FEDERAL RESERVE BANK OF SAN FRANCISCO

WORKING PAPER SERIES

Would the Euro Area Benefit from Greater Labor Mobility?

Vasco Cúrdia and Fernanda Nechio
Federal Reserve Bank of San Francisco

February 2024

Working Paper 2024-06

https://doi.org/10.24148/wp2024-06

Suggested citation:

Cúrdia, Vasco, and Fernanda Nechio. 2024. "Would the Euro Area Benefit from Greater Labor Mobility?" Federal Reserve Bank of San Francisco Working Paper 2024-06. https://doi.org/10.24148/wp2024-06

Would the euro area benefit from greater labor mobility?*

Vasco Cúrdia† and Fernanda Nechio‡

Federal Reserve Bank of San Francisco

February 27, 2024

Abstract

We assess how within euro area labor mobility impacts economic dynamics in response to shocks. In the analysis we use an estimated two-region monetary union dynamic stochastic general equilibrium model that allows for a varying degree of labor mobility across regions. We find that, in contrast with traditional optimal currency area predictions, enhanced labor mobility can either mitigate or exacerbate the extent to which the two regions respond differently to shocks. The effects depend crucially on the nature of shocks and variable of interest. In some circumstances, even when it contributes to aligning the responses of the two regions, labor mobility may complicate monetary policy tradeoffs. Moreover, the presence and strength of financial frictions have important implications for the effects of labor mobility. If the periphery's risk premium is more responsive to its indebtedness than our estimates, there are various shocks for which labor mobility may help stabilize the economy. Finally, the euro area's economic performance following the Global Financial Crisis would not have been necessarily smoother with enhanced labor mobility.

JEL classification codes: F41, F45, E44, E3, E4

Keywords: monetary union, labor mobility, credit frictions

*For comments and suggestions we thank seminar participants at the Federal Reserve Bank of San Francisco, the European Economic Association 2018, and the Computing in Economics and Finance 2017. The views expressed in this paper are those of the authors and do not necessarily reflect the position of the Federal Reserve Bank of San Francisco or the Federal Reserve System.

†*E-mail*: vasco.curdia@sf.frb.org

‡*E-mail*: fernanda.nechio@sf.frb.org

1 Introduction

> "If labor and capital are insufficiently mobile within a country then flexibility of the external price of the national currency cannot be expected to perform the stabilization function attributed to it, and one could expect varying rates of unemployment or inflation in the different regions." Mundell (1961)

The classic economic theory behind *optimal currency areas* (OCA) predicts that regions with strong economic ties and similar business cycles would benefit from a single currency provided labor and capital would freely move in the area (Mundell, 1961 and Kenen, 1969, among others). Free mobility of production inputs would help smooth business cycles and mitigate asymmetries across members of a monetary union.

In line with this prediction and since its inception, one of the main pillars of the European Monetary Union has been free mobility of inputs. In practice, however, while capital mobility has been unequivocally large and widespread across countries within the euro area, labor movement has been more limited. The within-region movement of workers has been relatively small relative to other large economies. As of 2021, for example, about 4% of the working-age European Union population lived in a country different from their birth one. Across U.S. states this number was about 30% (OECD, 2021).

Following the European sovereign debt crises in the early 2010s, this relatively limited labor mobility across euro area countries was frequently pointed out as a constraint, and even a possible contributor, to the region's slow economic recovery (*e.g.*, Basso, D'Amuri and Peri, 2019, Druant et al., 2012, IMF, 2012, and others). As the argument goes, enhanced labor mobility across countries at different stages of the sovereign debt crisis, would have mitigated the crisis effects in the euro area and helped speed up its economic recovery.

In this paper we assess whether greater labor mobility would benefit the euro area. To do so, we first build and estimate a two-region monetary union dynamic stochastic general equilibrium (DSGE) model that allows for a varying degree of labor mobility across the two regions, which we label core and periphery. Next, we consider a counterfactual monetary union with enhanced labor mobility and compare their responses to various shocks. Last, we consider the union's economic performance following the Great Financial Crisis had labor mobility being larger.

All three parts of the analysis point to a much more nuanced role for labor mobility in a monetary union. In short, we find that the estimates corroborate the evidence pointing to limited labor mobility across regions within the euro area. More importantly, our findings suggest that, in contrast with the traditional OCA predictions, labor mobility can either *augment* or *mitigate* the effects of shocks hitting the monetary union and its members. These effects are highly dependent on the nature of shocks hitting the economy and which variable's response one is focused on. This finding holds when considering either common or region-specific shocks. Moreover, financial friction play an important role in determining the implications of labor mobility in the economy. Finally, greater labor mobility would not have necessarily implied a smoother path through the Great Financial Crisis.

We model core and periphery symmetrically, except for the presence of credit frictions. We assume that the periphery borrows from core, and when it does, core incurs a transaction cost. This cost is modeled as in Cúrdia and Woodford (2011) and can be interpreted as a monitoring cost, which is a function of periphery's indebtedness and a risk premium, such that as the debt level increases (above some threshold), so does the transaction cost.[1]

A representative household in each region maximizes her utility function which establishes preferences for consumption and work-hours allocated to each region. We assume a utility function that features home bias in labor-hour allocation and sensitivity to wage differentials, which determines the number of hours allocated to each region. In the model, workers do not physically move from one region to another, but instead, choose the number of hours to supply to each region. Within this formulation, we can also consider the limiting cases in which a worker is indifferent between the two regions or only works on firms in her own region. We assume that the monetary authority in the model sets a unique policy for both regions. The remaining ingredients of the model are kept relatively standard to better shed light on the interactions between labor mobility, credit frictions, and the response to shocks. We estimate the model with Bayesian methods, as described by An and Schorfheide (2007).

Our estimates show that the data strongly favor a significant home bias in labor supply for both core and periphery. More importantly, the model with no labor mobility fits the data substantially better, corroborating the evidence that there is limited labor movement across countries within the euro area.

We use the best-fitting specification — *i.e.*, the specification that assumes away cross-region labor mobility — as the baseline, and consider a counterfactual monetary union that looks identical to the baseline except that it allows for cross-region labor mobility (to different degrees).[2] We then use this counterfactual economy to assess how the two regions and the aggregate monetary union perform in response to various common and region-

[1] Despite assuming symmetric functional forms, we allow for the parameters controlling preferences and technology to differ across the two regions.

[2] As detailed in Section 3, to compare the performance of the economies with and without labor mobility, we depart from the baseline model, draw the common parameters from its posterior, and consider a range of values for the parameters associated with labor mobility for the latter model.

specific shocks. Specifically, we consider shocks to the euro area's monetary policy and to its total factor productivity, as well as region-specific shocks to the discount rate, total factor productivity, labor disutility, government spending, price markups, and a shock to periphery's risk premium.

The comparison between the baseline and the counterfactual economies highlights the importance of the nature of shocks and the macroeconomic variables used to assess the effects of greater labor mobility in a monetary union. We find that, in contrast with OCA theory, enhancing labor mobility not necessarily benefits a single currency union. In other words, the streamlined classic OCA conjecture that labor mobility would help smooth the business cycles or mitigate asymmetries is substantially more nuanced and it only holds in particular cases.

For example, in response to shocks to a common shock to monetary policy or productivity, our analysis shows that enhanced labor mobility yields little change to the response of aggregate variables such as area-wide inflation or output. In contrast, labor mobility has a substantial impact in area-wide aggregates for some regional shocks, including periphery's relative productivity shock, regional demand shocks, regional labor supply shocks, and the shock to the periphery's risk premium.

Moreover, one of the key points in classic OCA theory was how goods and factor mobility would allow different regions to better withstand asymmetric shocks and that common shocks would lead to similar responses across regions within the monetary union. Using the same counterfactual experiment we can also assess whether labor mobility across regions can mitigate or augment regional asymmetric responses to different shocks. We find that a shock to core's households consumption demand provides an example in which labor mobility impacts aggregate outcomes. Increased core demand puts upward pressure on core goods prices due to home bias. It also increases demand for periphery's goods. Because it is inflationary, periphery's consumption falls. Labor mobility reduces the inflationary pressures by shifting labor to core, but in doing that, it increases the relative prices of the periphery, leading to lower consumption and output in core. Therefore, while labor mobility mitigates the aggregate effects of this shock, it makes disparities worse.

Another channel by which business cycles in a monetary union can be smoothed is through borrowing and lending to help absorb some of the asymmetric shocks and responses to shocks. However, there are possibly many financial frictions, including a limit to how much the periphery can borrow from the core. To capture these features, in the model, credit frictions are modeled through a function of the periphery's debt and risk premium such that the borrowing cost increases the larger is periphery's indebtedness.[3]

Interestingly, the estimated model suggest very little sensitivity of the risk premium to the degree of indebtedness of the periphery. This means that the endogenous financial channel in the estimated model is very weak, and the role of financial frictions is felt mostly through an exogenous shock to the periphery's risk premium. The weak endogenous financial frictions channel may be a function of the time period used to estimate the model, during which periphery's large debt is mostly ignored by financial markets and risk premia of indebted countries is low.[4] It is possible that, in certain periods, the risk premium will be more sensitive to the indebtedness of periphery countries.

Therefore we also investigate the implications of a counterfactual scenario with a larger endogenous response of the risk premium to periphery's debt. The exercise shows that in the baseline case (with little endogenous component) labor mobility exacerbates the deflationary pressures and increases the asymmetric responses of regional output and consumption. This is a stark example of how the OCA conjecture (that labor mobility is helpful in stabilizing a monetary union) does not apply. That picture changes when we consider a stronger endogenous risk premium. In that case, when we allow for enhanced labor mobility to coexist with endogenous risk premium, most of the regional and aggregate impacts of this shock disappear. Therefore the impact of labor mobility on aggregate and regional responses depends crucially on how endogenous the periphery's financial fragility is. More generally, there are various shocks for which labor mobility in the presence of endogenous risk premium substantially mitigates the financial frictions augmentation effects.[5]

Our model also has implications for the trade-offs that monetary policy aims to mitigate. While a full normative analysis is beyond the scope of this paper, our results suggest that, once again, the effects of labor mobility depend on the nature of shocks hitting the economy. One key example is the role of labor supply shocks. If the shock originates in the core, then labor mobility reduces inflationary pressures and output declines, thus reducing policy trade-offs. If instead, labor supply shocks originate in the periphery, labor mobility yields stronger inflationary pressures and output contracts further, thus complicating policy trade-

[3]This formulation aims to capture some of the dynamics of debt markets during the 2010 European sovereign debt crisis, when some countries saw substantial increases in sovereign debt yields and potential limits to their borrowing ability that resembled a sudden stop (*e.g.*, Lane, 2012, Shambaugh, 2012, and IMF, 2016).

[4]This is consistent with observed risk premia for periphery countries after they joined the euro area and before the 2008 financial crisis. The 2008 financial crisis and subsequent shock-waves in the European periphery suggest that this finding may not hold at all times.

[5]Section 5 analyzes in depth how endogenous financial frictions impacts economic dynamics with and without labor mobility for the different shocks in the model, including non-financial shocks.

offs, even if it mitigates asymmetric responses to this shock. Interestingly, labor mobility does not impact aggregate responses to regional price markup shocks, and hence, there are no obvious impact on policy tradeoffs for those shocks. In standard New-Keynesian models, labor supply and price markup shocks are often indistinguishable to first order, but the presence of labor mobility introduces a difference in economic dynamics that leads to distinguishable first-order responses of aggregate variables to these two types of shocks.

Finally, to put some perspective on these findings we look at the euro area's economic performance following the 2008 financial crisis and compare the relative performance observed vis-a-vis the counterfactual in which there were labor mobility. We find that allowing for labor mobility would have pushed aggregate output and inflation lower. In terms of regional effects, it would push output down in both regions, but it would affect inflation and consumption in the two regions differently, relative to the baseline with no labor mobility.

Our paper relates to the classical literature that studies optimal currency areas such as Mundell (1961) and Kenen (1969), and McKinnon (1963), among others. It also relates to the literature that estimates DSGE models such as An and Schorfheide (2007), and the literature that studies the economic effects of labor mobility within-country (*e.g.*, Blanchard and Katz, 1992, Blanchflower and Oswald, 2013, Dao, Furceri and Loungani, 2017), and across countries within the euro area (*e.g.*, Kahanec, 2013, Farhi and Werning, 2014, and Jauer et al., 2019). Our analysis differs and complements the latter set by considering the role of financial frictions on an estimated DSGE model. Finally, our paper more closely relates to House, Proebsting and Tesar (2018), who aims to quantify the benefits of labor mobility in the euro area. The authors compare counterfactual economies with greater mobility or flexible exchange rates, *i.e.*, the absence of a monetary union. We differ from their work by focusing on a comparison between the estimated and the counterfactual economy with greater labor mobility *within* a monetary union and by considering a wider range of shocks and exploring the role of financial frictions (which arguably played an important role during the sovereign debt crisis in the 2010s).

The rest of the paper proceeds as follows. Section 2 describes the model. Section 3 reports the estimation results and Section 4 discusses how labor mobility can impact the economy's response to shocks. Section 5 analyzes the interaction of labor mobility and financial frictions. Section 6 considers how results would change for alternative parameterizations. Section 7 considers the counterfactual evolution of the two regions in the recent period since the 2008 financial crisis if labor mobility was enhanced. Section 8 concludes.

2 Model

We set the model in terms of a monetary union (MU) with two regions, core and periphery, denoted by $j \in \{\mathcal{C}, \mathcal{P}\}$, respectively. Each region has a mass of households equal to ϖ^j that consume goods and can provide labor hours to both regions. Monetary policy is assumed MU-wide. Regions are symmetric except that, to introduce credit frictions in the model, we assume that periphery borrows from core, and when it does, core incurs a transaction cost. This cost is modeled as in Cúrdia and Woodford (2011) and can be interpreted as a monitoring cost, which is a function of periphery's indebtedness and an endogeneous risk premium. As the periphery's indebtedness raises above some threshold, this transaction cost increases.

In what follows we provide the main model ingredients. Since the two economies are mostly symmetric, we characterize the economy of core and note differences from periphery whenever the two economies differ.[6]

2.1 Households

The representative household in region $\mathcal{C}$ chooses her paths for consumption, $C_t^{\mathcal{C}}$, and labor supply to each labor market, $L_{\mathcal{C},t}^{\mathcal{C}}$ and $L_{\mathcal{P},t}^{\mathcal{C}}$, in order to maximize the intertemporal utility function:

$$E_t \sum_{T=t}^{\infty} (\beta^{\mathcal{C}})^T \xi_{\beta,T}^{\mathcal{C}} \left[\frac{\left(\frac{C_T^{\mathcal{C}}}{Z_T^{\mathcal{C}}} - h^{\mathcal{C}} \frac{C_{T-1}^{\mathcal{C}}}{Z_{T-1}^{\mathcal{C}}} \right)^{1-\sigma^{\mathcal{C}}}}{1-\sigma^{\mathcal{C}}} - \varphi^{\mathcal{C}} \xi_{l,T}^{\mathcal{C}} \frac{\left(\tilde{L}_T^{\mathcal{C}} \right)^{1+\nu^{\mathcal{C}}}}{1+\nu^{\mathcal{C}}} \right], \tag{2.1}$$

where $Z_t^{\mathcal{C}}$ is total factor productivity, $\beta^{\mathcal{C}} \in (0,1)$ is the time discount factor, $\xi_{\beta,t}^{\mathcal{C}}$ is a temporary shock to the time discount factor, $h^{\mathcal{C}} \in (0,1)$ is the parameter controlling the degree of consumption habits, $\sigma^{\mathcal{C}} > 0$ is the coefficient of relative risk-aversion, $\xi_{l,t}^{\mathcal{C}}$ is a temporary shock to the relative disutility of labor, and $\nu^{\mathcal{C}} > 0$ controls the convexity of disutility.

$\tilde{L}_t^{\mathcal{C}}$ stands for the disutility of supplying labor to firms in each region:

$$\tilde{L}_t^{\mathcal{C}} \equiv \left[(\gamma_l^{\mathcal{C}})^{-\frac{1}{\eta_l^{\mathcal{C}}}} (L_{\mathcal{C},t}^{\mathcal{C}})^{\frac{\eta_l^{\mathcal{C}}+1}{\eta_l^{\mathcal{C}}}} + (1-\gamma_l^{\mathcal{C}})^{-\frac{1}{\eta_l^{\mathcal{C}}}} (L_{\mathcal{P},t}^{\mathcal{C}})^{\frac{\eta_l^{\mathcal{C}}+1}{\eta_l^{\mathcal{C}}}} \right]^{\frac{\eta_l^{\mathcal{C}}}{\eta_l^{\mathcal{C}}+1}}, \tag{2.2}$$

[6] For additional details on the model, including a list of all variables and parameters, see the online Technical Appendix.

where $L^{\mathcal{C}}_{j,t}$ is labor supplied by households of region $\mathcal{C}$ to firms in region j, $\gamma^{\mathcal{C}}_l \in [0,1)$ controls the home bias in labor supply, and $\eta^{\mathcal{C}}_l$ controls the sensitivity of labor supply to the relative wage differential across the two regions.

The household in region $\mathcal{C}$ faces the budget constraint:

$$P^{\mathcal{C}}_t C^{\mathcal{C}}_t + B^{\mathcal{C}}_t + (1+\Upsilon_t) B^{\mathcal{C}}_{\mathcal{P},t} = R_{t-1} B^{\mathcal{C}}_{t-1} + R^{\mathcal{P}}_{t-1} B^{\mathcal{C}}_{\mathcal{P},t-1} + W^{\mathcal{C}}_t L^{\mathcal{C}}_{\mathcal{C},t} + W^{\mathcal{P}}_t L^{\mathcal{C}}_{\mathcal{P},t} + \mathcal{D}^{\mathcal{C}}_t + \mathcal{T}^{\mathcal{C}}_t, \quad (2.3)$$

where $P^{\mathcal{C}}_t$ is the aggregate price level in $\mathcal{C}$, $B^{\mathcal{C}}_t$ is the nominal value of government bonds from $\mathcal{C}$, R_t is the gross nominal interest rate of government bonds issued by $\mathcal{C}$ in period t, $B^{\mathcal{C}}_{\mathcal{P},t}$ is the (per capita) nominal value of bonds from $\mathcal{P}$ held by households of $\mathcal{C}$, Υ_t is a transaction cost incurred to invest in bonds from region $\mathcal{P}$, $R^{\mathcal{P}}_t$ is the gross yield on bonds from region $\mathcal{P}$ issued in period t, W^j_t is the wage received for labor supplied to j, $\mathcal{D}^{\mathcal{C}}_t$ are dividends distributed by the firms, and $\mathcal{T}^{\mathcal{C}}_t$ are government net transfers to households.

The budget constraint for a representative household in $\mathcal{P}$ differs from equation (2.3) to reflect her inability to invest or borrow using bonds from region $\mathcal{C}$. Instead, she can only borrow type $\mathcal{P}$ bonds, such that:

$$P^{\mathcal{P}}_t C^{\mathcal{P}}_t - B^{\mathcal{P}}_t = -R^{\mathcal{P}}_{t-1} B^{p}_{t-1} + W^{\mathcal{C}}_t L^{\mathcal{P}}_{\mathcal{C},t} + W^{\mathcal{P}}_t L^{\mathcal{P}}_{\mathcal{P},t} + \mathcal{D}^{\mathcal{P}}_t + \mathcal{T}^{\mathcal{P}}_t, \quad (2.4)$$

where $B^{\mathcal{P}}_t$ is the per capita level of borrowing by households of region $\mathcal{P}$.

The transaction cost, Υ_t, is taken as a given by households and is determined, in equilibrium, by:

$$1 + \Upsilon_t = (1+\Upsilon) \exp\left[\upsilon\left(\frac{B^{\mathcal{P}}_t}{P^{\mathcal{P}}_{y,t} Y^{\mathcal{P}}_t} - b^{\mathcal{P}}_y\right) + \xi_{B,t}\right], \quad (2.5)$$

where Υ is the steady state risk premium, υ controls the elasticity of the risk premium with respect to the ratio of debt to nominal output, $B^{\mathcal{P}}_t$ is the total amount of bonds issued by $\mathcal{P}$, $P^{\mathcal{P}}_{y,t} Y^{\mathcal{P}}_t$ is the nominal output in $\mathcal{P}$, $b^{\mathcal{P}}_y$ is the steady state ratio of debt to nominal output in $\mathcal{P}$, and $\xi_{B,t}$ is an exogenous shock to the risk premium.

2.2 Final Goods Firms

The final good is produced combining intermediate goods from both regions according to the technology:

$$\mathcal{Y}^{\mathcal{C}}_t = \left((\gamma^{\mathcal{C}}_y)^{\frac{1}{\eta^{\mathcal{C}}_y}} (Y^{\mathcal{C}}_{\mathcal{C},t})^{\frac{\eta^{\mathcal{C}}_y - 1}{\eta^{\mathcal{C}}_y}} + (1-\gamma^{\mathcal{C}}_y)^{\frac{1}{\eta^{\mathcal{C}}_y}} (Y^{\mathcal{C}}_{\mathcal{P},t})^{\frac{\eta^{\mathcal{C}} - 1}{\eta^{\mathcal{C}}_y}} \right)^{\frac{\eta^{\mathcal{C}}_y}{\eta^{\mathcal{C}}_y - 1}}, \quad (2.6)$$

where $\mathcal{Y}_t^{\mathcal{C}}$ is the level of final goods from region $\mathcal{C}$, $Y_{j,t}^{\mathcal{C}}$ is the amount of region j's intermediate goods used by region $\mathcal{C}$, $\eta_y^{\mathcal{C}} > 0$ is the elasticity of substitution across intermediate goods from the two regions, and $\gamma_y^{\mathcal{C}} \in [0, 1)$ controls for the home bias in consumption.

2.3 Intermediate Goods

There is a continuum of firms, with aggregate demand

$$Y_t^{\mathcal{C}} = \left(\int_0^1 Y_t^{\mathcal{C}}(i)^{\frac{\theta-1}{\theta}} di \right)^{\frac{\theta}{\theta-1}}, \tag{2.7}$$

where $\theta > 0$ is the price elasticity across varieties within each sector.

Each individual firm relies on production technology:

$$Y_t^{\mathcal{C}}(i) = Z_t^{\mathcal{C}} L_t^{\mathcal{C}}(i), \tag{2.8}$$

where $L_t^{\mathcal{C}}(i)$ is the labor used by firm i in region $\mathcal{C}$, regardless of where that labor originated from.

Individual firms' profits correspond to

$$\mathcal{D}_t^{f,\mathcal{C}}(i) = \left[P_{y,t}^{\mathcal{C}}(i) - \xi_{p,t}^{\mathcal{C}} MC_t^{\mathcal{C}} \right] \left(\frac{P_{y,t}^{\mathcal{C}}(i)}{P_{y,t}^{\mathcal{C}}} \right)^{-\theta} Y_t^{\mathcal{C}}(i)$$

where $\xi_{p,t}^{\mathcal{C}}$ is an exogenous markup over marginal costs.

Intermediate firms set prices as in Calvo (1983). We assume a fraction $\alpha_p^{\mathcal{C}}$ of firms are not able to reset their prices in any given period. In that case, they simply index the current price according to

$$P_{y,t}^{\mathcal{C}}(i) = P_{y,t-1}^{\mathcal{C}}(i)(\Pi_{t-1}^{\mathcal{C}})^{\iota_p^{\mathcal{C}}} \Pi^{1-\iota_p^{\mathcal{C}}}, \tag{2.9}$$

where Π is steady state gross inflation rate assumed constant across regions, and $\iota_p^{\mathcal{C}}$ is the indexation parameter. This setup implies firms that can reoptimize in period t, choose the price level $\bar{P}_{y,t}^{\mathcal{C}}(i)$ to maximize:

$$E_t \sum_{T=t}^{\infty} \left\{ (\alpha_p^{\mathcal{C}})^{T-t} \Lambda_{t,T}^{\mathcal{C}} \left[\bar{P}_{y,t}^{\mathcal{C}}(i) \left(\frac{P_{T-1}^{\mathcal{C}}}{P_{t-1}^{\mathcal{C}}} \right)^{\iota_p^{\mathcal{C}}} \Pi^{(1-\iota_p^{\mathcal{C}})(T-t)} - \xi_{p,T}^{\mathcal{C}} MC_T^{\mathcal{C}} \right] \right.$$
$$\left. \times \left[\frac{\bar{P}_{y,t}^{\mathcal{C}}(i)}{P_{y,T}^{\mathcal{C}}} \left(\frac{P_{T-1}^{\mathcal{C}}}{P_{t-1}^{\mathcal{C}}} \right)^{\iota_p^{\mathcal{C}}} \Pi^{(1-\iota_p^{\mathcal{C}})(T-t)} \right]^{-\theta} Y_T^{\mathcal{C}} \right\},$$

subject to aggregate demand (equation (2.7)), and technology (equation (2.3)).

2.4 Monetary Policy

The model is closed by assuming that the monetary authority sets the policy rate, R_t, according to:

$$\frac{R_t}{R} = \left(\frac{R_{t-1}}{R}\right)^{\rho_r} \left[\left(\frac{\Pi_t}{\Pi_t^*}\right)^{\phi_\pi} \left(\frac{Y_{z,t}}{Y_{z,t-1}}\xi_{z,t}^{\mathcal{C}}\right)^{\phi_{\Delta y}}\right]^{1-\rho_r} \xi_{m,t}, \tag{2.10}$$

where

$$Y_{z,t} \equiv (Y_{z,t}^{\mathcal{C}})^{\varpi_m^{\mathcal{C}}} (\xi_{z,t}^{\mathcal{P}} Y_{z,t}^{\mathcal{P}})^{1-\varpi_m^{\mathcal{C}}}, \tag{2.11}$$

$$\Pi_t \equiv (\Pi_t^{\mathcal{C}})^{\varpi_m^{\mathcal{C}}} (\Pi_t^{\mathcal{P}})^{1-\varpi_m^{\mathcal{C}}}, \tag{2.12}$$

and $\varpi_m^{\mathcal{C}}$ is the relative share of core's output and inflation on the response of monetary policy to economic conditions.

Finally, equilibrium is characterized by the optimality conditions of the household's utility- and firm's profit-maximization problems, and by market clearing in assets, goods, and labor markets. Figure 1 illustrates the various economic interactions across households and firms in the two regions.[7]

3 Empirical Analysis

We estimate the model with Bayesian methods, as described by An and Schorfheide (2007). Bayesian estimation combines prior information on the parameters and the model likelihood to form the posterior distribution. We construct the likelihood using a Kalman filter based on the state-space representation of the rational-expectations solution of the model. We consider two versions of the model. The first one does not allow for labor mobility (NLM), where we set $\gamma_l^{\mathcal{C}} = \gamma_l^{\mathcal{P}} = 1$ and $L_{\mathcal{P},t}^{\mathcal{C}} = L_{\mathcal{C},t}^{\mathcal{P}} = 0$. The second version allows for labor mobility (LM), where we set priors for $\gamma_l^{\mathcal{C}}$ and $\gamma_l^{\mathcal{P}}$ that allow for values below one. In the remainder of this section we describe the data and characterize the prior and posterior distributions.

[7] The online technical appendix includes all non-linear relations, steady state, and log-linearization of the model, as well as a full listing of parameters and variables.

3.1 Data

We use quarterly data for 10 euro area countries from 1998 to 2018. We split countries in two regions, which we label as core and periphery. Core includes Austria, Belgium, Finland, France, Germany, and the Netherlands, while periphery includes Ireland, Italy, Portugal, and Spain. We collect data from Eurostat on nominal GDP, population, per-capita real GDP growth, labor compensation, labor force, productivity (measured as GDP per-person employed), hours worked per person, debt-to-GDP ratio, and government expenses-to-GDP ratio. We obtain data for long- and short-term bond yields from Bloomberg, inflation rates from CEIC Data and the policy rate (Eonia) from the ECB. Labor force, labor compensation measures and inflation rates are seasonally adjusted before aggregation. To construct region-specific series, we weight countries by their nominal GDP. In Appendix A we provide details on how the data are constructed and the mapping to model state variables.

3.2 Priors

To parameterize the distributions of priors for each parameter, we assume Normal distributions for unconstrained parameters; Gamma distributions for parameters with support on the interval $[0, \infty]$; Beta distributions for parameters restricted to $[0, 1]$; and Inverse-Gamma distributions for the standard deviation of shock innovations.

Table 1 provides details and shows the prior types and percentiles for the main economic parameters in the two versions of the model.[8]

The first set of parameters are calibrated. More specifically, we set the population weight of core, $\varpi^{\mathcal{C}}$, to 0.61, which is consistent with our sample average. In the sample, core nominal GDP weight is about 0.68, which we use to calibrate the weight of core output and inflation in the policy rule, as well as the ratio of GDP needed to solve the steady state.[9] We further assume that the steady state ratio of hours allocated for the two regions are equal, $\tilde{L}^{\mathcal{P}} = \tilde{L}^{\mathcal{C}}$. The steady state ratio of government spending-to-GDP in core and periphery are set to their sample means, 0.49 and 0.45, respectively. Debt-to-GDP ratio in periphery is calibrated to 0.6, consistent with the euro area legal limits.[10] Finally, the elasticity across product varieties, θ, is set to 11, implying a common assumption of 10% price markup in steady state.

[8]In addition, the online Technical Appendix contains tables with the full listing of model parameters' priors. It also has a list of all model parameters with a brief description of each.

[9]See the online Technical Appendix for solution details.

[10]Many periphery and non-periphery countries currently have debt-to-GDP ratios well above this limit. This limit suggests that levels of debt-to-GDP ratio above the threshold should not be expected to be a steady state.

Turning to the priors, we set the prior mean of per-capita real GDP annual growth to 1.5%. The prior means for inflation and the real interest rates are set to 2%. We assume the steady-state risk premium has a prior mean of 0.5%. The parameters controlling the intertemporal elasticity of substitution for consumption, σ^j, in both regions have prior means of 2, and the habits parameters, h^j, have prior means of 0.5. The parameters controlling the elasticity of labor supply, ν^j, have prior means of 1.5.

The parameter controlling the sensitivity of the risk premium to periphery's debt, υ has prior mean of 0.3 with a standard deviation of 0.2, making it fairly uninformative. The home bias for goods, γ_y^j, has a prior mean of 0.75 and standard deviation of 0.05.

Price indexation parameters, ι_p^j, have prior means of 0.3 and the Calvo probability of not reoptimizing prices, α_p^j, have a prior mean of 0.7 in both regions. The interest rate smoothing parameter, ρ_r, has prior mean of 0.3, while the interest rate responses to inflation, ϕ_π, and output, ϕ_y, have prior means of 2 and 0.5, respectively.

In the NLM model, which assumes that there is no labor mobility, workers can only supply labor to their own region. This is equivalent to setting $\gamma_l^{\mathcal{C}}$ and $\gamma_l^{\mathcal{P}}$ to 1. In this case the elasticity of substitution between labor to the two regions is irrelevant. In the LM model, which allows for labor mobility, we set the prior mean for the home bias in labor supply, γ_l^j, to 0.75 and the standard deviation to 0.1. The elasticity of substitution of labor supply across the two regions, η_l^j, has prior mean of 2 and standard deviation of 0.1.

Finally, we assume shocks follow an AR(1), with auto-correlation coefficients, ρ_ξ^j with prior means of 0.7 and standard deviations of 0.2, for shock ξ in region j. The standard deviation of shock innovations, σ_ξ^j, have loose inverse-gamma priors with means set to 0.5 and standard deviation set to 2.

3.3 Estimation Results

We characterize the posterior distributions of the model parameters by first obtaining the posterior mode.[11] We then use a normal approximation around the mode as a jump distribution to form a sample of parameter-vector draws representative of the posterior distribution, according to the Metropolis random walk Markov Chain Monte Carlo (MCMC) simulation

[11] We get the mode by maximizing the posterior density function. This can be a challenging task with a high-dimensional problem like the one in this paper. In order to reduce the chances of extracting a local maximum, we perform 20 separate maximizations starting at different random initial guesses for the parameter vector. For each solution, we further test, at least five times, whether a new maximization, with a guess parameter vector in a small neighborhood of that solution, can achieve a higher level of the posterior density function.

method.[12] Table 1 reports the posterior marginal percentiles for each specification, which shows a few interesting patterns.

First, the last row of Table 1 shows the log-marginal likelihood for each model. The difference is quite substantial, with the NLM model achieving a much better fit than the LM model (-969.4 vs -993.3 log-points). This result suggests that the data strongly favors the model without labor mobility, corroborating the evidence that there is limited labor movement across countries within the euro area. Furthermore, the home bias in labor supply for the LM model has a posterior median of 0.98 for the core ($\gamma_l^{\mathcal{C}}$), and 0.99 for the periphery ($\gamma_l^{\mathcal{P}}$). These suggest that neither region is very likely to supply labor to the other region, even when we allow for labor mobility.

Second, the sensitivity of households' consumption to the real interest rate is higher in the periphery relative to the core in both models ($\sigma_{\mathcal{C}}$ has posterior median of 2.4 in both models, while $\sigma_{\mathcal{P}}$ has posterior median of 1.8 in the NLM specification and 1.7 in the LM specification). This implies that even common shocks to the entire region may lead to asymmetric regional effects due to how differently the two regions respond to changes in monetary policy.

Third, the sensitivity of the risk premium to debt (υ) is very low. One possible reason for the latter is that, in the data, the risk premium moves very little within the sample used to estimate parameters. The small sensitivity of the risk premium to debt implies that the results of Section 4 are not too strongly affected by the financial channel.

Fourth, we also note that the convexity of labor disutility is weaker in the periphery ($\nu_{\mathcal{P}} = 1.1 < 1.6 = \nu_{\mathcal{C}}$). When we allow for labor mobility the convexity increases a little($\nu_{\mathcal{P}} = 1.3$ and $\nu_{\mathcal{C}} = 1.9$), meaning that instead of increasing overall labor supply in response to shocks, households rather shift their labor supply composition.

Fifth, home bias in consumption is fairly strong in both regions (posterior medians of 0.84 and 0.85 for $\gamma_y^{\mathcal{C}}$ and $\gamma_y^{\mathcal{P}}$, respectively and in both models). This contributes to asymmetric effects of regional shocks.

[12] After obtaining four separate chains of 200,000 draws, we compute the covariance matrix (with a 25% burn-in) and generate four new chains of 200,000 draws. We repeat this step one more time with 200,000 for the NLM model; and two more times for the LM model with 500,000 and 2,000,000 draws per chain, respectively. Each time, we monitor the algorithm convergence, which is the reason why we need more draws in the LM specification. At this stage, we use these last four chains to extract the parameter posterior distribution properties.

4 Responses to Shocks and Labor Mobility

In this section we investigate how much labor mobility impacts the propagation of shocks through the euro area. We use the model specification with no labor mobility (NLM) as our baseline, since it is the best-fitting model. With this model we obtain impulse response functions (IRFs) of economic variables to various shocks. We then consider a counterfactual economy with the exact same parameterization as the reference model, except that we allow for labor mobility—henceforth referred as counterfactual labor mobility (CLM) model. More specifically, in the CLM model we set preference parameters such that labor supply elasticity η_l^j equals 2 and labor supply home bias γ_l^j equals 0.75 (for $j = \{\mathcal{C}, \mathcal{P}\}$). All other parameters are equal to the NLM model. The comparison between the two sets of responses allows us to isolate the effects of labor mobility and assess whether labor mobility impacts macroeconomic dynamics.

The model includes a set of eight common and region-specific shocks. Specifically, we consider shocks to the euro area's monetary policy and to its total factor productivity, as well as region-specific shocks to the discount rate, total factor productivity, labor disutility, government spending, price markups, and a shock to periphery's risk premium. For brevity, in the main text we report the responses to the common monetary and productivity shocks, and the responses to shocks to each region's labor supply and price markup. These shocks provide good examples of some of the main points of the paper. In the next section we focus on the interaction between financial frictions, the risk premium shock and labor mobility. Other shocks and IRFs are reported in Appendix B.[13] Table 2 gives a quick summary of qualitative results.

Aggregate shocks

Figure 2 shows the responses to a monetary policy shock. This is an aggregate shock with the same direct impact in both regions. Comparing the median responses with and without labor mobility we find that changing the degree of labor mobility has no impact on aggregate inflation (π) or aggregate output (Y_z)—the solid blue (NLM) and the dashed red (CLM) lines are on top of each other for those two variables. Despite being an aggregate shock, the impact on the two regions in the case without labor mobility is very different in terms of output, with a much larger drop in output in the periphery. This is the consequence of different intertemporal elasticities of substitution ($\sigma^{\mathcal{C}} > \sigma^{\mathcal{P}}$), implying that the periphery

[13]The online technical appendix provides additional robustness cases of responses to shocks under alternative parameters.

is more sensitive to real interest rate changes. If labor mobility is allowed across regions, then households from core reduce their supply of labor to the periphery (due to weaker relative wages there), further shifting relative prices. This leads to a smaller contraction in core output and an even larger contraction in the periphery. Consumption in the periphery falls slightly less with labor mobility as households benefit from higher wages in the core (from their cross-region supply).

We also considered the case in which the two regions were symmetric in both supply and demand—including preferences, technology, and nominal rigidities. In this case, the monetary policy shock would have a more similar economic impact in the two regions.[14] In that case, allowing for labor mobility would have mitigated most of the remaining different outcomes in response to the monetary policy shock.

In sum, an aggregate monetary policy shock leads to asymmetric economic outcomes in the two regions due to heterogeneous preferences, and those outcomes are pushed further apart in the presence of labor mobility. This is an important finding in the discussion of optimal currency areas. In the traditional OCA theory described in Mundell (1961), the presence of labor mobility was considered crucial for a successful currency union. What we find is that labor mobility does not have a meaningful impact on aggregate outcomes for the currency area as a whole, and it can further augment disparities in the responses of the two regions to monetary policy shocks, depending on the heterogeneity of preferences and technology.

Next, we consider another shock that impacts both regions equally, namely a core productivity shock. The economic responses to this shock are shown in Figure 3. In this case the peak impact of the responses of aggregate inflation and output are the same with or without labor mobility. However, the persistence of aggregate output changes. Without labor mobility it takes more than 24 quarters to stabilize output, while with labor mobility it takes only 8 quarters to stabilize output back to trend. Labor mobility both reduces the impact of the shock on the aggregate economy (by a small degree) and also mitigates the degree of asymmetry in the economic outcomes of the two regions, promoting convergence of outcomes in the two regions with respect to consumption, output and inflation.[15]

[14] In this scenario, we set $\sigma^{\mathcal{C}} = \sigma^{\mathcal{P}} = 2.1$, $h^{\mathcal{C}} = h^{\mathcal{P}} = 0.76$, $\nu^{\mathcal{C}} = \nu^{\mathcal{P}} = 1.35$, $\eta_y^{\mathcal{C}} = \eta_y^{\mathcal{P}} = 0.73$, $\gamma_y^{\mathcal{C}} = \gamma_y^{\mathcal{P}} = 0.84$, $\iota_p^{\mathcal{C}} = \iota_p^{\mathcal{P}} = 0.04$, and $\alpha_p^{\mathcal{C}} = \alpha_p^{\mathcal{P}} = 0.75$ (all roughly at the midpoint of the two regions corresponding posterior medians).

[15] If preferences and technologies were symmetric, as discussed for the monetary policy shock case, the level of aggregate output would stabilize in about 11 quarters without labor mobility and still 8 quarters with labor mobility. Additionally, the responses would be slightly more asymmetric without mobility, and more similar across the two regions with mobility. Heterogeneous preferences thus reduce slightly the ability of labor mobility to mitigate asymmetric responses to productivity shocks.

Therefore, for the two aggregate shocks in the model, labor mobility has a somewhat limited impact on aggregate outcomes but influences how similar or dissimilar the regional outcomes are in response to those shocks.

Region-specific shocks

Now we turn to the responses to regional shocks, which are inherently asymmetric shocks. A natural starting point is to consider shocks to labor supply. First, we consider a negative shock to the labor supply in the periphery, shown in Figure 4. In the absence of labor mobility this shock increases the marginal cost of periphery's goods leading to higher prices in those goods and a contraction in consumption in both regions, but especially in the periphery due to home bias in consumption. Reduced demand leads to lower output in the periphery, but because relative prices of core goods fell, there is a small boost to core output. In aggregate terms, output falls and inflation increases. Of notice, real wages increase in the periphery and fall in the core. Therefore, in the case with labor mobility, labor supply to the core by periphery's households falls by more than the labor they supply to their own region. Furthermore, core households increase the labor they supply to the periphery to chase higher wages. The lower supply of labor to core firms leads to higher wages and, thus, labor supply of core households to their region's firms increases a little more.

These labor shifts generate higher wages in both regions, but the increase in relative wages in the periphery (vis-a-vis core) is halved, and thus the relative price changes are much more subdued. This implies that output now falls in both regions, and the drop in consumption is relatively more similar across regions. This entails a smaller fall in consumption in the periphery and a much larger drop in consumption in the core. With relative wages changing less, inflation in core increases by relatively more in the presence of labor mobility. In the aggregate, however, euro area's output falls more while inflation increases more. This is a clear case in which labor mobility mitigates asymmetric responses to a shock in terms of consumption, output and inflation, but that comes at the cost of exporting more inflation to the core, and increasing the tradeoff between euro area's inflation and output stabilization.

In response to a shock to core's labor supply (shown in Appendix B), labor mobility also mitigates the asymmetric responses of consumption, output and inflation across regions, but in that case it also mitigates the aggregate impact on both output and inflation, so that the tradeoff between inflation and output stabilization is less severe.

Turning to price markup shocks, in the typical one region canonical New-Keynesian model, shocks to price markups are usually identical to first order to labor supply shocks and difficult to distinguish empirically in terms of the impact on output, consumption and inflation. In a two-region model without labor mobility that is also the case. However, in the presence of labor mobility that is no longer the case. Figure 5 shows the responses to a periphery price markup shock. In the absence of labor mobility responses are qualitatively similar to the labor supply shock already discussed. The key difference is that wages fall in both regions and, in particular, fall by relatively more in the periphery. This is critical when we consider the case with labor mobility. Now relative wages fall in the periphery, and thus there is an incentive for labor supply to shift from periphery to core, which is the opposite effect of the labor supply shock. As a result, relative prices move further from steady state, and thus, labor mobility yields further divergence of outcomes in core and periphery in terms of output, consumption, and inflation. Interestingly, the impact of labor mobility on area-wide inflation and output are negligible.

The role of labor mobility in the case of a shock to core price markups is similar, taking outcomes for output and inflation further apart across regions, and negligible aggregate implications. However, in this case consumption responds more similarly across regions. In the absence of labor mobility consumption in the periphery falls by less than in the core. With labor mobility, income in the periphery falls more in response to the shock, and consumption follows.

The set of results above shows that depending on the nature of shocks hitting the economy, labor mobility can exacerbate or mitigate the aggregate and relative effects of different shocks. This finding comes in contrast with the usual argument that labor mobility would mitigate or even speed up the euro area recovery from crises and do it in a more cohesive fashion. Our results show that this does not seem to hold necessarily, and that, if anything, labor mobility can exacerbate the responses of aggregate and regional variables. Importantly, there are cases in which labor mobility improves outcomes for some economic variable, but worsens outcomes for other variables.

5 Financial Frictions and Labor Mobility

We now turn to the interaction between financial frictions and labor mobility. In particular, we focus on the effects of a shock to risk premium in the periphery. Figure 6 shows the responses to the periphery's risk premium shock. In the absence of labor mobility, an exogenous increase in the periphery's risk premium leads to a sharp contraction in consumption and a decline in inflation in that region. This shifts relative prices leading to an increase in demand from core. On balance output in the periphery increases in this case. Essentially, the change to relative prices allow exports to mitigate the effects of the shock. Nevertheless, real wages fall sharply in the periphery, and increase moderately in the core.

It is then not surprising that if labor is allowed to move, households shift labor from the periphery to core, leading to a fall in real wages in both regions, as wages converge to some extent. This, in turn, implies higher real wages in the periphery, so that the drop in consumption is more short-lived, while core wages are weaker. The shock now implies area-wide weaker demand with lower inflation in both regions, prompting monetary policy to respond more aggressively by lowering interest rates twice as much. This allows output in the area to increase as much as in the absence of labor mobility, but comes with greater disparity in output. While core output increases, it now falls in the periphery, reflecting weaker demand in that region and the shift in labor away from the region makes it more expensive to produce. This means that labor mobility serves as an escape valve for the periphery to mitigate the asymmetric shock, but comes in the form of exodus of labor supply that leads a more asymmetric response of output in the two regions.

Overall, in response to a risk premium shock to the periphery, labor mobility replaces goods mobility in providing an mechanism to mitigate the needed contraction in consumption in that area. It also increases the pass-through via prices from the periphery to the core, yielding weaker inflation in the aggregate and stronger monetary policy action, which is able to stabilize output at similar levels to the no labor mobility case, while allowing inflation to be more negative in the area.

One key component of the response of the economy in the absence of labor mobility is the increase of output in the face of a contractionary shock, similar to a risk premium or sudden stop shock in an small open economy. Chari, Kehoe and McGrattan (2005) discuss that, in its simplest form, a small open economy with collateral constraints facing a sudden stop of capital inflows is equivalent to a positive government spending shock. Cúrdia (2007) shows that whether output increases or not in response to a risk premium shock depends importantly on the elasticity of demand for exports. We thus consider the case with alternative elasticity of goods demand across the two regions to evaluate how sensitive the response to the risk premium shock is in the case with and without labor mobility.[16]

We find that when the elasticity of substitution of goods across the two regions, η_y, increases from the posterior distribution (with medians of 0.7 and 0.76 for the two regions) to a fixed level of 0.85, the increase in output in the absence of labor mobility is stronger in the periphery, while the output drop with labor mobility is only slightly smaller relative to our baseline findings. It is still the case that labor mobility makes the asymmetric response

[16] Figures with the responses to each shock, in comparison to the baseline, are shown in the online technical appendix.

of the two regions worse; and that aggregate inflation falls twice as much with labor mobility, relative to the absence of labor mobility. So the interaction of financial frictions with labor mobility is quantitatively but not qualitatively impacted by the elasticity of goods demand.

Another important consideration with respect to financial frictions is the degree of endogeneity. In other words, aside from an exogenous periphery's risk premium shock, how much do financial frictions impact responses when the shocks originate in other parts of the economy? The posterior distribution of the response of the risk premium to the debt to output ratio is very small, implying that this channel is not a big part of the responses of the euro area to various other shocks. We thus consider the alternative case in which the elasticity of the risk premium to debt is higher.[17]

The response to a monetary policy shock, shown in Figure 7, is quite impacted by the degree of endogeneity of the risk premium. In the absence of labor mobility, there are significantly different responses of output and consumption in the two regions, because the periphery borrows to smooth the contractionary shock, but that hikes the risk premium more substantially and consumption in the periphery takes a significant tumble. This implies an increase in labor supply in the periphery that lowers wages, and thus relative prices in the region, bringing demand from the core to mitigate the situation. On balance consumption from core increases (after an initial drop), output in the core falls, and output in the periphery increases. In aggregate terms, output falls a little more than in the baseline simulations, but inflation falls by nearly 0.8 percentage points, with a much larger drop in inflation in the periphery relative to core.

With greater labor mobility, consumption and output in the two regions fall by more similar amounts, relative prices barely respond, and relative wages fall by similar amounts in the two regions. Aggregate inflation and output both fall by less. This is close to the perfect example of the traditional OCA theory in which labor mobility not only mitigates the effects of aggregate shocks, but also also brings the responses of the two regions closer together. A similar pattern takes place in the case of an aggregate productivity shock.

The picture is more complex when it comes to regional asymmetric shocks. For example, in response to a relative increase in periphery's productivity, labor mobility with endogenous risk premium would mitigate the impact on aggregate inflation, but augment the impact on aggregate output. In response to a core labor supply shock, labor mobility with endogenous risk premium, mitigates the impact on output but exacerbate the impact on inflation. And the opposite holds in the case of a labor supply shock originating in the periphery.

[17] To be precise we show results for the case in which υ is set to 0.1, instead of being drawn from the posterior distribution, which is concentrated in the neighborhood of 0.0003.

These patters are not too surprising. With endogenous risk premium, shocks that lead to increased debt in the periphery generate a contractionary effect on demand in that region and pressure households to work more hours. This is the augmentation effect from the endogenous risk premium that labor market flexibility can mitigate to some extent.

This is particularly salient in the case that the risk premium has a robust endogenous component and is subject to an exogenous shock, shown in Figure 8. In the absence of labor mobility, the contraction in periphery's consumption is nearly four times as severe as in the baseline case, leading the labor supply in periphery to increase more substantially, and lead to a drop in real wages that is twice as large. Essentially in the absence of labor mobility the asymmetric responses are even more asymmetric, because the risk premium acts increasingly as a wedge. Aggregate inflation falls by more, but aggregate output is similar. With labor mobility, the relative prices and wages stabilize nearly completely, yielding a mild contraction in consumption in the two regions. Inflation changes little in either region and in aggregate, while aggregate output is comparable to the baseline. In this case, labor supply shifts from the periphery to core, mostly rebalancing real wages and preventing large swings in relative prices, and thus, stabilizing the economy.

Therefore, risk premium is a wedge between the two regions with demand and supply effects. If it is mostly exogenous, there is not much that labor mobility can do to eliminate that wedge. It can mitigate its effects on consumption by partially exporting the problem, and reinforce the income of periphery's households, but it cannot eliminate the problem. If risk premium is also endogenous, then labor mobility can go further, and give enough incentives for households to mitigate the financial frictions wedge, not just its effects. Indeed debt increases in the absence of labor mobility, but falls when labor is mobile. Interestingly, because of the strong incentives, in equilibrium, labor actually shifts less from the periphery to core when risk premium is endogenous, compared to the exogenous case. Thus, the exodus from periphery is smaller as real wages endogenously equate.

6 Robustness

There are many features of the model that can, in principle, affect the results. We used the estimation to anchor the results to the data. There are however two parameters in the labor mobility counterfactual that are not estimated: the elasticity of labor supply across the two regions, η_l, and the degree of home bias in labor supply, γ_l. The higher the home bias and the lower the elasticity, the closer we are in theory to the no labor mobility case. The estimation of the model specification with labor mobility did not shed much light on elasticity—with the marginal posterior nearly identical to the prior—but pushed the degree of home bias to very high levels. Considering a labor mobility scenario with such high levels of home bias would not be very informative about the implications of labor mobility in the model, hence we considered a more stylized degree of home bias with $\gamma_l = 0.75$ and elasticity of $\eta_l = 2$.

To check whether our results are impacted by these choices, we consider alternative elasticities of $\eta_l = 0.5$ and $\eta_l = 5$. We also consider alternative degrees of home bias with $\gamma_l = 0.5$ and $\gamma_l = 0.95$.[18] The results show that the stronger the labor mobility is, with low home bias and higher elasticity of substitution, the stronger are the effects of labor mobility. There are no noticeable changes for aggregate monetary and productivity shocks. In the case of a labor supply shock in the core, the two regions responses are more aligned, the higher the elasticity and the lower the home bias, and aggregate effects on inflation and output are more mitigated by labor mobility. In the case of a labor supply shock to the periphery, the responses of the two regions are again more aligned with labor mobility, but the impact on aggregate inflation and output is augmented with higher elasticity of supply and lower home bias. Similarly, the impact of labor mobility in the response to a risk premium shock is also augmented with the higher elasticity and lower home bias.

In sum, higher elasticity of substitution of labor supply and lower home bias, augments the effects of labor mobility on economic dynamics, but qualitatively is the same as in our baseline simulations.

We also considered alternative elasticities of substitution and home bias in goods. Yet again all qualitative results hold, regarding the impact of labor mobility on economic dynamics. Of note, in the case of price markup shocks in the core and periphery, higher elasticity of substitution in goods demand yields little change relative to baseline responses in the absence of labor mobility. However, when we allow for labor mobility, the output responses are noticeably further apart in the two regions, even if consumption and inflation responses are fairly similar to baseline outcomes. So, quantitatively, the impact of labor mobility in response to price markup shocks is stronger, but the qualitative result is still the same—that labor mobility augments disparity in regional output and inflation responses, but no aggregate impact. Simulations with low home bias in goods demand, γ_y yields no substantive changes to our results.

Finally, considering symmetric preferences, technology, and nominal rigidities across regions, but preserving the existence of home bias in goods demand, and labor supply, yields

[18] Figures A6 to A13 in Appendix B report these comparisons.

no changes to our results qualitatively, with only small quantitative impact.[19]

Overall, our robustness analysis finds that the main factor that substantially affects the impact of labor mobility on economic dynamics is the sensitivity of the periphery's risk premium to its indebtedness, discussed in the previous section. The labor mobility specific parameters impact the results quantitatively in a predictable manner: the further we move towards free movement of labor, with less home bias and more elastic response to relative wages the more the impact of labor mobility is noticeable.

7 Labor mobility and the 2008 financial crisis

So far we discussed the impact of labor mobility on economic dynamics via responses to shocks. To give an idea of how it all comes together, in this section we apply our counterfactual analysis to an historic event to see how much it really matters. Namely, we analyze the impact that labor mobility could have had in the aftermath of the financial crisis of 2008. In order to achieve that we compare the relative response of the economy with and without labor mobility relative to the last quarter of 2007, just before the crisis unfolded.

We extract the state of the economy, including the external shocks to the economy, using the Durbin and Koopman (2002) simulation smoother. With that step we get the actual path of all the state variables under no labor mobility as in our baseline estimated model. Then we use the extracted series of shocks to simulate the economy in the counterfactual scenario with greater labor mobility. For this counterfactual, we set all model parameters in the NLM case, except for the labor mobility ones as we described in Section 4.

The two model specifications have possibly different steady states, so comparing the level of the paths or even log-deviations from steady state can be misleading. Moreover, if we want to isolate the effects in the aftermath of the 2008 crisis, we need to use an anchor that accounts for patterns exhibited prior to that crisis. As such we look at relative responses of the economy in the two cases, relative to the last quarter of 2007. Therefore, all series are in log-deviations from their levels in 2007q4. This way we are looking at approximately percentage deviations from pre-crisis levels.

Figures 9 through 11 show the median paths for selected macroeconomic variables in the baseline and the counterfactual economies. The top panels report euro-area's variables, while the middle and bottom panels report region-specific ones. The set of pictures show that aggregate inflation for the entire euro area would have fallen relative to pre-crisis more

[19]For brevity, impulse response functions reporting findings for alternative elasticities of substitution and home bias in goods, as well as symmetric parameterizations are shown in the online technical appendix.

substantially with greater labor mobility. In particular, in 2014-2017 aggregate inflation would have fallen more than half a percentage point in addition to how much it fell in the data. The aggregate output level would also have been further reduced relative to pre-crisis level—between 0.2 and 1.0 percentage point from 2008 through 2017.

We also find that with greater labor mobility both regions would have experienced lower levels of output. Core would also have experienced more depressed inflation, while the periphery would have had less depressed inflation. The level of consumption in the core would have been about 0.6 to 0.9 percentage point higher from 2012 onward, while the periphery's consumption level would have fallen 0.2 to 0.5 percentage point further (a small change relative to the deeply reduced levels of consumption in that region).

8 Conclusion

We apply theoretical and empirical DSGE analysis to discuss the decades-old question of whether or how much labor-mobility matters in a monetary union, for the specific application of the euro area. We find that empirically, there is little evidence of labor mobility in the euro area, with the data strongly preferring a model specification without labor mobility. For the case in which we allow for labor mobility, the data favors parameterization that push towards the absence of labor mobility, with a very high degree of home bias in labor supply.

Traditional OCA theory suggested that labor-mobility should smooth business cycles and outcomes in a monetary union, as labor mobility would equalize conditions in the different regions of the union, bringing them closer together, even for asymmetric shocks. In that case, monetary policy could more efficiently stabilize aggregate outcomes. Our findings suggest that this is not always the case. We show a few cases in which labor mobility impacts regional outcomes without noticeable aggregate outcomes. We also find instances in which labor mobility brings the two regions closer together in response to shocks, but others cases in which it pushes them further apart, depending on how the shock changes the incentives to provide work across regions. Finally, even in the case in which labor mobility brings the two regions closer together, it may mitigate or exacerbate aggregate outcomes and the tradeoffs that monetary policy in the union has to resolve.

Interestingly, if the periphery's risk premium is sensitive to that regions' indebtedness, then the results become substantially closer to the more traditional OCA view, in which labor mobility plays an important role in stabilizing the economy. This happens because labor mobility offers a way to reduce indebtedness in the periphery by providing labor to the core, and bring more income to the periphery, thus reducing the financial wedge between the two regions.

An application to the post-2008 period confirms that labor mobility does not necessarily imply smoother or closer business cycles and macroeconomic variables dynamics. We find that allowing for labor mobility would have pushed aggregate output and inflation lower. In terms of regional effects, would push output down in both regions, but it would push inflation and consumption in the two regions differently, relative to the baseline case with no labor mobility. This suggests that labor mobility *per se* would not have been necessarily the solution to the financial crisis.

References

An, Sungbae, and Frank Schorfheide. 2007. "Bayesian Analysis of DSGE Models." *Econometric Reviews*, 26: 113–172.

Basso, Gaetano, Francesco D'Amuri, and Giovanni Peri. 2019. "Immigrants, Labor Market Dynamics and Adjustment to Shocks in the Euro Area." *IMF Economic Review*, , (67): 528–572.

Blanchard, Olivier Jean, and Lawrence F. Katz. 1992. "Regional Evolutions." *Brookings Papers on Economic Activity*, 23(1): 1–76.

Blanchflower, David G., and Andrew J. Oswald. 2013. "Does High Home-Ownership Impair the Labor Market?" National Bureau of Economic Research, Inc NBER Working Papers 19079.

Calvo, Guillermo. 1983. "Staggered Prices in a Utility Maximizing Framework." *Journal of Monetary Economics*, 12: 383–398.

Chari, V. V., Patrick Kehoe, and R. McGrattan, Ellen. 2005. "Sudden Stops and Output Drops." *American Economic Review*, 95(2): 381–387.

Cúrdia, Vasco. 2007. "Monetary Policy under Sudden Stops." *Federal Reserve Bank of New York Staff Report No. 278.*

Cúrdia, Vasco, and Michael Woodford. 2011. "The central-bank balance sheet as an instrument of monetarypolicy." *Journal of Monetary Economics*, 58(1): 54 – 79. Carnegie-Rochester Conference Series on Public Policy: The Future of Central Banking April 16-17, 2010.

Dao, Mai, Davide Furceri, and Prakash Loungani. 2017. "Regional Labor Market Adjustment in the United States: Trend and Cycle." *The Review of Economics and Statistics*, 99(2): 243–257.

Druant, Martine, Juuso Vanhala, Michalis Ktoris, Valerie Jarvis, Muriel Bouchet, Katarzyna Budnik, Claire Childs, Nicole Kuttner, Magdalena Spooner, Jan De Mulder, and Boele and Bonthuis. 2012. "Euro area labour markets and the crisis." European Central Bank Occasional Paper Series 138.

Durbin, J., and S. J. Koopman. 2002. "A Simple and Efficient Simulation Smoother for State Space Time Series Analysis." *Biometrika*, 89(3): 603–615.

Farhi, Emmanuel, and Ivan Werning. 2014. "Labor Mobility Within Currency Unions." Revise and resubmit, Journal of Monetary Economics.

House, Christopher L, Christian Proebsting, and Linda L Tesar. 2018. "Quantifying the Benefits of Labor Mobility in a Currency Union." National Bureau of Economic Research Working Paper 25347.

IMF. 2012. "Euro Area Policies 2012 Article IV Consultation." International Monetary Fund Country Report 12/181.

IMF. 2016. *The IMF and the Crises in Greece, Ireland, and Portugal.* USA:International Monetary Fund.

Jauer, Julia, Thomas Liebig, John P. Martin, and Patrick A. Puhani. 2019. "Migration as an adjustment mechanism in the crisis? A comparison of Europe and the United States 2006–2016." *Journal of Population Economics*, 32(1): pp. 1–22.

Kahanec, Martin. 2013. "Labor mobility in an enlarged European Union." In *International Handbook on the Economics of Migration. Chapters*, , ed. Amelie F. Constant and Klaus F. Zimmermann, Chapter 7, 137–152. Edward Elgar Publishing.

Kenen, Peter B. 1969. "The Theory of Optimum Currency Areas: An Eclectic View." *Monetary Problems of the International Economy*, , ed. Robert Mundell and Alexander Swoboda, 41–60. Chicago: University of Chicago Press.

Lane, Philip R. 2012. "The European Sovereign Debt Crisis." *Journal of Economic Perspectives*, 26(3): 49–68.

McKinnon, Ronald I. 1963. "Optimum Currency Areas." *The American Economic Review*, 53(4): 717–725.

Mundell, Robert A. 1961. "A Theory of Optimum Currency Areas." *The American Economic Review*, 51(4): 657–665.

OECD. 2021. *OECD Economic Surveys: Euro Area 2021.*

Shambaugh, Jay. 2012. "The Euro's Three Crises." *Brookings Papers on Economic Activity*, 43(1 (Spring)): 157–231.

	Prior				NLM Posterior			LM Posterior		
	Dist	5%	Median	95%	5%	Median	95%	5%	Median	95%
$\varpi^{\mathcal{C}}$	C	—	0.610	—	—	—	—	—	—	—
$\varpi_m^{\mathcal{C}}$	C	—	0.680	—	—	—	—	—	—	—
$\varrho_y^{\mathcal{P}}$	C	—	0.500	—	—	—	—	—	—	—
$\varrho_{\tilde{L}}^{\mathcal{P}}$	C	—	1.000	—	—	—	—	—	—	—
$\varrho_{G,Y}^{\mathcal{C}}$	C	—	0.490	—	—	—	—	—	—	—
$\varrho_{G,Y}^{\mathcal{P}}$	C	—	0.450	—	—	—	—	—	—	—
$b_y^{\mathcal{P}}$	C	—	0.600	—	—	—	—	—	—	—
θ	C	—	11.000	—	—	—	—	—	—	—
400γ	G	0.783	1.445	2.406	0.825	1.197	1.618	0.787	1.170	1.590
$400(\Pi - 1)$	G	1.254	1.958	2.887	1.322	2.048	2.965	1.349	2.067	2.978
$400(\frac{R}{\Pi} - 1)$	G	1.254	1.958	2.887	0.660	0.991	1.394	0.704	1.046	1.471
400Υ	G	0.348	0.493	0.675	0.350	0.486	0.646	0.350	0.490	0.657
$\sigma^{\mathcal{C}}$	G	1.254	1.958	2.887	1.638	2.401	3.340	1.627	2.374	3.316
$\sigma^{\mathcal{P}}$	G	1.254	1.958	2.887	1.147	1.796	2.651	1.064	1.714	2.603
$h^{\mathcal{C}}$	B	0.335	0.500	0.665	0.614	0.722	0.818	0.600	0.720	0.823
$h^{\mathcal{P}}$	B	0.335	0.500	0.665	0.713	0.796	0.860	0.692	0.785	0.855
υ	G	0.061	0.257	0.686	0.000	0.000	0.001	0.000	0.002	0.006
$\gamma_l^{\mathcal{C}}$	B	0.570	0.760	0.897	—	1.000	—	0.949	0.975	0.990
$\gamma_l^{\mathcal{P}}$	B	0.570	0.760	0.897	—	1.000	—	0.973	0.986	0.994
$\nu^{\mathcal{C}}$	G	0.783	1.445	2.406	1.000	1.588	2.324	1.207	1.891	2.758
$\nu^{\mathcal{P}}$	G	0.783	1.445	2.406	0.766	1.108	1.529	0.851	1.258	1.776
$\eta_l^{\mathcal{C}}$	G	1.838	1.998	2.167	—	—	—	1.825	1.986	2.153
$\eta_l^{\mathcal{P}}$	G	1.838	1.998	2.167	—	—	—	1.802	1.960	2.128
$\eta_y^{\mathcal{C}}$	G	0.620	0.699	0.784	0.627	0.702	0.785	0.617	0.693	0.775
$\eta_y^{\mathcal{P}}$	G	0.620	0.699	0.784	0.666	0.760	0.865	0.657	0.748	0.851
$\gamma_y^{\mathcal{C}}$	B	0.664	0.752	0.828	0.754	0.835	0.895	0.753	0.831	0.890
$\gamma_y^{\mathcal{P}}$	B	0.664	0.752	0.828	0.791	0.854	0.900	0.783	0.845	0.894
$\iota_p^{\mathcal{C}}$	B	0.035	0.267	0.679	0.004	0.031	0.110	0.004	0.035	0.125
$\iota_p^{\mathcal{P}}$	B	0.035	0.267	0.679	0.005	0.046	0.163	0.006	0.054	0.184
$\alpha_p^{\mathcal{C}}$	B	0.524	0.707	0.853	0.646	0.726	0.808	0.641	0.722	0.801
$\alpha_p^{\mathcal{P}}$	B	0.524	0.707	0.853	0.699	0.782	0.858	0.729	0.817	0.885
ρ_r	B	0.035	0.267	0.679	0.627	0.729	0.797	0.679	0.758	0.816
ϕ_π	G	1.254	1.958	2.887	1.088	1.181	1.353	1.154	1.296	1.547
ϕ_y	G	0.222	0.474	0.868	0.096	0.197	0.351	0.146	0.282	0.470
Log-ML						-969.3904			-993.3396	

Notes: Prior distributions are Calibrated (C), Normal (N), Gamma (G), Beta (B), and Inverse-Gamma (IG). Bottom line shows the log-marginal likelihood of each model.

Table 1: Estimation results.

Shocks:	Impact on aggregate vars	Impact on disparities
Monetary Policy, ξ_m	none	augments (a little)
Agg Productivity, ξ_z	negligible: $\downarrow Y_z$	mitigates: Y_z, C_z augments: π
Periphery relative productivity, $\xi_z^{\mathcal{P}}$	small: $\uparrow \pi$, $\downarrow Y_z$	mitigates: π, Y_z, C_z
Core Demand, $\xi_\beta^{\mathcal{C}}$	Yes, $\downarrow \pi$, $\downarrow Y_z$	mitigates: π augments: Y_z, C_z (a little)
Periphery Demand, $\xi_\beta^{\mathcal{P}}$	Yes, $\uparrow \pi$, $\downarrow Y_z$	augments: π, Y_z, C_z
Core Govt Spending, $\xi_g^{\mathcal{C}}$	none	augments: Y_z, C_z
Periphery Govt Spending, $\xi_g^{\mathcal{P}}$	none	mitigates: C_z (a little)
Core labor supply, $\xi_l^{\mathcal{C}}$	$\downarrow \pi$, $\uparrow Y_z$	mitigates: π, Y_z
Periphery labor supply, $\xi_l^{\mathcal{P}}$	$\uparrow \pi$, $\downarrow Y_z$	mitigates: π, Y_z, C_z
Core Price Markup, $\xi_p^{\mathcal{C}}$	negligible	mitigates: C_z augments: π, Y_z
Periphery Price Markup, $\xi_p^{\mathcal{P}}$	negligible	augments: π, Y_z
Periphery Risk Premium, ξ_B	Yes, $\downarrow \pi$, $\approx Y_z$	mitigates: π augments: Y_z, C_z (short run)

Table 2: Summary of qualitative impact of labor mobility by shock type.

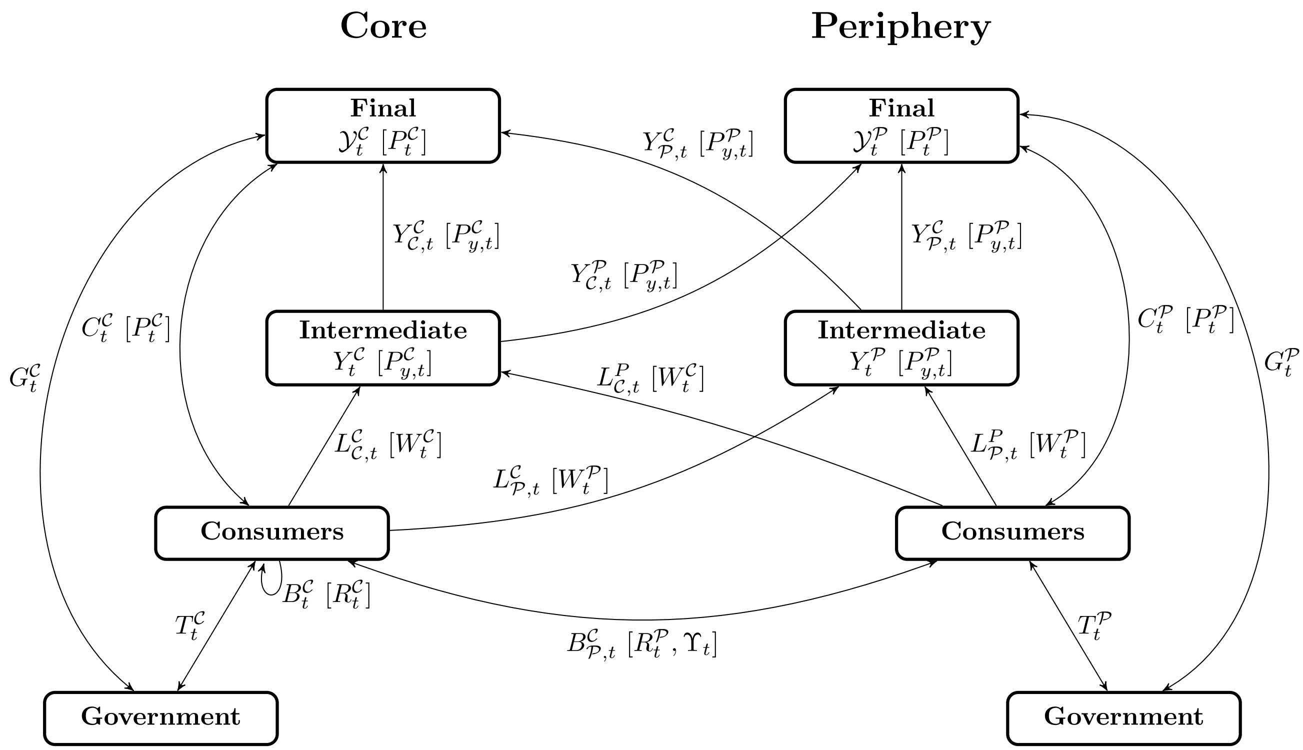

Figure 1: Model sketch and interactions across different types of agents.

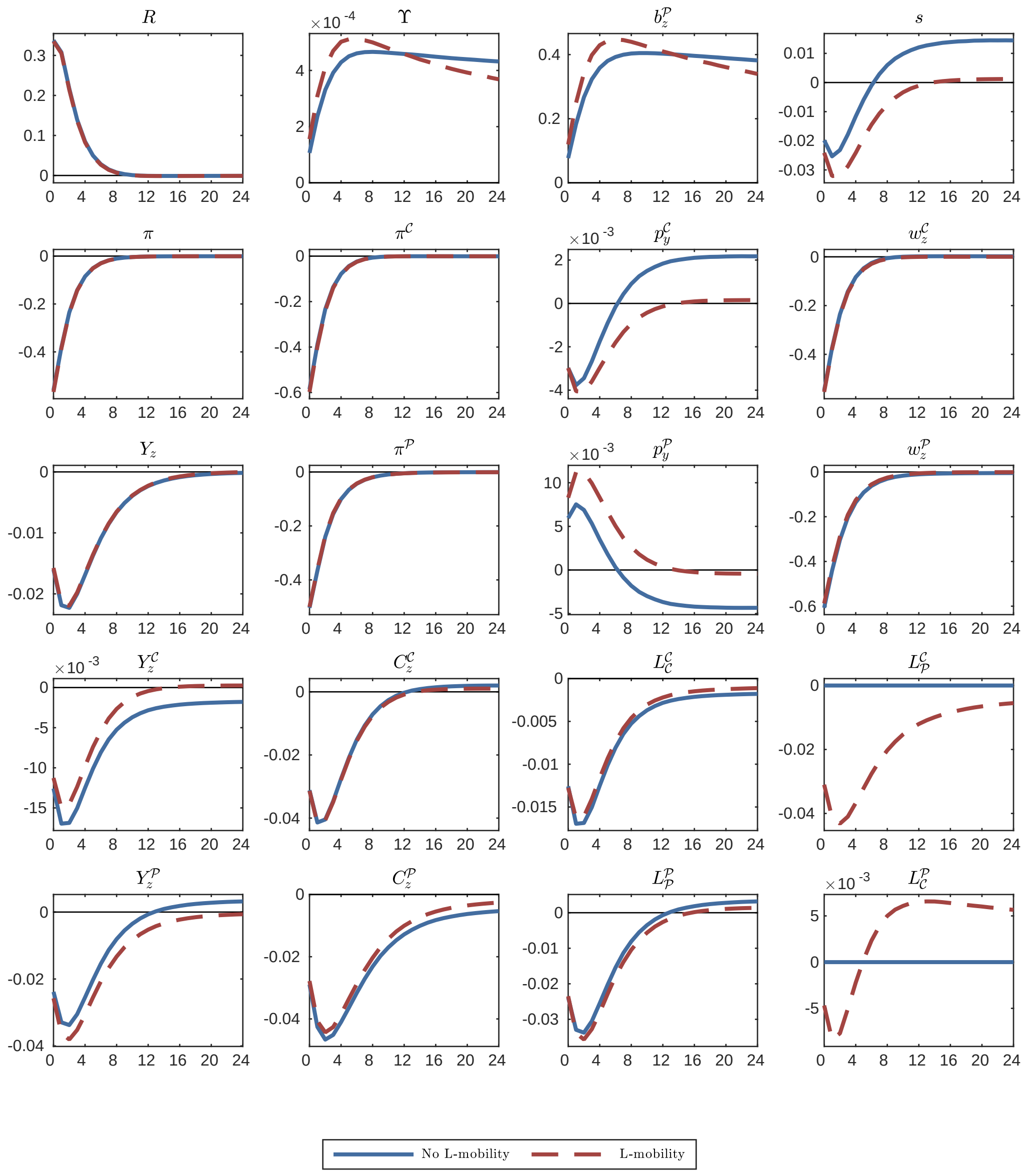

Figure 2: Responses to one standard deviation monetary policy shock. Blue solid lines show median responses for model with no labor mobility; red dashed lines show median responses for counterfactual model with labor mobility.

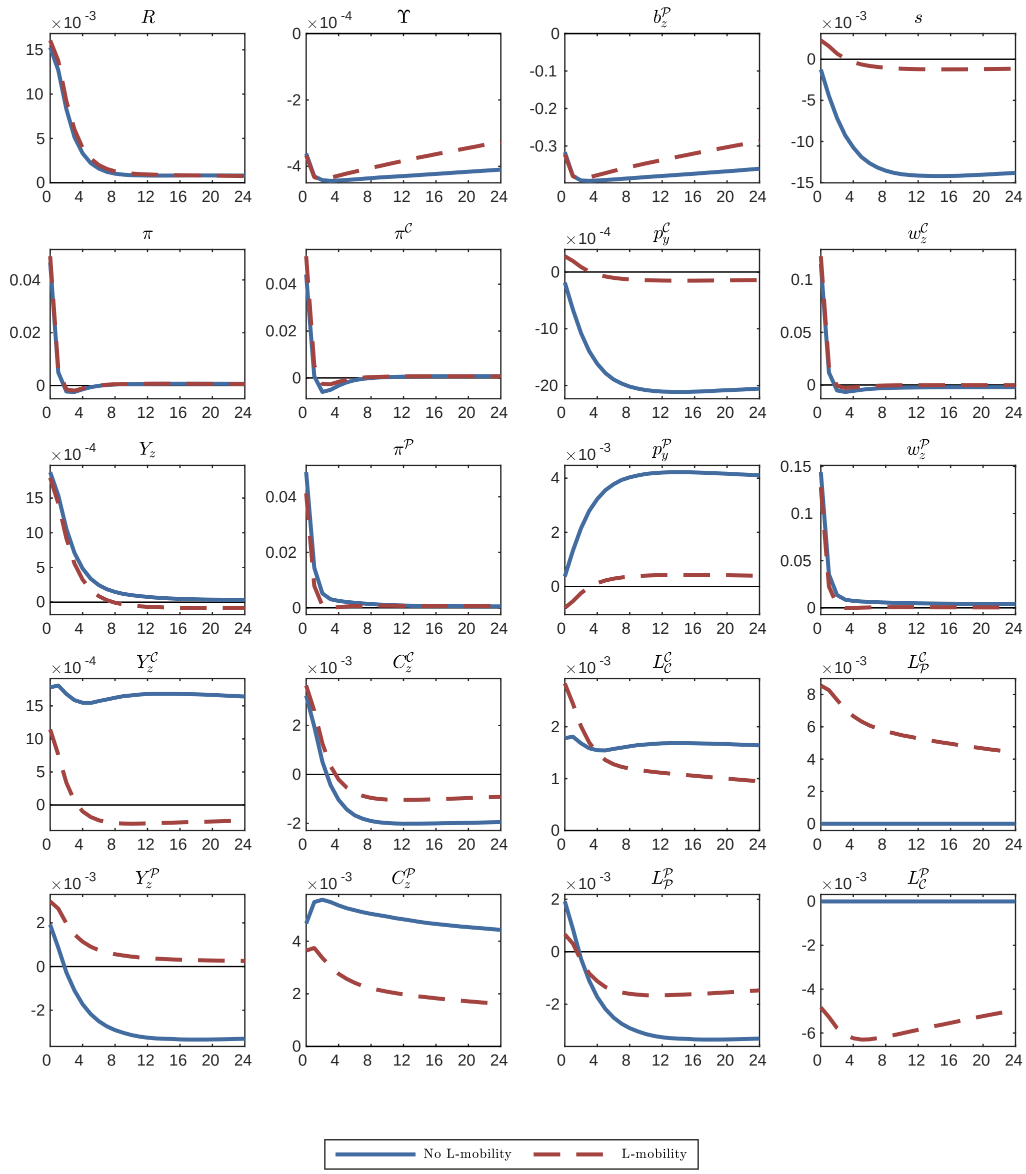

Figure 3: Responses to one standard deviation common productivity shock. Blue solid lines show median responses for model with no labor mobility; red dashed lines show median responses for counterfactual model with labor mobility.

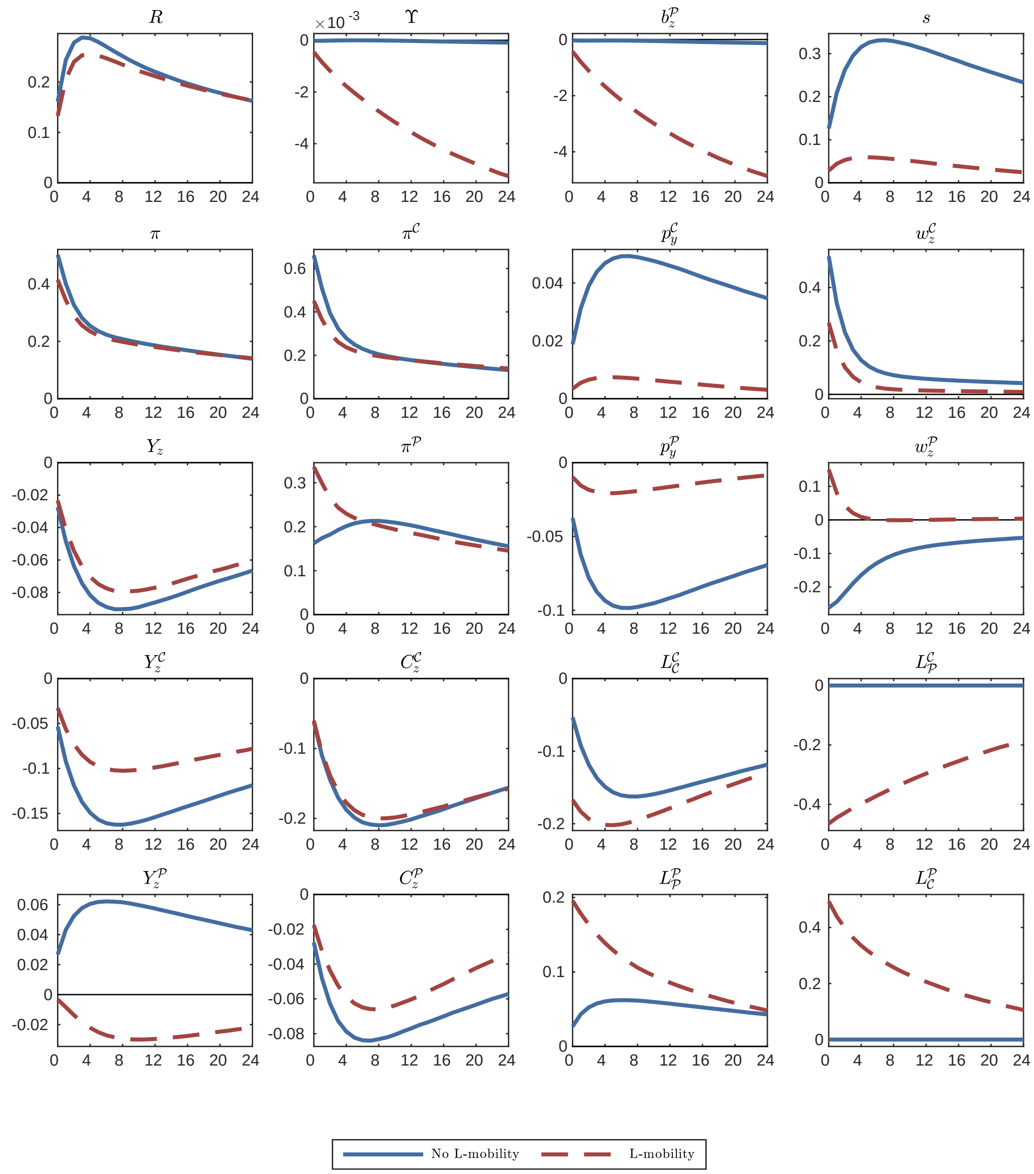

Figure 4: Responses to one standard deviation periphery labor supply shock. Blue solid lines show median responses for model with no labor mobility; red dashed lines show median responses for counterfactual model with labor mobility.

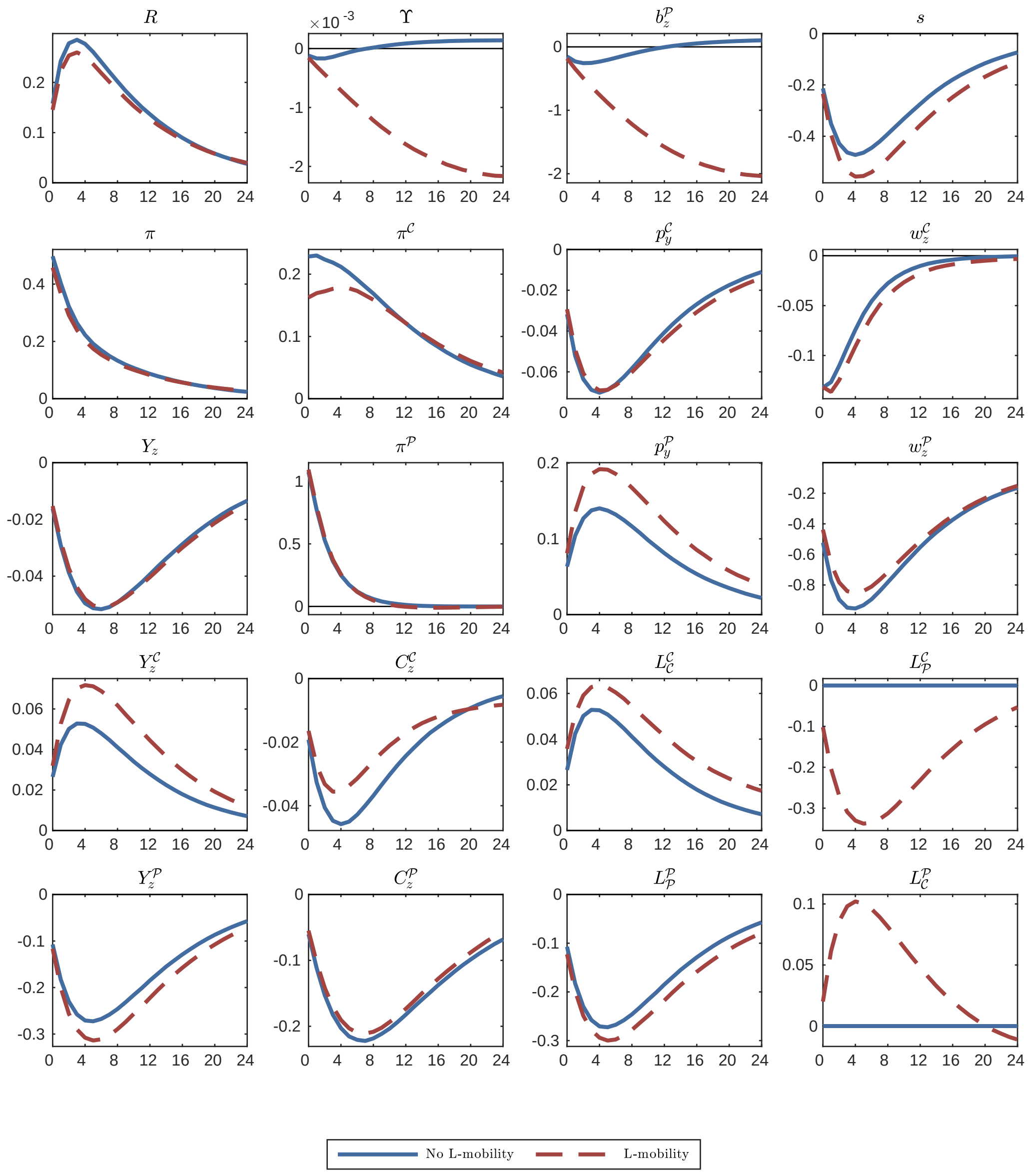

Figure 5: Responses to one standard deviation periphery price markup shock. Blue solid lines show median responses for model with no labor mobility; red dashed lines show median responses for counterfactual model with labor mobility.

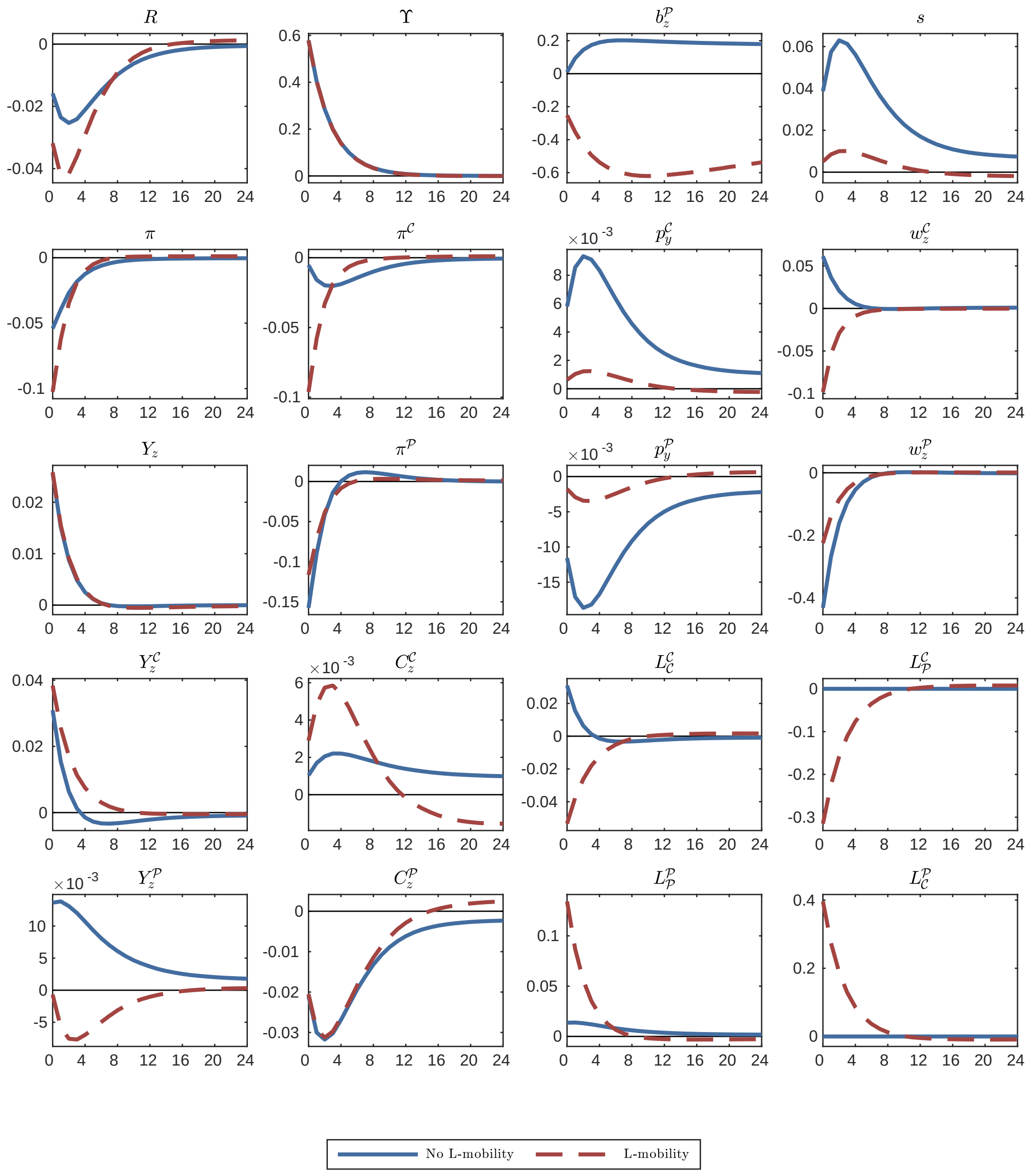

Figure 6: Responses to one standard deviation periphery risk premium shock. Blue solid lines show median responses for model with no labor mobility; red dashed lines show median responses for counterfactual model with labor mobility.

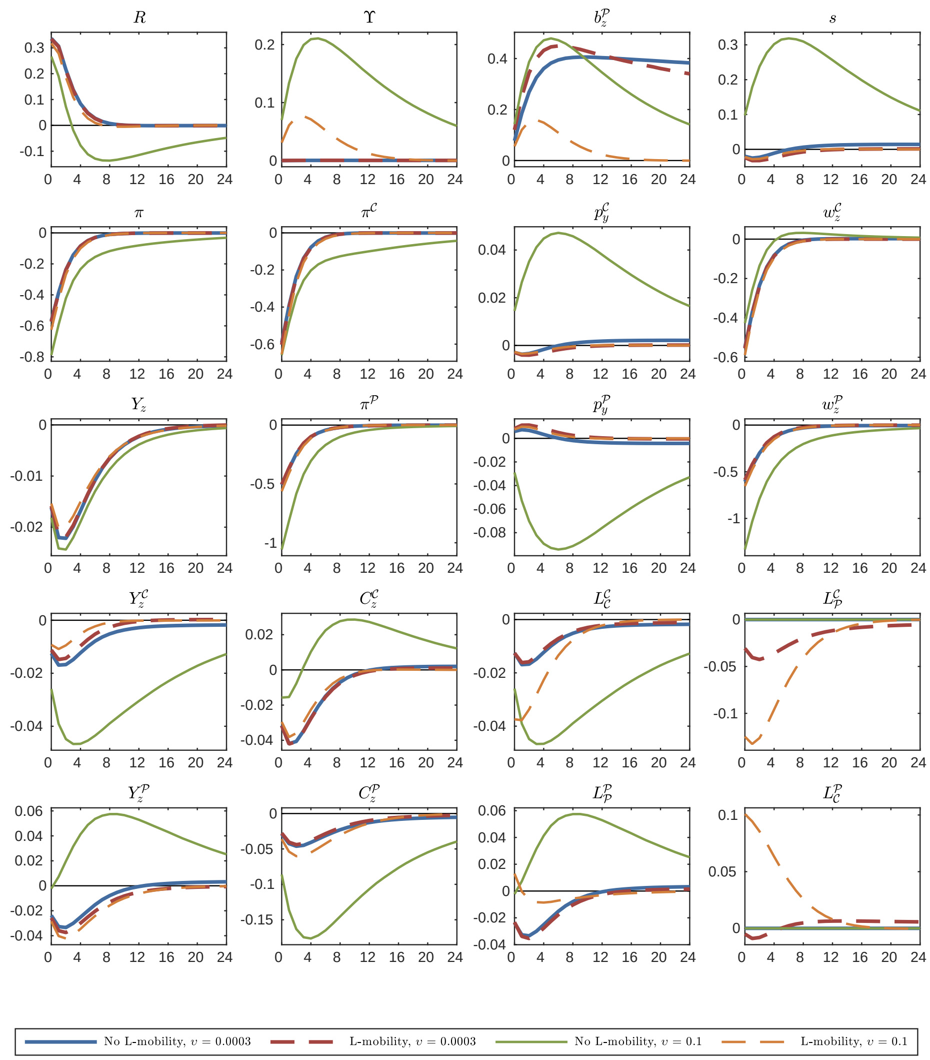

Figure 7: Responses to one standard deviation monetary policy shock in the case with stronger endogenous risk premium response to debt, υ.

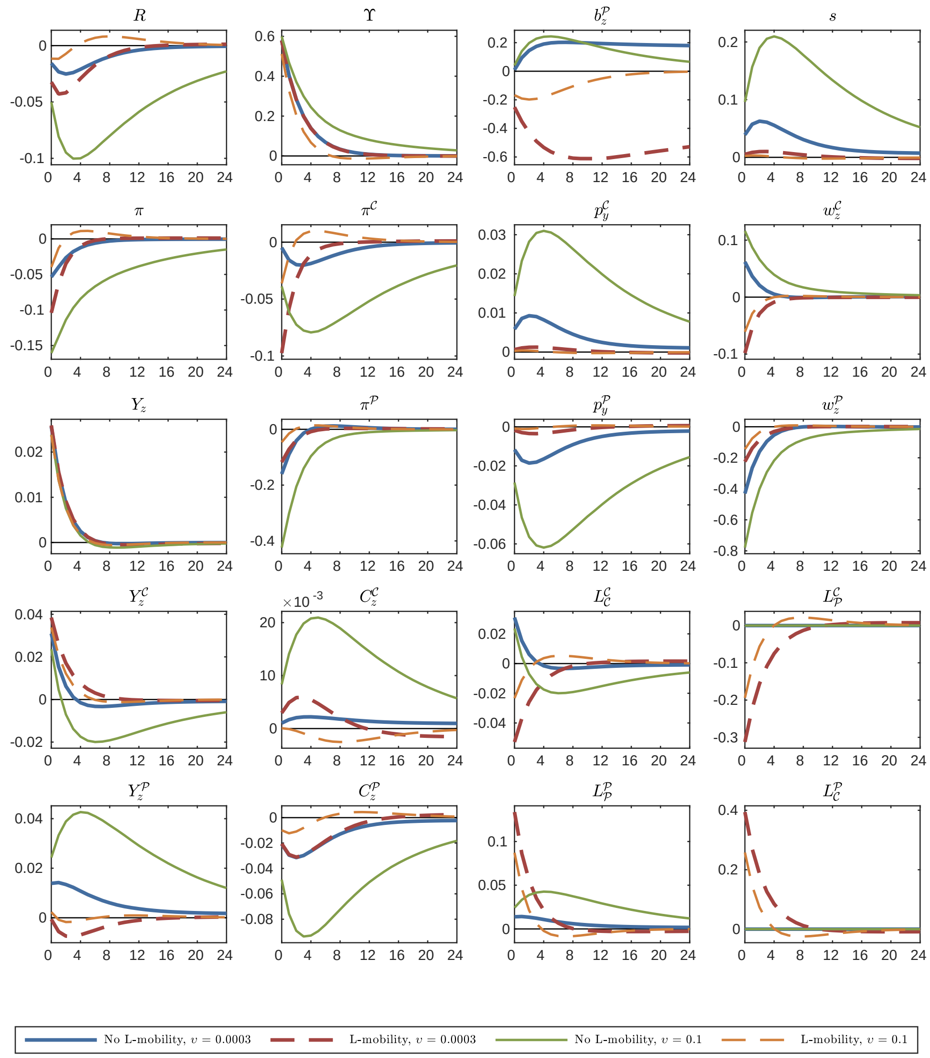

Figure 8: Responses to one standard deviation periphery risk premium shock in the case with stronger endogenous risk premium response to debt, υ.

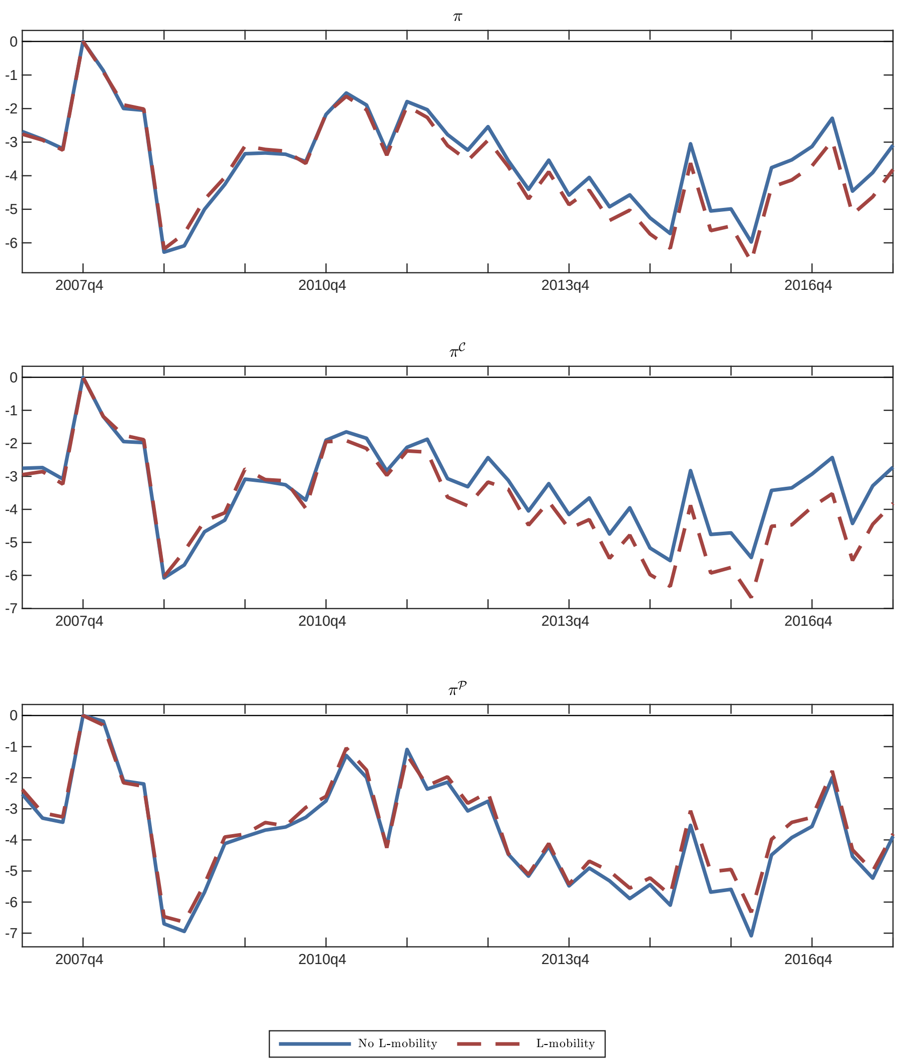

Figure 9: Historical outcomes for inflation relative to pre-2008 crisis in the data and in the counterfactual scenario with labor mobility.

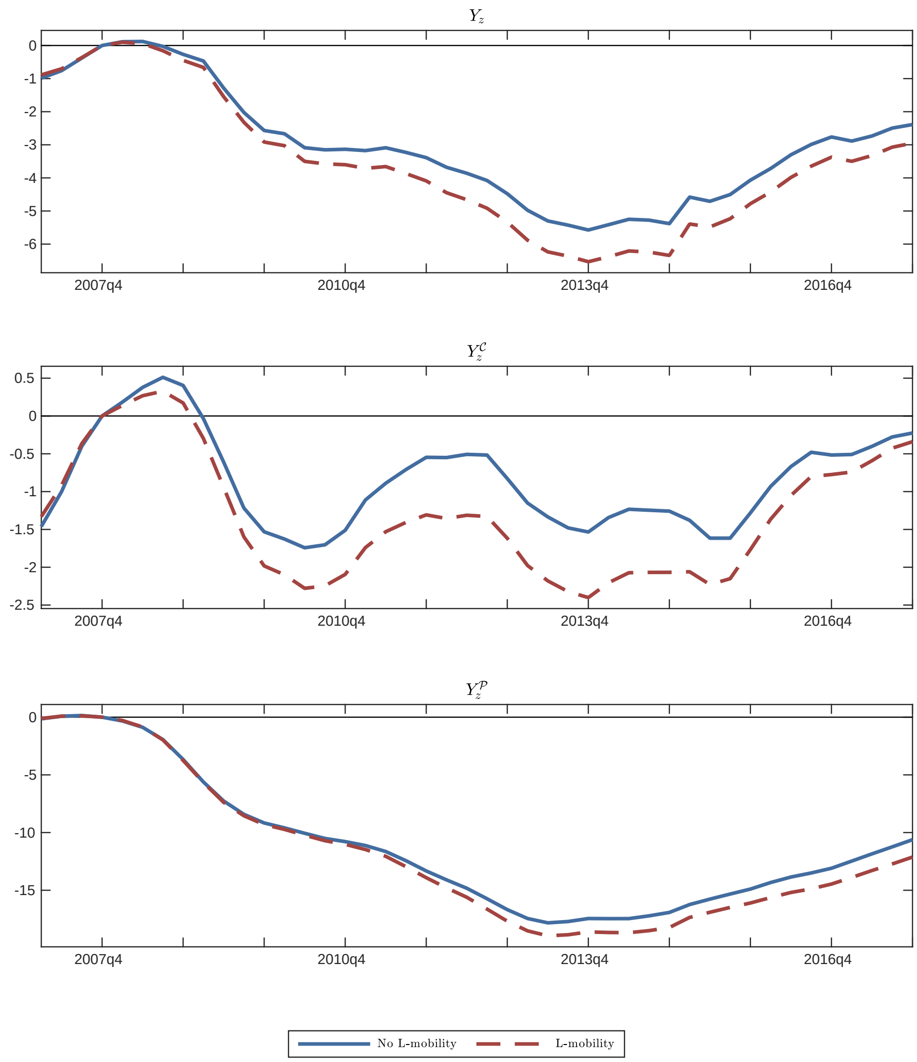

Figure 10: Historical outcomes for output relative to pre-2008 crisis in the data and in the counterfactual scenario with labor mobility.

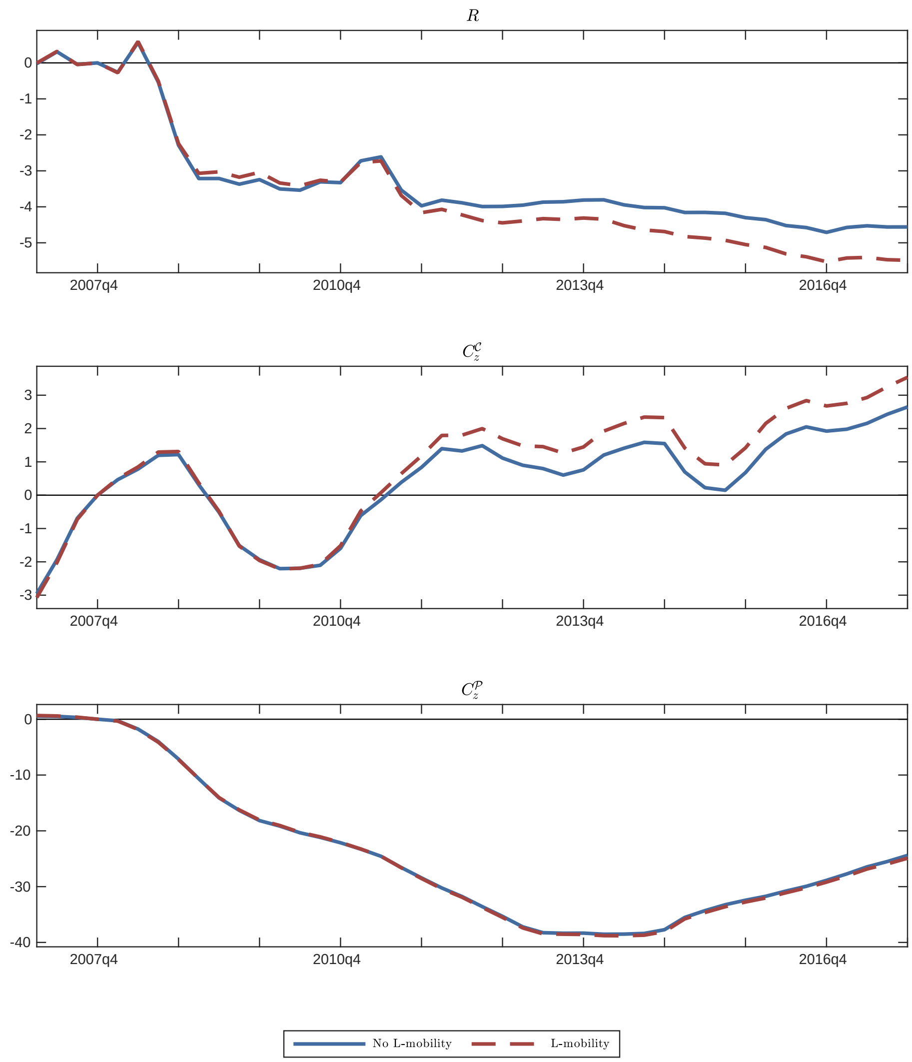

Figure 11: Historical outcomes for interest rate and consumption relative to pre-2008 crisis in the data and in the counterfactual scenario with labor mobility.

A Data details

We use quarterly data for 10 euro area countries from 1998 to 2018. Core countries are Austria, Belgium, Finland, France, Germany, and the Netherlands. Periphery countries are Ireland, Italy, Portugal, and Spain. We collect data from Eurostat on nominal GDP, chain linked real GDP (base 2010), population, labor compensation, labor force, productivity (measured as GDP per-person employed), hours worked per person, debt-to-GDP ratio, and government expenses-to-GDP ratio. We obtain data for long- and short-term bond yields from Bloomberg, inflation rates from CEIC Data and the policy rate (Eonia) from the ECB. Labor force, labor compensation measures and inflation rates are seasonally adjusted before aggregation.

The population data for each country is at annual frequency and we perform linear interpolation to get quarterly series, $Pop_{i,t}$.

The weight of country i within region j is given by

$$\varpi_{i,j} \equiv \frac{GDP_{i,t}}{\sum_{k \in j} GDP_{k,t}} \tag{A.1}$$

where $GDP_{i,t}$ is nominal GDP in country i.

To get each country's per capital real GDP growth we divide the real GDP series by the population for that country and then compute the annualized quarterly growth rate. Then we compute the weighted average of real GDP per capita growth for region j as

$$RGDPGrowth_t^j \equiv \sum_{i \in j} \varpi_{i,j} \left(\frac{RGDP_{i,t}/Pop_{i,t}}{RGDP_{i,t-1}/Pop_{i,t-1}} - 1 \right) \times 400, \tag{A.2}$$

where $RGDP_{i,t}$ is the real GDP of country i, seasonally adjusted.

For labor costs, due to data limitations, we use four-quarter change in compensation of employees (plus taxes minus subsidies) from the Eurostat. We compute the region average labor cost growth as

$$laborCost_t^j \equiv \sum_{i \in j} \varpi_{i,j} \left(\frac{LC_{i,t}}{LC_{i,t-4}} - 1 \right) \times 100, \tag{A.3}$$

where $LC_{i,t}$ is the labor compensation for country i, seasonally adjusted.

For hours worked per capita we use

$$hours_t^j \equiv \sum_{i \in j} \varpi_{i,j} \frac{WH_{i,t} LF_{i,t}}{Pop_{i,t}} \times 100, \tag{A.4}$$

where $WH_{i,t}$ is the average weekly hours of work in main job in country i, seasonally adjusted; and $LF_{i,t}$ is the labor force in country i. After aggregation, the hours series for each region is demeaned.

Inflation in region j is given by

$$inflation_t^j \equiv \sum_{i \in j} \varpi_{i,j} \left(\frac{HICP_{i,t}}{HICP_{i,t-1}} - 1 \right) \times 400, \tag{A.5}$$

where $HICP_{i,t}$ is the HICP index for country i, seasonally adjusted.

The interest rate in region j is given by

$$short_t^j \equiv \sum_{i \in j} \varpi_{i,j} SB1y_{i,t}, \tag{A.6}$$

where $SB1y_{i,t}$ is the Bloomberg 1-year government bond yield for country i.

These data series in region map into the model variables as follows:

$$\begin{aligned}
RGDPGrowth_t^{\mathcal{C}} &= 400\gamma + 400(\hat{Y}_{z,t}^{\mathcal{C}} - \hat{Y}_{z,t-1}^{\mathcal{C}} + \hat{\xi}_{z,t}^{\mathcal{C}}) && \text{(A.7)} \\
laborCost_t^{\mathcal{C}} &= 400\gamma + 400\pi + 100(\Delta W_{z,t}^{\mathcal{C}} + \Delta W_{z,t-1}^{\mathcal{C}} + \Delta W_{z,t-2}^{\mathcal{C}} + \Delta W_{z,t-3}^{\mathcal{C}}) && \text{(A.8)} \\
hours_t^{\mathcal{C}} &= \bar{L}^{\mathcal{C}} + 100\hat{\tilde{L}}_t^{\mathcal{C}} && \text{(A.9)} \\
inflation_t^{\mathcal{C}} &= 400\pi + 400\pi_t^{\mathcal{C}} && \text{(A.10)} \\
short_t^{\mathcal{C}} &= 400(R/\Pi - 1) + 400\pi + 400\hat{R}_t && \text{(A.11)} \\
RGDPGrowth_t^{\mathcal{P}} &= 400\gamma + 400(\hat{Y}_{z,t}^{\mathcal{P}} - \hat{Y}_{z,t-1}^{\mathcal{P}} + \hat{\xi}_{z,t}^{\mathcal{C}} + \hat{\xi}_{z,t}^{\mathcal{P}} - \hat{\xi}_{z,t-1}^{\mathcal{P}}) && \text{(A.12)} \\
laborCost_t^{\mathcal{P}} &= 400\gamma + 400\pi + 100(\Delta W_{z,t}^{\mathcal{P}} + \Delta W_{z,t-1}^{\mathcal{P}} + \Delta W_{z,t-2}^{\mathcal{P}} + \Delta W_{z,t-3}^{\mathcal{P}}) && \text{(A.13)} \\
hours_t^{\mathcal{P}} &= \bar{L}^{\mathcal{P}} + 100\hat{\tilde{L}}_t^{\mathcal{P}} && \text{(A.14)} \\
inflation_t^{\mathcal{P}} &= 400\pi + 400\pi_t^{\mathcal{P}} && \text{(A.15)} \\
short_t^{\mathcal{P}} &= 400(R/\Pi - 1) + 400\pi + 400\Upsilon + 400(\hat{R}_t + \hat{\Upsilon}_t) && \text{(A.16)}
\end{aligned}$$

with $\hat{x}_t \equiv ln(x_t/x)$, and

$$\Delta W^{\mathcal{C}} \equiv \hat{w}^{\mathcal{C}}_{z,t} - \hat{w}^{\mathcal{C}}_{z,t-1} + \pi^{\mathcal{C}}_t + \hat{\xi}^{\mathcal{C}}_{z,t} \tag{A.17}$$

$$\Delta W^{\mathcal{P}} \equiv \hat{w}^{\mathcal{P}}_{z,t} - \hat{w}^{\mathcal{P}}_{z,t-1} + \pi^{\mathcal{P}}_t + \hat{\xi}^{\mathcal{C}}_{z,t} + \hat{\xi}^{\mathcal{P}}_{z,t} - \hat{\xi}^{\mathcal{P}}_{z,t-1} \tag{A.18}$$

B Other shocks and robustness exercises

In response to a periphery-specific productivity shock, labor mobility has limited impact in area-wide outcomes. It mitigates somewhat divergent paths of output and inflation but yields a more noticeable divergence in consumption outcomes. Figure A1 reports the results. Note that it shows a drop in both $Y^{\mathcal{P}}_z$ and $C^{\mathcal{P}}_z$, but the level of productivity in the periphery increased by around 0.5, which means that the level of output and consumption in that region is higher than the trend in the absence of such shock.

Next we consider the economic responses to a core discount factor (demand) shock, shown in Figure A2. In the absence of labor mobility, it increases output in the core region more than in the periphery and increases the relative cost of core goods, due to the home bias in consumption. Because overall prices increase, the output in the periphery increases but consumption in that region falls. Allowing for labor mobility means that households from the periphery can increase supply of labor to the core, taking advantage of the higher wages, alleviating the price pressures in the core at the cost of increased costs in the periphery. As such, the price of core goods increase less relative to periphery's goods, and the increase in periphery's output is thus halved. In this case, labor mobility implies that a core-specific demand shock yields less of an indirect benefit to the periphery, because labor flees that region, mitigating the relative price changes. Aggregate output is a little smaller, reflecting the more subdued output in the periphery, and aggregate inflation is also somewhat lower. Despite reaching for higher wages, periphery's consumption falls slightly more. This is a case in which labor mobility reduces the aggregate economic boost led by core demand, and the degree of regional divergence is higher for both output and consumption. Inflation in both core and periphery is more subdued with labor mobility so the impact on asymmetric response of inflation is more ambiguous. A demand shock specific to the periphery, shown in Figure A3, yields a more pronounced change in relative prices and more output, with labor mobility; at the cost of more noticeable divergence in both consumption and inflation between core and periphery.

Labor mobility has limited impact in both aggregate and relative outcomes in response to shocks to government spending in either region, as reported in Figures A4 and A5.

Figures A6 to A13 report robustness exercises for varying the elasticity of substitution of labor supply (η_l) and the homes bias in labor sypply (γ_l).

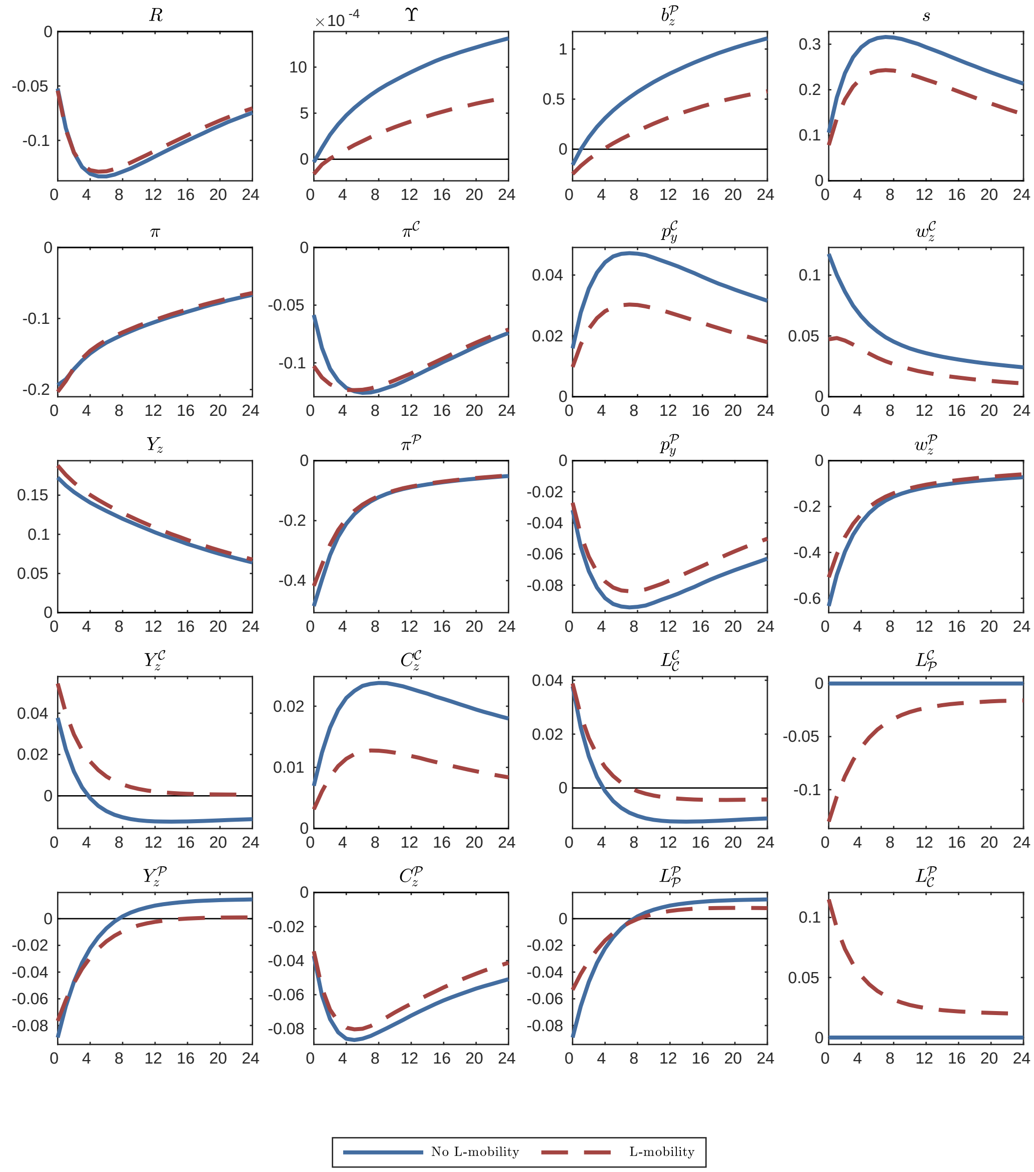

Figure A1: Responses to one standard deviation periphery productivity shock. Blue solid lines show median responses for model with no labor mobility; red dashed lines show median responses for counterfactual model with labor mobility.

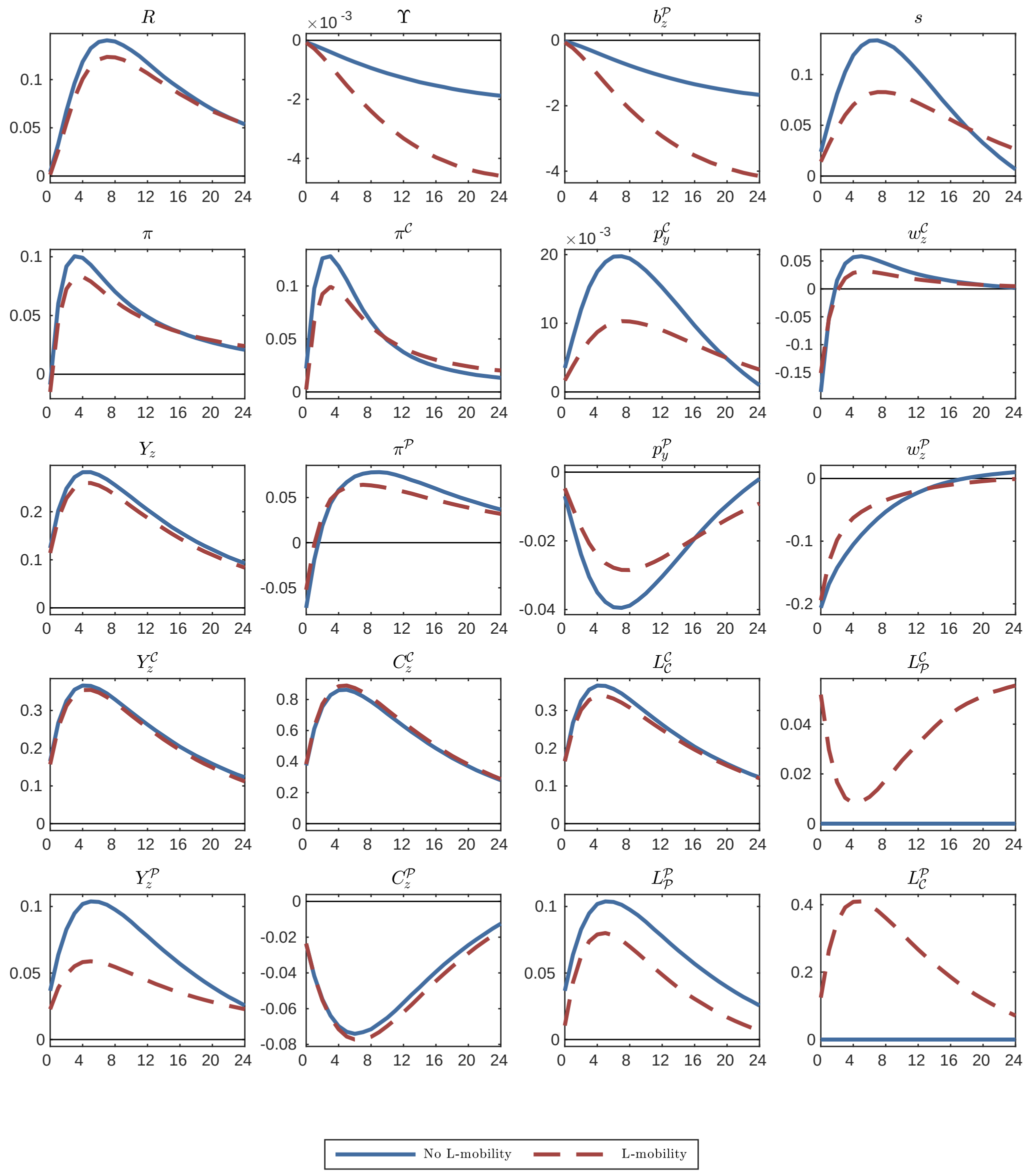

Figure A2: Responses to one standard deviation core discount factor shock. Blue solid lines show median responses for model with no labor mobility; red dashed lines show median responses for counterfactual model with labor mobility.

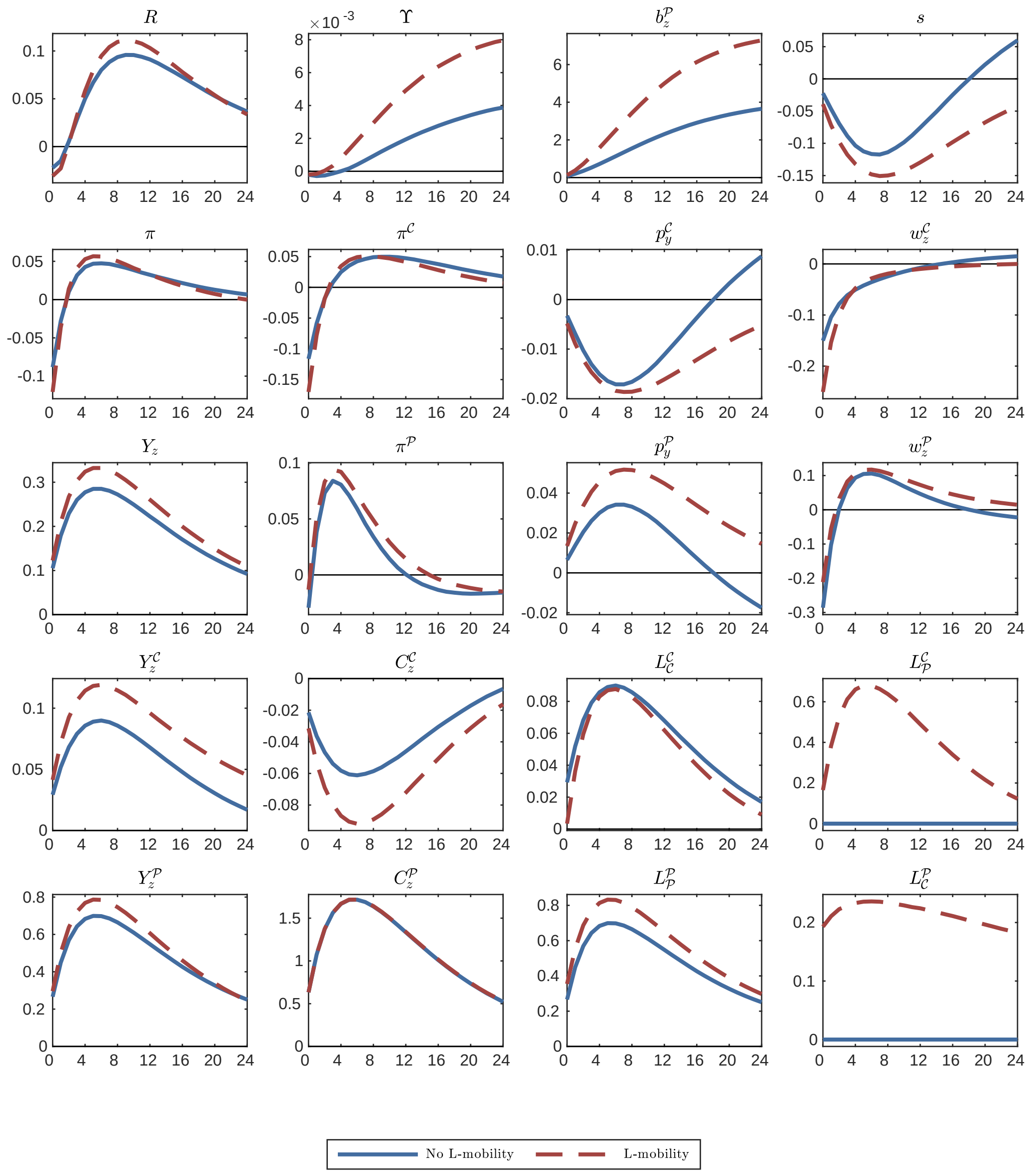

Figure A3: Responses to one standard deviation periphery discount factor shock. Blue solid lines show median responses for model with no labor mobility; red dashed lines show median responses for counterfactual model with labor mobility.

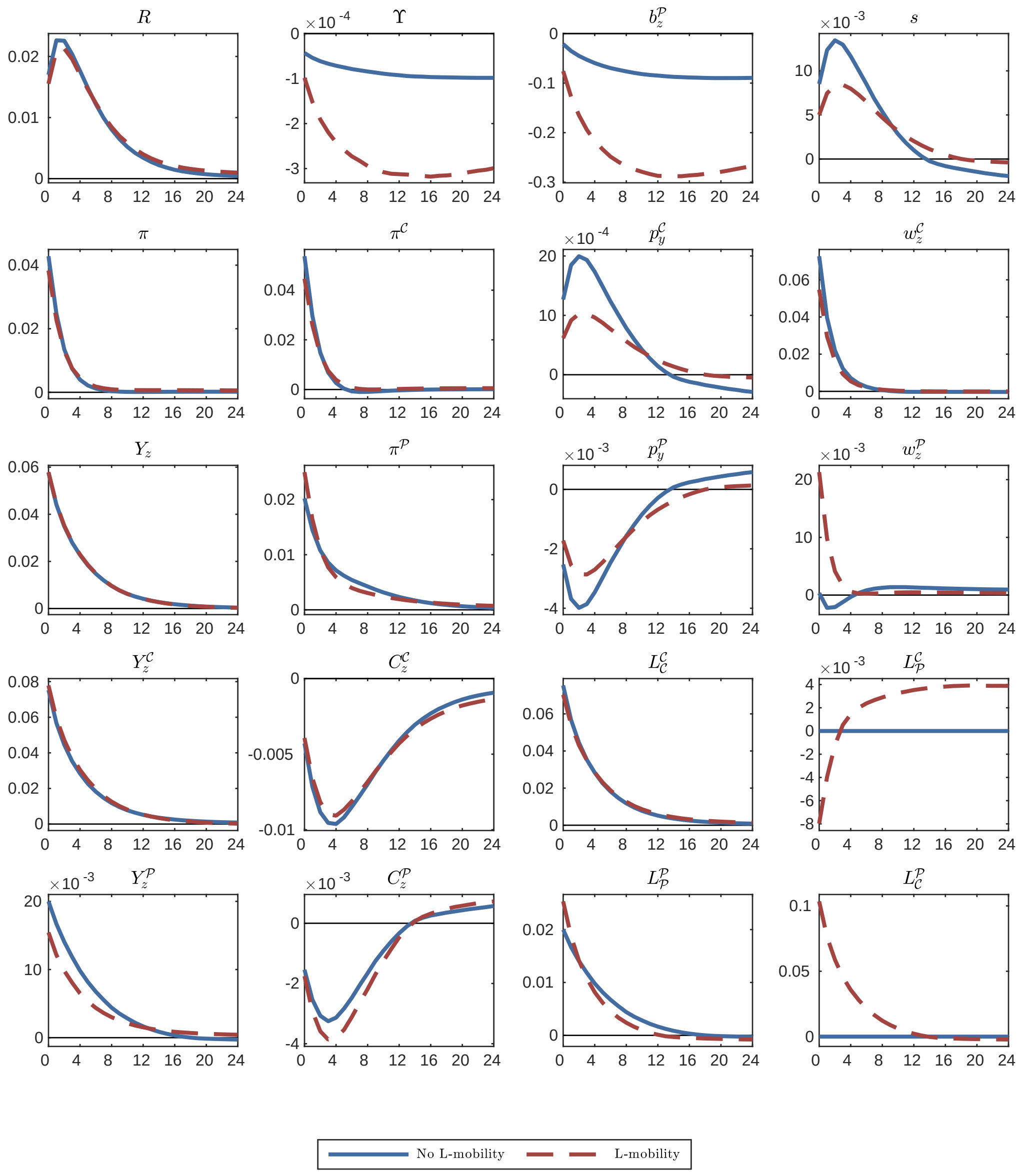

Figure A4: Responses to one standard deviation core government spending shock. Blue solid lines show median responses for model with no labor mobility; red dashed lines show median responses for counterfactual model with labor mobility.

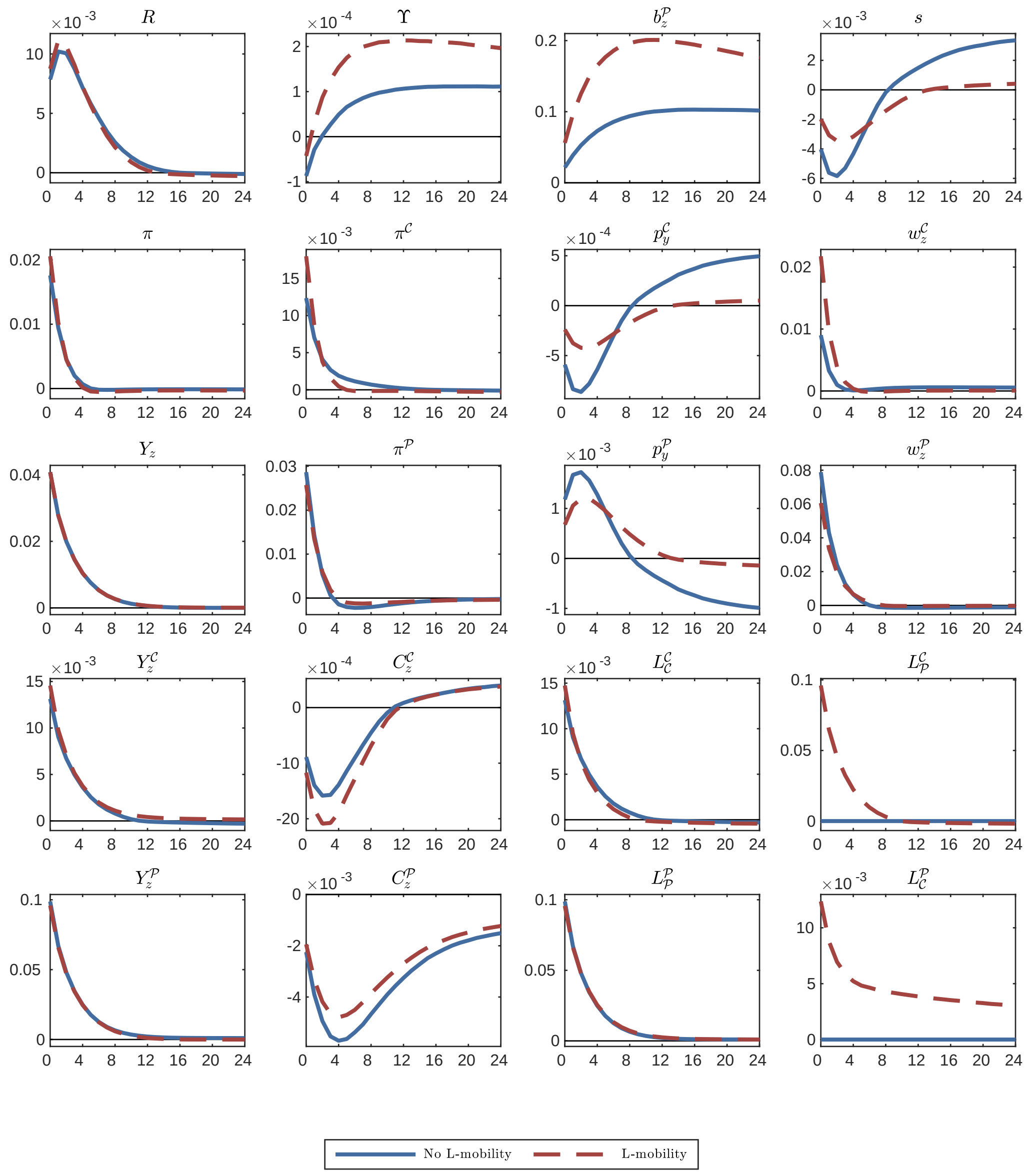

Figure A5: Responses to one standard deviation periphery government spending shock. Blue solid lines show median responses for model with no labor mobility; red dashed lines show median responses for counterfactual model with labor mobility.

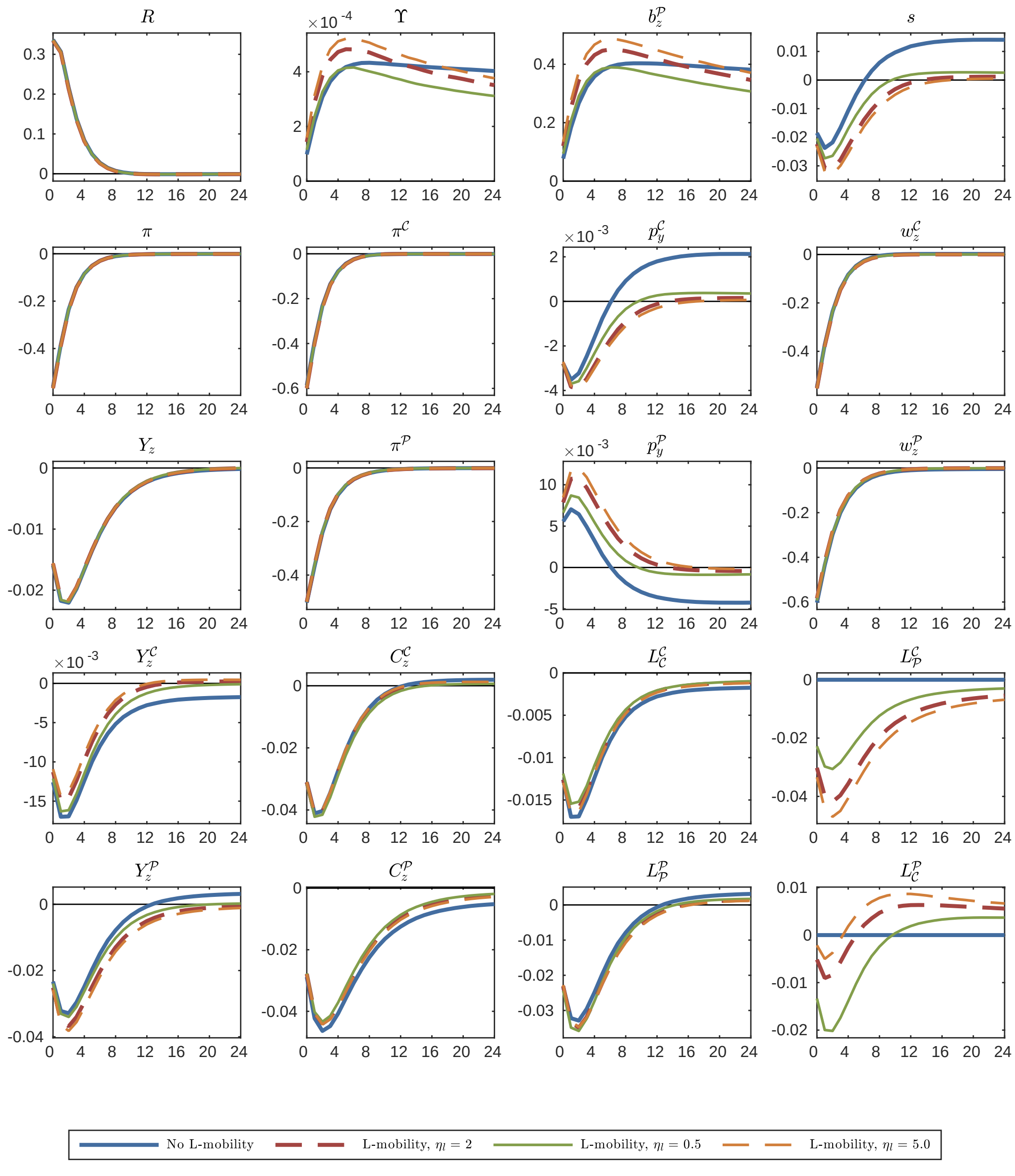

Figure A6: Responses to one standard deviation monetary policy shock for different degrees of the elasticity of substitution of labor supply. Blue solid lines show median responses for model with no labor mobility; red dashed lines show median responses for counterfactual model with labor mobility; green solid lines show the median responses with labor mobility and low elasticity of substitution of labor supply; dashed orange lines the median responses with labor mobility and high elasticity of substitution of labor supply.

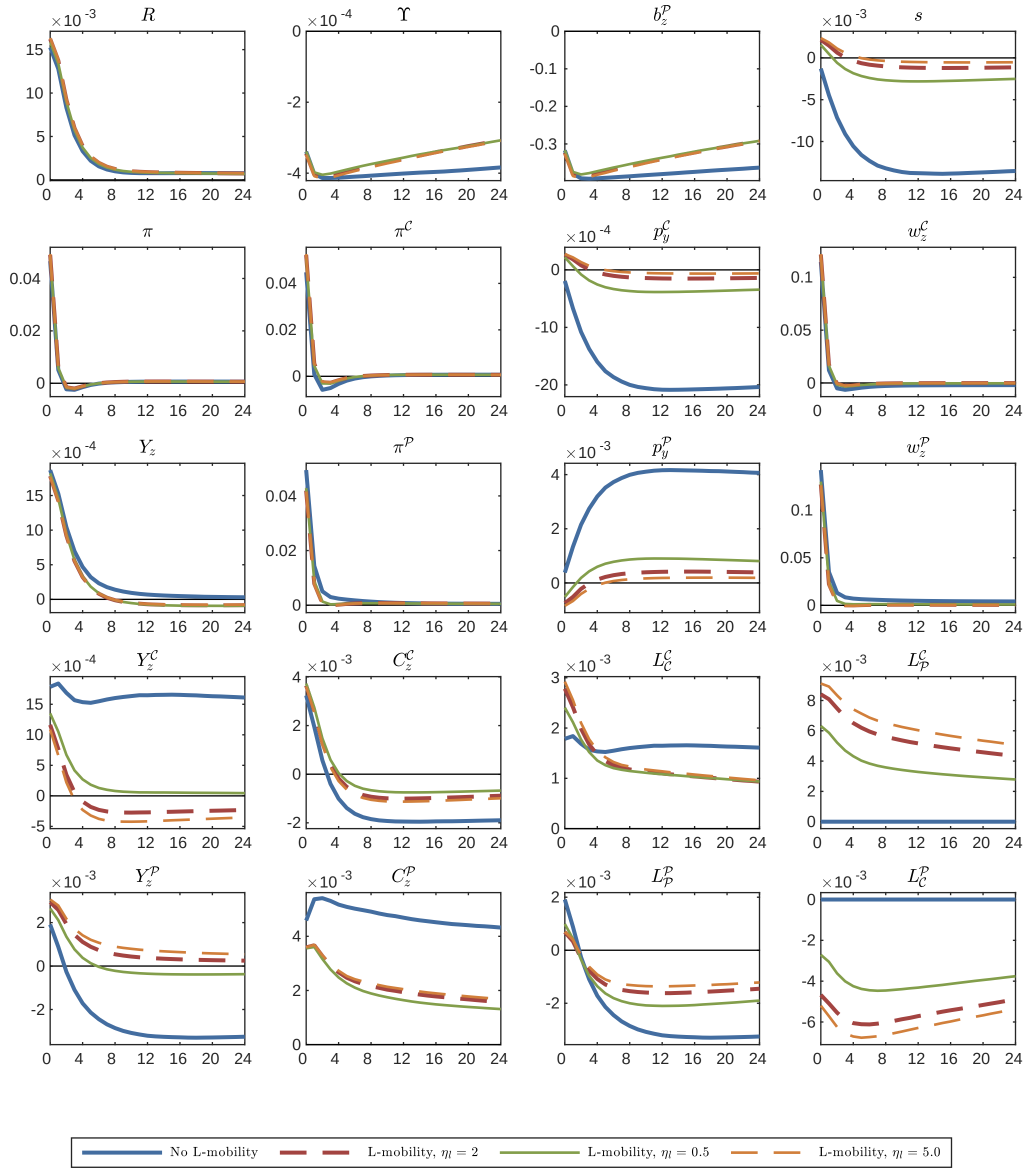

Figure A7: Responses to one standard deviation common productivity shock for different degrees of the elasticity of substitution of labor supply. Blue solid lines show median responses for model with no labor mobility; red dashed lines show median responses for counterfactual model with labor mobility; green solid lines show the median responses with labor mobility and low elasticity of substitution of labor supply; dashed orange lines the median responses with labor mobility and high elasticity of substitution of labor supply.

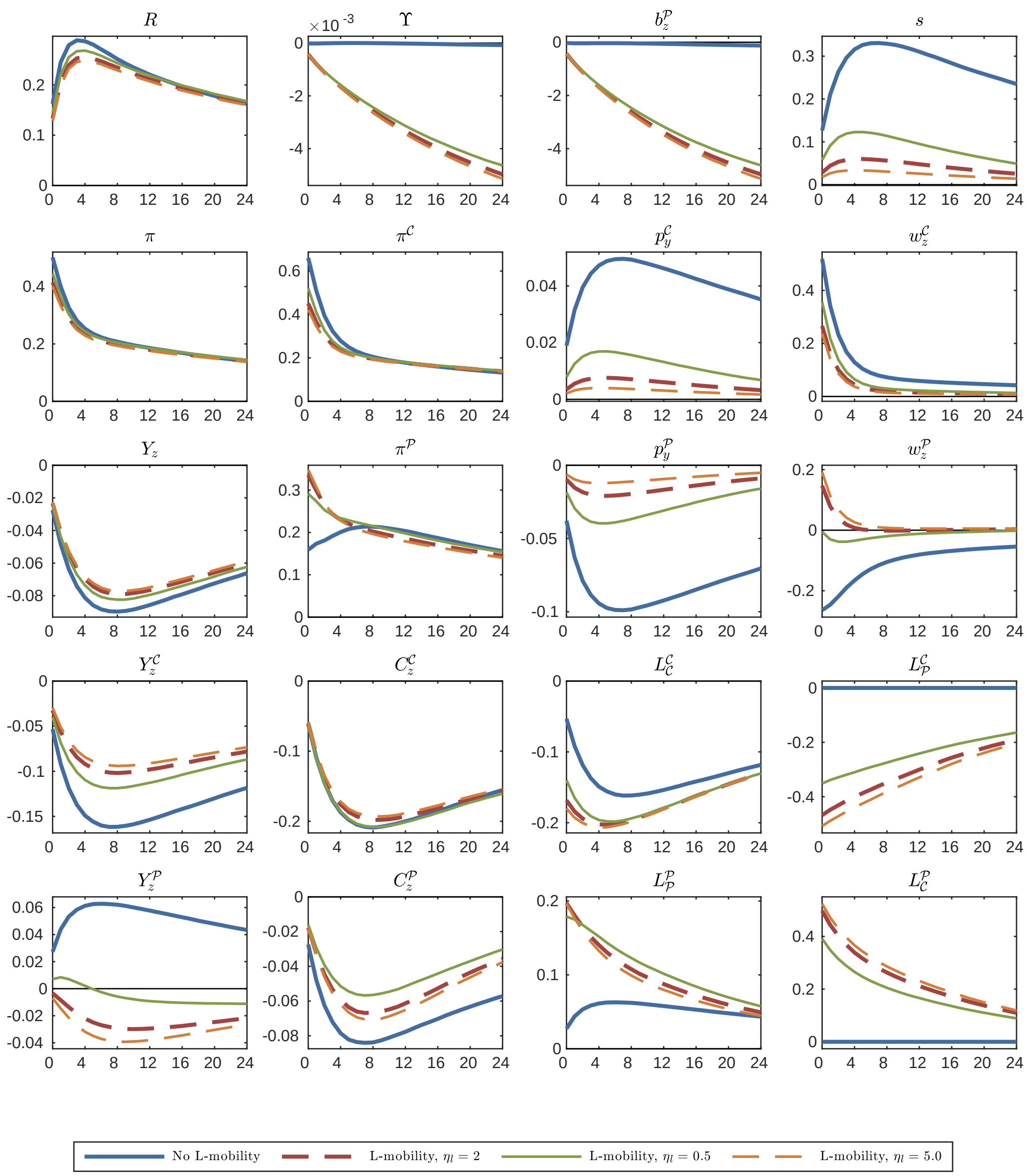

Figure A8: Responses to one standard deviation periphery labor supply shock for different degrees of the elasticity of substitution of labor supply. Blue solid lines show median responses for model with no labor mobility; red dashed lines show median responses for counterfactual model with labor mobility; green solid lines show the median responses with labor mobility and low elasticity of substitution of labor supply; dashed orange lines the median responses with labor mobility and high elasticity of substitution of labor supply.

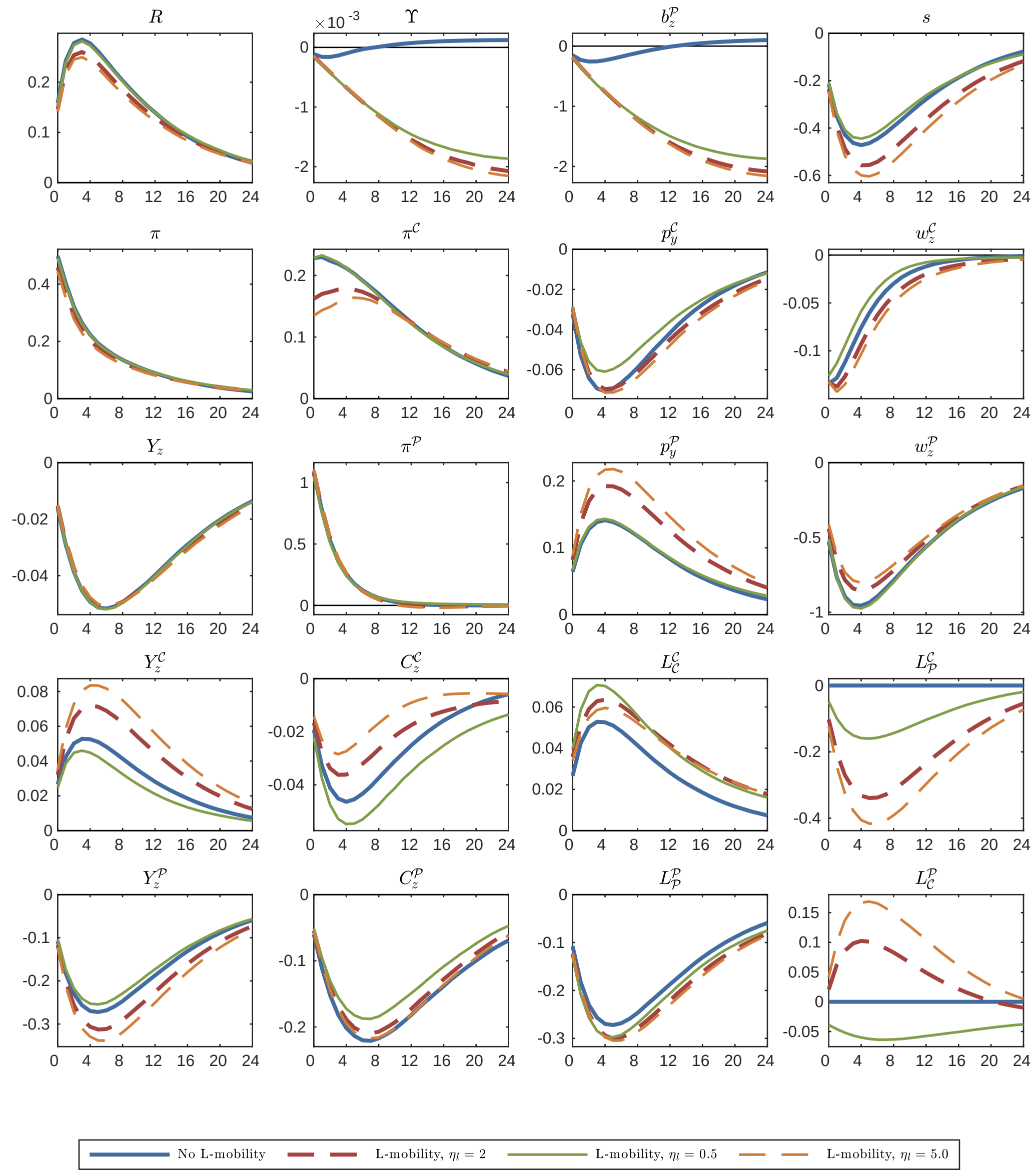

Figure A9: Responses to one standard deviation periphery price markup shock for different degrees of the elasticity of substitution of labor supply. Blue solid lines show median responses for model with no labor mobility; red dashed lines show median responses for counterfactual model with labor mobility; green solid lines show the median responses with labor mobility and low elasticity of substitution of labor supply; dashed orange lines the median responses with labor mobility and high elasticity of substitution of labor supply.

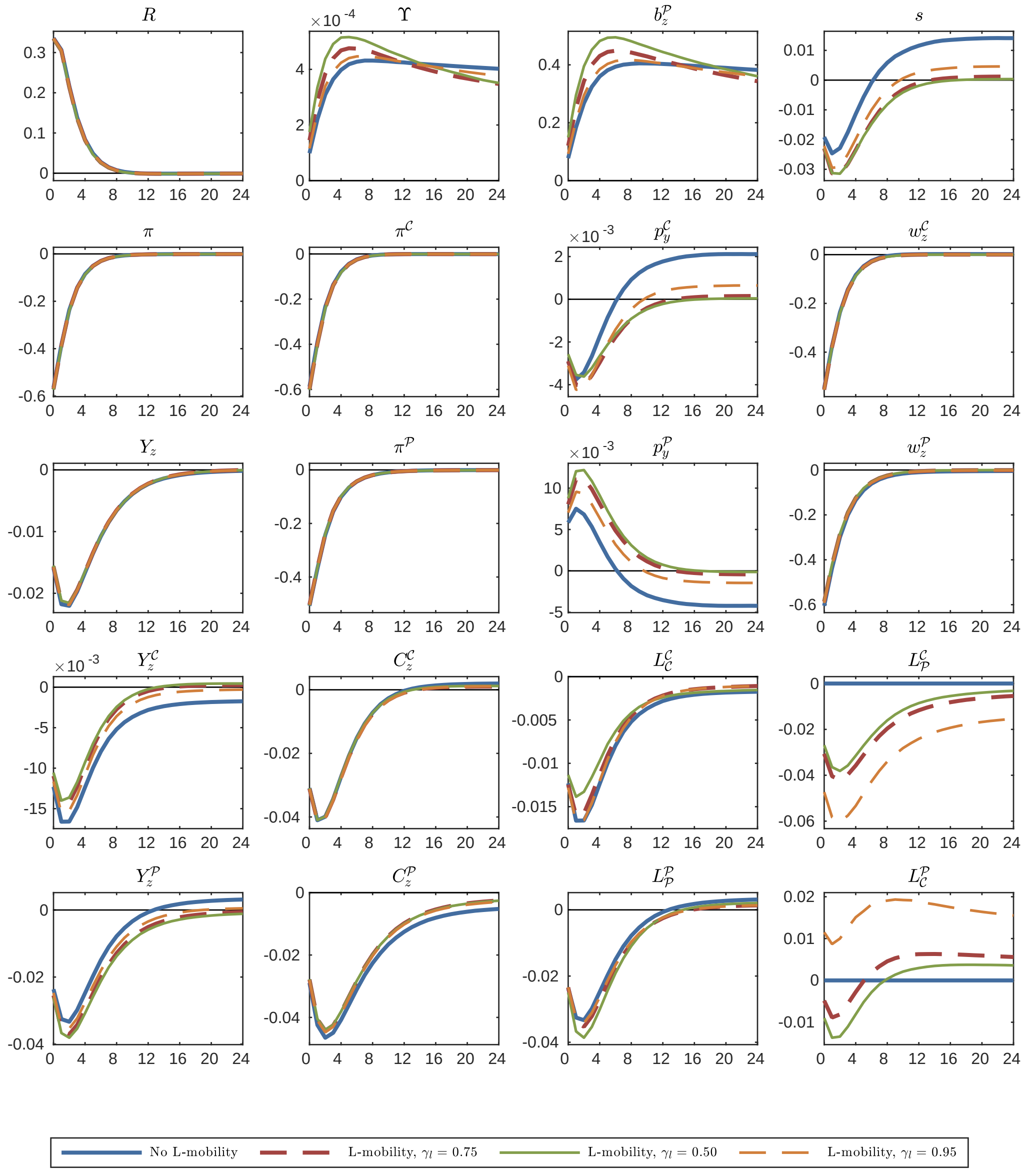

Figure A10: Responses to one standard deviation monetary policy shock for different degrees of home bias in labor supply. Blue solid lines show median responses for model with no labor mobility; red dashed lines show median responses for counterfactual model with labor mobility; green solid lines show the median responses with labor mobility and low home bias in labor supply; dashed orange lines the median responses with labor mobility and high home bias in labor supply.

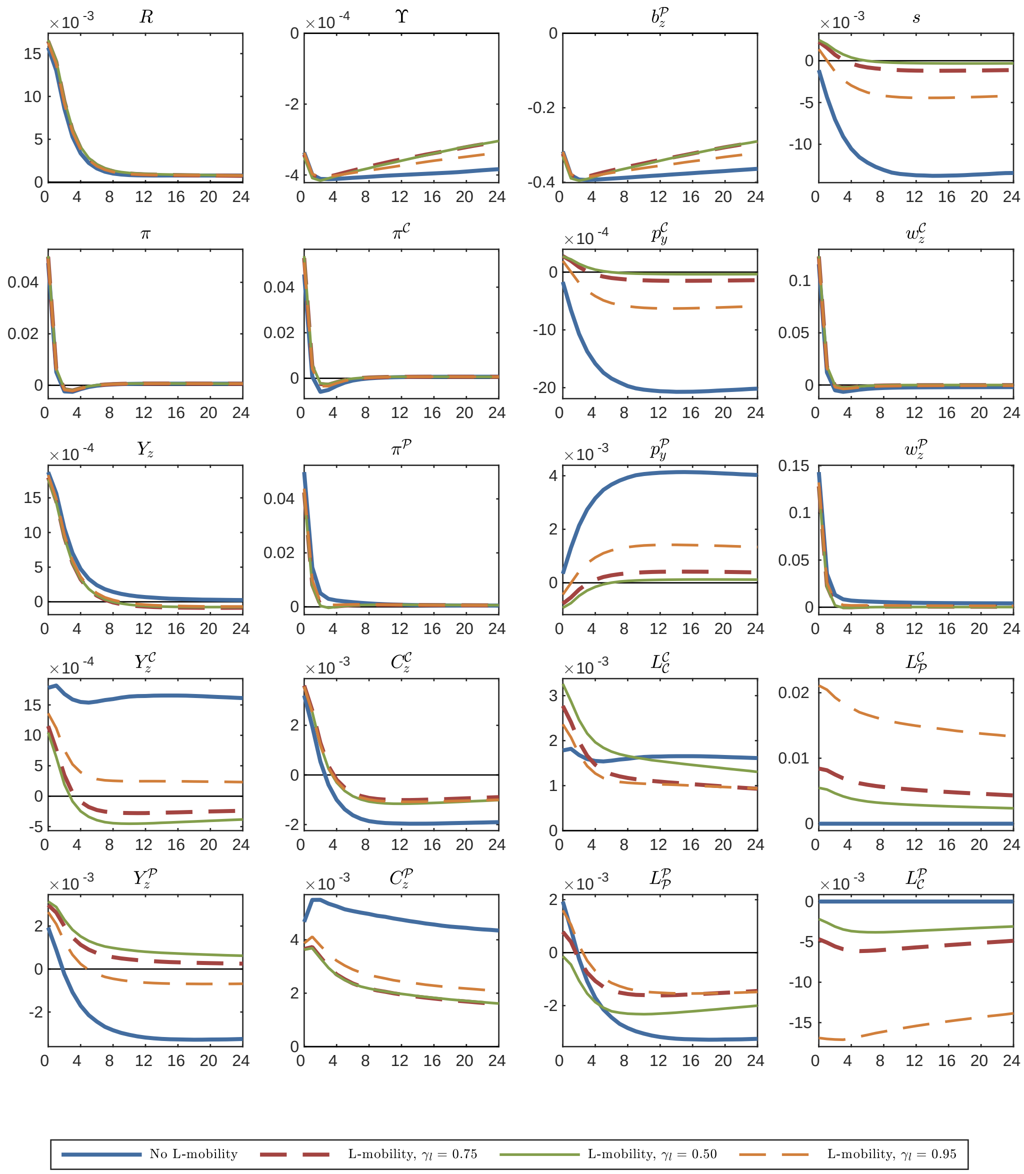

Figure A11: Responses to one standard deviation common productivity shock for different degrees of home bias in labor supply. Blue solid lines show median responses for model with no labor mobility; red dashed lines show median responses for counterfactual model with labor mobility; green solid lines show the median responses with labor mobility and low home bias in labor supply; dashed orange lines the median responses with labor mobility and high home bias in labor supply.

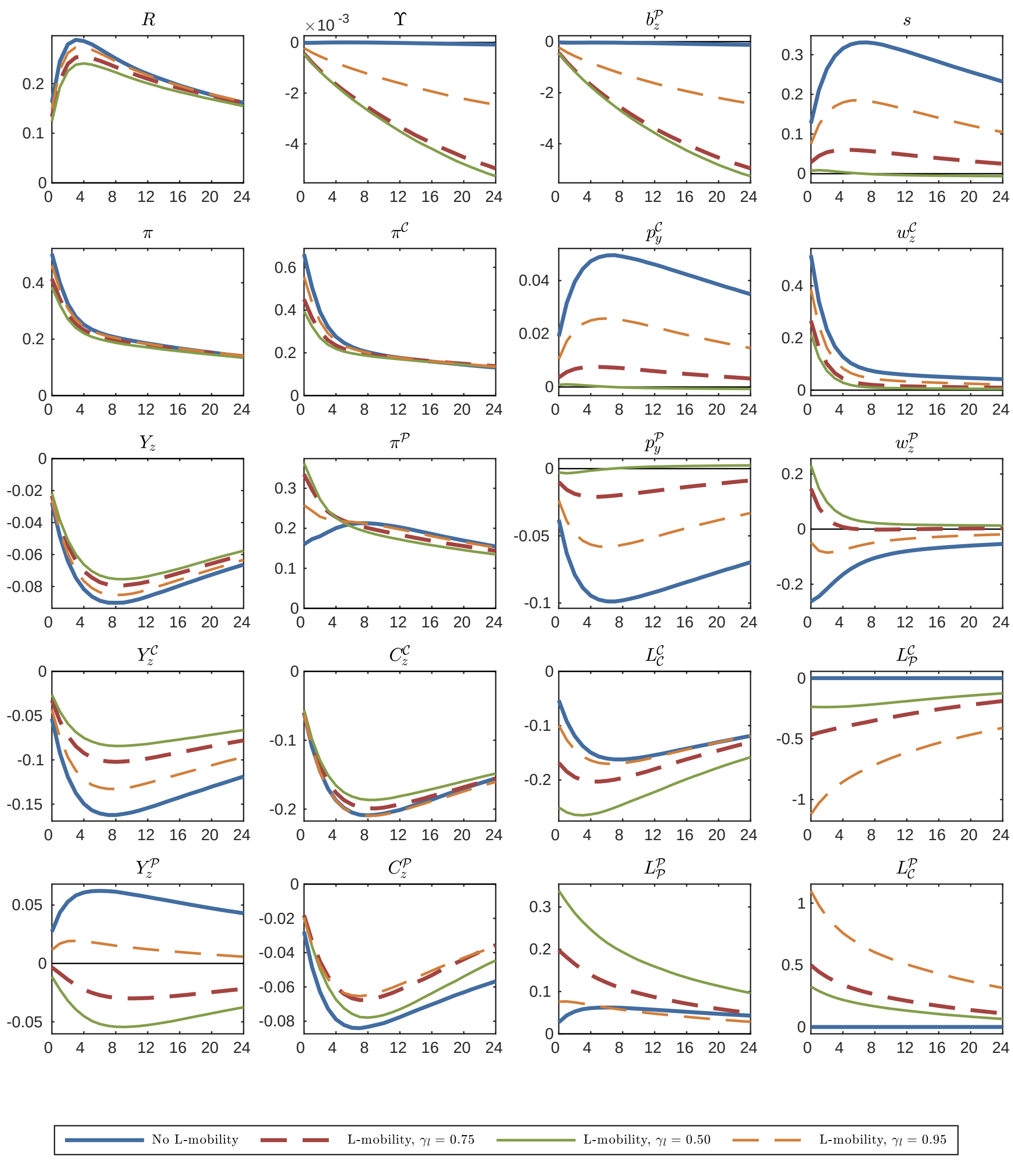

Figure A12: Responses to one standard deviation periphery labor supply shock for different degrees of home bias in labor supply. Blue solid lines show median responses for model with no labor mobility; red dashed lines show median responses for counterfactual model with labor mobility; green solid lines show the median responses with labor mobility and low home bias in labor supply; dashed orange lines the median responses with labor mobility and high home bias in labor supply.

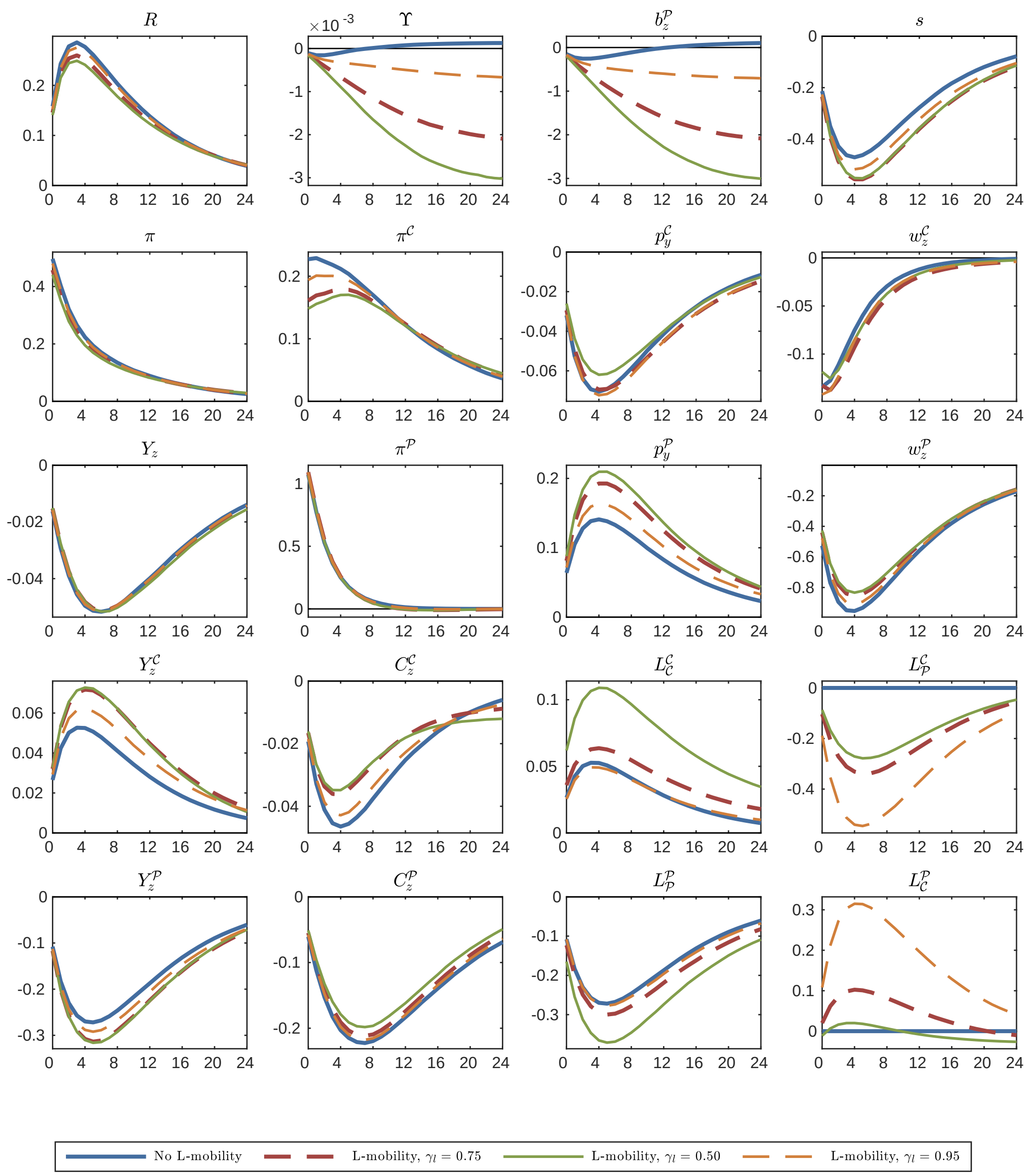

Figure A13: Responses to one standard deviation periphery price markup shock for different degrees of home bias in labor supply. Blue solid lines show median responses for model with no labor mobility; red dashed lines show median responses for counterfactual model with labor mobility; green solid lines show the median responses with labor mobility and low home bias in labor supply; dashed orange lines the median responses with labor mobility and high home bias in labor supply.