with an exogenous increase in import prices:

$$P_{F,t} = \mathcal{E}_t P_t^*(1+\varepsilon_t) > \mathcal{E}_t P_t^*. \tag{34}$$

Equation (34) shows that, relative to what the law of one price in equation (16) would dictate, the price of foreign goods expressed in domestic currency is increased according to ε_t, which can be interpreted as a transportation cost. We model ε_t as an AR(1) process with persistence 0.8 and we calibrate it so that, if the exchange rate were kept constant,

Figure 2: Response of aggregate variables



Notes: The figure depicts the response of aggregates, such as price index inflation π_t, real interest rate r_t, real exchange rate Q_t, exports EX_t, gross domestic product Y_t, real wage w_t, in deviations from the steady state after the shock to import prices.

$P_{F,t}$ would increase by 1% relative to its steady-state value on impact. The dynamics of the shock ε are displayed in figure 1.[17,18]

Equilibrium Responses: Aggregates. Figure 2 shows the response of some aggregate variables of interest to the exogenous increase in import prices.[19] Starting with the movements in the domestic price index, we can see that higher import prices lead to an increase in domestic inflation. Given the inflationary nature of our shock, captured by equation (5) this result is not surprising. Higher inflation is accompanied, as imposed by the Taylor rule in equation (28), by an increase in nominal interest rates by the domestic central bank. With a Taylor coefficient parameter, ϕ_π, of 1.5, the increase in nominal interest rates is enough to lead to an increase in the real interest rate, whose movements are displayed in the top-middle chart of figure 2. Since we are dealing with a small open economy, higher domestic nominal rates do not trigger a response by foreign central banks. As a conse-

[17] We also simulated larger shocks of up to 10 times relative to steady-state. Results go generally in the same direction of the ones described below, but with higher variation, as expected. Monetary policy has to be tightened more forcefully following a larger shock, but according to the pass-through to the price index targeted by the central bank.

[18] An alternative shock to the UIP premium is considered in Appendix J.

[19] Appendix D provides information on the response of additional variables to the shock.

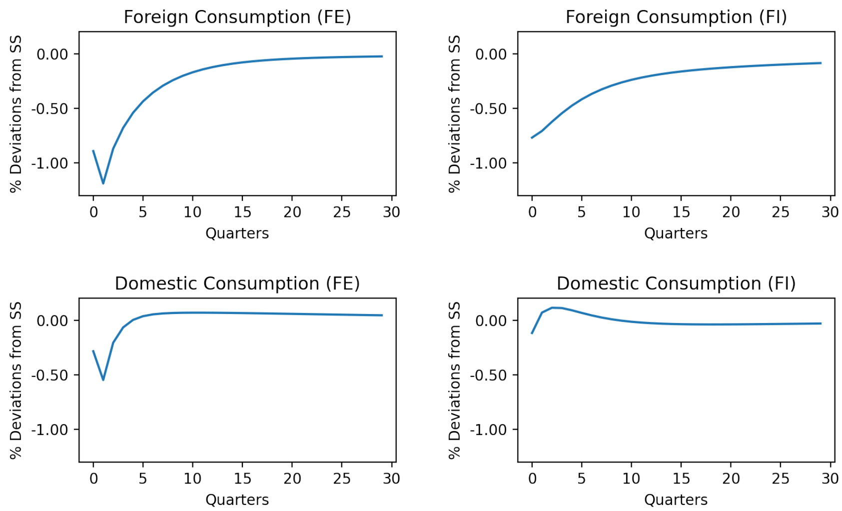
quence, the real exchange rate $\mathcal{Q}$ appreciates, respecting the UIP condition in equation (24). The real exchange rate appreciation triggers a contraction in external demand, which is reflected by a drop in domestic exports. Because the government keeps debt constant for a certain level of government expenditure, it increases taxes to compensate for higher interest rates, according to equation 27.

The bottom-middle panel in figure 2 shows the response of domestic GDP. The shock leads to an initial drop in output, followed by a recovery. The initial drop is the consequence of both the drop in exports and in domestic demand (see figure 3). The subsequent recovery in GDP is instead the consequence of both a recovery in exports, and a recovery in domestic demand due to an expenditure switching channel: as the price of foreign goods has become relatively more expensive, domestic consumers tilt their consumption basket toward consuming more domestically-produced goods. An important consequence of the movements of both inflation and output is that the shocks leads to a drop in the domestic real wage. On the one hand, higher inflation mechanically drives down the real wage. On the other hand, the drop in aggregate output leads to a drop in demand for labor services, putting an additional downward pressure on wages. Yet, given the presence of sticky wages, the drop in nominal wages takes place gradually, so that the overall response of the real wage over time is hump shaped.

Figure 3 shows the dynamics of home and foreign consumption of FI and FE agents. The top two charts show the response of foreign consumption, which is in line with our expectations: a shock that increases the relative price of imported goods leads to a drop in demand for these. Nonetheless, as a consequence of the presence of a subsistence level of consumption in foreign goods, the drop in demand is lower than what it would have been without subsistence (appendix E shows counterfactual scenarios obtained by varying the subsistence parameter, including a zero $\bar{c}$ that corresponds to no subsistence feature in the model). An additional consequence of the presence of subsistence is that, despite the drop in demand for foreign goods, households still end up devoting a substantial amount of their resources to buy these goods (whose price has increased), reducing the income available to purchase domestic goods. Given the dynamics in prices, subsistence requirements are relevant for monetary policy. The lower they are, the less the central bank needs to raise interest rates for the same shock on the price of the foreign good.

Looking at the bottom panel, we can see the different responses of home consumption. For both FE and FI households, the shock leads to an initial drop followed by a recovery.

Figure 3: Consumption of different households



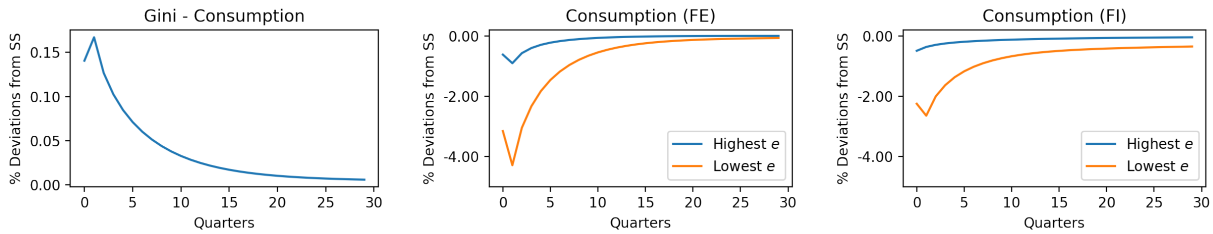
Notes: The figure depicts the evolution of consumption after the import price shock. The two left (right) panels depict the consumption of the foreign and domestic goods of the financial excluded (included) households.

For FE households, the initial drop is the consequence of lower wages (which is particularly important for these households, since labor income is their only source of income), and the negative income effect due to higher import prices. The subsequent recovery is mostly due to the reduction in foreign prices and an expenditure switching channel. For FI households, we can observe that the initial drop in consumption is less pronounced than that for FE households, and the recovery is more sustained, a direct outcome of their access to saving instruments.[20]

Equilibrium Responses: Distributional Impacts. The heterogeneous setup of our model allows us to analyse how the shock affects inequality. Figure 4 shows that, when the shock hits, there is an increase in consumption inequality, which then slowly reverts back to its steady-state level. The middle and right charts in the figure provide the intuition behind

[20]The possibility of running down assets to smooth consumption is important in face of several factors pushing in the direction of cutting it: (i) higher interest rates provide an incentive to save, especially for households far away from the borrowing constraint; (ii) higher interest rates imply higher debt service for the government, which responds by increasing the lump sum taxes imposed on FI households; (iii) the shock leads to a contraction in output, implying a drop in the value of the investment firm which affects FI agents through a negative revaluation of the equity they own of the firm.

Figure 4: Consumption inequality

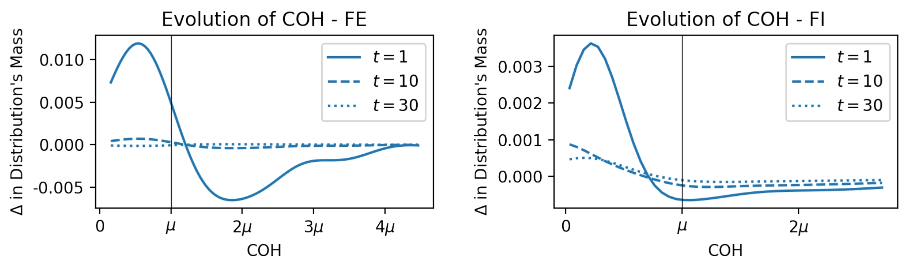


Notes: The figure depicts the evolution of consumption inequality. The left panel depicts the evolution of the Gini Index of consumption in deviations from the steady state. The center (right) panel depicts the evolution of consumption for the highest and lowest productivity financially excluded (included) households in deviations from the steady state.

this result. Both charts show, for FE and FI households respectively, the average response of overall consumption for households with the lowest, and highest, idiosyncratic productivity levels. As these two charts make clear, lower productivity households are disproportionately affected by the shock. The reason for this is twofold. On the one hand, the shock leads to a drop in real wages, compressing labor income. Since lower productivity households make less labor income for a given amount of hours worked, their income drops more than that of more skilled agents. On the other hand, for FI households, an additional channel is at play. Since higher productivity households tend to accumulate more assets over time, they also end up having more resources they can use to smooth out the shock once it hits the economy. Part of the assets of these agents is used to sustain consumption, making these suffer less than financially excluded households.

An additional way to investigate the consequences of the shock is to look at how it affected the distribution of agents. Figure 5 shows, for FI and FE households, the change in the mass, relative to steady-state, of agents at different Cash-on-Hand (COH) levels. In both charts, μ is the steady state average COH for FI and FE households. The different blue lines display the change in mass at different horizons since the shock hit (e.g., the solid blue line for $t = 1$ shows the change in mass after one period since the shock takes place). In both charts, we can see that, in the period immediately after the shock hits (solid blue line), there is an increase in mass of agents that have below mean steady-state COH level, and a corresponding decrease in agents with above mean steady-state COH. As time passes by, and the shock fades away, the distributions gradually move back to their steady-state values.

Figure 5: Movements in the distribution



Notes: The figure depicts the change in the distribution of cash-on-hand (COH) relative to its steady-state value at different horizons after the shock ($t = 1, 10, 30$). The left (right) panel depicts this evolution for financially excluded (included) households. μ represents the steady-state average COH for financially excluded (left panel) and financially included (right panel) households.

Overall, the analysis of our benchmark shock shows that an exogenous increase in import prices leads to both an increase in inflation and a contraction in output. Households react by reducing their consumption, and consumption inequality increases due to the fact that richer households have more resources to smooth away the adverse shock. Additionally, the shock leads to an overall worsening of the economic position of agents, which is reflected by an increase in the amount of households with below steady-state COH.

3.3 Normative Implications

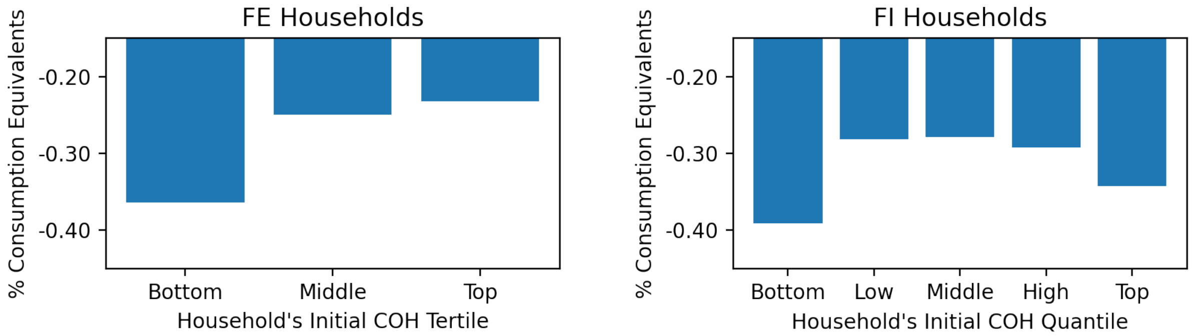
Thus far, our analysis has focused on the positive implications of an exogenous increase in the price of imported goods. This section moves to a normative analysis, highlighting the welfare effects of the shock on different households in the economy.

Welfare Criterion. We measure of welfare, Λ, in terms of consumption equivalents. In particular, Λ solves the following equation:

$$\mathbb{E}_0\left[\sum_{t=0}^{\infty}\beta^t U\Big(c_t, n_t\Big)\right] = \mathbb{E}_0\left[\sum_{t=0}^{\infty}\beta^t U\Big((1+\Lambda)c_t^{ss}, n_t^{ss}\Big)\right]. \tag{35}$$

Where c_t and n_t represent the consumption and hours worked in the periods after the price shock takes place, while c_t^{ss} and n_t^{ss} represent the consumption and hours worked in the steady-state economy. According to this definition, Λ captures the percentage increase

Figure 6: Welfare impact of the shock



Notes: The figure depicts the welfare effect (measured by Λ in equation 35) of the import price shock. Households are ranked based on their initial COH (tertiles in the left panel for financially excluded households, quantiles in the right panel for financially included households).

in steady-state consumption that is necessary for households to achieve the same lifetime utility that they obtain after the shock takes place. In other words, Λ captures the fraction of lifetime consumption that households would be willing to forgo in other to avoid being subject to the shock. It follows that negative values of Λ are associated with a negative impact of the shock on households' welfare.[21]

Welfare Effects of a Shock to Import Prices. Figure 6 displays the welfare effect of the shock. To better understand the impact of the shock on different households, the left-hand-side chart displays Λ for FE households, while the right-hand-side displays Λ for FI households, both ranked based on their time-zero COH. Before looking at the effect on different households, it is important to note that all bars in the two charts are negative: regardless of the initial position, all groups of households are negatively affected by the shock.

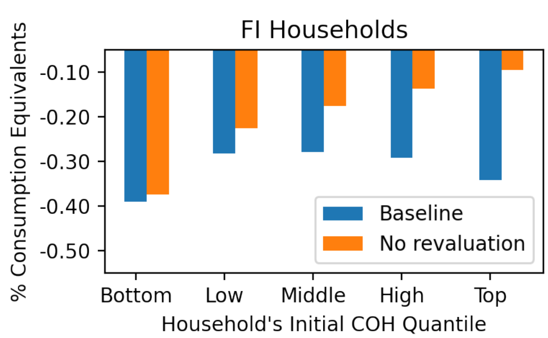
Starting with the chart on the left, the lower the initial COH level that a households starts with, the larger the drop in welfare. The underlying reason for this result is linked to the movements in the real wage, shown in figure 2. Since FE agents can only count on their labor income, the drop in wages that follows the shock negatively affects all of them. Nonetheless, households with lower initial COH positions are those with lower

[21]Computationally, we approximate ∞ by computing the expected utility of households for $T = 50$ periods, since our calibrated value for β implies marginal weights attributed to later periods.

productivity levels, who are also the ones getting the lowest labor income for unit of hour worked: their labor income is particularly negatively affected by the shock. As a consequence of this, low productivity FE households end up being among the ones suffering the most after the shock takes place.

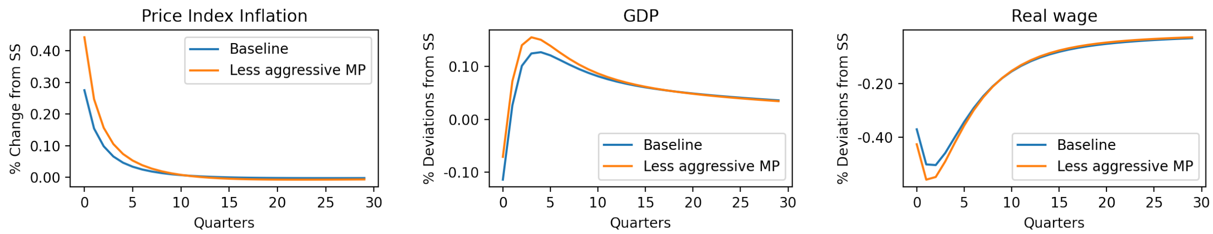
The chart on the right shows that the shock affects negatively all FI households. Similarly to the chart on the left, the households who end up suffering the most, within this group, are those at the bottom of the COH distribution. The reasoning for this is similar to that of the FE households, since households with low COH tend to have low productivity levels. As a consequence, their income structure is very similar to that of FE agents, with low assets and a major dependence on labor income. Interestingly, the chart shows that households at the top quantile suffer slightly more than those in the high and middle quantiles. The reason underlying this effect is that these households tend to have an income structure such that most of their resources come as return on assets they own. One of the implications of the shock is that, as mentioned previously, the output drop leads to a negative revaluation of the equity of the investment firm. Given their income structure, top quantile households are particularly sensitive to such a negative revaluation of those assets. To get an idea of the importance of such an effect, figure 7 shows the counterfactual welfare effect that would have taken place if FI were not subject to any negative revaluation of their assets after the shock. If this were to be the case, then the negative welfare effect would be lower, the lower the initial COH position of the household.

Figure 7: Counterfactual welfare effect: no revaluation



Notes: The figure depicts the baseline welfare effect (blue) and the counterfactual welfare effect (orange) of the shock under the assumption of no negative asset revaluation.

Figure 8: Response of aggregate variables - Less aggressive MP



Notes: The figure depicts the baseline (blue) and counterfactual (orange) responses of inflation (left), output (middle) and the real wage (right) in deviations from their steady-state levels. The counterfactual responses rely on a less aggressive monetary policy stance against inflation.

3.4 Welfare Implications of Monetary Policy Rules

Different monetary policy aggressiveness. Given that we are investigating an inflationary shock, it is of interest to understand the implications of different monetary policy reactions to higher inflation rates. For such reason, the next three sections will evaluate counterfactual scenarios under different assumptions regarding the conduct of monetary policy. In this section, we investigate how the transmission of the shock would differ if the monetary authority were to be less aggressive against inflation. We capture such a scenario changing the Taylor coefficient in equation (28) from $\phi_\pi = 1.5$ to $\phi_\pi = 1.15$. In the following charts, the blue line will show our baseline results, while the orange line shows the counterfactual results under the alternative scenario.

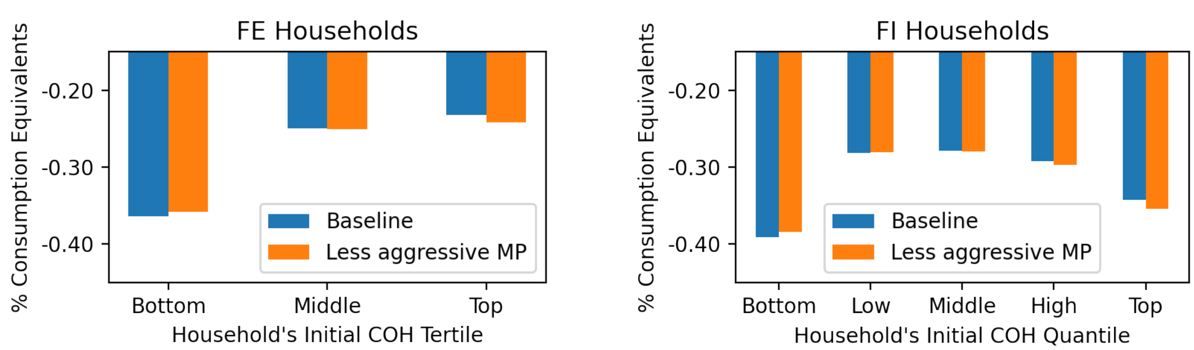
Figure 8 shows the counterfactual response of some relevant aggregate variables.[22] Since in our new scenario the central bank responds less to inflation, it is not a surprise that the shock becomes more inflationary. Importantly, the middle chart shows that GDP drops less when the central bank is less aggressive against inflation. This happens since, in order to react to inflation, the central bank increases the nominal interest rate creating an incentive for FI households to postpone consumption. Accordingly, when the central bank is less responsive, it creates less of such an incentive, so that domestic demand will drop less. Moving to the right chart, the real wage drops more in the new scenario. This is mostly the consequence of the presence of sticky nominal wages: since inflation increases more, the real wage is more negatively affected.

[22] Appendix F shows all other counterfactual IRFs.

The welfare implications of a less aggressive monetary policy stance are displayed in figure 9. In particular, the charts show that having a monetary authority that reacts to inflation less vigorously leads to a slightly lower welfare drop for households at the bottom of the COH distribution: in terms of consumption equivalents, they improve by only 0.005 percentage points. At the same time, the negative impact of the shock increases for households with high COH positions. In order to understand this result, it is important to consider that a less aggressive monetary policy response has two offsetting effects on households. On the one hand, real wages drop more as a consequence of higher inflation as mentioned above; on the other hand, since output drops by less, there is less of a drop in hours worked.

Figure 10 isolates these two opposing effects, and helps understand the results in figure 9. In the right-hand-side charts, the green bars show the counterfactual welfare effect on households under a less aggressive monetary policy, if wages were to move the same way they moved in the baseline scenario. The bars show that all households would have suffered less in the scenario with a less aggressive monetary policy, if it didn't imply a larger drop in real wages. This result is exactly in line with our expectations. The green bars in right-hand-side charts show the counterfactual welfare effect if, instead of fixing real wages to the baseline scenario, we fixed labor demand. In this case, we can see that the effects would be more nuanced: low COH households would suffer more, while the opposite would be true for high COH households. The reason underlying this result is

Figure 9: Comparison of the welfare impact of the shock - Less aggressive MP



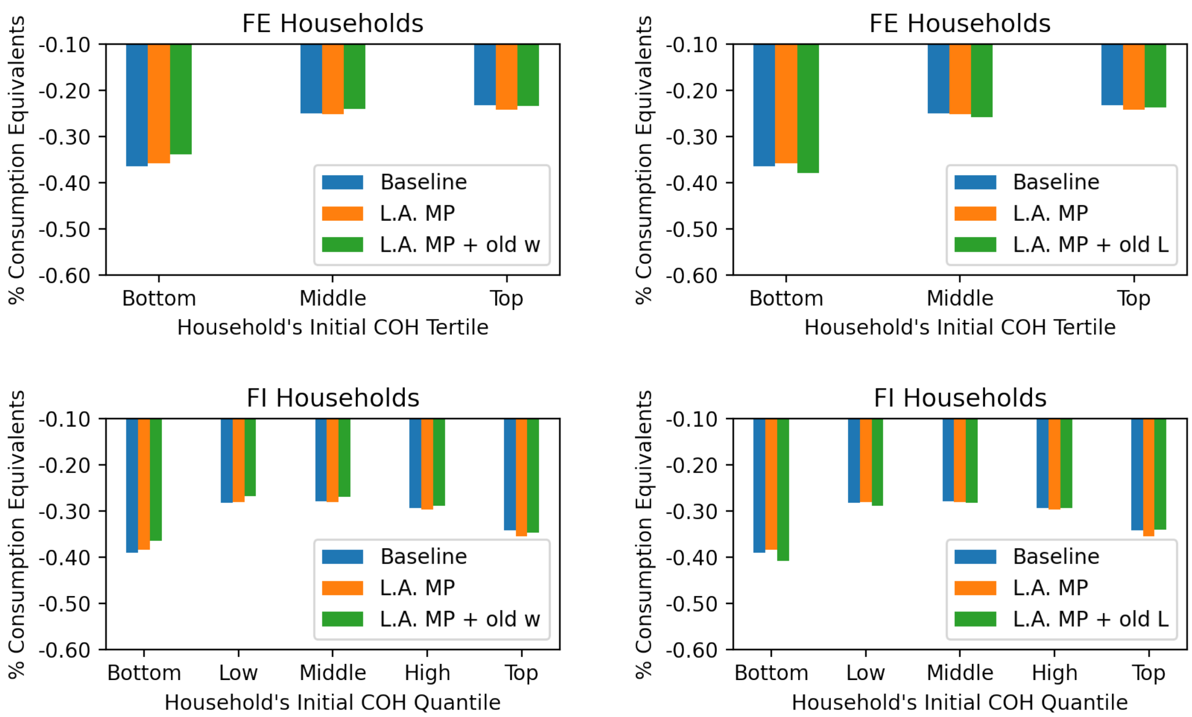
Notes: The figure depicts the baseline (blue) and counterfactual (orange) welfare effect of the import price shock with a less aggressive monetary policy stance. Households are ranked based on their initial COH (tertiles in the left panel for financially excluded households, quantiles in the right panel for financially included households).

that, for low COH households, the positive gain out of higher income only marginally overcomes the negative effect given by more hours worked. These households need as many resources as possible to sustain their consumption after the shock takes place, while this is not true for higher COH households. Hence, it is this different impact of higher hours worked that explain the different welfare effects in figure 9.

Monetary policy with interest rate smoothing This section evaluates the counterfactual responses that would take place if the monetary authority followed an interest-rate smoothing rule, which implies a gradual response to changes in the inflation rate. We capture this behaviour with the following Taylor rule:

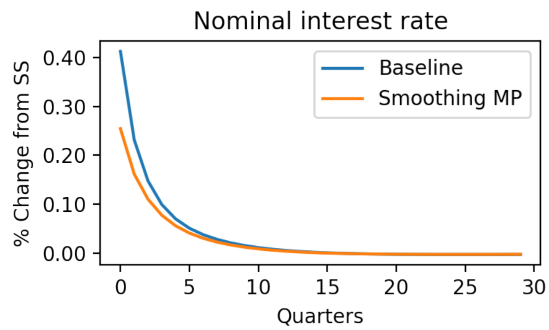
$$i_t = \rho i_{t-1} + \rho[r^* + \phi_\pi \pi_t] \tag{36}$$

Figure 10: Counterfactual effect of the shock - Less aggressive MP



Notes: The figure depicts the baseline (blue) and counterfactual (orange) welfare effect of the import price shock with a less aggressive monetary policy stance. The green bars show the counterfactual welfare effect that would materialize if there had been a less aggressive monetary policy response together with the same movement in real wages (left-side charts) or labor (right-side charts) as in the baseline scenario.

Figure 11: Different interest rate hikes



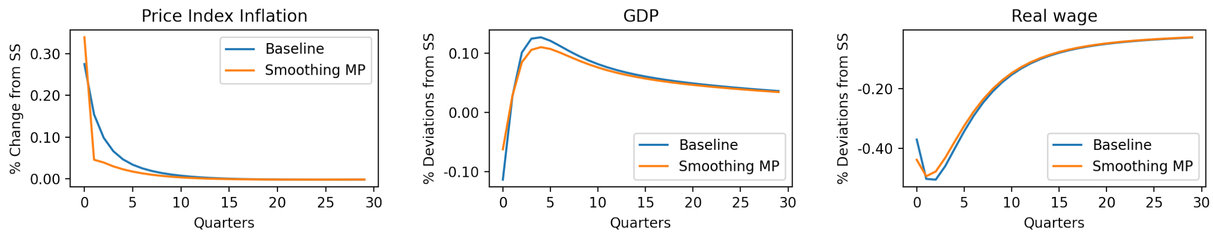
Notes: The figure depicts the baseline (blue) and counterfactual (orange) responses of the nominal interest rate i_t after the import price shock.

where ρ, which we set to 0.5 in our calibration, dictates the degree of smoothness. It is of interest to evaluate how the economy would react under this rule since central banks tend to adjust their nominal interest rates gradually over time. The main difference relative to the previous exercise is that, instead of being less responsive to movements in the inflation rate, the central bank is now slower to respond, albeit as aggressive as in the baseline scenario. Figure 11 shows the different interest rate movements in the two scenarios considered in this section.

Figure 12 displays the evolution of inflation, output and the real wage in this scenario.[23] On impact, inflation increases more than in the baseline scenario, but it also decreases more quickly. The reason underlying the higher response on impact is similar to that of the previous exercise: the central bank increases its rate by less on impact, leaving inflation free to spike. The subsequent decrease in inflation is instead the consequence of the fact that, by responding more slowly over time, the central bank shifts the timing of the movements in aggregate demand. In particular, agents don't decrease their consumption as much as in the baseline exercise on impact but, following the slower response by the monetary authority, they decrease it more in the subsequent periods. This mechanism is at the core both of the movements in inflation and of the movements in GDP which, as shown in the middle chart, drops by less on impact and has a muted rebound in subsequent periods. Finally, the response of the real wage mirrors the dynamics in the inflation rate: it drops more on impact, when inflation is higher, but has a faster recovery thanks to the lower inflationary pressures in the following periods.

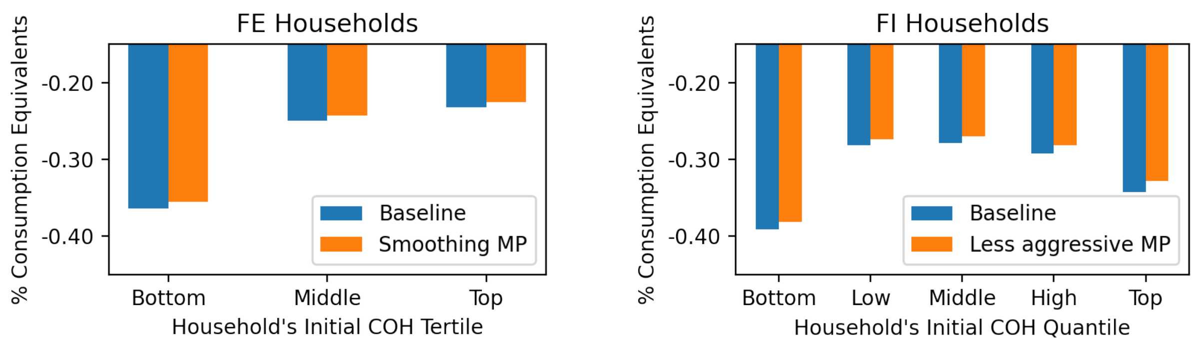
[23] Appendix G shows all other counterfactual IRFs.

Figure 12: Response of aggregate variables - MP with rate smoothing



Notes: The figure depicts the baseline (blue) and counterfactual (orange) responses of inflation (left), output (middle) and the real wage (right) in deviations from their steady-state levels. The counterfactual responses rely on the monetary policy rule entailing interest rate smoothing as expressed in equation 36.

Figure 13: Comparison of the welfare impact of the shock - MP with rate smoothing

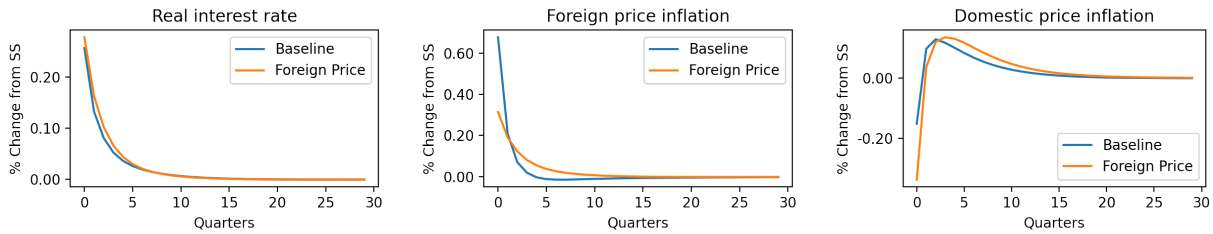


Notes: The figure depicts the baseline (blue) and counterfactual (orange) welfare effect of the import price shock with an interest rate smoothing monetary policy rule. Households are ranked based on their initial COH (tertiles in the left panel for financially excluded households, quantiles in the right panel for financially included households).

Figure 13 shows the counterfactual welfare effects of the shock with interest-rate smoothing. Differently than the previous exercise, we can see that all agents are better off under this rule. The reasons underlying these results are quite straightforward: the new dynamics of the real wage tend to benefit all households and, for FI agents, the lower drop in output is associated with a smaller negative revaluation of their assets, which is particularly beneficial to high COH households.

Monetary policy targeting foreign price inflation. This section evaluates the counterfactual responses that would take place if the monetary authority targeted the source of inflationary pressures: import prices. Accordingly, the Taylor rule in this scenario is the

Figure 14: Response of aggregate variables I - MP with foreign price inflation target



Notes: The figure depicts the baseline (blue) and counterfactual (orange) responses of the real interest rate (left), foreign price inflation (middle) and domestic price inflation (right) in deviations from their steady-state levels. The counterfactual responses rely on the monetary policy rule that targets foreign price inflation as in equation 37.

following:

$$i_t = r^* + \phi_\pi \pi_{F,t} \tag{37}$$

where $\pi_{F,t} = P_{F,t}/P_{F,t-1} - 1$ is foreign price inflation.

To gain intuition for the consequence of this rule, figure 14 shows the developments of the real rate, foreign price inflation and domestic price inflation in this scenario.[24] The first chart shows that the real interest rate increases more in this scenario, in line with our expectations: since we are sending a shock to foreign prices, these are the ones that increase the most after the shock, so that the central bank needs to increase its rate by more to contain them. As a consequence of this aggressive policy against foreign price inflation, import price inflation increases significantly less in this scenario than in the baseline (middle chart). Importantly, the right-hand side chart shows that domestic price inflation also drops significantly more: since the the real rate increases more, the central bank triggers a larger recession in the domestic economy, leading to a larger decrease in home-produced goods.

Figure 15 shows the movements in the three key aggregate variables: inflation, output and real wages. Price index inflation is a combination of foreign price and domestic price inflation. Since both of these drop significantly in this scenario, inflation is mostly unchanged on impact, and only increases in subsequent periods. Output drops more in this scenario since, as mentioned previously, the central bank has to largely decrease demand to contain the increase in import prices. Finally, despite a larger drop in labor demand,

[24]Appendix H shows all other counterfactual IRFs.

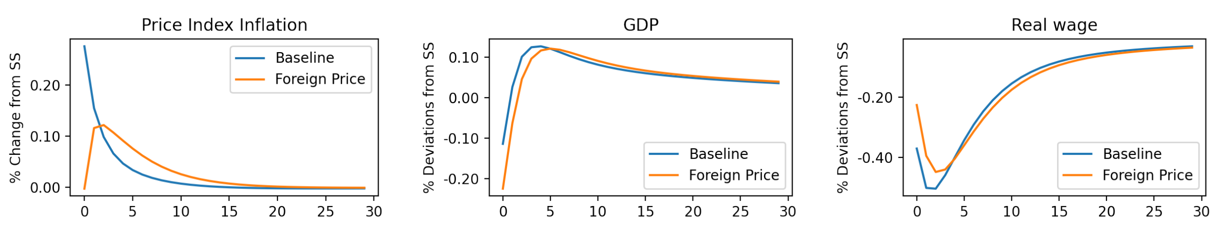
which leads to lower wages, the fact that inflation is much more contained in the initial periods after the shock leads to an overall increase in the real wages that households face.

Figure 16 displays the welfare consequences of the shock under the new monetary rule. With the exception of high COH households, the shock is more costly in this scenario. Looking at figure 17, we see that FE agents benefit from the new dynamics of real wages. Nonetheless, the drop in labor demand is particularly harmful to low COH households, while this is less the case for high COH agents. The underlying reason for this result is that, as mentioned in section 3.4, richer households are more productive and, as a consequence, they face less of a cost for higher hours worked. Looking at the bottom charts of figure 17, it is interesting to note the two opposing effects of larger negative asset revaluation and higher real interest rates, especially for high COH households. The larger negative revaluation, which follows the greater drop in output, negatively affects these households. Nonetheless, the higher return on their asset which follows the increase in the real rate benefits them so that, overall, the welfare of these agents in mostly unaffected under this alternative rule.

Monetary policy targeting domestic price inflation. To conclude our analysis of how different monetary policy stances may affect the transmission of the shock and complementing the previous section, this section evaluates the counterfactual responses that would take place if the monetary authority targeted only domestic prices according to the following Taylor rule:

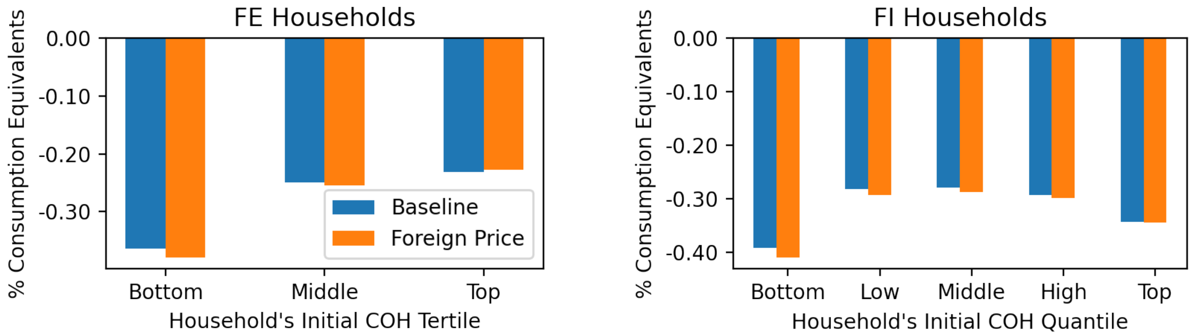
$$i_t = r^* + \phi_\pi \pi_{H,t} \tag{38}$$

Figure 15: Response of aggregate variables II - MP with foreign price inflation target



Notes: The figure depicts the baseline (blue) and counterfactual (orange) responses of inflation (left), output (middle) and the real wage (right) in deviations from their steady-state levels. The counterfactual responses rely on the monetary policy rule that targets foreign price inflation as in equation 37.

Figure 16: Comparison of the welfare impact of the shock - MP with foreign price target



Notes: The figure depicts the baseline (blue) and counterfactual (orange) welfare effect of the import price shock with a monetary policy rule that targets import price inflation. Households are ranked based on their initial COH (tertiles in the left panel for FE households, quantiles in the right panel for FI households).

with $\pi_{H,t}$ following the usual definition.

The rationale behind this exercise is to compare our results with those that focused on monetary policy and subsistence, such as Portillo et al. (2016), albeit in a representative agent context. In this sense, the interaction between heterogeneity and subsistence goes one step beyond those of previous studies. Those authors found that optimal policy calls in most cases for the stabilization of sticky prices non-food inflation, roughly correspondent to core inflation, even in the presence of subsistence. In our model, given that imported goods can be interpreted as food, the stabilization of "core" prices would correspond to monetary policy targeting only domestic prices.

Figure 18 depicts the movements in some relevant variables.[25] Given that the central bank is responding to domestic inflation, the path of interest rates is smoother than in the baseline. Rates are raised by less in the first moment, but kept higher for longer. The central bank is not responding to the shock to the prices of the foreign good *per se*, but "seeing through" it and instead reacting to potential contamination of "core" inflation. This creates different dynamics for other variables, with the economy taking a smoother path. The path of monetary policy, in addition to price differences between foreign and domestic goods caused by the shock, provokes a distinct reaction by financially included households, who inter-temporarily substitute less the consumption of the domestic good, with reflection in GDP.

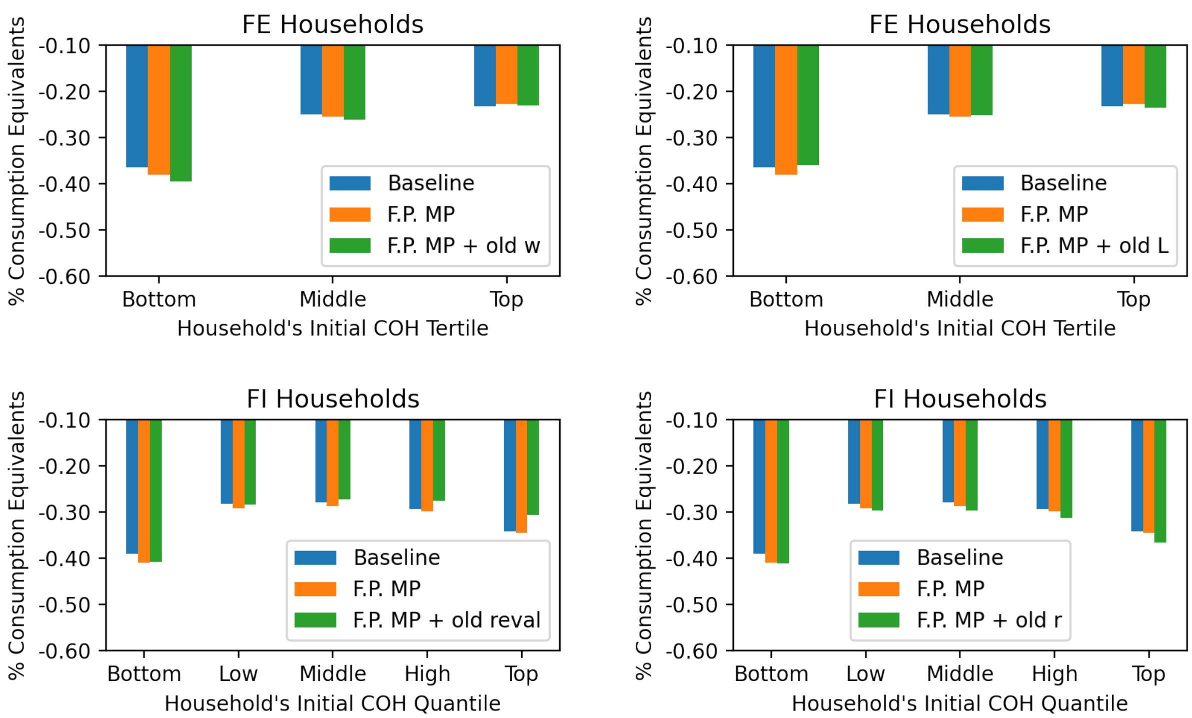
[25] Appendix I shows all other counterfactual IRFs.

What are the welfare consequences of the shock under this domestic price monetary policy rule? Figure 19 provides the answer. The rule focusing on domestic prices achieves less welfare loss for all levels of COH, both financially excluded and included. While the paths of GDP and domestic consumption should imply decreases in utility, the fact that consumers are able to smooth their consumption more increases their welfare, and consumption of the foreign good is higher. This is associated with higher real wages for FE agents and higher interest rates, which benefit returns on assets of FI agents.

3.5 The Role of Transfers

While we looked at monetary policy in the previous sections, fiscal policy might play a role and alleviate welfare loss for households in the bottom of the distribution of income.

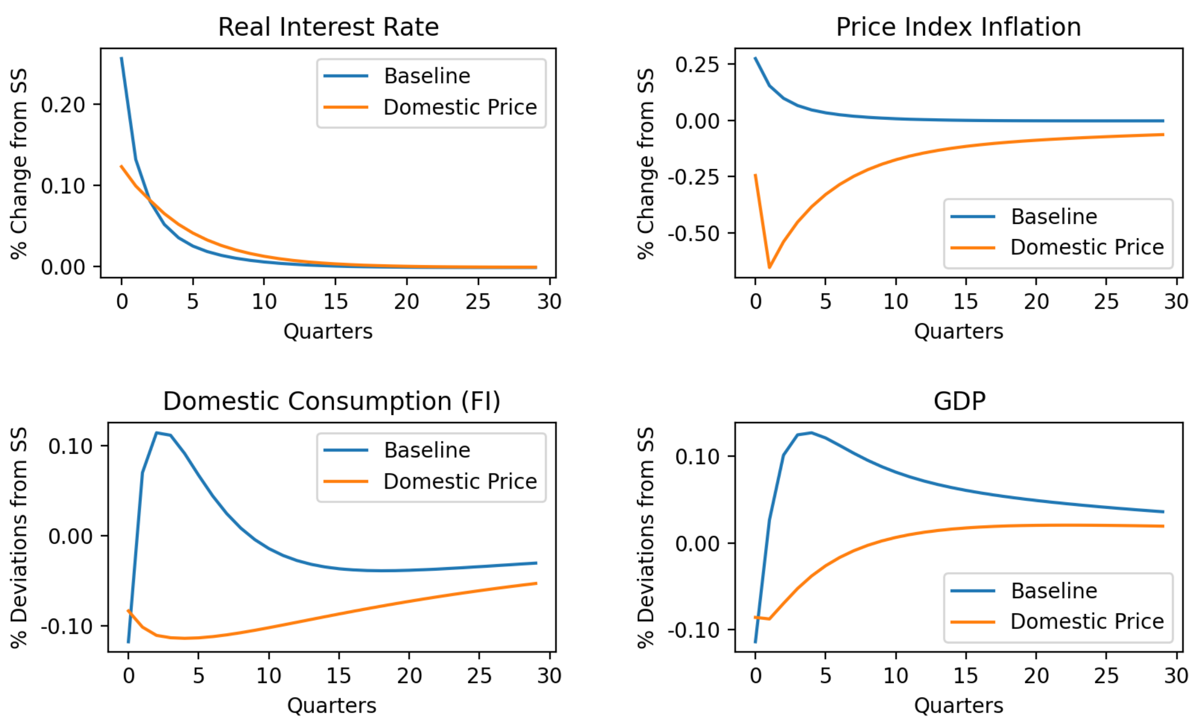
Figure 17: Counterfactual effect of the shock - MP with foreign price inflation target



Notes: The figure depicts the baseline (blue) and counterfactual (orange) welfare effect of the import price shock with monetary policy targeting foreign prices. The green bars in the top charts show the counterfactual welfare effect that would materialize if monetary policy had targeted import prices together with the same movement in real wages (left panels) or labor (right panels) as in the baseline scenario.

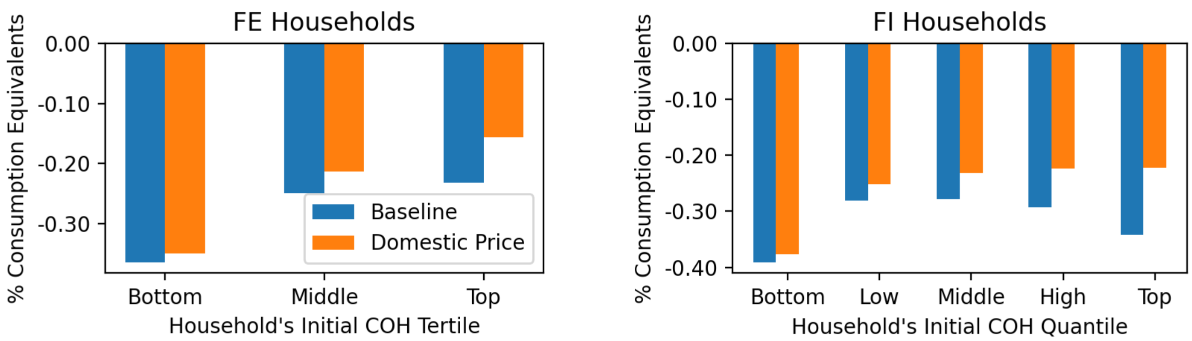
Figure 20 shows welfare losses according to the distribution of income. As clear from the sections above, households in the bottom of the income distribution, both financial excluded and included, are the ones that suffer more in terms of lost off consumption equivalents. In the exercise represented by the orange bars, we present a counterfactual in which the government still collects the same amount of taxes to sustain a zero deficit. But instead of taxing all income levels according to their productivity, it provides positive transfers to (or charges negative taxes from) those at the bottom of the income distribution. This means that the other group will pay more to compensate for the income transfers. While the result for macroeconomic variables is almost the same as in the baseline scenario, the government is able to offset a large part of the shock to those in the bottom of the distribution of income. Because of general equilibrium effects, this policy seems to be Pareto improving, given that the other groups also present a reduced loss of consumption equivalents.

Figure 18: Response of aggregate variables - MP with domestic price inflation target



Notes: The figure depicts the baseline (blue) and counterfactual (orange) responses of inflation (left), output (middle) and the real wage (right) in deviations from their steady-state levels. The counterfactual responses rely on the monetary policy rule that targets domestic price inflation as in equation 38.

Figure 19: Comparison of the welfare impact of the shock - MP with domestic price target

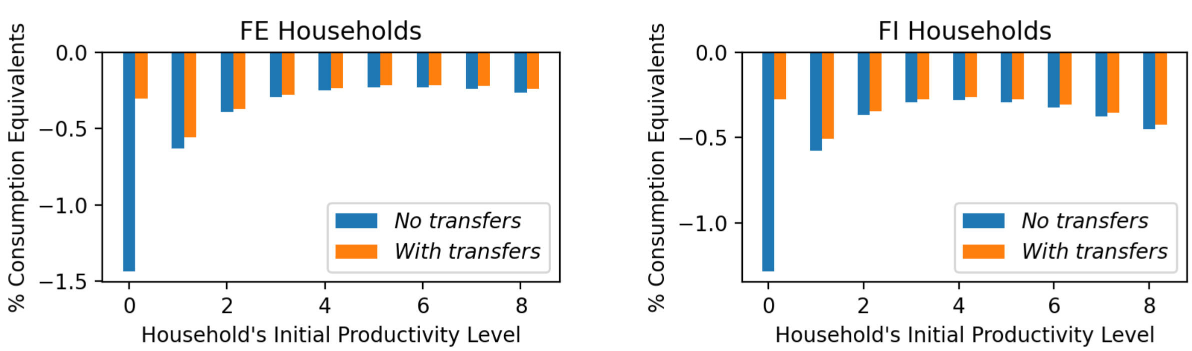


Notes: The figure depicts the baseline (blue) and counterfactual (orange) welfare effect of the import price shock with a monetary policy rule that targets domestic price inflation. Households are ranked based on their initial COH (tertiles in the left panel for FE households, quantiles in the right panel for FI households).

4 Conclusion

In this paper we presented an Open Economy HANK model with two relevant features for Low-Income Countries. First, in addition to limited insurance of income shocks, a fraction of poor households have no access to financial markets (hand-to-mouth). Second, more poor households spend a larger share of their resources in buying imported food items, which we model as a subsistence level of consumption for tradable goods. These charac-

Figure 20: Using transfers to offset distributional effects of shocks



Notes: The figure depicts the baseline (blue) and counterfactual (orange) consumption equivalent by productivity distribution after a shock to foreign prices. In the baseline, all households are taxed according to their productivity, while in the counterfactual households at the bottom of the productivity distribution receive positive transfers (negative taxes).

teristics are incorporated into the model to study monetary policy alternatives in response to a shock. The use of complex HANK models is necessary to study such heterogeneity, which are interesting by itself but also related to potential macroeconomic effects. Because LICs' reality is distant from usual calibrations from AEs or EMEs, we calibrate the model for an average LIC We then proceed to analyze the effects of a shock to external prices on macro aggregates and inequality, as well as potential monetary policy responses. As global trade fragments between different geopolitical groups of countries, it is likely that shocks as the one analyse in this paper become more frequent, presenting an increasing challenge to LICs.

With respect to the positive implications, the shock causes a consumption-led recession, an increase in inflation and a drop in real wages. In addition, consumption inequality increases because poor households cannot insure against the shock, while richer households smooth consumption through their wealth. Households at the bottom and at the top of the income distribution are the most negatively affected by the shock. The former suffer from lower wages and consumption; the latter from negative revaluation of their assets.

One of the features of the model presented here is its flexibility to analyze alternative monetary policy reactions, In this vain, we explore several scenarios, such as a less aggressive monetary policy stance, targeting import or domestic prices instead of the whole price index, smoothing the reaction of the central bank. It is usually the case that none of the alternatives benefit poorer households by much, given its offsetting effects on real wages and labor demand, with the possible exception of targeting only domestic prices, which in our model corresponds to core inflation. This is in line with previous results, which show that targeting core inflation seems to achieve better welfare results. But taking into consideration the distribution outcomes, the poorer still suffer the most. The answer for distributional issues might be beyond monetary policy. Fiscal transfers to the poorer seem to work well, without major decrease in the welfare of other income groups.

LICs have many idiosyncratic characteristics including several that our model does not incorporate, such as informality and incomplete markets. Here we chose to focus on the two key characteristics that we believe to be the main source of economic fictions: limited financial market participation and subsistence preferences. Future research could incorporate further idiosyncratic characteristics from LICs. The framework is also applicable to all developing economies, especially those in the bottom of the income scale that at large extent face similar constraints as those two identified in the model. In many cases, the main difference between LICs and EMs could be accomplished by a slightly different calibration, leading to a deeper understanding of differences between groups of countries.

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A Model and Solution Method

A.1 Quantitative Implementation: Transitional Dynamics

After we send a shock into the model, the algorithm proceeds in the following manner to find a solution:

1. Guess a path for Y_t, π_t, K_t
2. Given a path for π_t, we can use monetary policy (29) to back out a path for the real rate r_t
3. Given a path for r_t and one for i_t^*, which is exogenous in our framework, the UIP condition (24) gives us a path for the real exchange rate, $\mathcal{Q}_t$
4. Given a path for $\mathcal{Q}_t$, we can back out a path for $\frac{P_{H,t}}{P_t}, P^*_{H,t}, \frac{P_{F,t}}{P_t}$ using equations (18), (19), (20)
5. Given a path for $\frac{P_{H,t}}{P_t}$ and one for π_t, we can back out the path of domestic goods inflation, π_t^H
6. Given a path for r_t and $\frac{P_{H,t}}{P_t}$, the tax rule (27) gives us a path for T_t (importantly, we keep G_t fixed to its steady state level)
7. Given a path for Y_t, π_t^H, K_t, we can back out a path for the marginal product of capital r_t^k, the real wage w_t, and labor demand L_t using equations (11), (12) and the firm's Cobb-Douglas production function
8. Given a path for π_t and w_t, we can solve for the path of π_t^W using the definition of the real wage
9. Given a path for K_t we can back out a path for investment I_t using the law of motion of capital, a path for the investment firm's adjustment cost using its definition, and a path for q_t using equation (22)
10. Given a path for $r_t, w_t, \frac{P_{H,t}}{P_t}, \frac{P_{F,t}}{P_t}, T_t$, we can solve the household problems and obtain paths of A_t, C_t and IM_t[26]

[26]To solve the household problems we need to make an assumption about how taxes are levied on differ-

11. Given a path for $P^*_{H,t}$, equation (14) gives us a path for $C^*_{H,t}$
12. Given a path for r_t and TB_t, equation (30) allows us to back out a path for nfa_t
13. Finally, given a path for C_t, L_t, π^W_t, w_t, we can check whether the NKPC (10) holds.

Following these steps, we obtain all variables that are necessary to check whether the assets market in equation (33) hold, together with the NKPC (10) and the investment firm's optimality condition (23) (by Walras' law, the goods market will clear as well). If the equations hold, our guesses for Y_t, π_t and K_t were correct. If this is not the case, we update the guesses following a Newton's method as specified in Auclert et al. (2021a), which lets the code converge in a few steps.

A.2 Current Account

This appendix shows that Walras' law implies, in our setting, that the CA identity will hold. To see this, start by aggregating up the budget constraints of financially included and excluded households:

$$\alpha\left(\frac{P_{H,t}}{P_t}C^P_{H,t} + \frac{P_{F,t}}{P_t}C^P_{F,t}\right) + (1-\alpha)\left(\frac{P_{H,t}}{P_t}C^R_{H,t} + \frac{P_{F,t}}{P_t}C^R_{F,t} + A^R_t\right) = (1+r_{t-1})A_{t-1} + w_t\int n_{i,t}e_{i,t}di - \frac{P_{H,t}}{P_t}Tax_t$$

Assets market clearing implies:

$$\alpha\left(\frac{P_{H,t}}{P_t}C^P_{H,t} + \frac{P_{F,t}}{P_t}C^P_{F,t}\right) + (1-\alpha)\left(\frac{P_{H,t}}{P_t}C^R_{H,t} + \frac{P_{F,t}}{P_t}C^R_{F,t}\right) + B_t + nfa_t + q_tK_t = (1+r_{t-1})(B_{t-1} + nfa_{t-1} + q_{t-1}K_{t-1}) + w_t\int n_{i,t}e_{i,t}di - \frac{P_{H,t}}{P_t}Tax_t$$

Moreover, the government's budget constraint (26), labor markets clearing, and the production function, imply:

$$\alpha\left(\frac{P_{H,t}}{P_t}C^{FE}_{H,t} + \frac{P_{F,t}}{P_t}C^{FE}_{F,t}\right) + (1-\alpha)\left(\frac{P_{H,t}}{P_t}C^{FI}_{H,t} + \frac{P_{F,t}}{P_t}C^{FI}_{F,t}\right) + (1+r_{t-1})B_{t-1} + \frac{P_{H,t}}{P_t}G_t - \frac{P_{H,t}}{P_t}Tax_t + nfa_t = (1+r_{t-1})(B_{t-1} + nfa_{t-1}) + w_tL_t - \frac{P_{H,t}}{P_t}Tax_t$$

ent households. We assume that these are allocated proportionally to an agent's idiosyncratic productivity level, $e_{i,t}$. As a consequence, more productive households pay higher taxes.

Additionally, the firm's zero-profits condition implies that: $w_t L_t = \frac{P_{H,t}}{P_t} Y_t - \frac{P_{H,t}}{P_t} r_t^K K_{t-1}$. Substituting this and the firm's FOC into the previous equation, we get:

$$\alpha\left(\frac{P_{H,t}}{P_t}C^{FE}_{H,t} + \frac{P_{F,t}}{P_t}C^{FE}_{F,t}\right) + (1-\alpha)\left(\frac{P_{H,t}}{P_t}C^{FI}_{H,t} + \frac{P_{F,t}}{P_t}C^{FI}_{F,t}\right) + (1+r_{t-1})B_{t-1} + \frac{P_{H,t}}{P_t}G_t - \frac{P_{H,t}}{P_t}Tax_t + nfa_t + q_t K_t =$$
$$(1+r_{t-1})(B_{t-1} + nfa_{t-1} + q_{t-1}K_{t-1}) + \frac{P_{H,t}}{P_t}Y_t - \frac{P_{H,t}}{P_t}r_t^K K_{t-1} - \frac{P_{H,t}}{P_t}Tax_t$$

Simplifying:

$$\alpha\left(\frac{P_{H,t}}{P_t}C^{FE}_{H,t} + \frac{P_{F,t}}{P_t}C^{FE}_{F,t}\right) + (1-\alpha)\left(\frac{P_{H,t}}{P_t}C^{FI}_{H,t} + \frac{P_{F,t}}{P_t}C^{FI}_{F,t}\right) + \frac{P_{H,t}}{P_t}G_t + nfa_t + q_t K_t =$$
$$(1+r_{t-1})(nfa_{t-1} + q_{t-1}K_{t-1}) - \frac{P_{H,t}}{P_t}r_t^k K_{t-1} + \frac{P_{H,t}}{P_t}Y_t$$

Substituting goods market clearing:

$$\alpha\left(\frac{P_{H,t}}{P_t}C^{FE}_{H,t} + \frac{P_{F,t}}{P_t}C^{FE}_{F,t}\right) + (1-\alpha)\left(\frac{P_{H,t}}{P_t}C^{FI}_{H,t} + \frac{P_{F,t}}{P_t}C^{FI}_{F,t}\right) + \frac{P_{H,t}}{P_t}G_t + nfa_t + q_t K_t =$$
$$(1+r_{t-1})(nfa_{t-1} + q_{t-1}K_{t-1}) + \frac{P_{H,t}}{P_t}\left(C_t + C^*_{H,t} + G_t + I_t + \Xi_t\right) - \frac{P_{H,t}}{P_t}r_t^k K_{t-1}$$

Re-arranging and simplifying:

$$\underbrace{\alpha\left(\frac{P_{F,t}}{P_t}C^{FE}_{F,t}\right) + (1-\alpha)\left(\frac{P_{F,t}}{P_t}C^{FI}_{F,t}\right)}_{IM_t} + nfa_t + q_t K_t =$$
$$= (1+r_{t-1})(nfa_{t-1} + q_{t-1}K_{t-1}) + \underbrace{\frac{P_{H,t}}{P_t}C^*_{H,t}}_{EX_t} - \frac{P_{H,t}}{P_t}r_t^k K_{t-1} + \frac{P_{H,t}}{P_t}(I_t + \Xi_t)$$

Substitute the law of motion for capital to get:

$$-TB_t + nfa_t + q_t K_t = (1+r_{t-1})(nfa_{t-1} + q_{t-1}K_{t-1}) - \frac{P_{H,t}}{P_t}r_t^k K_{t-1} + \frac{P_{H,t}}{P_t}\left(K_t - (1-\delta)K_{t-1} + \Xi_t\right)$$

Note that we can re-write the investment firm's FOC (23) as:

$$q_{t-1}(1-r_{t-1})K_{t-1} = \frac{P_{H,t}}{P_t}\left[r_t^K K_{t-1} - \Xi_t - K_t + (1-\delta)K_{t-1}\right] + q_t K_t$$

Substituting this into the previous equation, we obtain:

$$-TB_t + nfa_t = (1+r_{t-1})nfa_{t-1} \Rightarrow CA_t = nfa_t - nfa_{t-1} = TB_t + r_{t-1}nfa_{t-1}$$

A.3 Investment Firm

Per period profits and the adjustment cost are given by:

$$\Pi_t^{Inv} = \left(r_t^k K_t - I_t - \Xi_t\right)\frac{P_{H,t}}{P_t},$$
$$\Xi_t(I_t, K_t) = \frac{\zeta}{2}\left(\frac{(1-\delta)K_t + I_t}{K_t} - 1\right)^2 K_t,$$

Define $R_t := \prod_{i=0}^{t} \frac{1}{1+r_i}$. The problem of the firm is given by

$$\max_{\{I_t, K_{t+1}\}_{t=0}^{t=\infty}} \sum_{t=0}^{\infty} \frac{\left(r_t^k K_t - I_t - \Xi_t(K_t, I_t)\right)\frac{P_{H,t}}{P_t}}{R_t}$$

subject to $K_{t+1} = (1-\delta)K_t + I_t$. The first order condition with respect to I_t is given by:

$$q_t = \left[1 + \zeta\left(\frac{K_{t+1}}{K_t} - 1\right)\right]\frac{P_{H,t}}{P_t} = \left[1 + \frac{d\Xi_t(I_t, K_t)}{dI_t}\right]\frac{P_{H,t}}{P_t}.$$

The first order condition with respect to K_{t+1} is given by:

$$q_t = \frac{\frac{P_{H,t+1}}{P_{t+1}}}{(1+r_{t+1})}\left[\left(r_{t+1}^k - \frac{\zeta}{2}\left(\frac{K_{t+2}}{K_{t+1}} - 1\right)^2 - \zeta\left(\frac{K_{t+2}}{K_{t+1}} - 1\right)\left(\frac{-I_{t+1}}{K_{t+1}}\right)\right)\right] + \frac{q_{t+1}(1-\delta)}{(1+r_{t+1})}.$$

which is exactly:

$$q_t = \frac{\frac{P_{H,t+1}}{P_{t+1}}}{(1+r_t)}\left[\left(r_{t+1}^k - \frac{d\Xi_{t+1}(K_{t+1}, I_{t+1})}{dK_{t+1}}\right)\right] + \frac{q_{t+1}(1-\delta)}{(1+r_t)}.$$

B Background for the calibration of the parameter $\bar{c}$ for subsistence

The calibration of the parameter $\bar{c}$ in our model is based on the relative imports of staple foods by LIDCs. According to our calculations (explained below), LIDCs' imports of staple foods is equivalent to 10% of their consumption basket, a similar figure to that of emerging markets (EMEs), but three times higher than for advanced economies (AEs).

The Food and Agricultural Organization of the United Nations (FAO) provides the minimal number of calories a person must consume to avoid undernourishment. Below this threshold, the average person is not achieving minimum dietary energy requirements to maintain a normal, active and healthy life. The FAO provides country-specific levels of minimum consumption of calories to avoid undernourishment, since the requirement vary with average age as well as genre composition of populations.

The FAO also publishes a Food Balances database, with detailed information on quantity of food items produced, imported and consumed by each country, as well as the number of calories provided by each item. The level of desegregation is rich and the database spans all the main food items from consumption baskets of the countries covered.

For each country, we rank food items according to their contribution to food intake for the period 2015-2019. We then check how many food items are necessary to achieve a level just above undernourishment. These items compose our country-specific baskets of staple foods, since they are the ones that the countries' populations need to overcome undernourishment. Figure 21 shows the main staples for each LIDC. As expected, some items are more important in different parts of the world, according to cultural traditions and local factors of production (such as rice in Asia), but rice, wheat and maize are relevant items for most countries. Countries such as Benin are less dependent on one specific staple food, having a more diversified diet, and in theory could be less vulnerable to shocks to the price of a specific food item.

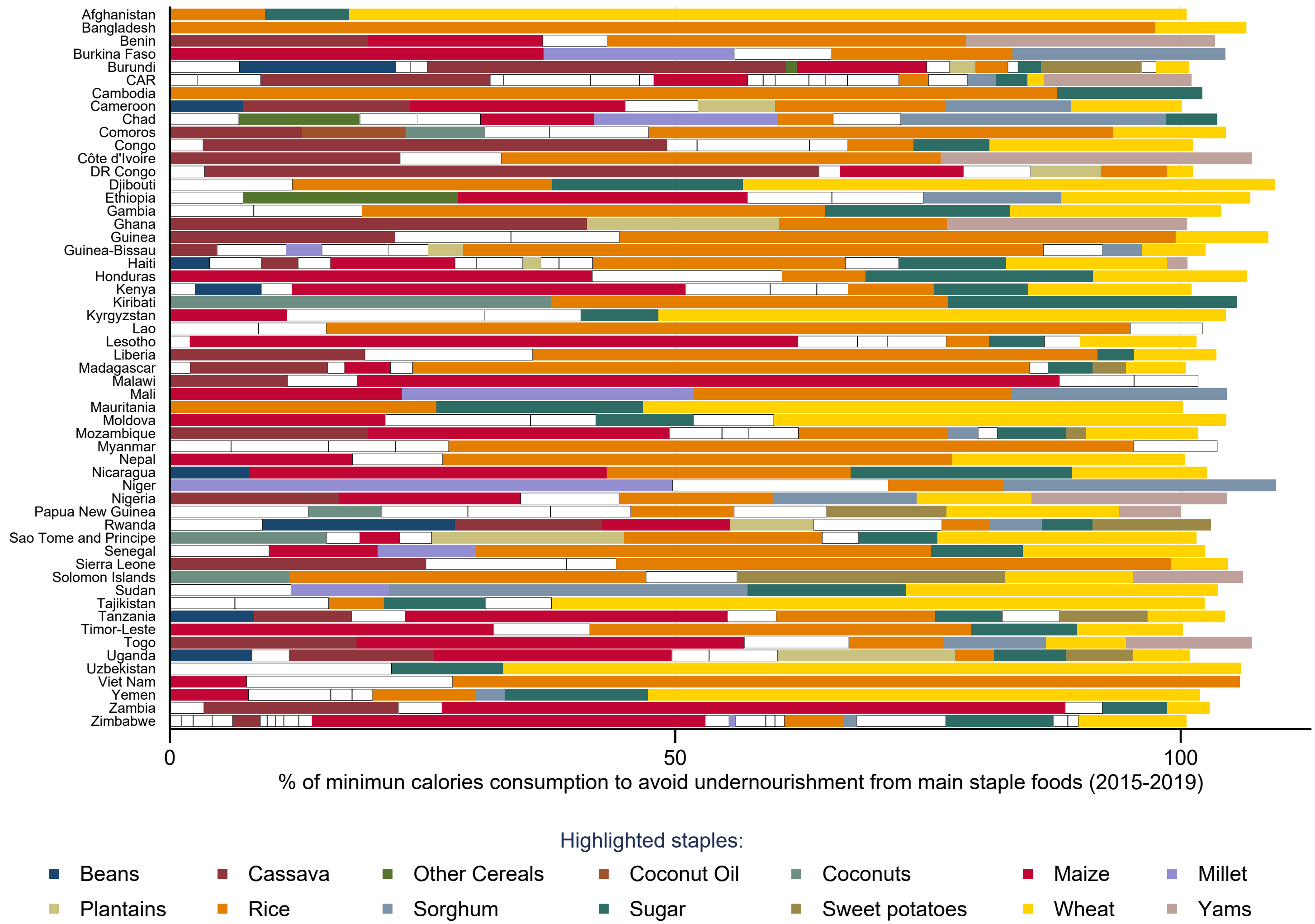


Figure 21: Main staple foods used to achieve consumption above undernourishment. Source: FAOSTAT Food Balances and authors' calculations. Note: According to FAO, undernourishment means that a person is not able to acquire enough food to meet the daily minimum dietary energy requirements, over a period of one year.

Using the information on what staples are relevant for each country, we then proceed to calculate how much countries import of those food items. Using the share of food as a percentage of their consumption basket (from the IMF's IFS), we calculate how much countries depend on the imports of staple foods (figure 22). AEs dependence on imports for staple foods is minimal, with an average of 2.5% of their consumption basket and most countries in this group import less than 10% of their needs (with just one exception). EMEs and LIDCs are much more dependent on imports, with averages (and medians) closer to 10% of their consumption basket. LIDCs are a particularly heterogeneous group, with at least 10% of the countries importing a quarter of their staple foods. We use the World Bank

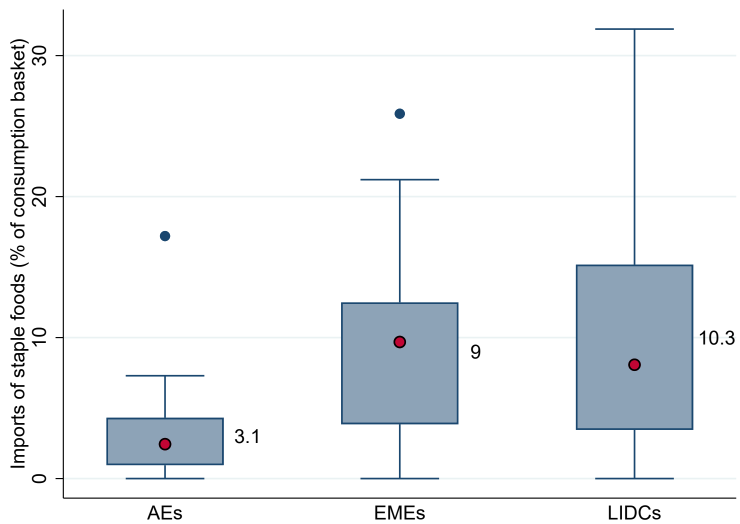


Figure 22: Import of staple food by country classification as % of their consumption baskets (floating numbers represent the averages). Source: FAOSTAT Food Balances, WB Consumption Database and authors' calculations

consumption database (for a more restricted sample of countries) to also analyze imports' dependence of staple goods by level of income within each group. The pattern is similar. Poorest households are the ones that depend more on imports for the consumption of staple foods required for subsistence. This is in sharp contrast with imports of luxury goods consumed by households in the top of the income distribution. The lowest level of income per capita in LIDCs imports the equivalent of 13% of their consumption basket in staple foods, in comparison to 5.5% of the same stratum in AEs. The higher level of income in LIDCs average imports of staple foods is equivalent to 4.8% of their consumption basket, in comparison to almost 2% for those in AEs. To further investigate the dependence of staple food imports, we run regressions of the variable constructed above on a indicator

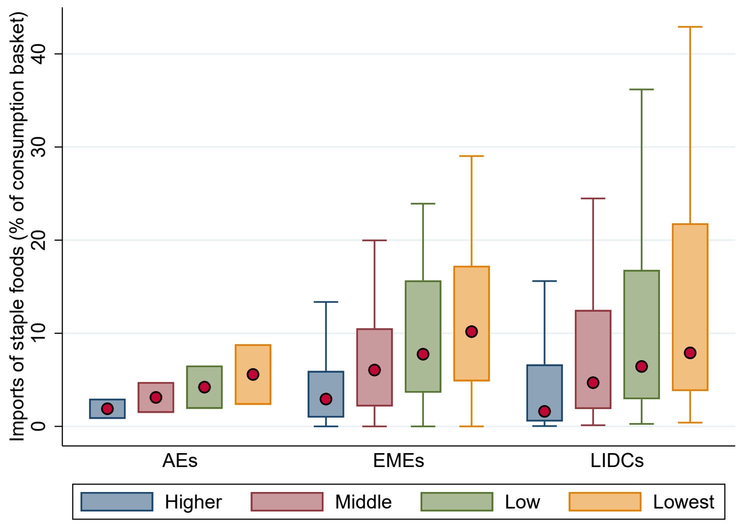


Figure 23: Import of staple food by country classification and income as % of their consumption baskets. Source: FAOSTAT Food Balances, WB Consumption Database and authors' calculations. Note: No outsides. The four levels of consumption used to segment the market in each country correspond to the rank of the global population by income per capita. 'Lowest' corresponds to 50th percentile and below; 'Low' to 51th–75th; 'Middle' to 76th–90th; and 'Higher' to 91st and above. The PPP$ thresholds per capita a day are: below 2.97 for 'Lowest', between 2.97 and 8.44 for 'Low', between 8.44 and 23.03 for 'Middle' and above 23.03 for 'Higher'.

variable for EMEs and LIDCs and progressively introduce controls that could explain why these countries are more dependent on imports for subsistence, testing if the new variables for each new specification are jointly significant. The coefficients of these regressions are represented in figure 24. Predictions based on the first specification without controls, as expected, show results similar to figure 22, with LICs dependence on imports three times higher than EMEs and around 10% of their consumption basket. The result does not change when the specification includes controls for population (in log) and for geographical characteristics: an indicator for small islands, percentage of land that is desert, average distance to nearest ice-free coast, and a population-weighted terrain ruggedness index. The last three indicators come from the database of Nunn and Puga (2012) (see also Unsal et al. (2022)). The ruggedness index is a proxy for the integration of domestic markets. In the case of food supply, it could help measure how difficult it is to transport food produced in one part of the country to other regions. All coefficients are significant at 5% levels and have the expected signs. Population works as a proxy for the size of the country, with a negative coefficient (measures of countries' area and density were not significant when included jointly with population). In the next step, we add an indicator variable for the African continent, meaning that the indicator variable for LIDCs covers only countries outside Africa. Results do not change by much and the African dummy is significant and positive: countries in Africa import on average more 3 percentage points of food for subsistence in their consumption basket. Results only change when the specification includes rule of law from the World Bank's Worldwide Governance Indicators database. When controlled for this variable, differences between group of countries, as represented by the indicator variable for LIDCs and EMEs, become non-significant. The channels by which rule of law can have an impact on the dependence of food imports are varied. Countries with lower levels of rule of law might be unable to adapt to new technologies to produce and distribute food more efficiently, leading to higher imports. Additionally, lower levels of rule of law might compromise availability of credit for agricultural production. Another channel might come from distorting taxes that are a consequence of governments' low fiscal capacity.

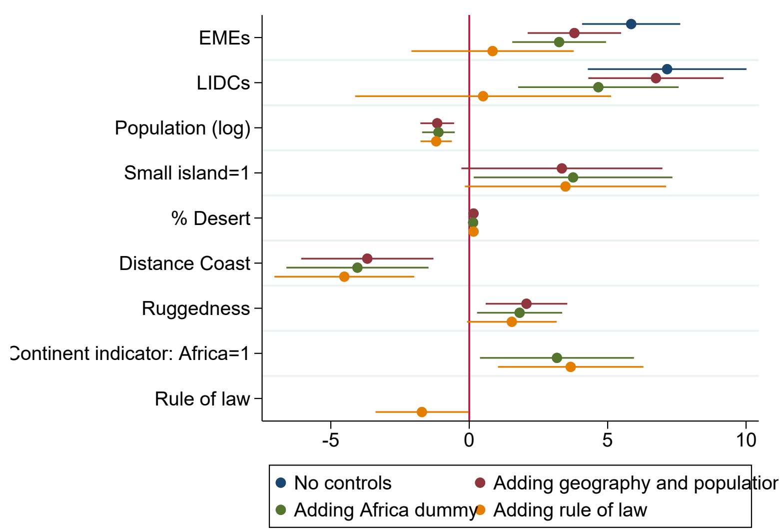


Figure 24: Coefficients of regressions using the import dependence of staple foods as dependent variable.

As a robustness exercise, we substitute the indicator variables for EMEs and LIDCs by GDP per capita and results are identical, in the sense that the higher the GDP, the lower is the dependence on food imports, even controlling by geographical characteristics and population. The exception, as in the basic specification above, is rule of law, which makes GDP per capita non-significant.

C Background for the calibration of the parameters ρ_l for persistence and σ_l for standard deviation of labour productivity.

As mentioned in the main text, in order to model idiosyncratic productivity risk, we follow the literature by assuming that the household's labor productivity, e, behaves accordingly to a AR(1) process $\log e_t = \rho_l \log e_t + \varepsilon_t$, with $\sigma_l = std(\varepsilon_t)$. Auclert et al. (2021b) mention that $\rho_l = 0.92$ and $\sigma_l = 0.6$ are typical estimates for these parameters, while aiming to calibrate the model for Mexico, an emerging market. Floden and Lindé (2001) seem to be the pioneers on estimating these parameters for the US and Sweden. Guerrieri and Lorenzoni (2017) also use the same estimates from the US, but transforming to quarterly frequency. Wöhrmüller et al. (2022) re-estimates Floden and Lindé (2001), but going beyond the wages of the head of the family. As far as our knowledge extends, there is no known estimation of these parameters for LICs.

We aim to fill this gap by using the ECG-ISSER Ghana Socieconomic Panel Survey (GSPS) to reproduce for Ghana the methodology of Floden and Lindé (2001). The survey was conducted in three waves in 2009/2010, 2013/2014, and 2017/2018, and follows individuals over time. Our measure of hourly wages derives from the variable *paid amount* and *paid other*, which refers to other types of payment. Because the amount received depends on the frequency of payment, we transform other frequencies of payment (such as quarterly and weekly) to hourly by dividing the amount by the number of weeks and days worked (these variables are available in the data set). In line with Floden and Lindé (2001), we assume that the lower bound for wages is 10% of the average wage and exclude all agents with less than 1000 work hours supplied. Table A1 shows the remaining values for wages in GHS (Ghanaian cedis) - $\overline{W}$ - as well as descriptive statistics for the constructed relative hourly wages w_t^i, which is agent i's hourly wage rate as a function of the average hourly wage rate in that wave. In comparison to the US and Sweden, the variability in the relative wages series is much larger and also increases more over time.

We follow the procedure of capturing permanent wage differences by individual specific characteristics such as age, education, and occupation. We regress the variable for (log of) hourly wages from the first wave on age, the square of age, a dummy variable for sex (equal to 1 if the individual's gender is male), and variables that are dummies for agents'

Table A1: Descriptive Statistics for Relative Wages

Statistic	Wave 1	Wave 2	Wave 3
$\overline{W}$	0.87	2.18	3.65
$Std(w^i)$	1.06	1.75	1.95
$Max(w^i)$	11.04	28.50	40.85
$Min(w^i)$	0.10	0.10	0.10

education levels and occupation. Results are in table A2. They are highly significant for age and sex and similar to those from the US and Sweden. For education, coefficients are positive, but those that refers to higher levels of education are more significant. Results for occupation are mixed, but generally positive coefficients are significant. The fit for both occupation and education are worse in comparison to Floden and Lindé (2001), maybe reflecting a smaller sample for the survey. Nonetheless, F-statistics are satisfactory and the adjusted r-square is reasonably high and similar to the regressions for Sweden and US. Results are similar when using robust standard erros, with significance improving substantially for all the coefficients of education levels.

Table A2: OLS Estimation Results for the Initial Relative Wage Level

	Initial Wage	
Variables	Estimate	Standard error
Age	0.0723***	(0.0139)
$Age^2/100$	-0.0675***	(0.0159)
Dmale	0.197***	(0.0595)
EDUC = 2	0.507	(0.751)
EDUC = 3	0.672	(0.749)
EDUC = 4	0.575	(0.745)
EDUC = 5	0.773	(0.748)
EDUC = 6	1.264*	(0.750)
EDUC = 7	1.321*	(0.747)
EDUC = 8	1.212	(0.747)
EDUC = 9	2.021*	(1.050)
EDUC = 10	1.770**	(0.755)
EDUC = 11	1.850**	(0.816)
OCC = 2	0.129	(0.125)
OCC = 3	0.506***	(0.138)
OCC = 4	0.431***	(0.154)
OCC = 5	-0.0192	(0.139)
OCC = 6	0.121	(0.185)
OCC = 7	0.331**	(0.137)
OCC = 8	-0.0158	(0.139)
OCC = 9	-0.187	(0.139)
Constant	-3.115***	(0.811)
Observations	847	
Adjusted R-squared	0.317	
F-test	19.69	
Prob > F	0.000	

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

From the results of the regression in table A2, we calculate permanent wage component $\hat{\psi}^i = \hat{x}^i_{wave1}$ from the fitted values of the regression. The calculated variance of these differences (σ^2_{ψ}) is 0.1843, meaning that we find higher permanent wage differences between individuals in Ghana than Floden and Lindé (2001) find for the US. From there, we calculate $\tilde{x}^i_t \equiv x^i_t - \hat{\psi}^i$ for the the 3 waves. Summary statistics for the transformed variables are in table A3. In contrast to the US and Sweden, the variability actually increases in comparison to table A1. This means that in Ghana, after controlling for systematic factors, dispersion increases.

Table A3: Descriptive Statistics for Transformed Relative Wages

Statistic	Wave 1	Wave 2	Wave 3
$Std(w^i)$	1.20	4.76	3.84
$Max(w^i)$	15.63	59.55	53.62
$Min(w^i)$	0.11	0.05	0.06

We use $\tilde{x}^i_t$ to construct unconditional moment conditions (7) in Floden and Lindé (2001) and estimate ρ, σ^2_{ε} and σ^2_{ς} using the general method of moments. The three waves for the survey allows us to use 6 moments. Results are in table A4. The persistence of the series for hourly wage is high, precisely estimated, and not much different from the typical estimates from advanced economies in the literature. The variance of temporary shocks is higher than what is estimated in the literature for the US and Sweden, which might be expected in countries with less developed markets. The coefficient is not precise (p-value is 0.117).

As in Floden and Lindé (2001), over-identifying restrictions do not seem to hold. As mentioned by those authors, it is possible that the wage process we are using is too crude an approximation and that parameters are different for sub-samples of the population. As expected and showed above, heterogeneity across households should be even larger in LICs, and education premiums more pronounced. This could explain why the fit of the model is less precise than when estimating it with AE data. The main results are that, even thought the variance of wages and temporary shocks are somehow larger when estimating the model for LICs, persistence of wages is similar.

The estimates above are for annual the annual moments. To convert these to a quarterly AR(1) process, we use the expressions for the variance and covariance of the yearly average of a quarterly AR(1) process, as derived in Wöhrmüller et al. (2022).

Table A4: GMM Estimation Results for the Wage Process

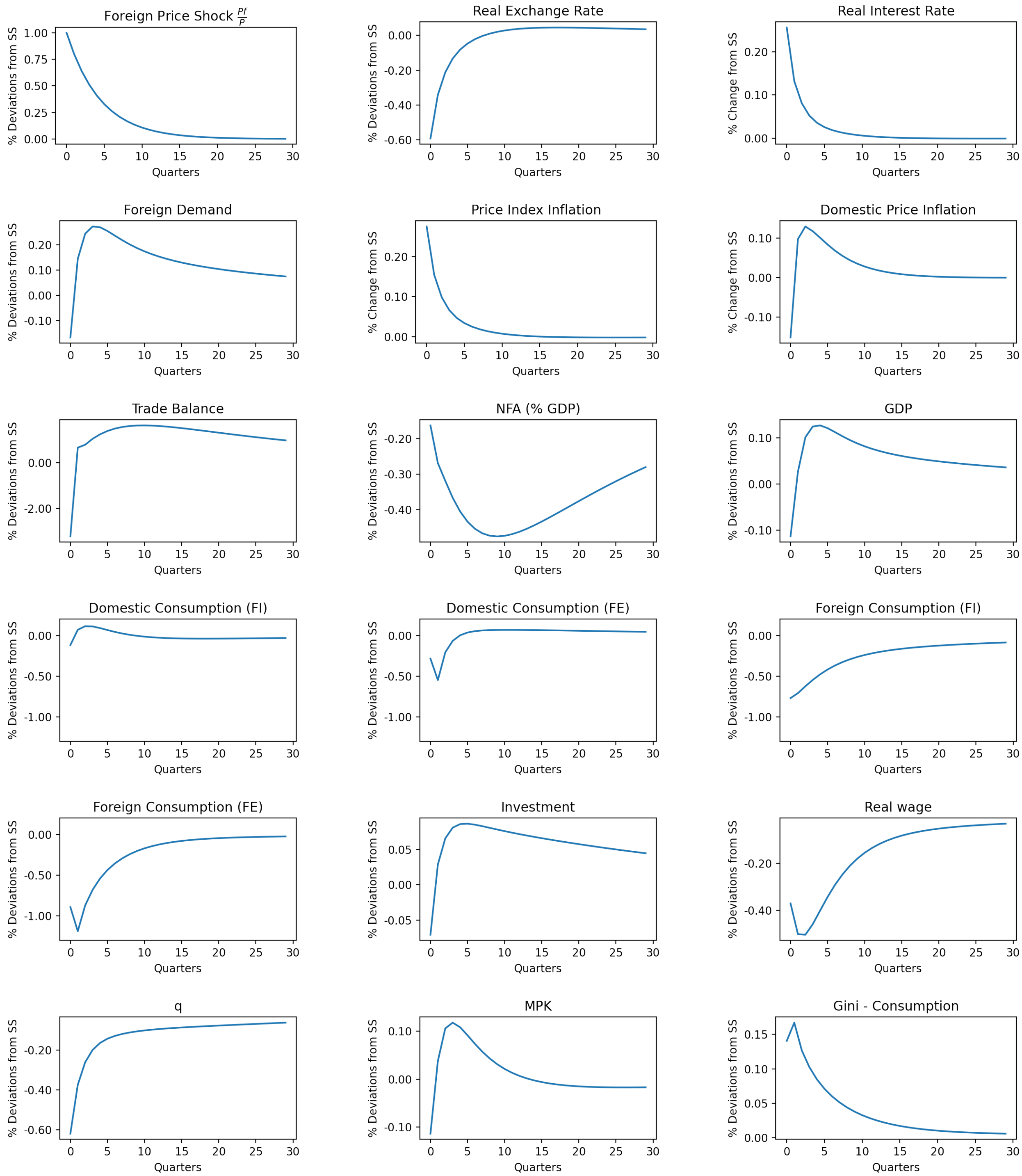
Parameter	Estimate	Standard error
ρ	0.922***	(0.0377)
σ_{ε}^2	0.0503	(0.0321)
σ_{ξ}^2	0.135*	(0.0693)
χ^2_{obs}	18.38	
$p - value$	0.0004	

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

D Additional IRFs for the baseline exercise

Figure 25: IRFs to an exogenous increase in import prices



E Levels of subsistence

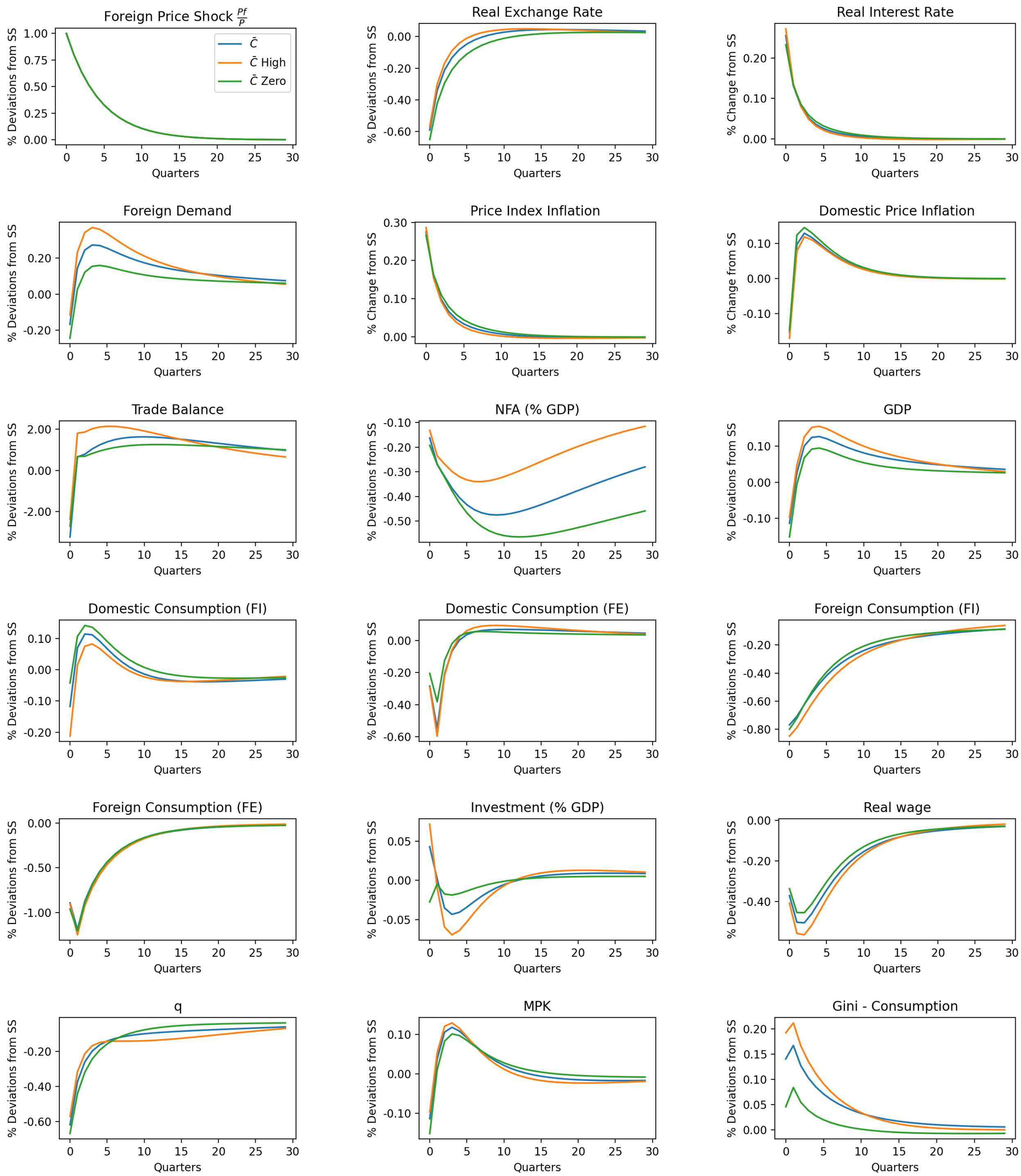
In this section, we analyse how the subsistence parameter $\bar{c}$ affects our baseline results. For this, in addition to the value of $\bar{c}$ used above (0.058), we present IRFs for a high $\bar{c}$ (0.068) and a $\bar{c}$ equal to zero.[27] The first one represents a society in which subsistence represents a higher of consumption. The case with a zero $\bar{c}$ corresponds to a society with no subsistence requirements. This allows us to analyze the importance of subsistence for the baseline results, as well as to compare those with models that do not contain that feature. These IRFs are in figure 26.

The direct effect of $\bar{c}$ on consumption is via two channels: disposable income and relative prices. When the subsistence requirement on the foreign good is loosened, it is natural that households will become more elastic to its consumption in comparison to the domestic good. At the same time, consumers' disposable income goes up, which means that households are able to consume more of both goods. As seen in the figure, when $\bar{c}$ is zero (i.e. lower subsistence level), financially excluded households switch between foreign and domestic goods - the fall in domestic good consumption by financially excluded households is less pronounced. Symmetrically, with a high $\bar{c}$, domestic consumption and domestic price inflation drop more on impact, with the associated lower prices leading to a lower drop in foreign demand/exports. These higher exports boost GDP after the first period. With lower levels of $\bar{c}$, the contribution of the external trade is weaker.

Given the dynamics in prices, the lower subsistence requirements are, the less the central bank needs to raise interest rates for the same shock on the price of the foreign good. This means that the presence of subsistence is a friction that decreases monetary policy power in a general equilibrium setting. The interest rate response, together with that of other variables, has a strong effect on investment. With higher levels of subsistence, investment is boosted in the first period and goes down subsequently. With lower levels of subsistence (we calculate that the threshold is around 0.03), investment becomes more stable, shrinking for most of the period.

[27] The value of $\bar{c}$ has an impact on the steady-state. This means that the different experiments presented in the charts start from different steady-states. To minimize differences, we used the same targets for all the relevant variables, such as debt/GDP ratio, fraction of financially excluded, average MPCs and others. But the fact that the different specifications have different starting point means that results can be counter-intuitive.

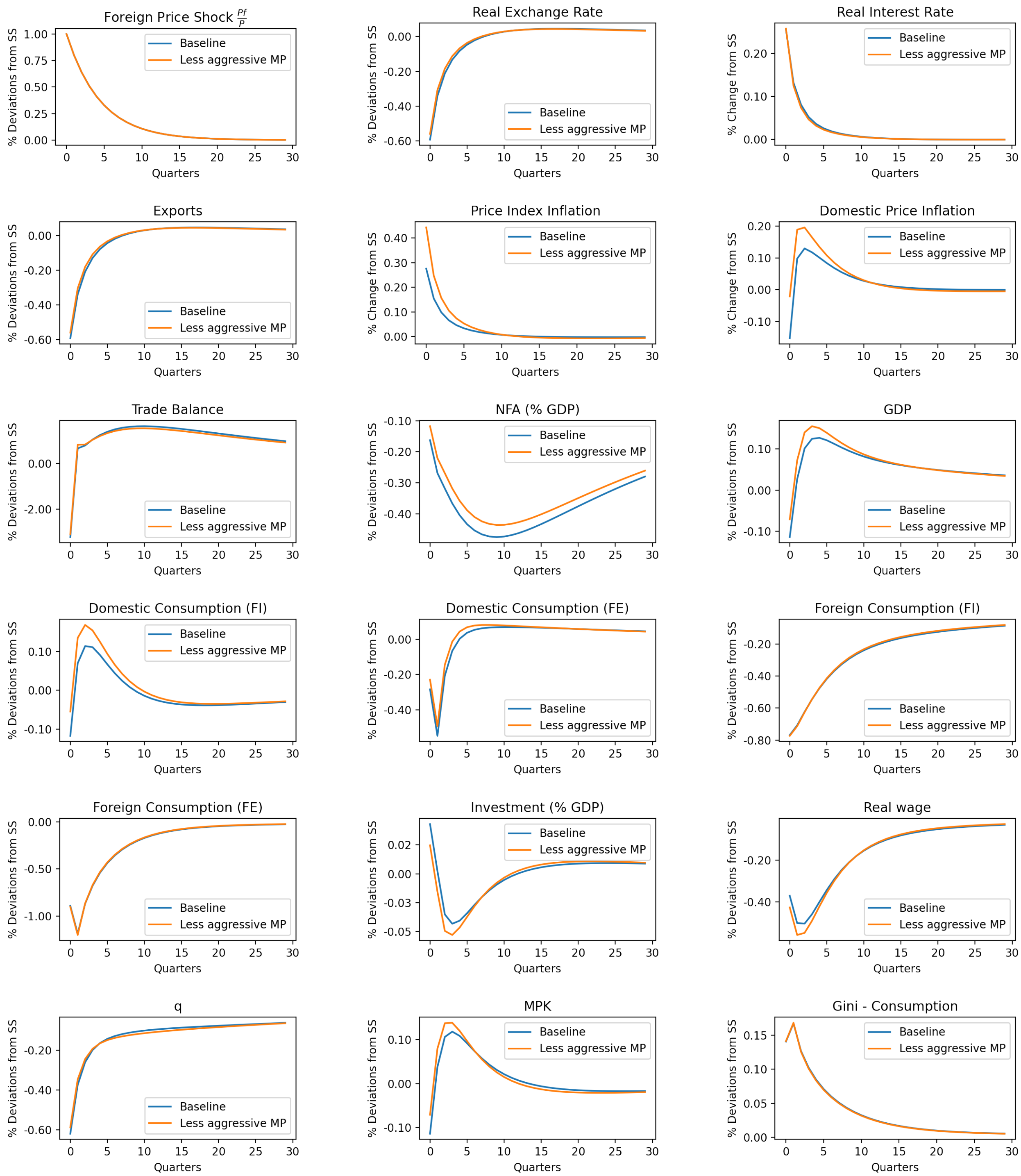
Figure 26: IRF comparison of different subsistence levels



In terms of inequality, when $\bar{c}$ is higher, the effect of inflation on real wages boosts the pattern of the distribution of labor income being compressed to the left, producing lower values of Gini. While labor income becomes less unequal, the boost in investment translates into higher dividends to rich households, increasing the Gini for cash-on-hand. The results for consumption Gini when $\bar{c}$ is higher represent a reversal compared to the baseline case. Because consumption of poor households is proportionally more exposed to imported goods, the adjustment to their overall consumption is much harsher than for rich households. This means that inequality increases dramatically from the first periods, remaining higher than in comparison to the baseline case in the long term. With $\bar{c}$ equal to zero, the rise on consumption inequality is much lower. This means that adding this friction to the model is relevant for the understanding of the dynamics of inequality.

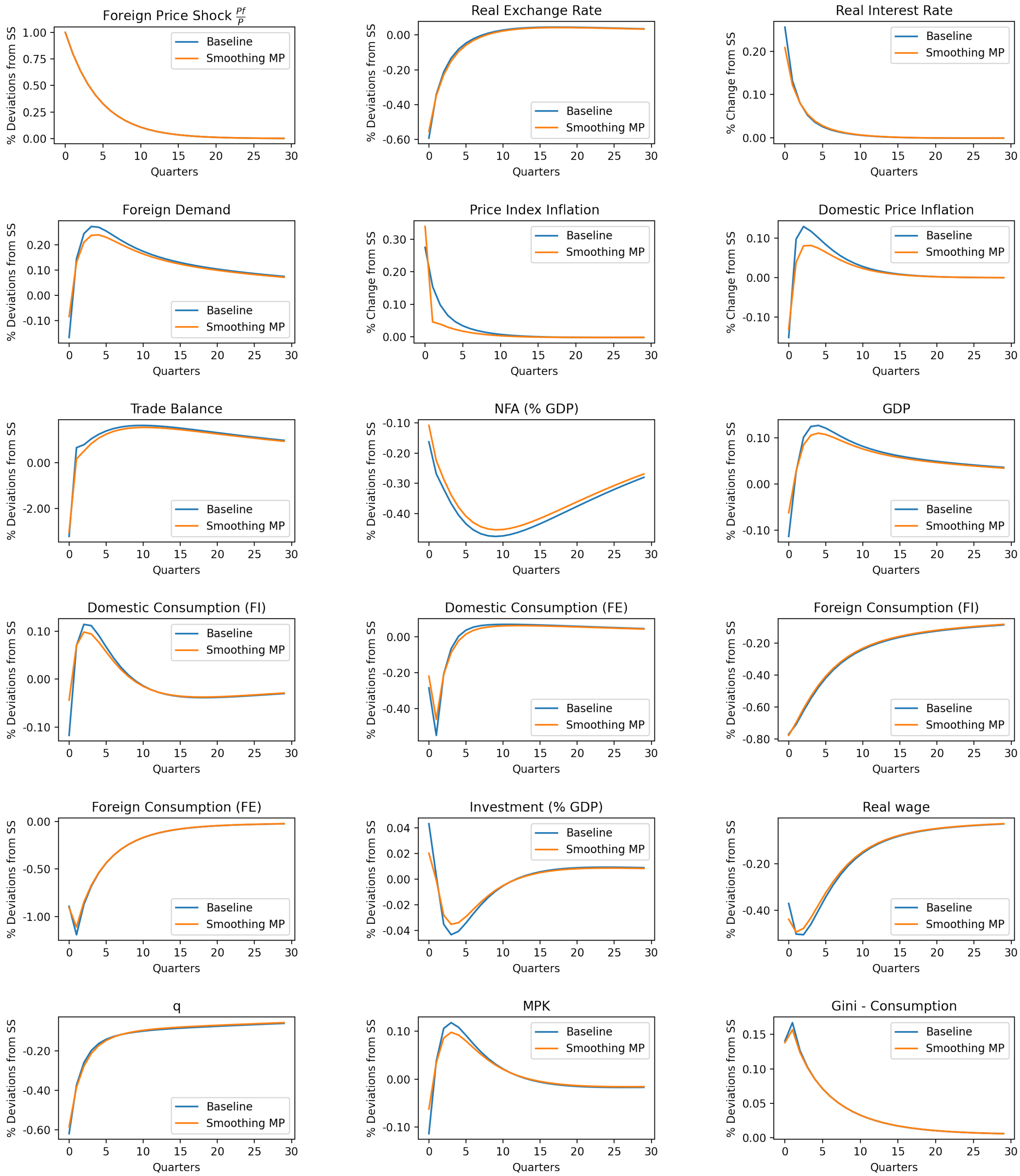
F Additional IRFs for the alternative MP exercise

Figure 27: Response of additional variables, alternative MP



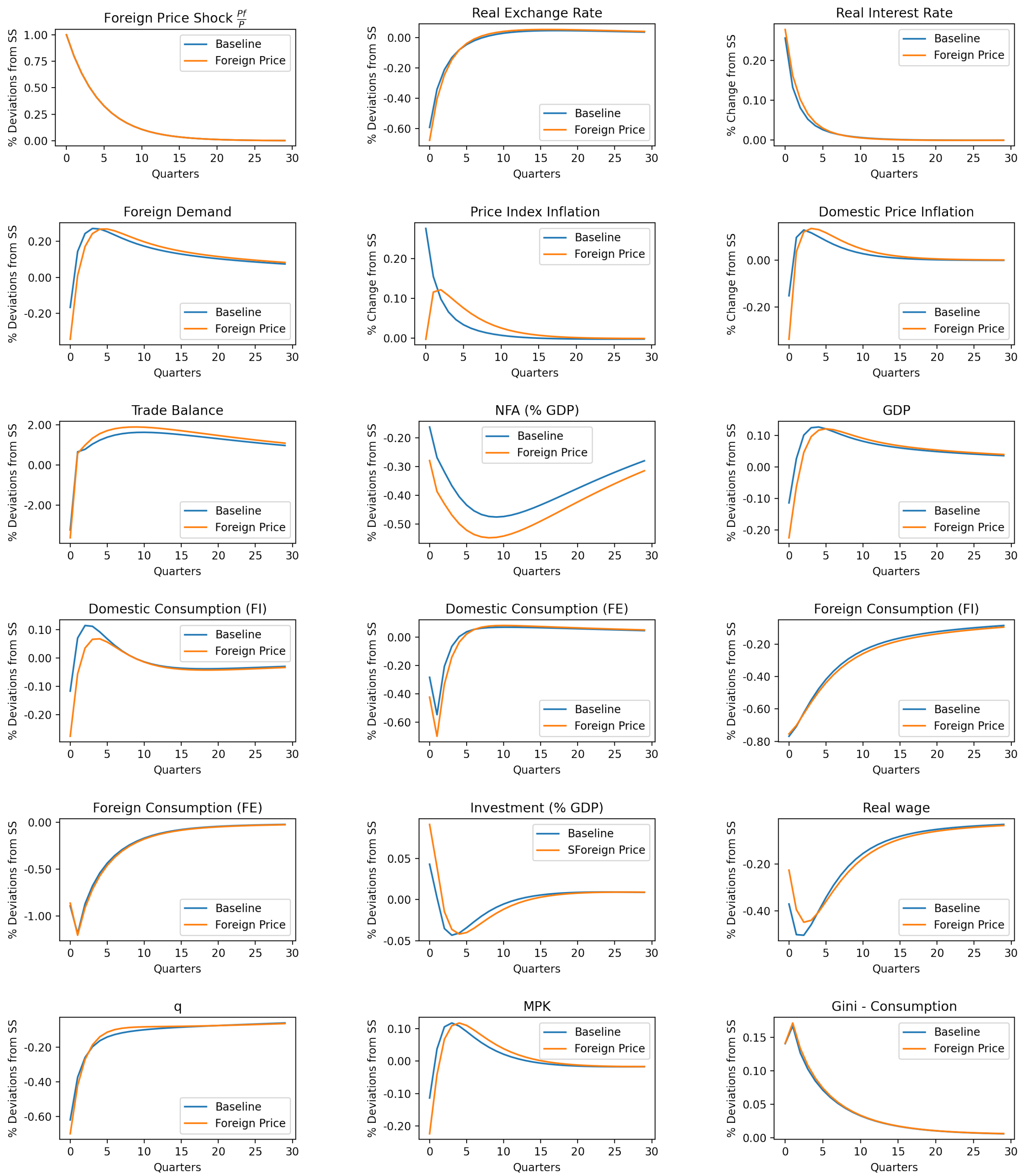
G Additional IRFs for the exercise with interest-rate smoothing

Figure 28: IRFs to an exogenous increase in import prices



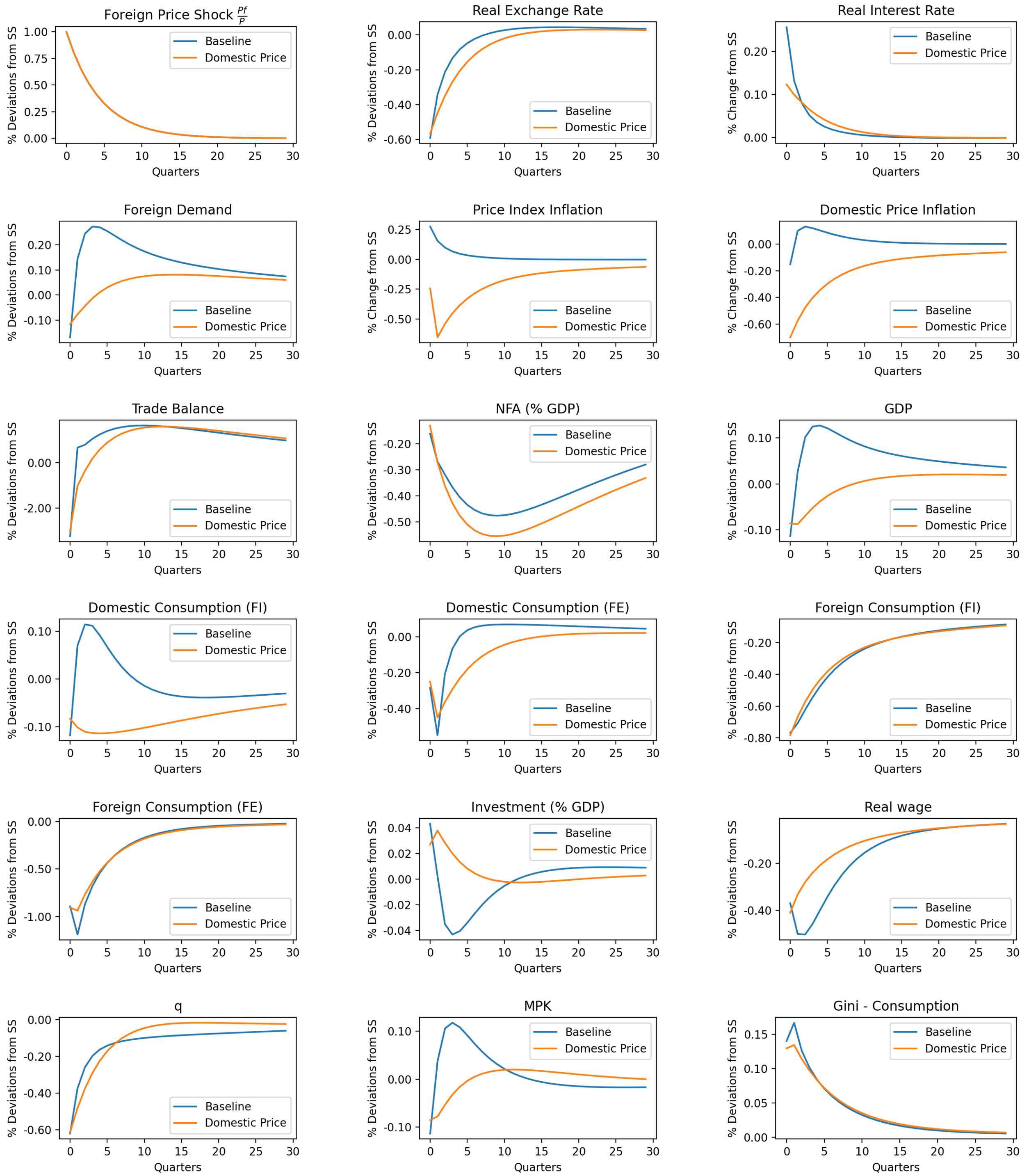
H Additional IRFs for the exercise with import inflation targeting

Figure 29: IRFs to an exogenous increase in import prices



I Additional IRFs for the exercise with domestic inflation targeting

Figure 30: IRFs to an exogenous increase in import prices



J Alternative shock to UIP premium

Figure 31 shows the IRFs of an alternative shock to the model: an increase in the UIP premium in equation 24:

$$(1 + r_t) = (1 + i_t^*)*(1 + \varepsilon_t)\frac{\mathcal{Q}_{t+1}}{\mathcal{Q}_t} > (1 + i_t^*)\frac{\mathcal{Q}_{t+1}}{\mathcal{Q}_t}, \tag{39}$$

where ε_t is the shock to the UIP premium. In practical terms, the shock is the same as one for i_t^*, given that i_t^* does not affect other equations in the model. As is the case with prices for the imported good, we model ε_t as an AR(1) process with persistence 0.8 and we calibrate it so that the response of real interest rates is the same as is the main text for ease of comparison. The shock can be seen in the top LHS chart of figure 31.

The responses to the shock are as expected and different from the baseline in the main text. The central bank raises interest rates and partially offsets the increase in the risk premium. Despite this action, the real exchange rate depreciates, leading to a large surplus in the trade balance. Because of this, the GDP reacts positively, despite the dynamics of consumption.

In comparison to the shock to prices of the foreign good, the effects on consumption of the UIP shock are milder. Consumers are still facing higher prices for foreign goods, including by the effect of the exchange rate, but they seem to benefit from a higher income, given the impact of GDP on employment. In comparison to the dynamics of consumption in figure 3, we can see that the consumption of financially included households seems to be similar, while that of *FE* improves with respect to the baseline. Financially included households are smoothing consumption in all cases, but those excluded benefit from higher working hours when facing a UIP premium shock. The contrast with the main text is particularly striking when looking at domestic consumption for financially excluded households.

While the inequality of consumption increases, it does by half of the variation of the case considered in the main text. What does this imply for welfare? The calculation of consumption equivalents (not shown) indicates that all consumers fare better in comparison to the main text. For most COH groups, the coefficient calculated in equation 35 indicates losses of hlaf the size of the ones in the main text. But the pattern of households in the bottom of the COH scale being hit harder is still present.

Figure 31: IRFs of a shock to UIP