United in Diversity: A HANK^2 model of monetary unions

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Abstract

The heterogeneity of monetary unions is much discussed ever since Mundell (1961). Traditionally, the focus is heterogeneity at the macro level and on whether countries benefit from maintaining a monetary union. In this paper, we zoom in on the heterogeneity *within* countries as we put forward a heterogeneous agent New Keynesian model of two countries: HANK^2. We calibrate the model to the euro area and study the transmission of asymmetric shocks. Their distributional impact is much larger within than across countries, independently of the exchange rate regime. Contrasting a currency union to a scenario of monetary autonomy we find that macro spillovers are smaller and the distributional impact of shocks within countries more aligned across countries.

Keywords: HANK^2, OCA theory, Two-country model, monetary union, spillovers, monetary policy, heterogeneity, inequality, welfare

JEL-Codes: F45, E52, D31

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1 Introduction

The costs and benefits of maintaining a monetary union are typically analyzed at the country level. The more homogeneous the countries which share a common currency, the lower the costs of foregoing monetary autonomy. Asymmetric shocks, instead, give rise to difficult trade-offs for a common monetary policy, making it potentially very costly. Optimum currency area (OCA) theory, as originally developed by Mundell (1961), is thus concerned with the question of whether a monetary union is sufficiently homogeneous for the benefits of a participating country to outweigh its costs. And indeed, many policy debates are framed in terms of a country's welfare, as the euro area's 20-odd years' history exemplifies: Would Greece or Italy be better off without the euro? Is the euro doing Germany any good? Implicit in these questions is the assumption that national welfare can be understood through the lens of a representative agent in order to keep the focus on cross-country heterogeneity.

In this paper, we offer a change of perspective. We start from the insight that economic heterogeneity within countries dwarfs the heterogeneity across countries—notably when it comes to income risk and wealth. Against this background we ask: How does a common currency alter the distributional impact of country-specific shocks, both *within* and *across* countries? To address this question, we put forward a heterogeneous agent New Keynesian model of two countries: $HANK^2$. A key feature of the model is that households face idiosyncratic income risk which, in turn, governs saving decisions and portfolio choice and, eventually, results in an unequal distribution of wealth. We calibrate the model to the euro area (EA) and study how a common currency shapes spillovers of asymmetric shocks at the macro level as well as their distributional impact within across countries. Throughout we assume countries to be perfectly isomorphic and leave the analysis of cross-country differences in household heterogeneity to a companion paper (Bayer et al. 2022).

Our analysis yields three main results. First, at the macro level, spillovers of country-specific shocks are generally moderate in the currency area. In fact, for output they tend to be smaller than in case countries operate independent monetary policies. Second, the distributional impact of country-specific shocks is generally much larger within than across countries, independently of the exchange rate regime. What matters for their welfare impact is not so much a household's country of residence but where it is located in the wealth distribution. Third, a common currency amplifies the welfare impact of foreign shocks in the tails of the wealth distribution. Both, the rich and the poor are more exposed to foreign shocks in this case. At the same time, the welfare impact of domestic shocks is more equally distributed. In sum, the distributional impact of shocks is more similar in the monetary union—countries are (more) united in their diversity.

More in detail, our model embeds the closed-economy HANK structure developed in earlier work by Bayer et al. (2020) in a symmetric two-country model as put forward, for instance, by Corsetti et al. (2012). The model features a rich set of frictions which operate both at the micro and the macro level. As shown by Bayer et al. (2020) the model is therefore able to capture essential aspects of aggregate data along the business cycle as well as key features which characterize the cross-section of households. This makes a two-country version of the model—HANK^2—ideally suited for our analysis. In a nutshell, countries specialize in the production of goods which are used for consumption and investment in both countries. Firms operate under monopolistic competition and adjust prices infrequently. Financial markets are incomplete. Within each country, households face the same uninsurable, idiosyncratic income risk and borrowing constraints. Households can save in illiquid capital, which pays a higher return in equilibrium but has only limited insurance value and is not traded across countries. In addition, households may trade liquid government bonds, both within and across countries.

In the baseline, a common monetary policy adjusts short-term interest rates in response to union-wide inflation. In an alternative setup, we assume that monetary policy operates autonomously in each country and adjust short term rates in response to domestic inflation while the exchange rate floats freely. Fiscal policy is always conducted at the country level. Government spending is exogenous while a proportional labor tax is adjusted to stabilize the level of public debt. In order to study the effects asymmetric shocks in isolation, we calibrate the model to represent isomorphic countries. This holds, in particular, for within-country heterogeneity in terms of income and wealth. To pin down parameter values we target key features of the wealth distribution in Italy. For the macro parameters we either rely on estimates by Bayer et al. (2020) or on customary values.

In our baseline scenario we focus on an adverse TFP shock that originates in the domestic economy and compare its effects in the domestic economy and abroad. While the domestic economy contracts sharply, there are only moderate spillovers at the macro level if countries operate a common currency. Foreign output is hardly affected, consumption and investment decline somewhat because area-wide inflation and hence interest rates increase. If countries run independent monetary policies, spillovers tend to be quite a bit larger for output. A similar picture emerges as we turn to government spending shocks. They impact the domestic economy but generate hardly any spillovers at the aggregate level. If anything, spillovers are larger under independent monetary policies. Our results are largely consistent with earlier findings which suggest that altering the exchange rate regime has little bearing on macro spillovers and international business cycle co-movements, based on both model simulations and time-series analysis (Baxter and Stockman 1989; Enders et al. 2013; Corsetti et al. 2021).

As a distinct contribution, we study the welfare impact of country-specific shocks, both within and across countries. For this purpose we measure welfare in terms of consumption-equivalent variation, that is, the permanent consumption change which makes a specific household just as well off as does the shock under consideration. We compare the average welfare effect of shocks within a country and find that it differs not much across countries—being of the same sign throughout. In contrast, the welfare impact of shocks differs very much within countries along the wealth distribution. In fact, in this case the sign typically differs for the rich and the poor. This result holds independently of whether countries operate in a currency area or not and testifies to the importance of accounting for within-country heterogeneity in the assessment of international spillovers.

Our ultimate interest lies in how a common currency alters the welfare impact of shocks along the wealth distribution within countries. Consider first the welfare spillovers of an adverse TFP shock to the foreign economy. Its inflationary impact induces an union-wide monetary tightening which raises asset return and thus benefits the rich abroad. At the same time wages decline which hurts the poor disproportionately. These effects are much amplified relative to a scenario of flexible exchange rates because in that case monetary policy abroad reacts much less. The opposite holds for the domestic economy because here monetary conditions tighten relatively less in the currency-union scenario. Overall, the distributional impact of shocks within countries is thus more aligned across the countries which form a currency area. Consistently, we find that the Gini coefficient for consumption co-moves more strongly across countries in a monetary union than in case of independent monetary policies.

To inspect the mechanism which drives our results we decompose the overall welfare effects into their partial equilibrium effects, in turn, caused by distinct price movements. It turns out that the welfare effect is dominated by asset returns for the rich, by wages for the poor, and balanced for the middle class. In each instance, the strength of the effect depends on how monetary policy responds to the shock and thus on whether countries form a monetary union. In this sense our findings give new meaning to the traditional notion that a common monetary policy doesn't fit all. Also, because monetary conditions tighten disproportionately abroad in response to shocks, the foreign economy is exposed to something like a monetary policy shock which has been found to have sizable distributional effects (Coibion et al. 2017). At the same time, the distributional impact in the domestic economy is mitigated under a common currency. Consistent with this result, Challe and Acharya (2022) find for a small open-economy HANK model that optimal monetary policy implies considerable exchange-rate stabilization, in contrast to what the representative agent version of the model implies (Galí and Monacelli 2005). As disclaimer, we stress that our analysis does neither feature a full-blown welfare analysis nor an analysis of optimal monetary policy.

The remainder of the paper is organized as follows. We conclude this introduction by clarifying the paper's contribution relative to the existing literature. Section 2 presents our HANK^2 model. Section 3 provides details on our calibration. Results are presented in Sections 4 and 5. A final section offers some conclusions.

Related literature. Our analysis builds on two earlier generations of OCA theory. The first generation stresses the homogeneity of countries which form a currency area. In his original contribution Mundell (1961) emphasizes that economic regions as opposed to nation states or countries are—in theory—the relevant category when it comes to operating a common currency. Yet he also acknowledges that is generally not feasible to reorganize currencies accordingly because "a currency domain is partly an expression of national sovereignty." Other contributions to the first generation of OCA theory stress the role of trade openness and the asymmetry of shocks (McKinnon 1963; Kenen 1981; Bayoumi and Eichengreen 1992; Krugman 1993). Lastly, influential work has emphasized the potential endogeneity of the OCA criteria (Frankel and Rose 1998; Rose 2000).

The second generation of OCA theory zooms in on specific aspects, notably on the trade-offs faced by monetary and fiscal policy in monetary unions as well as on the conduct of optimal policy, relying on explicit welfare criteria (Beetsma and Uhlig 1999; Alesina and Barro 2002). These criteria are typically microfounded within New Keynesian models featuring representative agents (see, for instance, Benigno 2004; Benigno and López-Salido 2006; Beetsma and Jensen 2005; Corsetti 2008; Gali and Monacelli 2008; Galí and Monacelli 2016; Farhi and Werning 2017; Hettig and Müller 2018; Groll and Monacelli 2020).

The present paper belongs to a new set of studies which explicitly accounts for within country-heterogeneity when revisiting open-economy issues. In particular, several studies rely on small open-economy HANK models to reassess the merits of alternative exchange-rate policies. Ferra et al. (2021) find that household heterogeneity rationalizes "fear of floating" in the face of sudden stops. Auclert et al. (2021), in turn, stress that household heterogeneity can amplify the real income channel of exchange rates, potentially giving rise to contractionary depreciations. Guo et al. (2020) find that fixing the exchange rate leads to larger spillovers of foreign shocks but dampens their distributional impact, in contrast to what we find for HANK^2. Oskolkov (2021) and Zhou (2021) also study the distributional impact of foreign shocks and exchange-rate policies in small open-economy HANK models. Lastly, Aggarwal et al. (2022) study the implications of fiscal deficits through the lens of a multi-country HANK model. What sets our paper apart is the two-country structure of HANK^2: it permits a comparison of how alternative exchange rate arrangements shape the distributional impact of shocks in the domestic economy and abroad.

2 Model

We model a two-country New Keynesian model with incomplete markets, idiosyncratic risk, and heterogeneous agents (HANK^2). There are two countries which form a currency area in the baseline. But we also consider the alternative where monetary policies are independent. The structure in each country mimics the closed-economy set up of Bayer et al. (2020), except for the fact that there is trade across the two countries, both in goods and financial markets.

Each country consists of a firm sector and a household sector. The firm sector of each country comprises (a) perfectly competitive intermediate goods producers who rent out labor services and capital on a national labor and a national capital market, respectively; (b) final goods producers that face monopolistic competition when selling differentiated final goods, in turn produced on the basis of homogeneous domestic intermediate inputs; (c) a representative consumption good bundler bundling domestic and imported foreign final goods to consumption goods; (d) producers of capital goods that turn consumption goods into capital subject to adjustment costs; (e) labor packers that produce labor services combining differentiated labor from (f) unions that differentiate raw labor rented out from households. Price setting for the final goods as well as wage setting by unions is subject to a pricing friction à la Calvo (1983). Only final goods are traded across countries.

In each country, there is a continuum of households of size $n_A \in (0,1)$ and $n_B = 1 - n_A$, respectively, such that the total population is 1. Households in both countries consume a bundle which consists of domestically produced and imported goods. Households earn income from supplying (raw) labor and capital to the national labor and the national capital markets and from owning their national firm sector, absorbing all its rents that stem from the market power of unions and final good producers, and decreasing returns to scale in capital goods production.

In the baseline there is a common monetary authority and the exchange rate is permanently fixed. Fiscal policy is run at the country level. It levies taxes on labor income and profits, issues bonds, and adjusts taxes to stabilize the level of outstanding debt in the long run. Public debt is risk free and thus yields the same return in both countries, in turn, determined by monetary policy by means of a simple interest rate feedback rule. We assume that countries are perfectly symmetric and differ only because of asymmetric shocks. In what follows, our exposition thus focuses on the domestic economy and use an asterisk to denote foreign variables whenever they are relevant in "Home."

2.1 Households

The household sector is subdivided into two types of agents: workers and entrepreneurs. The transition between both types is stochastic. Both rent out physical capital, but only workers supply labor. The efficiency of a worker's labor evolves randomly exposing worker-households to labor-income risk. Entrepreneurs do not work but earn all pure rents in our economy except for the rents of unions which are equally distributed across workers. All households self-insure against the income risks they face by saving in a liquid nominal asset (bonds) and a less liquid asset (capital). Trading illiquid assets is subject to random participation in the capital market. To be specific, there is a continuum of ex-ante identical households of measure n_A, indexed by i. Households are infinitely lived, have time-separable preferences with time discount factor β, and derive felicity from consumption c_{it} and leisure. They obtain income from supplying labor, n_{it}, from renting out capital, k_{it}, and from earning interest on bonds, b_{it}, and potentially from profits or union transfers. Households pay taxes on labor and profit income.

2.1.1 Productivity, labor supply, and labor income

A household's gross labor income $w_t n_{it} h_{it}$ is composed of the aggregate wage rate on raw labor, w_t, the household's hours worked, n_{it}, and its idiosyncratic labor productivity, h_{it}. We assume that productivity evolves according to a log-AR(1) process with time-varying volatility and a fixed probability of transition between the worker and the entrepreneur state:

$$\tilde{h}_{it} = \begin{cases} exp(\rho_h log\tilde{h}_{it-1} + \epsilon^h_{it}) & \text{with probability } 1-\zeta \text{ if } h_{it-1} \neq 0, \\ 1 & \text{with probability } \iota \text{ if } h_{it-1} = 0, \\ 0 & \text{else.} \end{cases} \tag{1}$$

with individual productivity $h_{it} = \frac{\tilde{h}_{it}}{\int \tilde{h}_{it} di}$ such that $\tilde{h}_{it}$ is scaled by its cross-sectional average, $\tilde{h}_{it} di$, to make sure that average worker productivity is constant. The shocks ϵ^h_{it} to productivity are normally distributed with variance $\sigma^2_{h,t}$. With probability ζ households become entrepreneurs ($h = 0$). With probability ι an entrepreneur returns to the labor force with median productivity. In our baseline specification, an entrepreneur obtains a share of the pure rents (aside from union rents), Π^F_t, in the economy (from monopolistic competition in the goods sector and the creation of capital). We assume that the claim to the pure rent cannot be traded as an asset. Union rents, Π^U_t are distributed lump sum across workers, leading to labor-income compression. For tractability, we assume union profits to be taxed at a fixed rate independent of the recipient's labor income.[1]

With respect to leisure and consumption, households have Greenwood et al. (1988) (GHH) preferences and maximize the discounted sum of felicity:

$$E_0 \max_{\{c_{it}, n_{it}\}} \sum_{t=0}^{\infty} \beta^t u[c_{it} - G(h_{it}, n_{it})] \tag{2}$$

The maximization is subject to the budget constraints described further below. The felicity function u exhibits a constant relative risk aversion (CRRA) with risk aversion parameter $\xi > 0$,

$$u(x_{it}) = \frac{1}{1-\xi} x_{it}^{1-\xi}, \tag{3}$$

where $x_{it} = c_{it} - G(h_{it}, n_{it})$ is household i's composite demand for goods consumption c_{it} and leisure and G measures the disutility from work. The consumption good c is a bundle of domestic and imported foreign final goods described in Section 2.2.2 below.

Assuming a linear income-tax schedule, a household's net labor income, y_{it}, is given by

$$y_{it} = (1 - \tau_t^L) w_t h_{it} n_{it}, \tag{4}$$

where w_t is the aggregate wage rate and τ_t^L determines the level of the tax rate. Given net labor income, the first-order condition for labor supply is

$$\frac{\partial G(h_{it}, n_{it})}{\partial n_{it}} = (1 - \tau_t^L) w_t h_{it} n_{it} = \frac{y_{it}}{n_{it}}. \tag{5}$$

Assuming that G has a constant elasticity w.r.t. n, $\frac{\partial G(h_{it}, n_{it})}{n_{it}} = (1+\gamma)\frac{G(h_{it}, n_{it})}{n_{it}}$ with $\gamma > 0$, we can simplify the expression for the composite consumption good, x_{it}, making use of this first-order condition (5), and substitute $G(h_{it}, n_{it})$ out of the individual planning problem:

$$x_{it} = c_{it} - G(h_{it}, n_{it}) = c_{it} - \frac{1}{1+\gamma} y_{it}. \tag{6}$$

When the Frisch elasticity of labor supply is constant and the tax schedule has the form (4), the disutility of labor is always a fraction of labor income and constant across households. Therefore, in both the household's budget constraint and felicity function, only after-tax

[1] This modeling strategy serves two purposes. First and foremost, it generally solves the problem of the allocation of pure rents without distorting factor returns and without introducing another tradable asset. Second, we use the entrepreneur state in particular – a transitory state in which incomes are very high – to match the income and wealth distribution following the idea by Castaneda et al. (1998). The entrepreneur state does not change the asset returns or investment opportunities available to households.

income enters and neither hours worked nor productivity appears separately.

What remains to be determined is individual and aggregate effective labor supply. Without further loss of generality, we assume $G(h_{it}, n_{it}) = h_{it} \frac{n_{it}^{1+\gamma}}{1+\gamma}$. This functional form simplifies the household problem in the stationary equilibrium as h_{it} drops out from the first-order condition and all households supply the same number of hours $n_{it} = N(w_t)$. Total effective labor input, $\int n_{it} h_{it} di$, is hence also equal to $N(w_t)$ because we normalized $\int h_{it} di = 1$.[2]

Households after-tax labor income, plugging in the optimal supply of hours, is then:

$$y_{it} = (1 - \tau_t^L) w_t h_{it} n_{it} = (1 - \tau_t^L)^{\frac{1+\gamma}{\gamma}} w_t^{\frac{1+\gamma}{\gamma}} h_{it}. \tag{7}$$

2.1.2 Consumption, savings, and portfolio choice

Given this labor income, households optimize intertemporally subject to their budget constraint:

$$\begin{aligned} c_{it} + b_{it+1} + q_t k_{it+1} &= b_{it} \frac{R(b_{it}, R_t^b)}{\pi_t^{CPI}} + (q_t + r_t) k_{it} + \mathbb{I}_{h_{it} \neq 0} \Pi_t^U + \mathbb{I}_{h_{it} = 0} \Pi_t^F \\ &\text{and } k_{it+1} \geq 0,\ b_{it+1} \geq \underline{B}. \end{aligned}$$

Here Π_t^U are union profits taxed at the labor tax rate τ_t^L (see Equation (38)), Π_t^F are firm profits, b_{it} are real bond holdings, k_{it} is the amount of illiquid assets, q_t is the price of these assets, r_t is their dividend, $\pi_t^{CPI} = \frac{P_t}{P_{t-1}}$ is realized domestic CPI inflation, and R is the nominal interest rate on bonds, which depends on the portfolio position of the household and the central bank's interest rate R_t^b, which is set one period before. As we further describe below, households access capital markets only infrequently. All households that do not participate in the capital market ($k_{it+1} = k_{it}$) still obtain dividends and can adjust their bond holdings. Depreciated capital has to be replaced for maintenance, such that the dividend, r_t, is the net return on capital. Holdings of bonds have to be above an exogenous debt limit $\underline{B}$; and holdings of capital have to be non-negative.

Substituting the expression $c_{it} = x_{it} + \frac{1}{1+\gamma} y_{it}$ for consumption, we obtain the budget constraint for the composite leisure-consumption good:

$$\begin{aligned} x_{it} + b_{it+1} + q_t k_{it+1} &= b_{it} \frac{R(b_{it}, R_t^b)}{\pi_t} + (q_t + r_t) k_{it} + \frac{\gamma}{1+\gamma} z_{it} + \mathbb{I}_{h_{it} \neq 0} \Pi_t^U + \mathbb{I}_{h_{it} = 0} \Pi_t^F \\ &\text{and } k_{it+1} \geq 0,\ b_{it+1} \geq \underline{B}. \end{aligned} \tag{8}$$

[2] This means that we can read off average productivity risk from the estimated income risk series in the literature. Without scaling the labor disutility by productivity, we would need to translate productivity risk to income risk through the endogenous hour response.

Households make their savings decision and their portfolio choice between liquid bonds and illiquid capital in light of a capital market friction that renders capital illiquid because participation in the capital market is random and i.i.d. in the sense that only a fraction λ of households are selected to be able to adjust their capital holdings in a given period. Specifically, we assume:

$$R(b_{it}, R_t^b) = \begin{cases} R_t^b & \text{if } b_{it} \geq 0 \\ R_t^b + \bar{R} & \text{if } b_{it} < 0 \end{cases}. \tag{9}$$

The extra wedge for unsecured borrowing, $\bar{R}$, creates a mass of households with zero unsecured credit but with the possibility to borrow, though at a penalty rate.

Since a household's saving decision—(b'_a, k') for the case of adjustment and (b'_n, k') for non-adjustment—will be some non-linear function of that household's wealth and productivity, inflation and all other prices will be functions of the domestic joint distribution, Θ_t, of (b, k, h) in t and the foreign joint distribution, Θ_t^*. This makes Θ and Θ^* state variables of the household's planning problem and these distributions evolves as a result of the economy's reaction to aggregate shocks. For simplicity, we summarize all effects of aggregate state variables, including the distributions of wealth and income, by writing the dynamic planning problem with time-dependent continuation values.

This leaves us with three functions that characterize the household's problem: value function V^a for the case where the household adjusts its capital holdings, the function V^n for the case in which it does not adjust, and the expected continuation value, $\mathbb{W}$, over both:

$$\begin{aligned} V_t^a(b, k, h) &= \max_{k', b'_a} u[x(b, b'_a, k, k', h] + \beta \mathbb{E}_t \mathbb{W}_{t+1}(b'_a, k', h) \\ V_t^n(b, k, h) &= \max_{b'_n} u[x(b, b'_n, k, k, h] + \beta \mathbb{E}_t \mathbb{W}_{t+1}(b'_n, k, h) \\ \mathbb{W}_{t+1}(b', k', h) &= \lambda V_{t+1}^a(b', k', h) + (1 - \lambda) V_{t+1}^n(b', k, h). \end{aligned} \tag{10}$$

Expectations about the continuation value are taken with respect to all stochastic processes conditional on the current states. Maximization is subject to the corresponding budget constraint.

2.2 Firm sector

The firm sector of each country consists of five sub-sectors: (a) a labor sector composed of "unions" that differentiate raw labor and labor packers who buy differentiated labor and then sell labor services to intermediate goods producers, (b) intermediate goods producers who hire labor services and rent out capital to produce goods, (c) final goods producers who differentiate intermediate goods and then sell them to (d) goods bundlers who combine them with foreign final goods and finally sell them as consumption goods to households and to (e) capital goods producers, who, in turn, transform bundled goods into capital goods. None of these products and goods can be traded between both countries, except for the differentiated final goods.

When profit maximization decisions in the firm sector require intertemporal decisions (i.e. in price and wage setting and in producing capital goods), we assume for tractability that they are delegated to a mass-zero group of households (managers) that are risk neutral and compensated by a share in profits. They do not participate in any asset market and have the same discount factor as all other households. Since managers are a mass-zero group in the economy, their consumption does not show up in any resource constraint and all but the unions' profits go to the entrepreneur households (whose $h = 0$). Union profits go lump-sum to worker households.

2.2.1 Labor packers and unions

Worker households sell their labor services to a mass-n_A continuum of unions indexed by j, each of whom offers a different variety of labor to labor packers who then provide labor services to intermediate goods producers. Labor packers produce final labor services according to the production function

$$N_t = \left(\int_0^{n_A} \hat{n}_{jt}^{\frac{\eta_W - 1}{\eta_W}} \, dj \right)^{\frac{\eta_W}{\eta_W - 1}}. \tag{11}$$

out of labor varieties $\hat{n}_{jt}$. Cost minimization by labor packers implies that each variety of labor, each union j, faces a downward-sloping demand curve

$$\hat{n}_{jt} = \left(\frac{W_{jt}}{W_t^{fi}} \right)^{-\eta_W} N_t \tag{12}$$

where W_{jt} is the nominal wage set by union j and W_t^F is the nominal wage at which labor packers sell labor services to final goods producers. Since unions have market power, they pay the households a wage lower than the price at which they sell labor to labor packers. Given the nominal wage W_t at which they buy labor from households and given the nominal wage index W_t^F, unions seek to maximize their discounted stream of profits. However, they face a Calvo (1983) type adjustment friction with indexation; where λ_w is the probability that wages cannot be adjusted optimally. They therefore maximize

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \lambda_w^t \frac{W_t^{fi}}{P_t} N_t \left\{ \left(\frac{W_{jt}(\bar{\pi}_W)^t}{W_t^{fi}} - \frac{W_t}{W_t^{fi}} \right) \left(\frac{W_{jt}(\bar{\pi}_W)^t}{W_t^{fi}} \right)^{-\eta_W} \right\}. \tag{13}$$

by setting W_{jt} in period t; unless the wage is reoptimized it is indexed to π_W, the steady state wage inflation rate.

Since all unions are symmetric, we focus on a symmetric equilibrium and obtain the linearized wage Phillips curve from the corresponding first-order condition as follows, leaving out all terms irrelevant at a first-order approximation around the stationary equilibrium:

$$log\left(\frac{\pi_t^W}{\bar{\pi}^W}\right) = \beta \mathbb{E}_t log\left(\frac{\pi_{t+1}^W}{\bar{\pi}^W}\right) + \kappa_w \left(mc_t^w - \frac{1}{\mu^W} \right), \tag{14}$$

with $\pi_t^W := \frac{W_t^F}{W_{t-1}^F} = \frac{w_t^F}{w_{t-1}^F}\pi_t^{CPI}$ being domestic wage inflation, w_t and w_t^F being the respective *real* wages for households and firms, $mc_t^w = \frac{w_t}{w_t^F}$ is the mark-down of wages the unions pay to households, W_t, relative to the wages charged to firms, W_t^F and $\kappa_w = \frac{(1-\lambda_w)(1-\lambda_w\beta)}{\lambda_w}$. Union profits paid to workers therefore are $\Pi_t^U = (w_t^F - w_t)N_t$.

2.2.2 Consumption Good Bundler

The consumption goods are bundles of domestically produced and imported final goods and are not traded across countries. Letting F_t denote the consumption good and A_t and B_t bundles of domestically and imported final goods, we assume the following aggregation technology

$$F_t = \left\{ (1-(1-n_A)\omega_A)^{\frac{1}{\sigma}} A_t^{\frac{\sigma-1}{\sigma}} + ((1-n_A)\omega_A)^{\frac{1}{\sigma}} B_t^{\frac{\sigma-1}{\sigma}} \right\}^{\frac{\sigma}{1-\sigma}}, \tag{15}$$

$$F_t^* = \left\{ (n_A\omega_B)^{\frac{1}{\sigma}} A_t^{\frac{\sigma-1}{\sigma}} + (1-n_A\omega_B)^{\frac{1}{\sigma}} B_t^{\frac{\sigma-1}{\sigma}} \right\}^{\frac{\sigma}{1-\sigma}}. \tag{16}$$

Here σ measures the terms of trade elasticity of the relative demand for domestically produced goods. $\omega_A \in [0,1]$ provides a measure for the home bias, in the sense that with $\omega_A = 1$, the Country A has no home bias. The bundles of domestically and imported final goods are defined as follows:

$$A_t = \Big[\Big(\frac{1}{n_A}^{\frac{1}{\sigma}} \int_0^{n_A} A_t(j)^{\frac{\epsilon-1}{\epsilon}} dj\Big)\Big]^{\frac{\epsilon}{\epsilon-1}},\ B_t = \Big[\Big(\frac{1}{1-n_A}^{\frac{1}{\sigma}} \int_{n_A}^{1} B_t(j)^{\frac{\epsilon-1}{\epsilon}} dj\Big)\Big]^{\frac{\epsilon}{\epsilon-1}}, \tag{17}$$

where $A_t(j)$ and $B_t(j)$ denote final goods produced in Home and Foreign, respectively, and ϵ measures the elasticity of substitution between final goods produced within the same country. Let $P(j)$ denote the price of a final good expressed in domestic currency. Then, letting $\mathcal{E}_t$ denote the nominal exchange rate (price of domestic currency in terms of foreign currency) and assuming that the law of one price holds, we have

$$P_t^*(j) = \mathcal{E}_t P_t(j). \tag{18}$$

In case both countries form a currency area we have $\mathcal{E}_t = 1\ \forall t$; otherwise the exchange rate adjusts freely.

The problem of the good bundler is to minimize expenditures subject to $F_t = C_t + I_t$, and the aggregation technologies (15) and (17). Assuming that government consumption, G_t, is a bundle which is isomorphic to consumption goods, but consists of domestically produced goods only, global demand for a generic final good produced in Home and Foreign is given, respectively, by

$$Y_t^d(j) = \Big(\frac{P_t(j)}{P_{At}}\Big)^{-\epsilon}\Big\{\Big(\frac{P_{At}}{P_t}\Big)^{\sigma}(1-(1-n_A)\omega_A)(C_t+I_t) + (1-n_A)\omega_B Q_t^{-\sigma}(I_t^* + C_t^*) + G_t\Big\} \tag{19}$$

and

$$Y_t^d(j)^* = \Big(\frac{P_t(j)^*}{P_{Bt}^*}\Big)^{-\epsilon}\Big\{\Big(\frac{P_{Bt}^*}{P_t^*}\Big)^{\sigma}(n_A\omega_A)Q_t^{\sigma}(C_t+I_t) + (1-n_A\omega_B)(I_t^* + C_t^*) + G_t^*\Big\}, \tag{20}$$

where the price indices are given by

$$P_{At} = \Big[\frac{1}{n_A}\int_0^{n_A} P_t(j)^{1-\epsilon} dj\Big]^{\frac{1}{1-\epsilon}},\ P_{Bt} = \Big[\frac{1}{1-n_A}\int_{n_A}^{1} P_t(j)^{1-\epsilon} dj\Big]^{\frac{1}{1-\epsilon}} \tag{21}$$

and

$$P_t = [(1-(1-n_A)\omega_A)P_{At}^{1-\sigma} + ((1-n_A)\omega_A)P_{Bt}^{1-\sigma}]^{\frac{1}{1-\sigma}}, \tag{22}$$

$$P_t^* = [(n_A\omega_B)(P_{At}^*)^{1-\sigma} + (1-n_A\omega_B)(P_{Bt}^*)^{1-\sigma}]^{\frac{1}{1-\sigma}}. \tag{23}$$

The real exchange rate is given by

$$Q_t = \frac{P_t \mathcal{E}_t}{P_t^*}. \tag{24}$$

2.2.3 Final goods producers

Similar to unions, final goods producers in the home country differentiate the homogeneous home intermediate good and set prices. They face the global demand (19) for each good $j \in [0, n_A]$ and buy the intermediate good at the national nominal price, MC_t. As we do for unions, we assume price adjustment frictions à la Calvo (1983) with indexation.

Under this assumption, the firms' managers maximize the present value of real profits given this price adjustment friction, i.e., they maximize

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \lambda_Y^t (1 - \tau_t^L) \left\{ \left(\frac{p_{jt}(\bar{\pi})^t}{P_t} - \frac{MC_t}{P_t} \right) Y_t^d(j) \right\} \tag{25}$$

with a time-constant discount factor.

The corresponding first-order condition for price setting implies a domestic Phillips curve

$$log\left(\frac{\pi_{At}}{\bar{\pi}}\right) = \beta \mathbb{E}_t log\left(\frac{\pi_{At+1}}{\bar{\pi}}\right) + \kappa_Y \left(mc_t - \frac{1}{\mu^Y}\right) \tag{26}$$

where we again dropped all terms irrelevant for a first-order approximation and have $\kappa_Y = \frac{(1-\lambda_Y)(1-\lambda_Y\beta)}{\lambda_Y}$. Here, $\pi_{At} := \frac{P_{At}}{P_{At-1}}$, is gross domestic producer price inflation rate, i.e., the gross inflation rate of domestic final goods, $mc_t := \frac{MC_t}{P_t}$ are the domestic real marginal costs, $\bar{\pi}$ is steady-state inflation, and $\frac{1}{\mu^Y} = \frac{\eta-1}{\eta}$ is the target markup. National profits paid to domestic entrepreneurs therefore are $\Pi_t^F = (1 - mc_t)Y_t$.

2.2.4 Intermediate goods producers

Intermediate goods are produced with a constant returns to scale production function:

$$Y_t = Z_t(N_t)^{\alpha}(u_t K_t)^{(1-\alpha)} \tag{27}$$

where Z_t is total factor productivity and follows an autoregressive process in logs, and $u_t K_t$ is the effective capital stock taking into account utilization, u_t, i.e., the intensity with which the existing capital stock is used. Using capital with an intensity higher than normal increases depreciation of capital according to $\delta(u_t) = \delta_0 + \delta_1(u_t - 1) + \delta_2/2(u_t - 1)^2$, which, assuming $\delta_1, \delta_2 > 0$, is an increasing and convex function of utilization. Without loss of generality, capital utilization in the steady state is normalized to 1, so that δ_0 denotes the steady-state depreciation rate of capital goods.

Let mc_t be the relative price at which the intermediate good is sold to final goods producers. The intermediate goods producer maximizes profits,

$$mc_t Z_t Y_t - w_t^F N_t - [r_t^F + q_t \delta(u_t)] K_t, \tag{28}$$

where r_t^F and q_t are the rental rate of firms and the (producer) price of capital goods, respectively. The intermediate goods producer operates in perfectly competitive national markets, such that the real wage and the user costs of capital are given by the marginal product of labor and effective capital:

$$w_t^F = \alpha mc_t Z_t \left(\frac{u_t K_t}{N_t} \right)^{1-\alpha} \tag{29}$$

$$r_t^F + q_t \delta(u_t) = u_t (1-\alpha) mc_t Z_t \left(\frac{N_t}{u_t K_t} \right)^{\alpha} \tag{30}$$

We assume that utilization is decided by the owners of the capital goods, taking the aggregate national supply of capital services as given. The optimality condition for utilization is given by

$$q_t [\delta_1 + \delta_2 (u_t - 1)] = (1-\alpha) mc_t Z_t \left(\frac{N_t}{u_t K_t} \right)^{\alpha}, \tag{31}$$

i.e., capital owners increase utilization until the marginal maintenance costs equal the marginal product of capital services.

2.2.5 Capital goods producers

Capital goods producers take the relative price of capital goods, q_t, as given in deciding about their output, i.e., they maximize

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t I_t \left\{ q_t \left[1 - \frac{\phi}{2} \left(log \frac{I_t}{I_{t-1}} \right)^2 \right] - 1 \right\}. \tag{32}$$

Optimality of the capital goods production requires (again dropping all terms irrelevant up to first order)

$$q_t\left[1-\phi log\frac{I_t}{I_{t-1}}\right]=1-\beta\mathbb{E}_t\left[q_{t+1}\psi log\left(\frac{I_{t+1}}{I_t}\right)\right], \tag{33}$$

and each capital goods producer will adjust its production until (33) is fulfilled.

Since all capital goods producers within a country face symmetric problems, we obtain as the law for motion for domestic aggregate capital

$$K_t-(1-\delta(u_t))K_{t-1}=\left[1-\frac{\phi}{2}\left(log\frac{I_t}{I_{t-1}}\right)^2\right]I_t \tag{34}$$

The functional form assumption implies that investment adjustment costs are minimized and equal to zero in steady state.

2.3 Monetary and fiscal policy

In our baseline analysis, the two countries form a monetary union while each country runs fiscal at the national level. Monetary policy controls the nominal interest rate on liquid assets in both countries, while the national fiscal authorities issue government bonds in an union-wide bond market to finance deficits, set the tax rate, and decide on government consumption and transfers.

2.3.1 Monetary Union

We assume that monetary policy sets the nominal interest rate, which is the same in both countries, following a Taylor (1993)-type rule with interest rate smoothing:

$$\frac{R^b_{t+1}}{\bar{R}^b}=\left(\frac{R^b_t}{\bar{R}^b}\right)^{\rho_R}\left(\frac{n_A\pi_{At}+(1-n_A)(\pi_{Bt})}{\bar{\pi}}\right)^{(1-\rho_R)\theta_\pi}\left(n_A\frac{Y_t}{Y_{t-1}}+(1-n_A)\frac{Y^*_t}{Y^*_{t-1}}\right)^{(1-\rho_R)\theta_Y}\epsilon^R_t. \tag{35}$$

The coefficient $\bar{R}^b\geq 0$ determines the nominal interest rate in the steady state, Y^*_t determines output in Country B, and π_{Bt} is the producer price inflation in Country B. The coefficients $\theta_\pi,\theta_Y\geq 0$ govern the extent to which the central bank attempts to stabilize producer price inflation and the output growth in the monetary union. $\rho_R\geq 0$ captures interest rate smoothing and ϵ^R_t is an i.i.d. monetary policy shock.

2.3.2 Fiscal Policy

The budget constraint of the national fiscal policy reads

$$G_t = B_{t+1} + T_t - \frac{R_t^b}{\pi_t^{CPI}} B_t. \tag{36}$$

Hence, the government has expenditure for government spending, G_t, and repaying its debt, B_t. It finances its expenditures by issuing new debt and tax revenue, T_t. Tax revenue is

$$T_t = \tau_t^L (HI_{it} + \mathbb{I}_{h_{it} \neq 0} \Pi_t^U), \tag{37}$$

with $HI_{it} = w_t n_{it} h_{it} + \mathbb{I}_{h_{it}=0} \Pi_t^F$ being the households labor/profit income. We assume that the tax level is a feedback function of government debt:

$$\frac{\tau_t^L}{\bar{\tau}^L} = \left(\frac{B_{t+1}}{\bar{B}} \right)^{\gamma_B^\tau}, \tag{38}$$

where γ_B^τ governs the speed with which debt returns to its target.

2.4 Goods, bonds, capital, and labor market clearing

The domestic labor market clears at the competitive wage given in (29). Bond markets clearing requires:

$$\begin{aligned} B_{t+1} &= B^d(R_t^b, r_t, q_t, \Pi_t^{fi}, \Pi_t^U, w_t, \pi_t, \tau_t^L, \Theta_t, \Theta_t^*, \mathbb{W}_{t+1}) - \frac{B_{Bt+1}}{Q_t} \\ &:= \mathbb{E}_t[\lambda \mathbb{B}_{a,t} + (1-\lambda)\mathbb{B}_{n,t}] - \frac{B_{Bt+1}}{Q_t}, \\ B_{t+1}^* &= B^{d,*}(R_t^b, r_t^*, q_t^*, \Pi_t^{fi,*}, \Pi_t^{U,*} w_t^*, \pi_t^{CPI,*}, \tau_t^{*,L}, \Theta_t, \Theta_t^*, \mathbb{W}_{t+1}^*) + \frac{n_A}{1-n_A} B_{Bt+1} \\ &:= \mathbb{E}_t[\lambda \mathbb{B}_{a,t}^* + (1-\lambda)\mathbb{B}_{n,t}^*] + \frac{n_A}{1-n_A} B_{Bt+1}, \\ B_{t+1}^d + B_{t+1}^{d,*} &= B_{t+1} + B_{t+1}^* \end{aligned} \tag{39}$$

where $\mathbb{B}_{a,t}$, $\mathbb{B}_{n,t}$ are functions of the states (b, k, h), and depend on how domestic households value asset holdings in the future, $\mathbb{W}_{t+1}$, and the current set of prices (and tax rates) $(R_t^b, r_t, q_t, \Pi_t^{fi}, \Pi_t^U, w_t, \pi_t^{CPI}, \tau_t^L)$.[3] Future prices do not show up because we can express the value functions such that they summarize all relevant information on the expected future

[3] The same logic applies for $\mathbb{B}_{a,t}^*$, $\mathbb{B}_{n,t}^*$ abroad.

price paths. Expectations in the right-hand-side expression are taken w.r.t. the distributions in both countries $\Theta_t(b,k,h)$ and $\Theta_t^*(b,k,h)$. The net amount of domestic holdings of foreign bonds, B_{Bt}, is given aggregating over households' budget constraints:

$$\begin{aligned}(1-\tau_t^L)(w_tN_t+\Pi_t^U+\Pi_t^F)+(P_{At}Y_t-w_tN_t-(\Pi_t^U+\Pi_t^F))+B_tR_t^b/\pi_t^{CPI}\\ +B_{Bt}R_t^b/(\pi_t^{CPI,*}Q_t))=C_t+I_t+\bar{R}*BD_t+B_{t+1}+B_{Bt+1}/Q_t,\end{aligned} \tag{40}$$

where BD_t is the total amount of domestic. Since both government bonds pay the same interest rate, we do not need to take track of the share of domestic vs. foreign bond holdings in each household's portfolio. Equilibrium requires the total *net* amount of bonds the household sectors in both countries demand to equal the supply of government bonds. In gross terms there are more liquid assets in circulation as some households borrow up to $\underline{B}$.

In addition, the national markets for capital have to clear. For the domestic economy, we have:

$$\begin{aligned}K_{t+1}=K^d(R_t^b,r_t,q_t,\Pi_t^{fi},\Pi_t^U,w_t,\pi_t^{CPI},\tau_t^L,\Theta_t,\Theta_t^*,\mathbb{W}_{t+1})\\ :=\mathbb{E}_t[\lambda(\mathbb{K}_t)+(1-\lambda)(k)]\end{aligned} \tag{41}$$

where the first equation stems from competition in the production of capital goods, and the second equation defines the aggregate supply of funds by domestic households—both those that trade capital, $\lambda(\mathbb{K}_t)$ and those that do not, $(1-\lambda)(k)$. Again $\mathbb{K}_t$ is a function of the current prices and continuation values.

Finally, goods markets clearing requires:

$$\begin{aligned}Y_t=((1-(1-n_A)\omega_A)\left(\frac{P_{At}}{P_t}\right)^{-\sigma}\left[C_t+I_t+BD_t\bar{R}\right]+(1-n_A)\omega_BQ_t^{-\sigma}\left[C_t^*+I_t^*+BD_t^*\bar{R})\right]+G_t\\ Y_t^*=n_A\omega_AQ_t^{\sigma}\left(\frac{P_{Bt}^*}{P_t^*}\right)^{-\sigma}\left[C_t+I_t+BD_t\bar{R}\right]+(1-n_A\omega_B)\left[C_t^*+I_t^*+BD_t^*\bar{R})\right]+G_t^*.\end{aligned} \tag{42}$$

2.5 Equilibrium

A sequential equilibrium with recursive planning in our two-country model is a sequence of policy functions $\{\mathbb{X}_{at},\mathbb{X}_{nt},\mathbb{B}_{at},\mathbb{B}_{nt},\mathbb{K}_t\}$ in Country A and $\{\mathbb{X}_{at}^*,\mathbb{X}_{nt}^*,\mathbb{B}_{at}^*,\mathbb{B}_{nt}^*,\mathbb{K}_t^*\}$ in Country B, a sequence of value functions $\{V_t^a,V_t^n\}$ in Country A and $\{V_t^{a,*},V_t^{n,*}\}$ in Country B, a sequence of prices $\{w_t,w_t^F,\Pi_t^U,\Pi_t^F,q_t,r_t,R_t^b,\pi_t^{CPI},\pi_{At},\pi_t^W,\frac{P_{At}}{P_t},\tau_t^L,Q_t\}$ in Country A and $\{w_t^*,w_t^{F,*},\Pi_t^{U,*},\Pi_t^{F,*},q_t^*,r_t^*,\pi_t^{CPI,*},\pi_{Bt},\pi_t^{W,*},\frac{P_{Bt}^*}{P_t^*},\tau_t^{L,*}\}$ in Country B, a sequence of of the shock ϵ_t^R, aggregate capital, labor supply, and foreign bond holdings $\{K_t,N_t,B_{Bt}\}$ in Country A and

$\{K_t^*, N_t^*\}$ in Country B, distributions Θ_t in Country A and Θ_t^* in Country B over individual asset holdings and productivity, and expectations for the distribution of future prices, Γ, such that

1. Given the functionals $\mathbb{E}_t\mathbb{W}_{t+1}$ and $\mathbb{E}_t\mathbb{W}_{t+1}^*$ for the continuation value and period-t prices, policy functions $\{\mathbb{X}_{at}, \mathbb{X}_{nt}, \mathbb{B}_{at}, \mathbb{B}_{nt}, \mathbb{K}_t\}$ and $\{\mathbb{X}_{at}^*, \mathbb{X}_{nt}^*, \mathbb{B}_{at}^*, \mathbb{B}_{nt}^*, \mathbb{K}_t^*\}$ solve the households' planning problem; and given the policy functions $\{\mathbb{X}_{at}, \mathbb{X}_{nt}, \mathbb{B}_{at}, \mathbb{B}_{nt}, \mathbb{K}_t\}$ and $\{\mathbb{X}_{at}^*, \mathbb{X}_{nt}^*, \mathbb{B}_{at}^*, \mathbb{B}_{nt}^*, \mathbb{K}_t^*\}$ and prices, the value functions $\{V_t^a, V_t^n\}$ and $\{V_t^{a,*}, V_t^{n,*}\}$ are a solution to the Bellman equation.

2. Distributions of wealth and income evolve according to households' policy functions.

3. All markets clear in every period, interest rates on bonds are set according to the central bank's Taylor rule, fiscal policies are set according to the fiscal rules, and stochastic processes evolve according to their law of motion.

4. Expectations are model consistent.

We solve the model with perturbation method of Bayer and Luetticke (2020).

3 Calibration

In this section, we explain how we pin down parameter values in order to solve the model numerically. To keep our analysis focused on the issue at hand, we assume that countries are perfectly symmetric, except for the incidence of shocks. Hence, all parameter values are the same in Home and Foreign. Table 3.1 provides an overview. We set the labor share in production, α, to 68% corresponding to a labor income share of 62%. Our elasticity of substitution between differentiated goods of 11 yields a markup of 10%. The elasticity of substitution between labor varieties is also set to 11, yielding a wage markup of 10%. We set the depreciation rate to 1.8% yielding an annual depreciation of 7% in steady state and the increase in depreciation, δ_1, to 5.0. The investment adjustment cost is set to 4.0. We set the Calvo parameters for price and wage adjustment probability both to 0.25. All are standard values in the literature.

We set the size of both countries to $n_A = n_B = 0.5$. We set the home bias parameter, ω, to 0.66 which results in a 26% import share, in line with data for Italy. In addition, we set the terms of trade elasticity to 0.9 (Heathcote and Perri 2002). Such a low value is also consistent with results by Enders and Müller (2009) and Corsetti et al. (2008).

At the heart of our calibration is the incomplete markets problem of the households in both countries. We set relative risk aversion, ξ, to 4, which is common in the incomplete

Table 3.1: Baseline Calibration

	Description	Value	Source/Target
Households			
β	Disc. factor	0.9854	see targets table
ξ	Risk aversion	4	Kaplan and Violante (2014)
γ	Inv. Frisch elast.	2	Chetty et al. (2011)
λ	Portfolio adj. prob.	0.071	see targets table
ρ_h	Pers. labor inc.	0.9815	Standard value
σ_h	STD labor inc.5	0.135	Gini market incomes
ζ	Trans. prob. W to E	0.0007	see targets table
ι	Trans prob. E to W	0.0625	see targets table
$\bar{R}$	Borrowing penalty	0.029	see targets table
Firms			
α	Share of labor	0.68	62% lab. income
η	El. of substitution	11	10% Price markup
η_W	El. of substitution	11	10% Wage markup
κ	Price adj. prob.	0.25	1 year avg. price duration
κ_W	Wage adj. prob.	0.25	1 year avg. wage duration
ϕ	Inv. adj. cost	4.0	Bayer et al. (2020)
δ_0	Depreciation rate	0.018	see targets table
δ_1	Depr. rate increase	5.0	Bayer et al. (2020)
Open economy			
σ	Trade-price elasticity	0.9	Heathcote and Perri (2002)
ω	Home bias	0.66	Import share 26%
n_A	Country size	0.5	Same size
Government			
$\bar{\tau}^L$	tax rate	0.3	Standard value
$\frac{\bar{G}}{\bar{Y}}$	Gov. cons. share	0.21	Balance budget
$\bar{R}^b$	St St Interest rate	1.00	0% annually
ρ_R	Pers. in Taylor rule	0.0	standard value
θ_π	Reaction to Infl.	1.5	standard value
θ_Y	Reaction to Output	0	ECB mandate

Notes: Parameter values for baseline calibration. Symmetric countries.

markets literature; see Kaplan and Violante (2014). We set the Frisch elasticity to 0.5; see Chetty et al. (2011). We set the idiosyncratic income risk, $\rho_h = 0.9815$ and $\sigma_h = 0.135$ such that the Gini of market incomes is the same as in Italy. We use the remaining parameters, the discount factor, the portfolio adjustment probabilities, the transition of workers to become entrepreneurs and the transition from entrepreneurs to become workers again, as well as the borrowing penalty to match six targets in Italy: the debt level, capital per GDP, the wealth Gini, the share of wealth owned by the Top 10% wealthiest households, the wealth share of

Table 3.2: Calibration targets in model and data

Description	**Model Country**	**Data ITA**
Debt level	132%	132%
Capital per GDP	3.3	3.3
Wealth gini	0.60	0.61
Top 10 wealth share	0.43	0.44
Bottom 50 wealth share	0.10	0.09
Mass of borrowers	0.08	0.08

the bottom 50% wealthiest households, and the mass of borrowers (see Table 3.2).

Finally, we set the parameters of the government to standard values in the literature. We set the share of government consumption to $\frac{\bar{G_A}}{\bar{Y_A}} = 0.21$ and the steady state real rate to 0. This implies a steady state tax level of 0.3. We assume that monetary policy only targets inflation, as is the official mandate of the ECB, and set the Taylor coefficient to 1.5. We further abstract from smoothing in the Taylor rule.

4 The macro impact of asymmetric shocks

In this section, we present results for the transmission of asymmetric shocks. We focus on country-specific shocks which originate in the domestic economy and show how they impact both the domestic economy and the foreign economy. We show results for adverse TFP shocks and expansionary government spending shocks, first assuming that both countries form a monetary union and then for the case of independent monetary policies.

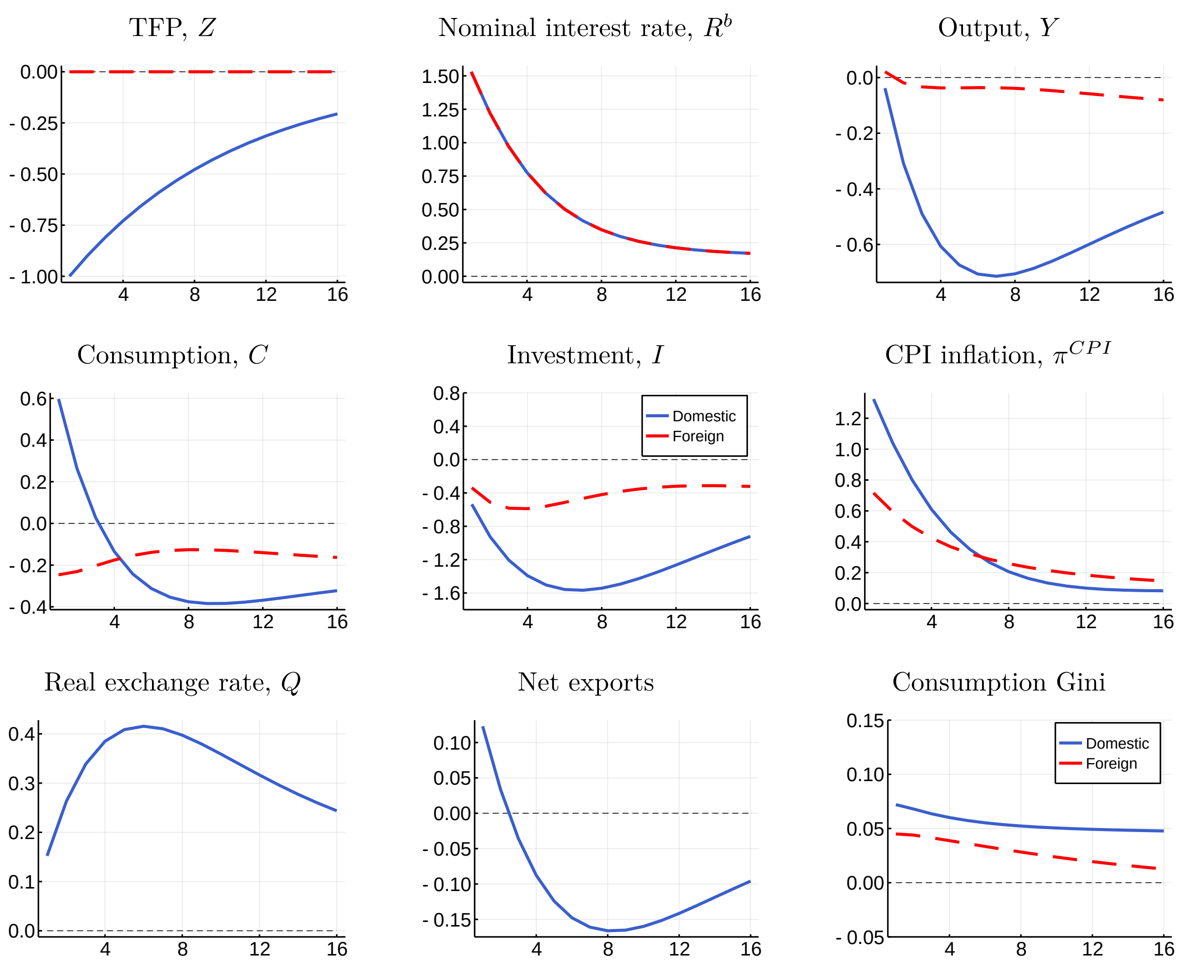
4.1 Monetary Union

Figure 4.1 shows the impulse responses to a contractionary TFP shocks which originates in the domestic economy. TFP is assumed to drop by 1% and reverts back to its steady state value following an AR(1)-process with a coefficient of 0.9 while foreign TFP stays constant. The blue solid lines shows the response of variables in the domestic economy, while red dashed lines show the adjustment abroad. Note that since we consider perfectly symmetric countries, the red, dashed lines can also be interpreted as the impulse responses in the home country to an shock in the foreign country.[4]

Figure 4.1 also shows that inflation increases in both countries which leads the common monetary policy to increase nominal interest rates. Turning to the impulse responses in

[4] Throughout the paper, we will use both perspectives (foreign countries response to a shock at Home and domestic response to a foreign shock) interchangeably when we refer to the red lines.

Figure 4.1: Impulse responses to domestic TFP contraction

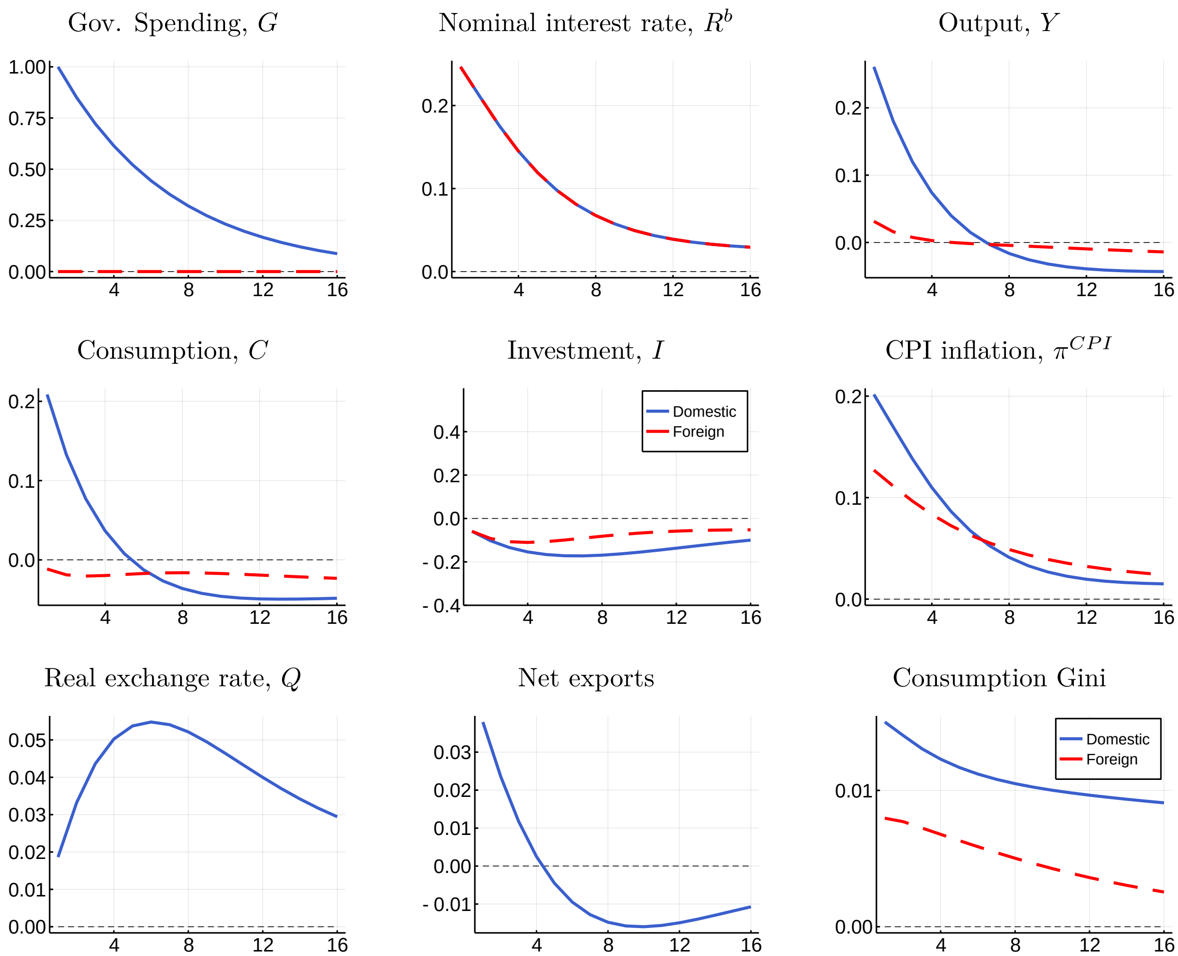


Notes: Effect of contractionary TFP shocks in a monetary union. Y-axis: Percentage deviation from steady state, percentage points in case of inflation and interest rate. X-axis: Quarters.

the home country, output and investment fall. Consumption increases in the first quarters, before it decreases after four quarters, reflecting the fact that interest rates do not increase as strictly due to the fact that average inflation in the monetary union increases by less than in the home country. Home's real exchange rate appreciates in response to an adverse TFP shock.

In the non-shocked country, output, consumption, and investment decrease, but all decrease only mildly. Especially, output barely moves. All in all, spillovers from a foreign shock on at the aggregate level appear moderate. We compare them to what happens under independent monetary policies below. Lastly, we note that the Gini coefficient for consumption, shown in the right-bottom panel of Figure 4.1 increases in the both countries

Figure 4.2: Impulse responses to domestic spending shock



Notes: Effect of government spending shock in currency union. Y-axis: Percentage deviation from steady state, percentage points in case of inflation and interest rate. X-axis: Quarters.

and, what's more the increase is quantitatively comparable. This seems noteworthy given that the foreign economy seems not much affected by the shock at the aggregate level. We will get back to this issue below.

We verify that results are not specific to TFP shocks and turn to a government spending shock which originates again in the domestic economy. Figure 4.2 shows the simulation results. Higher spending raises inflation both in Home and in Foreign and the common monetary policy responds by raising interest rates. Still, in the domestic economy, both output and consumption first increase and eventually decrease. Investment decreases mildly. Importantly, the spillovers to the foreign country are again small: output, consumption, and investment all barely move. CPI Inflation increases on impact half as much as in the Home country.

In addition, Figure 4.2 shows that after an asymmetric increase in government spending, the domestic real exchange rate appreciates. Net exports first increase and then decrease down the road. As with the TFP shock we observe a fairly synchronized increase in the Gini coefficient for consumption even though macro spillovers appear small (lower-right panel).

To sum up: an asymmetric shock in the home country induces spillovers to the foreign country. For economic activity, we find these spillovers to be rather small while for consumption inequality these spillovers are larger as the foreign consumption Gini increases by around half as much as in the Home country.

4.2 Independent Monetary Policies

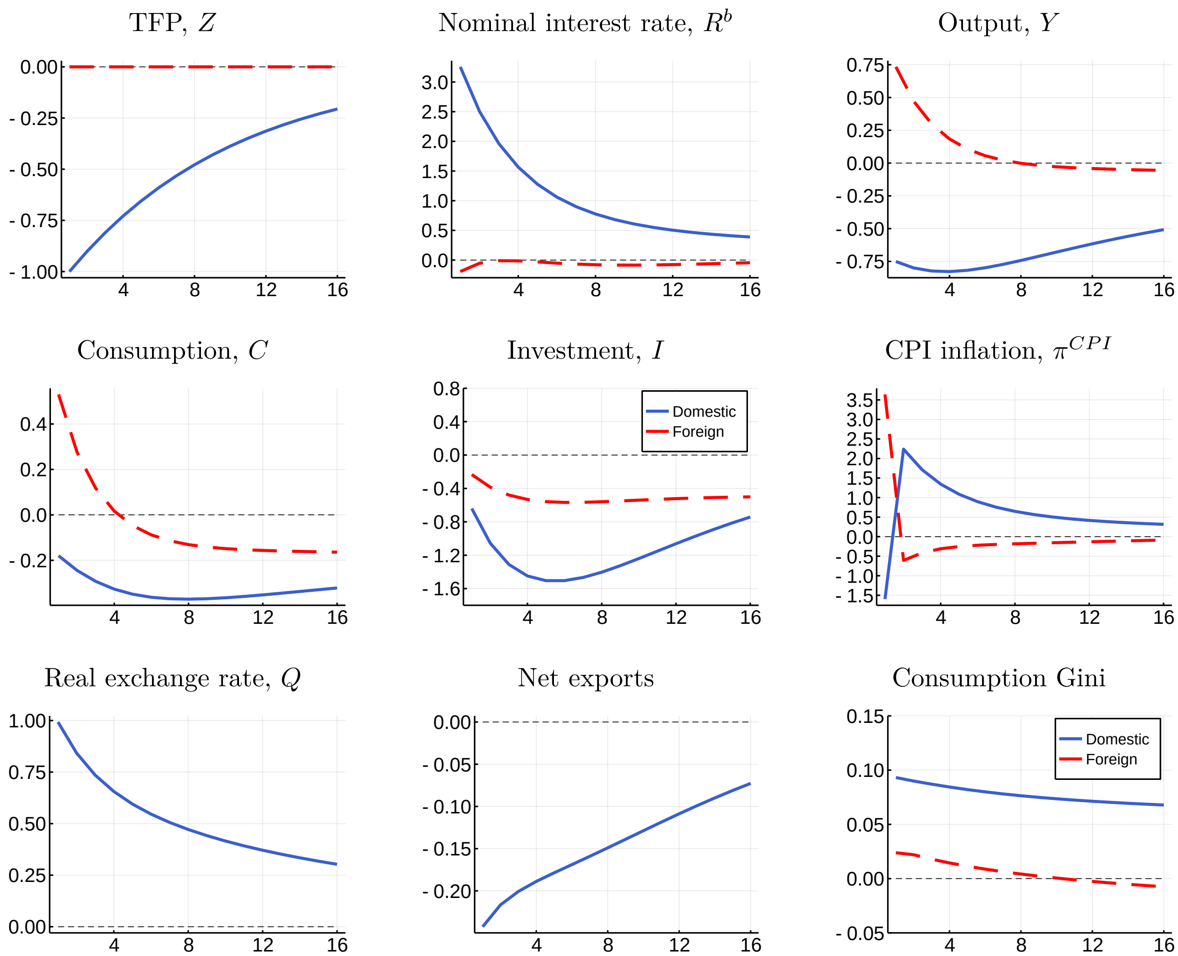
To highlight how the monetary union shapes the international transmission of asymmetric shocks, we turn to an alternative scenario where each country operates an independent monetary policy. For this scenario we assume that interest rates are adjusted in response to domestic inflation, while the interest rate rule is otherwise the same as in the monetary union, see equation (35) above. The exchange rate adjusts freely. We consider the same two shocks as above.

We consider first the effects of the asymmetric TFP shock under independent monetary policies, shown in Figure 4.3. The first thing to notice is that nominal interest rates adjust quite differently. They increase sharply in the domestic economy where domestic inflation (not shown) increases strongly but hardly move abroad. The domestic exchange rates appreciates strongly, both in nominal and real terms. This is why CPI inflation in Home declines on impact. Consistent with the strong appreciation, Home's net exports decline strongly, as does consumption and investment. The result is a much sharper recession in Home, compared to the case of a monetary union shown in Figure 4.1 above. At the same time the shock is now much more expansionary in the foreign country: output and consumption first increase, before they mildly decrease after some time.

In sum, we find that macro spillovers of the adverse shock are larger under independent monetary policies. At the same time the consumption Gini in Foreign is now fairly unresponsive to the shock, while it increases even more strongly in the domestic economy. In other words, while spillovers on real economic activities are stronger compared to the monetary union case, the spillover on consumption inequality is relatively small with independent policies.

We also revisit the transmission of a government spending shock under independent monetary policies and show results in Figure 4.4. Now as with the TFP shock, nominal interest rates increase more strongly in the domestic country, somewhat dampening the

Figure 4.3: Impulse responses to domestic TFP contraction w/ independent monetary policies

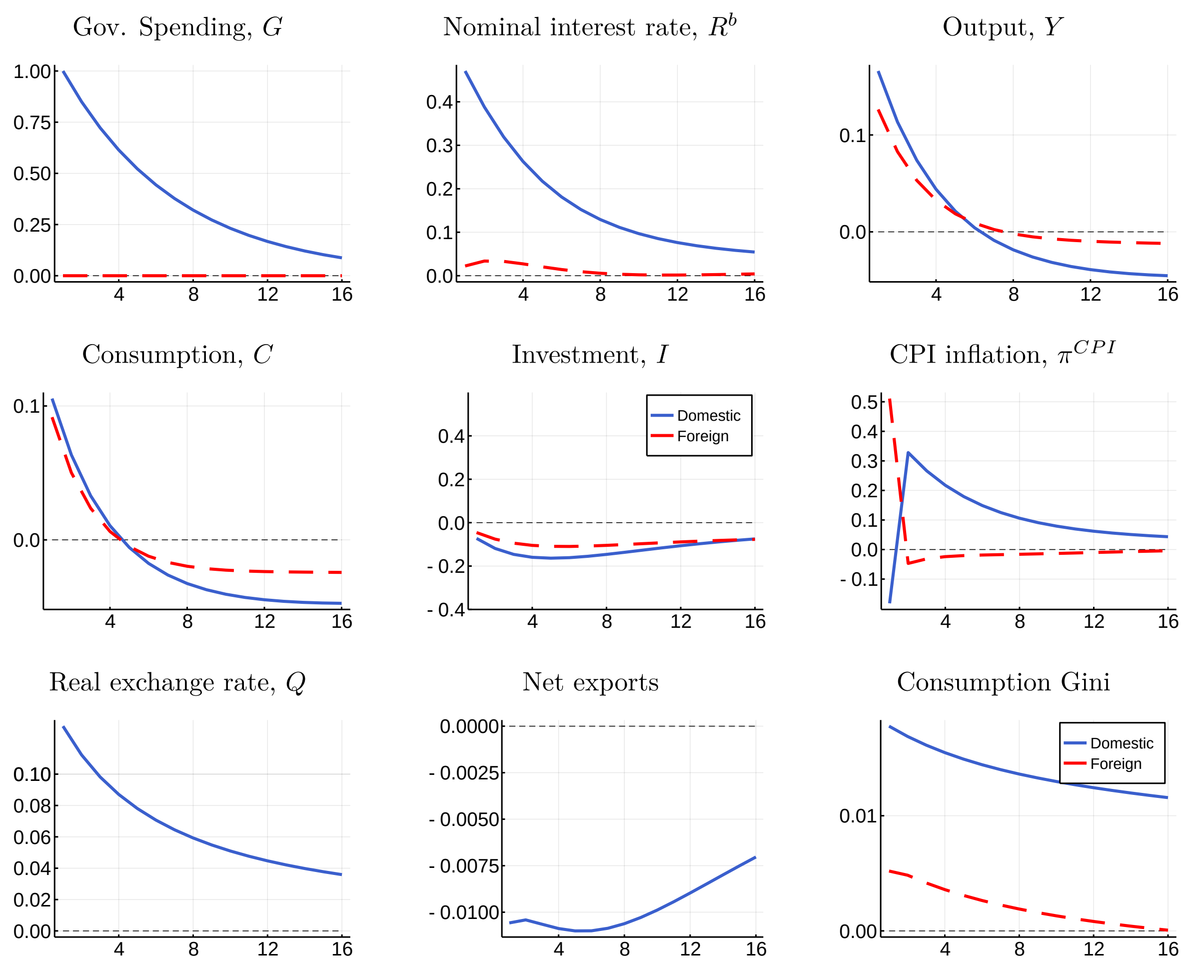


Notes: Effect of contractionary TFP shocks with independent monetary policies. Y-axis: Percentage deviation from steady state, percentage points in case of inflation and interest rate. X-axis: Quarters.

increase in output and consumption. In contrast, in the foreign country the nominal interest rates now barely move, such that output and consumption increases slightly stronger than in the monetary union baseline, see again Figure 4.2 above.

Figure 4.4 also shows that now consumption inequality increases more substantially in the country in which the shock takes place, but much less in the foreign economy. In sum, the spillovers on real activities are larger than in the monetary union baseline, while the spillovers on inequality are smaller with independent policies.

Figure 4.4: Impulse responses to domestic spending shock w/ independent monetary policies



Notes: Effect of government spending shock w/ independent monetary policies. Y-axis: Percentage deviation from steady state, percentage points in case of inflation and interest rate. X-axis: Quarters.

5 The distributional impact of asymmetric shocks

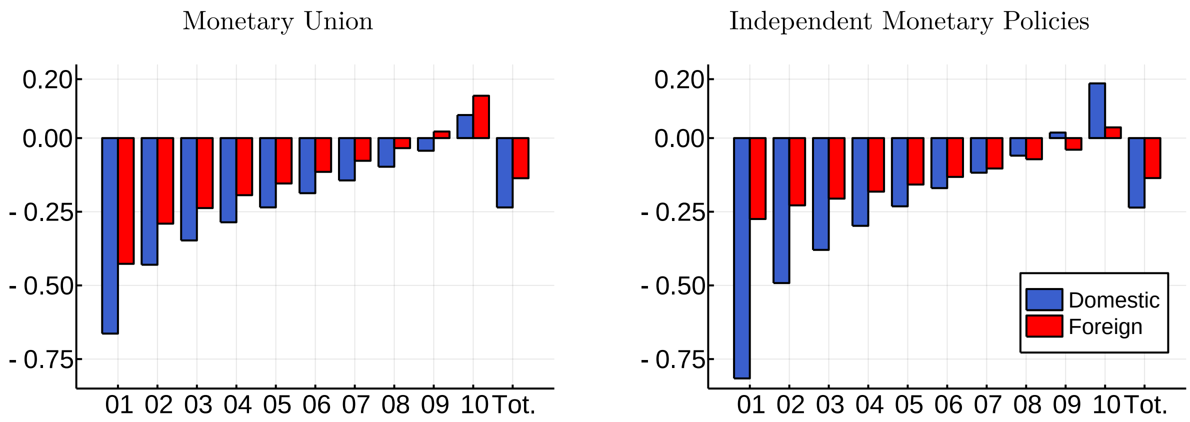
We are now in a position to take up the question which motivates our analysis: How does a common currency alter the distributional impact of country-specific shocks, both *within* and *across* countries? For this purpose we compute the welfare impact of shocks across the wealth distribution and contrast results for the monetary union with what happens under independent monetary policies. Our welfare measure is the consumption equivalent variation, that is, the permanent consumption change which makes an individual household just as well off as does the shock under consideration. As a caveat, we stress that we evaluate one sided-welfare only rather than providing a full-fledged welfare analysis based on a second-order approximation of the utility function.

Figure 5.1 shows the welfare impact of an adverse TFP shock on households along the wealth distribution. Specifically it reports the average consumption equivalent for each decile of the distribution as well as the country average. The left panel shows the result for the monetary union, the right panel shows the result for independent monetary policy. We consider the monetary union case first and make three observations. First, in this case, the average welfare impact is fairly similar across countries. This is shown by the rightmost bars in the panel (a). The welfare impact is negative in both countries, but Foreign is almost as badly hit—on average—as is Home. This indicates that there are sizable welfare spillovers.

Second, we observe that *within* countries differences in the welfare impact of the shock are very large: the welfare loss due to a domestic TFP shock decreases monotonically in the wealth deciles: the loss of the the poorest households amounts to more than half percent (measured in consumption equivalence units), the wealthiest households actually benefit from the decline in TFP. Third, the distributional impact of the domestic shock is comparable in Foreign: not only in terms of size, but also in terms of shape. Again the poor abroad lose out, while the rich benefit from the shock. Overall the welfare impact abroad is more benign than in Home, but overall the impact is very similar and the difference in terms of welfare within wealth groups across countries tend to be quite small.

Turning, to the case of independent monetary policies, shown in the right panel, we make again a number of observations. First, the average welfare effect is more or less the same as in the monetary union case. Second, the distributional impact is now more different. Spillovers are now considerably smaller at the tails of the wealth distribution: Poorer households are hit relatively less by the foreign shock, whereas the welfare impact on the richer households is now very small. In contrast, in home where the shock originates, the distributional impact is considerably larger: the adverse impact on the poor is now strongest, while the wealthiest households benefit even more from the contractionary shock than in case of a monetary union.

Figure 5.1: Welfare impact across the wealth distribution in Home and Foreign



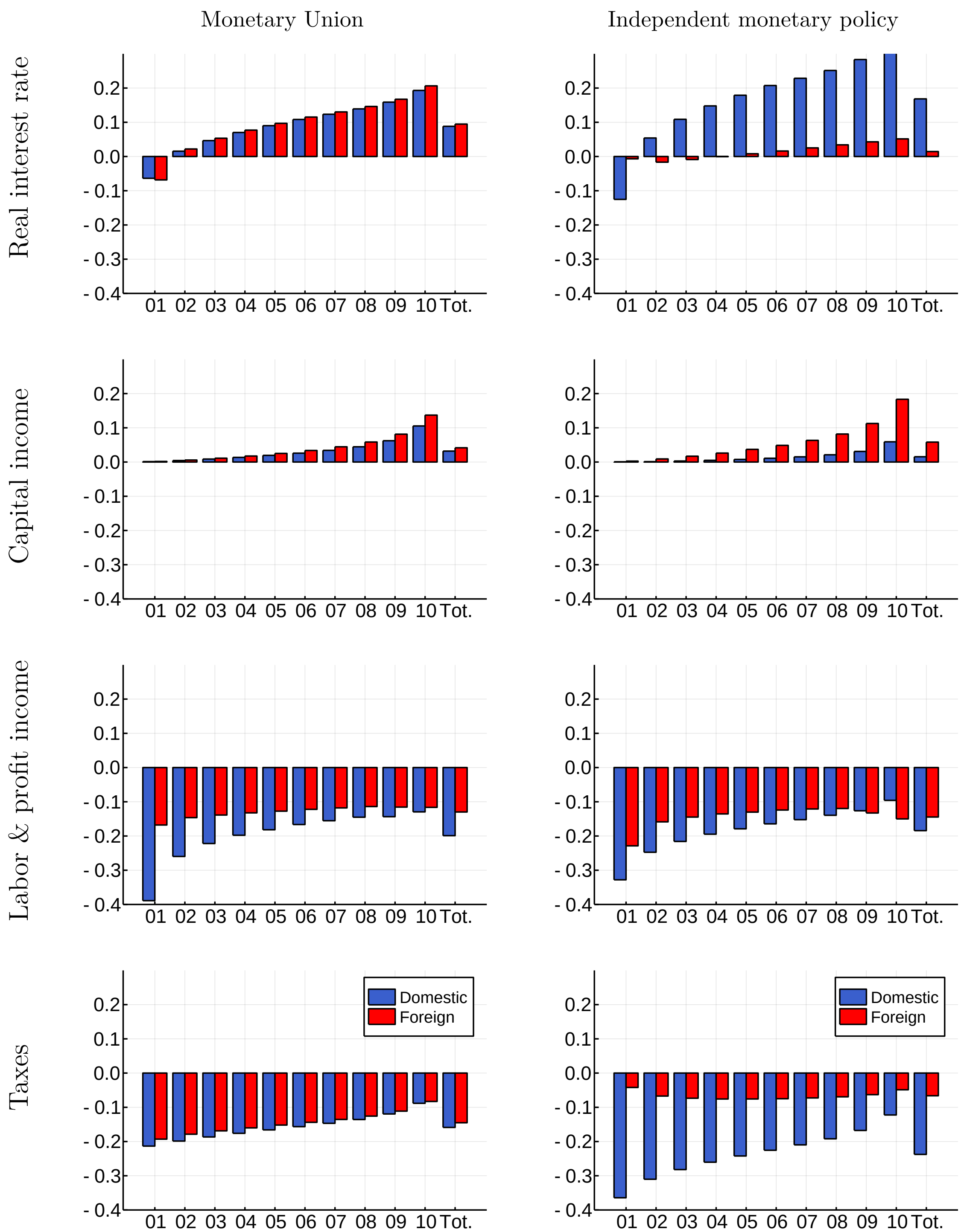
Notes: Average welfare in terms of consumption equivalences across different wealth deciles after asymmetric, contractionary TFP shocks. Wealth includes both liquid and illiquid wealth.

To sum up: the monetary union does barely affect the average welfare of countries in the face of asymmetric shocks. Yet, it dampens the distributional effect of domestic shocks while it amplifies the distributional effects of foreign shocks. In this way, the monetary union synchronize the welfare effects within wealth groups across countries. A similar pattern emerges for the welfare effects of a domestic government spending shock. We show the results in Figure A.1 in the Appendix.

The welfare effect (measured in terms of consumption equivalent variation) captures the total effect for specific households. As such it reflects the overall adjustment of the economy to the shock which, in turn, is characterized by various changes in prices and taxes. All these changes affect households potentially differently, depending on where they are located in the wealth distribution. We thus decompose the total welfare effect into its partial equilibrium components. Specifically, we compute the consumption equivalent variation induced by partial equilibrium changes in the real interest rate, in capital income, in labor and profit income, and in taxes.

Figure 5.2 shows this decomposition for the monetary union in the left column and for the case of independent monetary policies in the right. The top panel shows the effect of the increase in the real interest rates and the capital income on households along the wealth distribution, both in Home and Foreign. The strong positive welfare impact of the changes in real returns explain the overall positive welfare implication on the top 10% wealthiest households in both countries. For independent monetary policies, shown in the right column, a different pattern emerges. Note that in this case the domestic monetary policy reacts much

Figure 5.2: Decomposition of welfare effect



Notes: Decomposition of average welfare effect of asymmetric, contractionary TFP shock in Home.

stronger while the foreign monetary policy reacts much less strong than a common monetary policy. Hence, the changes in real interest rate have an even larger distributional impact in Home. At the same time, in Foreign there is hardly a distributional effect.

We show the contribution of capital income, labor and profit income in the middle panels of the figure. In these instances we observe smaller differences when comparing results in the left and the right column. Hence whether countries operate in a monetary union or not matters less in this regard. Although we note that labor and profit income contribute to the distributional impact of the shock: their effect on the poor is particular adverse. This reflects that wages decline in response to an adverse TFP shock and wage income is more important for the households at the lower end of the wealth distribution.

Lastly, we observe that the contribution of taxes in Foreign changes quite a bit in the monetary union. In the currency union taxes in Foreign increase more as interest rates go up since the level of government debt is quite large. This affects all households adversely. Instead, in Home the impact of taxes on welfare is reduced in the currency union—precisely because here interest rates and hence the tax burden goes up by less. Figure A.2 in the Appendix shows that similar patterns emerge when we decompose the welfare impact of government spending shocks.

Overall, Figure 5.2 shows that the wealthiest households enjoy large welfare gains from changes in the real returns which explains their overall positive welfare impact in the monetary union. In contrast, the poorest households suffer a lot from the reduced labor income which explains their welfare loss after the TFP shock. For the middle class, these opposite effects are fairly balanced overall, explaining their smaller losses in welfare. Our decomposition also explains why a monetary union amplifies may reduce the aggregate impact of foreign shocks while, at the same time, amplifying their distributional impact. Monetary union in particular alters the response of real interest which shapes the distributional effects.

6 Conclusion

Asymmetric shocks are a classic theme of OCA theory. They bring to the fore the "one size doesn't fit all" problem from which monetary unions may suffer at times. We revisit the issue through the lens of a heterogeneous agent New Keynesian model with two countries: HANK^2. It belongs to a class of models which breaks with the representative agent paradigm and thus opens up new perspectives. In particular, in contrast to earlier generations of OCA theory we are no longer confined to analyzing what membership in a monetary union means for national welfare.

Instead, we investigate how monetary union alters the welfare implications of shocks for specific households and, more generally, its distributional impact. A key result of our analysis is that the welfare impact of shocks differs much within countries and much more than across countries—independently of whether countries form a monetary union or not. Monetary union also barely alters the average welfare of asymmetric shocks. Yet, it dampens the distributional effect of domestic shocks, but amplifies the distributional effects of foreign shocks. Monetary union thus results, for better or worse, in countries being (more) united in their diversity.

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A Welfare of Asymmetric Government Spending Shocks

The left panel of Figure A.1 shows the welfare impact of asymmetric government spending shocks in the monetary union. The picture is very similar to asymmetric TFP shocks. The differences within countries dwarf the difference across countries and households are affected similarly in the same wealth percentiles across countries. Low wealth households are hit hardest irrespective of their country of residence while the wealthiest households benefit. Comparing it with the right panel, which shows the welfare impact of asymmetric government spending shocks with independent policies shows that also for government spending shocks, the monetary union reduces the distributional impacts of domestic shocks compared to independent monetary policies while it increases the distributional impacts of foreign shocks.

Decomposition of welfare impacts. The partial equilibrium decomposition looks very similarly compared to the one after TFP shocks: wealthy households benefit a largely from increases in the real interest rate and capital income, while low wealth households (in particular in the shocked country) are hit hardest by the decrease in labor income. Taxes (which are now substantially larger in the shocked country, given that it needs to finance the government spending) are regressive in its impact of welfare along the wealth distribution.

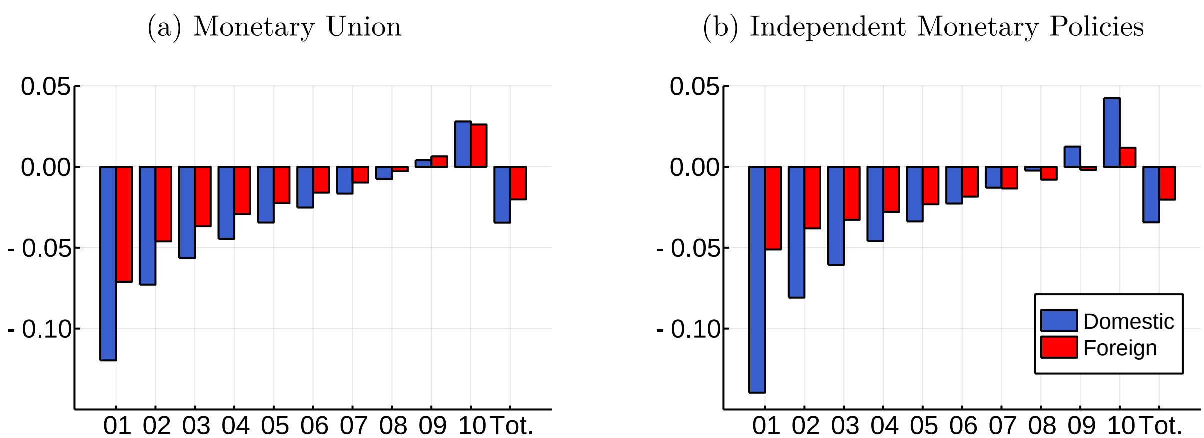
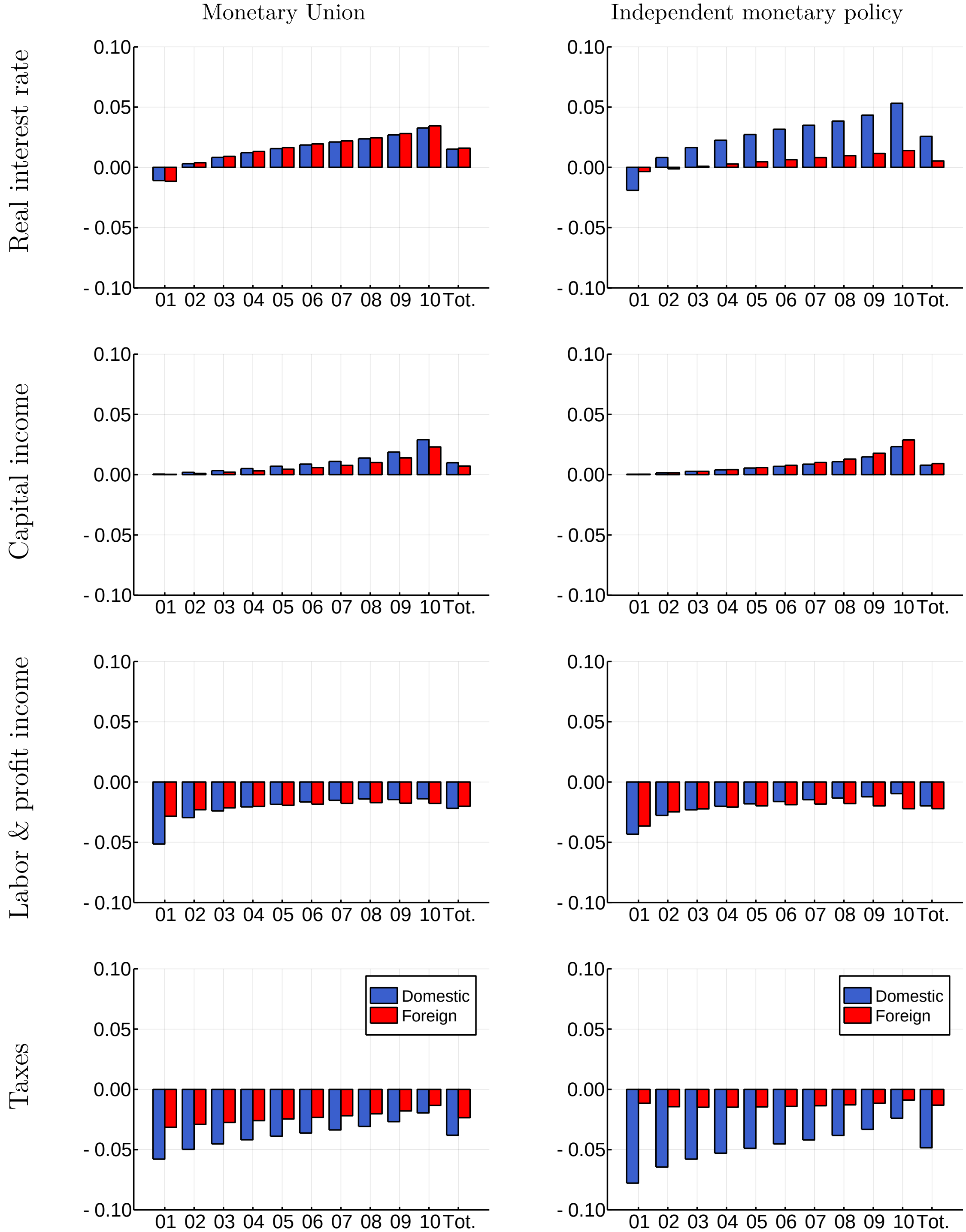


Figure A.1: Average welfare in terms of consumption equivalences across different wealth percentiles after asymmetric, expansionary government spending shocks. Wealth includes both liquid and illiquid wealth.

Figure A.2: Decomposition of welfare effect



Notes: Decomposition of average welfare effect of asymmetric, expansionary G shock in Home.