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Abstract

We assess to which degree an international transfer mechanism can enhance consumption risk sharing as well as allocative efficiency and apply our results to the implicit transfers generated by a potential European unemployment benefit scheme (EUBS). Specifically, we first develop a simple model with nominal rigidities to build intuition by deriving analytical results. We then use a rich DSGE model, calibrated to the Core and the Periphery of the euro area, to quantitatively analyze the changing dynamics that a EUBS brings about. We find that a EUBS can provide risk sharing by stabilizing relative consumption as well as unemployment differentials. Following supply shocks, however, the cross-country transfer embodied in the unemployment benefits is spent to a large degree on relatively inefficiently produced goods in the receiving countries. This renders the allocation even more inefficient by opening country-specific labor wedges further, also after government-spending shocks. Yet, since this trade-off between allocative efficiency and consumption risk sharing does not exist after certain demand shocks, the welfare effects of a EUBS depend on the cause for international unemployment differentials. A EUBS that is only active after specific shocks would therefore maximize overall welfare. Even without this feature, a EUBS would raise Core's welfare in the quantitative model, leaving Periphery's welfare almost unchanged.

JEL-Codes: F450, F440, E320.

Keywords: cross-country transfers, international unemployment insurance, EMU European business cycles, optimum currency area, structural reforms.

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1 Introduction

After the creation of the Economic and Monetary Union (EMU) in 1992, European integration culminated in the introduction of the euro in 1999. Today, 19 countries in Europe share the same currency and delegate monetary policy for the euro area to the European System of Central Banks. The surrender of monetary autonomy at the member-state level involves the loss of a powerful capacity to stabilize the economy in the face of asymmetric shocks.[1]

The lack of a stabilizing mechanism became evident in the so-called 'euro crisis' that was characterized by strongly diverging developments among the member states. As a result, many policy makers and academics have called for a completion of the euro zone to prevent this episode from happening again in the future (see, for example, Bénassy-Quéré et al., 2018). Various theoretical contributions propose risk-sharing mechanisms that are designed to compensate for the costs of a monetary union.[2] The most prominent example that is taken up in policy circles is a European unemployment benefit scheme (EUBS in the following). The effects of stabilizing workers' income via an unemployment insurance in a closed-economy setting are well documented in the literature.[3] Cross-country individual insurance schemes additionally imply international transfers when business cycles are asynchronous. However, analyzing their impact on allocative efficiency and consumption risk sharing has been neglected so far.

In this paper, we evaluate whether transfer schemes, such as a EUBS, can provide a stabilizing role for a monetary union in which member states face asymmetric shocks. We find that fluctuations of international consumption and unemployment differentials would indeed be reduced by a EUBS. Yet, this stabilization comes at the cost of a more inefficient international allocation of factor inputs following supply and government spending shocks. Thus, whether a EUBS is beneficial depends on the reason for international unemployment differentials.

In our analysis, we particularly focus on the impact of cross-country transfers induced by the scheme and proceed in two steps. First, to build intuition, we develop a simple two-country model of a monetary union with incomplete markets, dynamic distortions, and shocks to technology, government spending, financial-frictions, and monetary policy. Using this model, we show analytically that a transfer which is (directly or indirectly) tied to relative economic performance can increase production efficiency only after some disturbances, while it necessarily reduces efficiency after the remaining shocks. For example, a transfer that flows *towards* the country hit by a contractionary financial-friction shock enhances efficiency in both countries. Rigid prices in combination with a consumption home bias, however, cause the optimal transfer to flow *out* of the country hit by a contractionary supply shock. That is, the direction of the

[1] This is the main argument of the Theory of Optimum Currency Areas (OCA), which was first coined by Mundell (1961) and McKinnon (1963). The OCA literature contrasts the costs of the surrender of flexible exchange rates with the benefits from lower transaction costs.

[2] Dixit and Lambertini (2003), Galí and Perotti (2003), Galí and Monacelli (2008), and Evers (2015), among others, study the conduct of fiscal policy in monetary unions and the introduction of a fiscal authority at the European level. European fiscal unification, however, is currently not feasible from a political perspective. Hence, other mechanisms for automatic stabilization in the face of asymmetric shocks are on the agenda. Kenen (1969) already noted that a transfer scheme might serve such a purpose. The effects of international transfers were subject of the famous discussion between Keynes (1929) and Ohlin (1929).

[3] See, for instance, Blanchard and Tirole (2008), Jung and Kuester (2015), or McKay and Reis (2016).

optimal transfer depends on the level of price rigidities, such that sticky prices give rise to a trade-off between consumption risk sharing and production efficiency.

To explain these findings, we derive deviations from the first-order conditions of the corresponding social-planner solution, so-called 'wedges'. A transfer that flows to the less productive country following supply shocks boosts consumption and thus enhances risk sharing. With rigid prices, however, a relatively large part of the additional demand is spent on inefficiently produced goods, that is domestic goods from the perspective of the receiving country. These increased inefficiencies are visible by an opening of the wedges. We show that this trade-off exists for shocks to technology and government spending, but not for financial-friction shocks (which are equivalent to shocks to household preferences or expectations in the model and take the role of 'pure' demand shocks in our analysis).

Second, to explore where the euro zone stands in this trade-off, we investigate the introduction of a EUBS in a comprehensive two-country DSGE model. The model is carefully calibrated to match key asymmetries between Core and Periphery countries of the EMU. We find, in line with the intuition from the small model, that a EUBS increases international comovements of consumption, output, and unemployment at the cost of aggravating the inefficient distribution of factor inputs after supply and government-spending shocks. The increase in international asymmetries can—by construction—not be eliminated fully by a EUBS: cross-border transfers only flow if unemployment rates are unequal across countries. Overall, results from the quantitative model suggest that a EUBS improves welfare for the Core, while it has almost no impact on Periphery's welfare. With a EUBS that is only active after certain shocks, both countries clearly gain in welfare. Our analysis hence shows that it can be beneficial to trigger the EUBS only after specific demand shocks, such as disturbances to monetary policy or financial-friction shocks. Furthermore, it reinforces calls for structural reforms in case of international productivity asymmetries to avoid a 'zombification' of inefficient sectors.

In the quantitative model, we aim to capture the European situation in detail and consider important aspects of the market structure that are likely to impact on risk sharing. That is, our model incorporates a more detailed goods market structure than other models in the related literature. Intermediate firms in both countries produce differentiated exports goods, which are traded within the union. In addition, we include a non-tradeable intermediate goods sector in each country. Thus, we account for risk sharing (or amplification) via changes in relative purchasing power and movements in the terms of trade (see Chari et al., 2002; Stockman and Tesar, 1995). Moreover, we include a labor market with search-and-matching frictions along the lines of Mortensen and Pissarides (1994) and credible wage bargaining following Hall and Milgrom (2008).

Our paper contributes to the literature that deals with transfers in a monetary union in general settings and to the studies of a specific European unemployment insurance scheme. Farhi and Werning (2017) show that transfer schemes can enhance welfare even if international financial markets are complete. In particular, they analytically demonstrate in a dynamic setting that the optimal transfer flows to countries that experience an improvement in their technology.[4] In

[4]Similarly, using a quantitative model of a monetary union, Evers (2012) finds that a transfer rule that

our analysis, we extend, on the one hand, this analytical finding of Farhi and Werning (2017) to non-technology shocks and non-unitary values of the intertemporal elasticity of substitution, thereby deviating from the 'Cole-Obstfeld case'. On the other hand, we demonstrate that their result no longer holds for a broad range of combinations of price rigidities and the home bias. Furthermore, we show that following specific demand shocks the trade-off between risk sharing and efficiency disappears.

There are only few papers so far that also consider the effects of a European unemployment insurance in dynamic stochastic general equilibrium (DSGE) models. Jung et al. (2020) study a federal unemployment insurance in a DSGE model featuring a union of small open economies and search-and-matching labor markets. Their focus is on a setting where the member states can adjust country-specific labor-market polices in response to the federal insurance scheme. They conclude that coordination of the federal and country-specific schemes could provide insurance against fluctuations and increase welfare. Their analysis abstracts from structural cross-country differences, effects of monetary policy, and trade patterns. Different to them, we neglect political and moral hazard-aspects of international risk sharing.

Moyen et al. (2019) develop a two-country DSGE model with search-and-matching frictions and a cross-country unemployment insurance system. The authors first derive an analytical solution for a tractable one-period version, which abstracts from private bond trading and assumes a homogenous international consumption good. Their focus lies on optimal replacement rates, which turn out to be countercyclical. They also run simulations in a calibrated dynamic version of the model and find that sizeable cross-country transfers in a EUBS can stabilize consumption mainly in the Periphery. The production side of their model, however, does not account for capital formation or a non-tradeable goods sector.

Abrahám et al. (2019) analyze the flows between employment, unemployment, and inactivity in a DSGE model with search frictions in the labor market, which is based on the model of worker flows set out in Krusell et al. (2011). The authors find only limited space for insurance at the European level and stress the role of country-specific labor-market policies. Importantly, their analysis focuses only on the extensive margin of labor supply.

The remaining literature is mostly restricted to simulation exercises based on micro data, using static models that do not account for aggregate dynamics and general-equilibrium effects of the introduction of a EUBS. For example, Beblavý et al. (2017) present a comprehensive report for the European Commission on the design features of a EUBS. The authors document legal and operational implications of different schemes as well as their strengths and weaknesses. Based on micro-simulations, they find that the introduction of a EUBS has potential for automatic stabilization. This is in line with the conclusions of other policy papers, for example Dullien and Fichtner (2013) and Andor et al. (2014). Dolls et al. (2015) and Jara et al. (2016) run quantitative simulations with micro data using the EUROMOD tax-benefit model and find that a EUBS could have provided significant risk sharing during the global financial crisis.

targets regional fiscal deficits enhances consumption risk sharing but has negative welfare effects, while the opposite is true for a rule that targets regional differences in labor income. In the QUEST III model of the euro area, Roeger and Vogel (2017) find that fiscal transfers alone tend to crowd out alternative risk-sharing mechanisms, leading to small stabilization gains.

The remainder of this paper is organized as follows. Section 2 presents the tractable two-country model. In Section 3 we introduce the quantitative model, with the calibration and model simulations in Section 4. We discuss the effects of an introduction of a EUBS in Section 5 and resulting policy implications in Section 6. Section 7 concludes. Data sources, a detailed description of the analytical model, and all proofs are in the appendix.

2 Analytical model

In this section, we derive a simple and analytically tractable model of a monetary union, consisting of two symmetric countries. Only a fraction of firms can change prices in reaction to shocks in the same period (as in Fischer, 1977). In this setup, agents in both countries expect to arrive at a new steady state in the period after a temporary shock (similar to Obstfeld and Rogoff, 1995). We consider four disturbances: a supply shock (technological innovations), a 'pure' demand shock (changes in financial frictions, expectations or preferences), an expansionary shock that reduces available resources for consumption (disturbances to government spending), and a union-wide monetary-policy shock. These shocks cover a broad enough range of developments to arrive at our main insights regarding the role of transfers in a monetary union. In particular, we analytically investigate whether international transfers can mitigate the negative effects of the two dynamic distortions in the economy, namely rigid prices cum monetary union and incomplete markets. We will then show that the intuition obtained in this simplified version of the full model developed in Section 3 carries over to the large model featuring a European unemployment benefit system.

2.1 Setup

We will outline only the domestic side of the model, the Home economy, with symmetric structures existing in the Foreign economy. Foreign variables are denoted with an asterisk. Both countries are populated by a representative household each. The household maximizes lifetime utility

$$\sum_{t=0}^{\infty} \beta^t \mathcal{U}_t,$$

with the instantaneous utility function

$$\mathcal{U}_t = \ln C_t - \frac{H_t^2}{2},$$

where C_t is consumption and H_t are hours worked in the production of the domestic good. The corresponding budget constraint is

$$W_t H_t + \Theta_t + \Upsilon_t = P_t C_t + R_t^{-1} \Theta_{t+1} + T_t + P_{A,t} G_t,$$

with W_t denoting the nominal wage, Υ_t stands for potential profits or losses of the domestic firms, and T_t is a cross-country transfer flowing to Foreign (if positive) or Home (if negative), i.e., $T_t = -T_t^*$. The household can engage in lending or borrowing international bonds Θ_{t+1}, which pay one dollar in period $t+1$ and cost R_t^{-1} in period t. The household also has to pay lump-sum taxes that are then used for wasteful government spending G_t, which falls on domestic goods with the price index $P_{A,t}$. Government spending follows a white noise process. In the above budget constraint, the balanced budget rule of the government is already inserted. Finally, P_t is the price of the final consumption good in the domestic market. This consumption good consists of a domestically produced good, A_t, and an imported good, B_t, as follows

$$C_t = \left[\omega^{\frac{1}{\sigma}} A_t^{\frac{\sigma-1}{\sigma}} + (1-\omega)^{\frac{1}{\sigma}} B_t^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}}, \tag{1}$$

with ω determining the home bias, i.e., the fraction of total expenditure falling on domestic goods in case of equal prices. We assume that $0.5 < \omega < 1$, such that we have open economies with at least a small degree of home bias. The parameter $\sigma \geq 1$ is the trade-price elasticity. As standard in models with monopolistic competition, A_t and B_t are constant-elasticity-of-substitution bundles of a continuum of domestically produced and imported varieties, respectively. Given that demand for each variety plays only a marginal role for the linearized system analyzed below, we omit a more detailed discussion. A unit mass of domestic firms sell the amount A_t to the domestic market and export A_t^* to the Foreign economy. Total output Y_t is produced according to a simple aggregate production function with labor and technology Z_t as the only input factors, where technology follows a white-noise process with a mean of unity,

$$Y_t = Z_t H_t = A_t + A_t^*.$$

For our analysis, we assume that both economies are in a steady state up until period t. Price setting of monopolistic-competitive firms is then constrained in the sense that only a random fraction ξ with $0 \leq \xi \leq 1$ of all firms in both countries can set a new price after observing potential shocks in period t. All firms can schedule new prices for the period $t+1$. We hence obtain the following equations determining the price of the domestic good in period t and the expected price in $t+1$

$$P_{A,t} = \xi(\mathcal{M} W_t/Z_t) + (1-\xi)P_{A,t-1}, \qquad E_t P_{A,t+1} = \mathcal{M} E_t W_{t+1}/Z_{t+1},$$

where $P_{A,t-1}$ is the steady-state price, as we only consider shocks occurring in period t. The optimal markup $\mathcal{M}$ depends on the elasticity of substitution between the varieties produced by the individual firms.

Additional to the technology and government-spending shock, we also introduce a white-noise financial-friction shock Δ_t. Following Smets and Wouters (2007) and Christiano et al. (2015), this reduced-form shock is introduced as a 'consumption wedge' in the first-order condition regarding savings, i.e., the Euler equation reads as

$$\mathcal{U}_{C,t} = \beta E_t \mathcal{U}_{C,t+1} \frac{R_t \Delta_t}{\Pi_{t+1}},$$

where $\mathcal{U}_{C,t}$ and Π_t refer to marginal utility of consumption and inflation, respectively.

Fisher (2015) shows that Δ_t can be interpreted as a disturbance to the demand for safe and liquid assets. Since the Euler equation determines current consumption based on the interest rate, the discount factor, and expected future consumption, it can equivalently represent a shock to household's time preferences or their expectations. Our preferred interpretation, however, is a wedge between the nominal central-bank rate and the one offered to households.[5] A positive spread, i.e., $\Delta_t > 1$, lowers current consumption, all else equal. Ultimately, it serves as pure demand shock in our context: given fundamentals, it changes demand for consumption goods. In order to close the model, we need to pin down the union-wide real interest rate $E_t R_t \overline{P}_t / \overline{P}_{t+1}$ between the period of the shock and the following period, where $\overline{P}_t$ is the union-wide price index. We assume that the central bank can set this rate, simplifying the solution. The corresponding nominal rate can then be backed out via a Taylor-type feedback rule.

We define deviations from the first-order conditions of the corresponding social-planner solution regarding the optimal labor input as 'wedges', see also Farhi and Werning (2017). However, we define the wedges in a slightly different way compared to these authors and introduce several labor wedges. First, the difference between the marginal disutility from producing the Home good and the marginal utility derived from its consumption in the Home economy (the 'Home@Home' wedge), the difference between these costs and the marginal utility derived from the consumption of the Home good in the Foreign economy (the 'Home@Foreign' wedge), and the corresponding Foreign wedges (called 'Foreign@Foreign' and 'Foreign@Home' wedges). Second, we combine the Home@Home and the Home@Foreign wedges by calculating a quantity-weighted average of the marginal utilities derived from the Home good in both countries to obtain an overall Home labor wedge; similarly for Foreign. Finally, we also calculate the deviations from the so-called risk-sharing condition (Backus and Smith, 1993). This gives us the following wedges, with corresponding labor wedges for Foreign (all variables refer to the period of the shock, time indices are omitted for the sake of exposition):

$$\begin{aligned}
&\text{Home@Home:} && \frac{-\mathcal{U}_H}{MP} - \mathcal{U}_C C_A \\
&\text{Home@Foreign:} && \frac{-\mathcal{U}_H}{MP} - \mathcal{U}^*_C C^*_A \\
&\text{Overall Home:} && \frac{-\mathcal{U}_H}{MP} - \left[\frac{A}{Y}\mathcal{U}_C^\sigma C_A^\sigma + \frac{A^*}{Y}\mathcal{U}_C^{*\sigma} C_A^{*\sigma}\right]^{\frac{1}{\sigma}} \\
&\text{Risk Sharing:} && \frac{\mathcal{U}_C}{\mathcal{U}^*_C} - \frac{P}{P^*},
\end{aligned}$$

where C_A denotes the derivative of the consumption bundle (1) with respect to good A. MP stands for the marginal product of labor and $\mathcal{U}_H$ for the marginal disutility of labor. The wedges are defined such that a positive value corresponds either to 'too large' values of hours worked and production, relative to the marginal utility derived from consuming the produced goods,

[5] As such it is related to the loan-deposit spread. The interpretation plays a role for the dynamics in the complete-markets case and the determination of the risk-sharing condition. With our interpretation, perfect risk sharing is achieved if the standard risk-sharing condition is fulfilled, see below.

or to 'too high' consumption in the Foreign country in the case of the risk-sharing wedge. In the social-planner solution, these wedges are zero. Because of the frictions in the economy, this is not the case in the decentralized equilibrium. Below we will explore if a transfer scheme between the two countries can alleviate the distortions introduced by the dynamic frictions.[6] To this end, we analytically solve the model by linearizing the relevant first-order conditions around the symmetric, zero-inflation steady state. The resulting linear equations are listed in Appendix A. We only consider Foreign shocks throughout, with symmetric results for Home shocks. For demonstrational purposes, we set $\sigma = 1$ in the main text. The proofs for all propositions and Lemma 1 for $\sigma \geq 1$ can also be found in Appendix A.[7] The lemma and the propositions are valid for both cases.

Because it will be important for the interpretation of the direction of the transfer, we first define the terms 'boom' and 'recession' countries before analyzing the effects of the individual shocks. Specifically, we define the recession (boom) country to be the one with a relatively low (high) output, compared to the other country (before policy interventions). This definition is different to that in Farhi and Werning (2017), who define the recession country to be the one with a negative output gap. For example, experiencing a negative technology shock leads to falling output but a positive output gap under rigid prices. In our definition, such a country is labelled recession country, in line with the terminology in policy debates. With this definition, we obtain the following lemma.[8]

Lemma 1 (Boom and recession countries) *Following negative Foreign technology or government-spending shocks, Foreign is a 'recession country', while Home is a 'boom country' (with fully rigid prices, outputs are unaffected after technology shocks). After financial-friction shocks, it depends on parameter values whether Foreign is a recession or boom country.*

Proof for $\sigma = 1$: The difference between Home and Foreign output in the period of the shock is

$$y_t - y_t^* = -\frac{2\xi}{1+\xi} z_t^* - \frac{1}{1+\xi} g_t^* - \frac{\xi - 2\omega + 1}{(r_s + 1)(1+\xi)} \hat{\Delta}_t^*,$$

where lower-case letters, or $\hat{\Delta}_t$ in the case of Δ_t, denote percentage deviations from steady state. The exceptions are t_t and g_t^*, which equal the transfer T_t and Foreign government spending over steady-state output of a single country, as well as r_s, the gross steady-state interest rate on bond holdings (r_t is the percentage deviation from this value). This difference increases after negative technology or government-spending shocks in Foreign. Only with fully

[6] Due to monopolistic competition, labor wedges are not zero in steady state. To combat this distortion, however, other instruments than dynamic cross-country transfers should be employed. For this reason and to simplify the description of the analysis, although not entirely correct, we refer to the situation with wedges at their steady-state values as optimal throughout.

[7] For very low values of σ (below unity), the effects of a cross-country transfer are mirrored. However, similar to what will be shown for $\sigma \geq 1$, the transfer that closes the labor wedges changes direction depending on the value of ξ.

[8] Note that a positive financial-friction shock Δ^* in Foreign is always contractionary for Foreign. If prices are relatively flexible (high ξ) and/or the consumption home bias is low (low ω), however, Periphery output falls by less compared to Home, due to labor-supply and expenditure-switching effects.

rigid prices ($\xi = 0$), outputs are unaffected after technology shocks. For contractionary Foreign financial-friction shocks ($\Delta^* > 0$), the reaction depends on whether ξ is larger (output difference decreases) or smaller (difference increases) than $2\omega - 1$. ■

2.2 Supply shocks

In this section, we focus on Foreign supply shocks, i.e., unexpected changes in Foreign technology in period t, such that $g_t^* = \hat{\Delta}_t^* = 0$. Section 2.3 deals with demand disturbances.

2.2.1 Analytical results

With $\sigma = 1$, we obtain the solutions for the overall labor wedges and the risk-sharing wedge in the period of the shock as

$$\text{Overall Home:} \quad -\frac{2\xi}{1+\xi} z_t^* + \frac{\xi - 2\omega + 1}{(1+\xi)(1-\omega)} \frac{r_s}{1+r_s} t_t - 2r_t \tag{2}$$

$$\text{Overall Foreign:} \quad -\frac{2}{1+\xi} z_t^* - \frac{\xi - 2\omega + 1}{(1+\xi)(1-\omega)} \frac{r_s}{1+r_s} t_t - 2r_t \tag{3}$$

$$\text{Risk Sharing:} \quad \frac{1}{1-\omega} \frac{r_s}{1+r_s} t_t. \tag{4}$$

Note the differential impact of Foreign technology on the Home and Foreign labor wedges. Assume for illustrational purposes that $\xi = 0$, that is, completely fixed prices. After a deterioration of Foreign technology z_t^*, the Home labor wedge remains constant: since prices do not move, consumption and production patterns are left unchanged. In Foreign, however, the reduction in z_t^* calls for a lower labor input, seen from an efficiency perspective. Since prices stay constant, this reduction does not take place: the Foreign labor wedge becomes positive. Put differently, marginal disutility of working is too high relative to the utility derived from consumption of the produced goods. As also visible, the transfer that closes the risk-sharing gap for $\sigma = 1$ is zero (Cole and Obstfeld, 1991). Hence, the outcome without a transfer corresponds to the complete-market allocation in this case. It is then straightforward to derive the following propositions.

Proposition 1 (Flexible Prices) *In the case of flexible prices ($\xi = 1$), overall labor wedges and the risk-sharing wedge can be closed following technology shocks by setting the real interest rate to $\check{r}_t = -z_t^*/2$. The corresponding transfer is either zero ($\sigma = 1$) or flows to the recession country ($\sigma > 1$).*

Proof for $\sigma = 1$: Set $\xi = 1$ in equations (2)-(4) with $t_t = 0$ to obtain

$$\text{Overall Home:} \quad -z_t^* - 2r_t$$

$$\text{Overall Foreign:} \quad -z_t^* - 2r_t$$

$$\text{Risk Sharing:} \quad 0.$$

■

If prices are sticky, matters become more complicated. At most two of the three wedges can then be closed simultaneously.[9]

Proposition 2 (Rigid Prices) *In the case of rigid prices ($0 \leq \xi < 1$), a trade-off between closing the overall labor wedges and the risk-sharing wedge arises following technology shocks, as no combination of the transfer and the real interest rate can close both overall labor wedges and the risk-sharing wedge simultaneously.*

Proof for $\sigma = 1$: If $\xi \neq 2\omega - 1$, solve for the value of $\check{t}_t$ and $\check{r}_t$ that close the overall labor wedges of Home and Foreign. Inserting these values into the risk-sharing wedge yields

$$\text{Risk sharing:} \qquad \frac{\xi - 1}{\xi - 2\omega + 1}.$$

If $\xi = 2\omega - 1$, the transfer has no impact on the overall labor wedges. The risk-sharing wedge is then closed for $t_t = 0$ and monetary policy can close only one labor wedge, see equations (2)-(4). ■

In contrast to the flexible-price case, the labor-wedge-closing transfer may now flow *away* from the recession country.

Proposition 3a (Direction of wedge-closing Transfer) *For weak price rigidities (high ξ), the transfer that closes both labor wedges flows from the boom country to the recession country following technology shocks. For strong price rigidities (low ξ), the direction of this transfer reverses. This opens the risk-sharing wedge (for $\sigma > 1$: opens the risk-sharing wedge even further). The stronger the home bias (high ω), the weaker the price rigidities need to be for the transfer to reverse.*

Proof for $\sigma = 1$: For $\xi \neq 2\omega - 1$, the transfer that closes both labor wedges, given that the real interest rate equals $\check{r}_t = -z_t^*/2$, results as

$$\check{t}_t = -\frac{(1-\omega)(1-\xi)}{\xi - 2\omega + 1} \frac{1 + r_s}{r_s} z_t^*.$$

For $\xi > (<) 2\omega - 1$, we obtain $\check{t} > (<) 0$ for $z_t^* < 0$. For $\xi = 2\omega - 1$, we get $\check{t}_t = 0$. ■

We can furthermore derive the optimal transfer by maximizing a second-order approximation of the equally-weighted sum of country-specific welfare, where welfare of a single country is its utility in the period of the shock plus the discounted expected utility of all following periods.[10]

[9] A closely related observation was made by Farhi and Werning (2017) in a similar model: under complete markets, which imply a closed risk-sharing wedge, the constrained optimum is generally not reached. However, below we show that this not the case for specific demand shocks.

[10] Note that the solution to this problem does not necessarily correspond to the social-planer outcome, as the effects of the transfer depend on (distorted) prices. Put differently, it might be not feasible to implement the social-planner solution with the transfer alone.

This measure hence takes the future effects of today's transfer into account and uses a non-linear approximation of the welfare function. Details and the proof of the following Proposition 3b are given in Appendix A. The approach confirms that also the welfare-maximizing transfer changes direction for high price rigidities.[11]

Proposition 3b (Direction of Optimal Transfer) *With flexible prices, the transfer that maximizes equally weighted welfare flows from the boom country to the recession country following technology shocks. With rigid prices, the direction of this transfer reverses.*

To build intuition for the simulation of the large model in Section 3, however, we are primarily interested in the effects on efficiency and risk sharing in the period of the shock (Proposition 3a). Finally, the following proposition is helpful for the same purpose.

Proposition 4 (Reason for Transfer Reversal) *The labor wedge that corresponds to the domestic good consumed in the recession country (Foreign@Foreign, if Foreign is the recession country) depends negatively on domestic technology and positively on transfers towards the recession country.*

Proof for $\sigma = 1$: Assume, without loss of generality, that Foreign is the recession country. The Foreign@Foreign wedge results as

$$\text{Foreign@Foreign:} \qquad \frac{\omega(1-\xi)}{(1-\omega)(1+\xi)} \frac{r_s}{1+r_s} t_t - \frac{2}{1+\xi} z_t^* - 2r_t.$$

Remember that t_t is positive if the transfer flows to Foreign. ■

This shows that a negative technology shock at Foreign opens up the Foreign@Foreign wedge: since prices are rigid, they fail to reflect the true costs of production. Thus, Foreign households consume an inefficiently large amount of the Foreign good, given the disutility that its production causes. With at least some price stickiness, a transfer to Foreign tends to open the Foreign@Foreign wedge even further, as Foreign consumption of the Foreign good rises. At the same time, Home consumers spend less on the Foreign good, which exerts a downward pressure on the Foreign@Home wedge. For a high home bias (high ω), the first effect is large and the second small. Additionally, with high price stickiness (low ξ), relative prices change little and

[11] The correspondence between Proposition 3a and 3b is in line with the finding of Farhi and Werning (2017) that at a constrained Pareto-efficient equilibrium, labor wedges are zero (in the absence of uncertainty). Yet, the content of Propositions 3a and 3b, i.e., the transfer reversal, seems to stand in contradiction to Farhi and Werning (2017), who do not find such a reversal. In their dynamic model, which comes closest to our model since it features production in a tradeable sector, they derive analytical results for the cases of fully rigid prices ($\xi = 0$, translated to our notation) and complete home bias ($\omega = 1$), both for $\sigma = 1$ and technology shocks only. Our derivations confirm their finding, extended to $\sigma \geq 1$, that the transfer flows to the country with a negative output gap, as $\xi < 2\omega - 1$ holds in both cases. Moreover, we generalize this finding for different types of shocks below. Deviating from these extreme parameterizations, however, reveals that the transfer may flow the other way around.

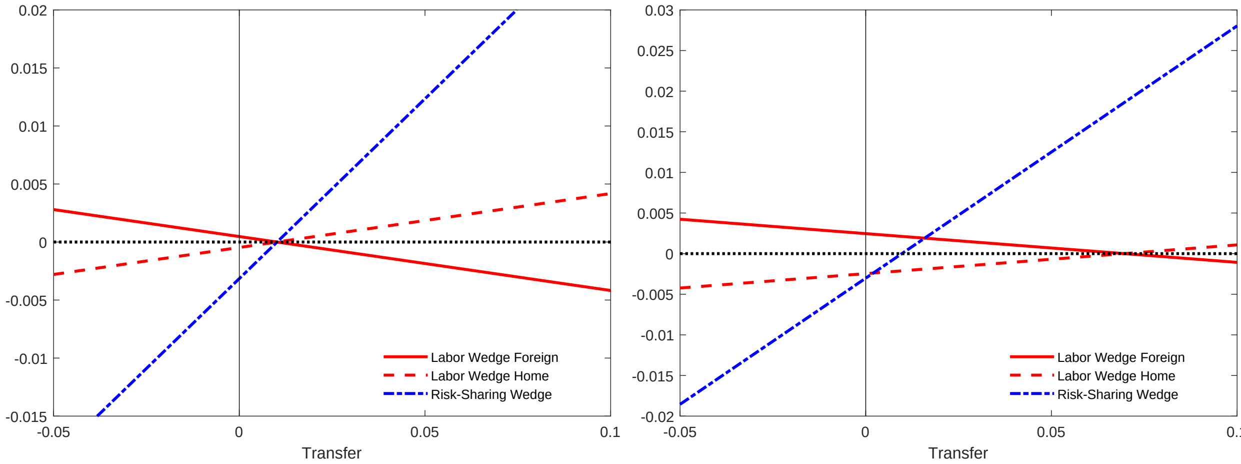

Figure 1: Wedges for flexible prices and moderate price rigidities
Notes: Flexible prices ($\xi = 1$, left) and moderate price rigidities ($\xi = 0.9$, right).

expenditure switching away from the Foreign good is small. Taken together, the opening of the Foreign@Foreign wedge following a transfer towards the recession country dominates the reaction of its overall labor wedge if price rigidities and the home bias are high.

2.2.2 Numerical examples

In this section, we illustrate the above findings graphically in a stylized manner. To generate figures 1 - 2, we set $\omega = 0.85$, i.e., a relatively high but realistic home bias. The discount rate β is 0.9, while σ, the trade-price elasticity, is set to two. The steady-state price markup over marginal costs, needed for the welfare calculations, is 20%. We simulate a temporary shock of -5% to Foreign technology z_t^* for all figures. The central bank adjusts the nominal interest rate in a way that the real interest rate equals $r_t = -z_t^*/2$, such that a transfer can close both overall labor wedges simultaneously in the case of flexible prices. The x-axes of all figures measure t_t, the lump-sum transfer from Home to Foreign over steady-state GDP of one country in the period of the shock. Transfers in all following periods are zero throughout; also technology in Foreign returns to its steady-state level. All figures depict period t, the period of the shock.
The left-hand panel of Figure 1 shows the case of flexible prices. Given that $\sigma \neq 1$, together with the assumption of incomplete markets, the risk-sharing condition is violated in case of no transfers. The fall in z_t^* causes firms in the Foreign economy to increase prices. If σ was equal to unity, quantities would adjust such that the risk-sharing condition would be fulfilled without a transfer (Cole and Obstfeld, 1991). Since $\sigma > 1$, however, quantities react more strongly to this price change, such that Home obtains a relatively large share of world expenditure. Seen from a risk-sharing perspective, its marginal utility of consumption is hence too low; the risk-sharing wedge is negative. Shifting resources from Home to Foreign increases Home's marginal utility of consumption. At the point of a closed risk-sharing wedge, utility costs of production are in line with the associated gains in utility; both labor wedges are closed. That is, implementing the same transfer that would result from the trade of a full set of state-contingent securities closes all wedges simultaneously, replicating the complete-markets solution.

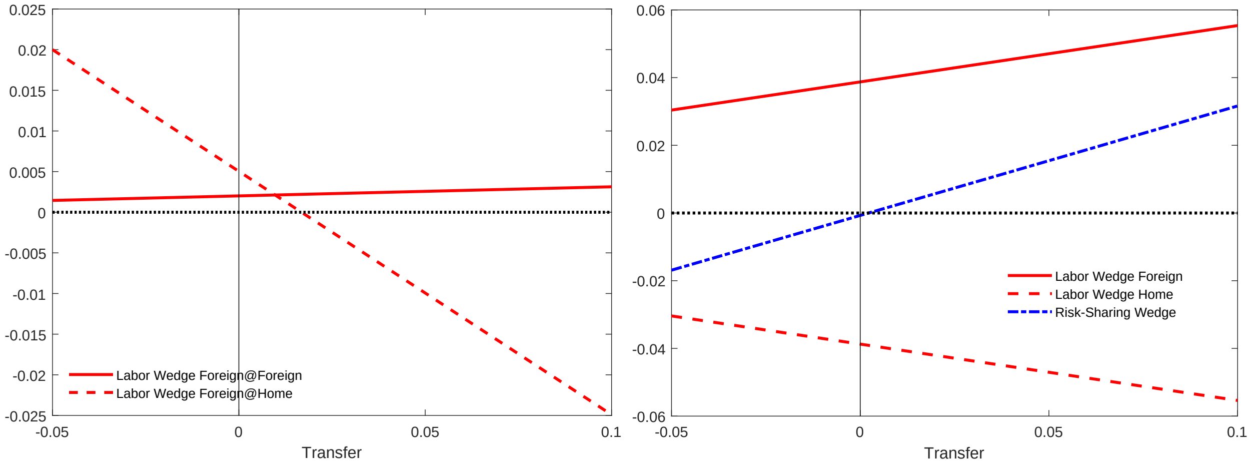

Figure 2: Wedges for moderate and strong price rigidities
Notes: Individual wedges of Foreign good for moderate price rigidities ($\xi = 0.9$, left) and labor and risk-sharing wedges for strong price rigidities ($\xi = 0.1$, right).

This, however, is no longer possible with rigid prices. The right-hand panel of Figure 1 depicts the outcome under relatively modest price rigidities ($\xi = 0.9$). As visible, a trade-off between closing the labor wedges (efficient allocation of production) and the risk-sharing wedge (efficient distribution of consumption) obtains. The intuition is straightforward. Closing the risk-sharing wedge means that relative marginal utilities align with the relative prices of purchasing consumption in both countries. Given that these prices no longer move one-to-one with the disutility of producing consumption goods, production is allocated inefficiently even with a closed risk-sharing wedge. In particular, the Foreign price is 'too low' at this point, in the sense that, due to price rigidities, it rises by less than the increase in marginal costs. Hence, a positive Foreign labor wedge obtains. Implementing a larger transfer closes the labor wedges, but violates the risk-sharing condition. The overall Foreign labor wedge is closed primarily because the transfer decreases Home's consumption level, raising the marginal utility derived from consuming the Foreign good. This reduces the Foreign@Home wedge, see the left-hand panel of Figure 2. Because of the home bias, Foreign spends the largest part of the transfer on the Foreign good. Thus, its marginal utility of consuming this good falls and production increases, exerting an upward pressure on the Foreign@Foreign wedge. However, the resulting increase in Foreign's price has a dampening impact on the surge in demand. Hence, the wedge rises slowly compared to the fall in the Foreign@Home wedge and the overall Foreign labor wedge diminishes until overall consumption utility from the Foreign good equals its costs of production.

Matters become even worse for higher price rigidities. First, without a transfer, depicted in the right-hand panel of Figure 2, labor wedges open up much wider, given the muted reaction of the relative price to the change in technology.[12] Second, the effect of the transfer reverses.

[12] At the same time, the risk-sharing wedge is smaller. Consider the case of completely fixed prices as an example. Expenditure and hence income would be unaffected by the technology shock, such that consumption levels and the price ratio would remain at their steady-state values. Obviously, production would not be allocated efficiently in this case, visible in open labor wedges.

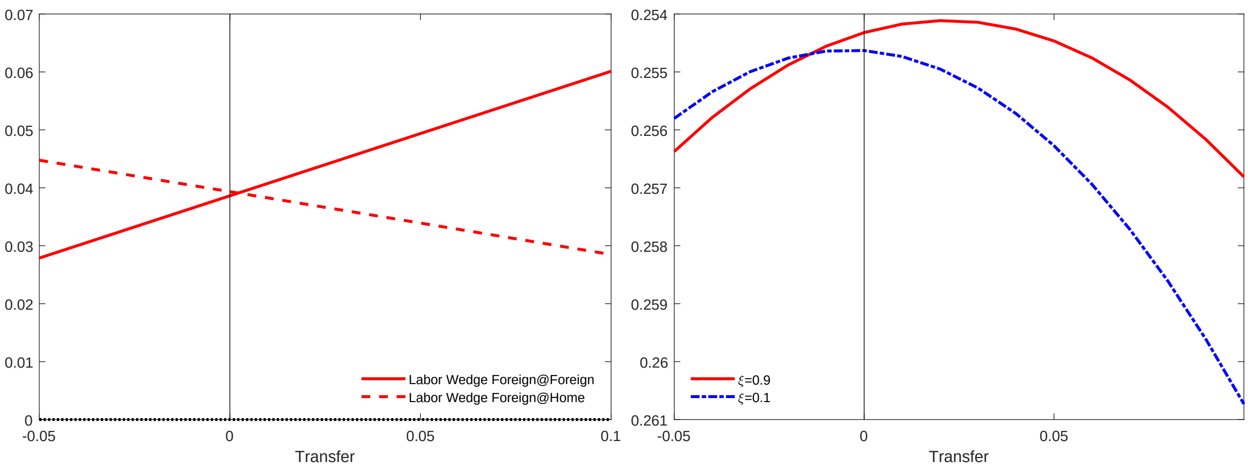

Figure 3: Wedges for strong price rigidities and welfare
Notes: Individual wedges of Foreign good with for strong price rigidities ($\xi = 0.1$, left), and equally-weighted welfare losses (right, inverted y-axis).

A transfer towards Foreign still increases the marginal consumption utility of Home, which, as before, reduces the Foreign@Home wedge, see the left-hand panel of Figure 3. Yet, this improvement is overturned by a counteracting effect in the Foreign country. The transfer to Foreign is again spent primarily on the Foreign good. This time, however, the muted price reaction leads to a more pronounced surge in demand. Production rises strongly while Foreign's marginal utility of consumption drops, such that the further opening in the Foreign@Foreign wedge dominates the overall Foreign labor wedge. Thus, labor wedges start to close if the transfer is conducted *away* from the country with the negative technology shock. The risk-sharing wedge, however, opens up even further in this case, aggravating the described trade-off. As a result, while welfare (measured here by the equally-weighted discounted sum of Home and Foreign current and future utilities) increases with a transfer towards Foreign after a negative technology shock in that country under relatively flexible prices, the opposite is true under relatively rigid prices. This is depicted in the right-hand panel of Figure 3, which shows welfare losses as a percentage of steady-state consumption.[13] Both countries are harmed by a lower Foreign technology, Foreign more than Home. A transfer to the Foreign country always harms Home and benefits Foreign, but joint welfare effects depend on parameter values as described. To summarize, our analytical model shows that raising allocative efficiency by usage of an international transfer scheme may actually require transfers that are opposite of what a EUBS would imply, if unemployment is relatively higher in the recession country. If home bias and sticky prices, both realistic features, are prevalent, a transfer to the country with a temporarily inferior production technology may actually decrease efficiency and welfare, although bringing consumption levels closer to each other.

[13] Calculations for the figure are based on inserting first-order approximations into the non-linear welfare functions. Expected transfers are assumed to be zero from period $t+1$ onwards, as the economies are expected to reach the new steady state then and we rule out steady-state transfers. Welfare effects are naturally small, as we are measuring the effects of a one-time shock and transfer by a permanent reduction in consumption. We invert the y-axis, such that a maximum denotes minimal welfare losses.

2.3 Demand shocks

To contrast the results for supply shocks with those for demand shocks, we next analyze the effects of financial-friction and government-spending shocks. Because the former introduce a consumption wedge in the Euler equation, they can be seen as 'pure' demand shocks. We show in Section 2.3.1 that a combination of monetary policy and transfer policy can perfectly offset the effects of such a shock. Although government-spending shocks are in principle demand shocks as well, they additionally open up labor wedges because government spending is assumed to be wasteful. We demonstrate in Section 2.3.2 that this feature introduces the same trade-off as for supply shocks, but with opposite signs. Finally, we look at the effects of a union-wide monetary-policy shock.

2.3.1 Financial-friction shock

A contractionary financial-friction shock ($\hat{\Delta}_t^* > 0$) in Foreign reduces Foreign consumption and output for given fundamentals and interest rates. International economic policy can fend off its effects by setting union-wide monetary policy to adjust average activity in both countries and by using the transfer to offset the asymmetric effects.

Proposition 5 (Financial-friction Shock) *The risk-sharing wedge and both overall labor wedges can be closed simultaneously by implementing a transfer that flows towards country experiencing a contractionary financial-friction shock ($\Delta^* > 0$), supported by an appropriate monetary-policy response. This result holds independently of the degree of price rigidities.*

Proof for $\sigma = 1$: For $g_t^* = z_t^* = 0$, the wedges result as

$$\begin{aligned}
&\text{Overall Home:} && -\left[1 + \frac{\xi - 2\omega + 1}{(1+\xi)(1+r_s)}\right]\hat{\Delta}_t^* + \frac{\xi - 2\omega + 1}{(1+\xi)(1-\omega)}\frac{r_s}{1+r_s}t_t - 2r_t \\
&\text{Overall Foreign:} && -\left[1 - \frac{\xi - 2\omega + 1}{(1+\xi)(1+r_s)}\right]\hat{\Delta}_t^* - \frac{\xi - 2\omega + 1}{(1+\xi)(1-\omega)}\frac{r_s}{1+r_s}t_t - 2r_t \\
&\text{Risk Sharing:} && -\frac{1}{1+r_s}\hat{\Delta}_t^* + \frac{1}{1-\omega}\frac{r_s}{1+r_s}t_t.
\end{aligned}$$

All wedges can be closed by setting

$$\begin{aligned}
\check{r}_t &= -\frac{1}{2}\hat{\Delta}_t^* \\
\check{t}_t &= \frac{1-\omega}{r_s}\hat{\Delta}_t^*,
\end{aligned}$$

where the derivative of t_t with respect to $\hat{\Delta}_t^*$ is positive. ■

2.3.2 Government-spending shock

A positive government-spending shock increases demand and wastes the produced goods. It has therefore different welfare implications compared to a 'pure' demand shock, discussed above.

Specifically, the Foreign labor wedge opens up following a positive government-spending shock in Foreign, even if prices are fully flexible. Since the produced goods are wasted, Foreign workers work 'too much', given the corresponding low marginal utility of consumption in Home and Foreign. This resembles the situation after a negative technology shock. For flexible prices, the transfer that closes the wedge flows towards Foreign. The strong price responses lets Home's marginal utility of consuming the Foreign good increase without raising production too much. That is, the transfer flows towards the *boom* country. For relatively high price rigidities, however, the wedge-closing (and the optimal) transfer reverses out of the same logic as for supply shocks. Rigid prices limit the substitution effect, such that a transfer away from Foreign reduces strongly Foreign production, and hence the disutility of working. A transfer towards Foreign would raise production in Foreign considerably, although workers already work 'too much.' In both cases, the risk-sharing wedge is opened by the usage of a transfer. The following propositions summarizes the results.

Proposition 6 (Government-Spending Shock) *In case of a government-spending shock, overall labor wedges and the risk-sharing wedge cannot be closed simultaneously by setting the real interest rate and implementing a cross-country transfer, independently of price rigidities. The transfer that is needed to close both labor wedges flows to the country experiencing a positive government-spending shock (boom country), or away from this country in the case of high price rigidities (low ξ). The relevant threshold for the price rigidity is lower for high values of the home bias ω.*

Proof for $\sigma = 1$: In case of $z_t^* = \hat{\Delta}_t^* = 0$, the wedges are

$$\text{Overall Home:} \quad \frac{\xi}{1+\xi} g_t^* + \frac{\xi - 2\omega + 1}{(1+\xi)(1-\omega)} \frac{r_s}{1+r_s} t_t - 2r_t \tag{5}$$

$$\text{Overall Foreign:} \quad \frac{\xi+2}{1+\xi} g_t^* - \frac{\xi - 2\omega + 1}{(1+\xi)(1-\omega)} \frac{r_s}{1+r_s} t_t - 2r_t \tag{6}$$

$$\text{Risk Sharing:} \quad \frac{1}{1-\omega} \frac{r_s}{1+r_s} t_t, \tag{7}$$

such that the risk-sharing wedge is zero without a transfer and the overall Foreign labor wedge is positive in case of $g_t^* > 0$, independently of the value of ξ. Now solve (5)-(6) for the transfer and real interest rate that close both labor wedges. This results in

$$\check{r}_t = \frac{g_t^*}{2}$$
$$\check{t}_t = \frac{1-\omega}{\xi - 2\omega + 1} \frac{1+r_s}{r_s} g_t^*.$$

For $\xi \neq 2\omega - 1$, the risk-sharing wedge is then

$$\text{Risk Sharing:} \quad \frac{1}{\xi - 2\omega + 1} g_t^*.$$

The transfer $\check{t}_t$ that is, in addition to the given value of the real interest rate, required to close the labor wedges for $g_t^* > 0$ is positive (negative) if $\xi > (<) 2\omega - 1$. For $2\omega - 1 = \xi$, the transfer has no impact on the labor wedges, such that at least one remains open. ■

2.3.3 Monetary-policy shocks

Given the symmetry of the model, monetary-policy shocks have an identical effect on Home and Foreign.

Proposition 7 (Monetary-policy Shock) *Following monetary-policy shocks (autonomous changes in r_t), labor wedges in Home and Foreign open and have the same sign, while the risk-sharing wedge remains closed. A transfer can close only one of the two labor wedges, but opens the risk-sharing wedge and the remaining labor wedge even further.*

Proof for $\sigma = 1$: In case of $z_t^* = \hat{\Delta}_t^* = g_t^* = 0$, the wedges are

$$\text{Overall Home:} \quad \frac{\xi - 2\omega + 1}{(1+\xi)(1-\omega)} \frac{r_s}{1+r_s} t_t - 2r_t \tag{8}$$

$$\text{Overall Foreign:} \quad -\frac{\xi - 2\omega + 1}{(1+\xi)(1-\omega)} \frac{r_s}{1+r_s} t_t - 2r_t \tag{9}$$

$$\text{Risk Sharing:} \quad \frac{1}{1-\omega} \frac{r_s}{1+r_s} t_t. \tag{10}$$

■

2.4 Transfer schemes

Combining the analytical results of the previous sections with the shock reactions of other cross-country differences gives rise to the following proposition.

Proposition 8 (Simple International Transfer Schemes) *An international transfer that flows to the country with the relatively lower shock response of either output, the output gap, consumption, or hours worked opens at least one labor wedge following at least one shock for a certain degree of price rigidities, even in combination with a suitable monetary policy response. Specifically, a transfer scheme tied to the relative output response opens at least one labor wedge following some shock(s), irrespective of price rigidities. A scheme tied to the relative output-gap response reduces all labor wedges following all shocks, but only in the case of high price rigidities. A scheme tied to the relative consumption response reduces all labor wedges following all shocks, but only in the case of low price rigidities. A scheme tied to the relative response of hours worked reduces all labor wedges following all shocks, but only in the case of high price rigidities and a low trade-price elasticity.*

Proof for $\sigma = 1$: Propositions 3a, 5, 6, 7 show that for low (high) price rigidities, a transfer that reduces both labor wedges, in combination with a suitable monetary-policy response, flows to Foreign if $z_t^* <(>)0$, $g_t^* >(<)0$ or $\hat{\Delta}_t^* > 0$. Low (high) price rigidities are present if $\xi > (<) 2\omega - 1$. The direction of such a transfer in response to $z_t^* < 0$, $g_t^* > 0$, and $\hat{\Delta}_t^* > 0$ for low (high) price rigidities can hence be summarized by $\{+,+,+\}$ ($\{-,-,+\}$). The responses of relative variables are given in Lemma 1 and below (for $t_t = 0$, i.e., pre-transfer).

$$\begin{aligned}
\bar{y}_t - \bar{y}_t^* &= \frac{1-\xi}{1+\xi} z_t^* - \frac{1-\xi}{2(1+\xi)} g_t^* + \frac{(1-\xi)\omega}{(1+r_s)(1+\xi)} \hat{\Delta}_t^* \\
c_t - c_t^* &= -2\xi \frac{2\omega - 1}{1+\xi} z_t^* + \xi \frac{2\omega-1}{1+\xi} g_t^* + \frac{1+\xi[1-2\omega(2\omega-1)]}{(1+r_s)(1+\xi)} \hat{\Delta}_t^* \\
h_t - h_t^* &= \frac{1-\xi}{1+\xi} z_t^* - \frac{1}{1+\xi} g_t^* - \frac{\xi - 2\omega + 1}{(1+r_s)(1+\xi)} \hat{\Delta}_t^*,
\end{aligned}$$

where $\bar{y}_t$ is the output gap, i.e., the difference between output under flexible ($\xi = 1$) and rigid prices ($\xi < 1$). The derivative of $c_t - c_t^*$ w.r.t. $\hat{\Delta}^*$ is positive, while the derivative of $h_t - h_t^*$ w.r.t. $\hat{\Delta}^*$ is positive (negative) if $\xi < (>) 2\omega - 1$. That is, the direction of the transfer induced by the reaction of $y_t - y_t^*$ to $z_t^* < 0$, $g_t^* > 0$, and $\hat{\Delta}_t^* > 0$ for low (high) price rigidities can be summarized by $\{+,-,-\}$ ($\{+,-,+\}$), the reaction of $\bar{y}_t - \bar{y}_t^*$ by $\{-,-,+\}$, the reaction of $c_t - c_t^*$ by $\{+,+,+\}$, and the reaction of $h_t - h_t^*$ by $\{-,-,-\}$ ($\{-,-,+\}$), where a '+' means non-negative and a '−' stands for non-positive. Comparing these reactions with the transfer direction needed for closing both labor wedges completes the proof. ■

We conclude that, additional to the discussed trade-off between efficient risk sharing and production efficiency, there are important obstacles to a practical implementation of a transfer scheme that aims at allocative efficiency. Such an implementation could be based on a specific cross-country differential. As shown in Proposition 8, however, there is no such simple transfer scheme that reaches the goal of allocative efficiency for all degrees of price rigidities.
Against this background, we explore the European situation by calibrating a quantitative business cycle model to the euro area in the next section. As we will see, unemployment differentials in the large model are inversely correlated to consumption differentials.[14] If price rigidities were low enough, a transfer scheme that enhances allocative efficiency could therefore be implemented. Yet, price rigidities will turn out to be severe, such that a scheme based on relative unemployment, like a EUBS, fails to enhance allocative efficiency after all shocks. That is, efficiency can be enhanced the most if the scheme is activated only after specific shocks.

3 Quantitative model

In this section, we provide an exposition of our quantitative business cycle model. We mainly draw on the medium-size two-country model laid out in Enders et al. (2013), which is itself related to models in Mortensen and Pissarides (1994), Stockman and Tesar (1995), and Chari et al. (2002). This model features several potential channels for risk sharing (international bonds,

[14]In contrast, output and hours worked increase following, e.g., government-spending shocks. Yet, unemployment rises as well over time because of the positive labor-supply effect induced by lower consumption.

time-varying terms of trade with differentiated traded and non-traded goods) and search-and-matching labor market frictions. We add financial-friction shocks and a flexible specification for unemployment insurance schemes, ranging from national insurance schemes to a fully international EUBS. The 'Home' region (called 'Core') in our model is a euro area Core aggregate, whereas the 'Foreign' region (called 'Periphery') represents a euro area Periphery aggregate. The relative size of Core, as measured by its GDP divided by Periphery GDP, is denoted by n. Since both country aggregates share the same model structure, the exposition focuses on Core. We refer to Periphery with an asterisk where required.

There are a representative household, a final good firm, intermediate goods firms, and a government in each region. The final good firm combines domestically produced tradeable and non-tradeable as well as imported intermediate goods into a final good used for consumption, investment, and government spending. Monetary policy is set at the union-wide level. The model is closed with feedback rules for government spending and monetary policy.

3.1 Representative household

The representative household chooses consumption of final goods, C_t, and supplies hours worked, H_t. Preferences are represented by the following lifetime utility function

$$\mathcal{U}_t = E_0 \sum_{t=0}^{\infty} \beta_t \left(\frac{C_t^{1-\gamma} - 1}{1-\gamma} - \vartheta \frac{H_t^{1+\mu}(1-U_t)}{1+\mu} \right)$$
$$\beta_0 = 1, \ \ \beta_{t+1} = \beta(C_t)\beta_t, \ \ \beta(C_t) = \frac{1}{1+\psi C_t},$$

where $\gamma > 0$ denotes the coefficient of relative risk aversion, $\mu > 0$ refers to the inverse Frisch elasticity, and $\vartheta > 0$ determines the disutility of hours worked. The discount factor β_t is endogenous and decreases in response to a rise in average consumption.[15] The parameter $\psi > 0$ pins down the value of the steady-state discount factor. The measure of unemployed workers is denoted by U_t.

The employed measure of workers earns the hourly wage W_t, which is taxed at rate $\tau_t = \tau_{EU,t} + \tau_{L,t}$, where $\tau_{EU,t}$ is a union-wide tax and $\tau_{L,t}$ is region specific. The unemployed measure receives unemployment benefits b_t. The benefits are distributed by an unemployment insurance scheme, which we describe in more detail below. Labor and capital are immobile across countries. The capital stock in the traded goods sector $K_{A,t}$ and the capital stock in the non-traded goods sector $K_{N,t}$ are owned by the household and are used in the production of intermediate goods. Financial markets are incomplete such that households can only trade international risk-free one-period bonds, Θ_t. The budget constraint of the domestic household is given by

$$(1-\tau_t)W_t H_t(1-U_t) + R_{A,t}K_{A,t} + R_{N,t}K_{N,t} + \Upsilon_t + \Theta_t + b_t U_t = P_{F,t}(C_t + T_t + X_t) + \frac{\Theta_{t+1}}{R_t},$$

[15] The effect is not internalized by the household. Schmitt-Grohé and Uribe (2003) show that this assumption ensures stationarity around a deterministic steady state.

where R_t refers to the gross nominal interest rate, T_t denotes lump-sum taxes and Υ_t measures profits generated by intermediate and labor market firms. $R_{A,t}$ and $R_{N,t}$ are the rental rates of $K_{A,t}$ and $K_{N,t}$, respectively. Total investment is defined as $X_t = X_{A,t} + X_{N,t}$ and, following Christiano et al. (2005), adjusting the growth rate of investment is costly. Capital in each intermediate goods sector evolves according to

$$K_{k,t+1} \quad = \quad (1-\delta)K_{k,t} + \digamma(X_{k,t}, X_{k,t-1}), \text{ with } \digamma = \left[1 - \frac{\kappa}{2}\left(\frac{X_{k,t}}{X_{k,t-1}} - 1\right)^2\right] X_{k,t},$$

where the index $k \in \{A, N\}$ refers to the traded or non-traded goods sector and $\kappa \geq 0$ determines the amount of investment-adjustment costs.

Utility maximization gives rise to a standard intertemporal Euler equation for international bonds. Following Smets and Wouters (2007) and Christiano et al. (2015), we introduce a disturbance which drives a non-zero spread between the nominal interest rate set by the central bank and the return on assets owned by the household. The Euler equation is therefore given by

$$\mathcal{U}_{C,t} = \beta_t E_t \mathcal{U}_{C,t+1} \frac{R_t \Delta_t}{\Pi_{t+1}},$$

where $\mathcal{U}_{C,t}$ and Π_t refer to marginal utility of consumption and inflation P_t/P_{t-1}, respectively, and Δ_t denotes the spread. This is a reduced-form way of capturing financial frictions in the economy. The spread follows an autoregressive process of the form

$$\ln \Delta_t = \rho_\Delta \ln \Delta_{t-1} + \varepsilon_{\Delta,t}, \tag{11}$$

where $\varepsilon_{\Delta,t}$ denotes a financial-friction shock.

3.2 Final good firm

The final good F_t is composed of traded and non-traded intermediate goods produced by a continuum of monopolistically competitive intermediate goods firms in both countries. Intermediate goods firms and the corresponding varieties and prices are indexed by $j \in [0, 1]$. The representative final good firm operates under perfect competition and aggregates domestically produced intermediate goods $A_t(j)$, imported intermediate goods $B_t(j)$, and domestically produced non-traded goods $N_t(j)$. We assume that the final good is not traded across countries. The resource constraint is therefore given by

$$\begin{aligned} F_t &= C_t + X_t + G_t + \chi V_t \\ &= \left\{ \begin{array}{c} \upsilon^{\varrho+1}\left[\omega^{\varsigma+1}\left(\int_0^1 A_t(j)^{-\varepsilon} dj\right)^{\frac{\varsigma}{\varepsilon}} + (1-\omega)^{\varsigma+1}\left(\int_0^1 B_t(j)^{-\varepsilon} dj\right)^{\frac{\varsigma}{\varepsilon}}\right]^{\frac{\varrho}{\varsigma}} \\ +(1-\upsilon)^{\varrho+1}\left(\int_0^1 N_t(j)^{-\varepsilon} dj\right)^{\frac{\varrho}{\varepsilon}} \end{array} \right\}^{-\frac{1}{\varrho}}, \end{aligned}$$

where G_t denotes government spending and χV_t captures the resource loss due to vacancy posting in the frictional labor market discussed below. The parameter $\epsilon \equiv (1+\varepsilon)^{-1}$ measures the elasticity of substitution between intermediate goods of the same type, $\sigma \equiv (1+\varsigma)^{-1}$ denotes the trade price elasticity of substitution, and $\eta = (1+\varrho)^{-1}$ refers to the elasticity of substitution between traded and non-traded goods. The home bias, i.e., the weight of domestically produced goods in the traded goods bundle, is measured by ω, whereas the weight of traded goods in the final good bundle is given by υ.

3.3 Intermediate goods firms

Intermediate goods are produced by monopolistically competitive firms in each sector $k \in \{A, N\}$ according to the production function

$$Y_{k,t}(j) = Z_{k,t} K_{k,t}(j)^{\theta} L_{k,t}(j)^{1-\theta}, \tag{12}$$

where $Z_{k,t}$ refers to technology and $K_{k,t}(j)$ and $L_{k,t}(j)$ are capital and labor inputs used by firm j in sector k. The capital and labor shares in production are given by θ and $1-\theta$, respectively. Technology evolves according to the following sector-specific process

$$\ln Z_{k,t} = \rho_k \ln Z_{k,t-1} + \varepsilon_{k,t}, \tag{13}$$

where $\varepsilon_{k,t}$ denotes a technology shock in sector k. The input factors capital and labor are not firm-specific and can be adjusted every period. Intermediate goods firms pay $P_{L,t}$ to the labor market firms to hire one hour of labor, see below.

Price setting follows a discrete-time version of Calvo (1983) pricing. Each intermediate goods firm can adjust its price with a given probability $1-\xi_k$, where ξ_k denotes the sector-specific Calvo parameter. The chance to re-set prices might come at different points in time for domestically-sold and exported goods, where the frequency of price changes depends on the destination market of the product, not on the origin. Thus, the law of one price does not necessarily hold.

3.4 Labor market

The model features a non-Walrasian search-and-matching labor market à la Mortensen and Pissarides (1994). Specifically, labor market firms meet total demand for labor by intermediate goods firms, $L_t = L_{A,t} + L_{N,t}$, where each firm represents a match between a single worker and single firm. Labor market firms operate under perfect competition and produce a homogenous labor good according to a production function linear in hours worked. The equilibrium is symmetric, i.e., all matches provide the same amount of labor. The final labor market good is given by the aggregate of individual matches, $L_t = (1-U_t)H_t$. A standard Cobb-Douglas matching function maps the number of vacancies V_t and unemployed U_t into the number of matches M_t

$$M_t = s V_t^{\Psi} U_t^{1-\Psi},$$

where s denotes a scaling constant and Ψ measures the matching elasticity. The probability of filling a vacancy from the firms' perspective, $\pi_{f,t}$, and the probability of finding a job from the workers' perspective, $\pi_{ue,t}$, are given by

$$\begin{aligned}\frac{M_t}{V_t} &\equiv \pi_{f,t} = s\left(\frac{V_t}{U_t}\right)^{\Psi-1}, \\ \frac{M_t}{U_t} &\equiv \pi_{ue,t} = s\left(\frac{V_t}{U_t}\right)^{\Psi}.\end{aligned}$$

The profits of a labor market firm J_t and the worker's surplus of the match $\widetilde{V}_t$ are given by

$$\begin{aligned}J_t &= \frac{P_{L,t}H_t - W_tH_t}{P_{F,t}} + E_t(1-f)\rho_{t,t+1}J_{t+1}, \\ \widetilde{V}_t &= \frac{W_tH_t - b_t}{P_{F,t}} - \frac{\vartheta}{\mathcal{U}_{C,t}}\frac{H_t^{1+\mu}}{1+\mu} + E_t\rho_{t,t+1}(1-f-\pi_{ue,t})\widetilde{V}_{t+1},\end{aligned}$$

where f denotes the exogenous separation rate of the match and the pricing kernel is $\rho_{t,t+1} = \beta_t E_t \mathcal{U}_{C,t+1}/\mathcal{U}_{C,t}$. The firms' profits and the corresponding vacancy postings depend on the wedge between the price for labor paid by the firms $P_{L,t}$ and the wage W_t. The surplus of the worker is determined by the wedge between the wage and the outside option, which is given by the unemployment benefits $b_t = \widetilde{b}WH_t$ and the saved amount of leisure. The unemployment benefits are a fraction of steady-state wage per hour W, where $\widetilde{b} \in [0,1]$ denotes the replacement rate.

Following Hall and Milgrom (2008) and Jung and Kuester (2011), we assume that the threat point of the worker in the bargaining process is given by the cost of delaying bargaining for one period rather than the value of being unemployed, used in standard Nash-bargaining.[16] The labor-market friction implies that the wage is a convex combination of productivity and the outside option

$$W_t = \Omega P_{L,t} + (1-\Omega)\left[\frac{P_{L,t}}{1+\mu} + \widetilde{b}W\right],$$

where Ω denotes the bargaining power of the worker.

We assume free entry such that firms make on average zero profits when posting a new vacancy;

$$\chi = \pi_{f,t}E_t\rho_{t,t+1}J_{t+1},$$

where χ are real vacancy posting costs expressed in terms of the consumption good, representing a resource loss for the economy. The unemployment rate U_t evolves according to the law of motion given by

$$U_{t+1} = U_t(1-f-\pi_{ue,t}) + f. \tag{14}$$

[16]This assumption yields the efficient static bargaining solution for hours worked $\vartheta H_t^{\mu}/\mathcal{U}_{C,t} = P_{L,t}/P_{F,t}$, which is equal to the choice in the neoclassical limiting case.

3.5 Unemployment insurance and policy rules

In the baseline specification, which captures the status quo of the EMU, both regions feature separate unemployment insurance systems. In each region, an agency collects labor taxes and disburses unemployment benefits. The taxes are raised at the regional level only, i.e., $\tau_{EU,t} = 0$. Assuming a balanced budget in every period, the agency's constraint is given by

$$\text{Ben}_t \equiv b_t U_t = \tau_{L,t} W_t H_t (1 - U_t) \equiv \tau_{L,t} \text{TaxBase}_t, \tag{15}$$

where Ben_t are disbursed benefits. In the counterfactual scenario, a EUBS is introduced. A union-wide labor tax $\tau_{EU,t}$ raises resources in both regions that are pooled at the European level and there are no additional region-specific taxes, i.e., $\tau_{L,t} = \tau^*_{L,t} = 0$. Benefits are then distributed to the unemployed workers in both regions. The constraint of the international agency (with a balanced budget) is as follows

$$\text{Ben}_t + \frac{\text{Ben}^*_t}{n} = \tau_{EU,t} \text{TaxBase}_t + \tau^*_{EU,t} \frac{\text{TaxBase}^*_t}{n}. \tag{16}$$

We fix the (multiplicative) spread c between labor tax rates across regions at a value that ensures zero cross-regional transfers in steady state, i.e., $\tau^*_{EU,t} = c\, \tau_{EU,t}$.
Furthermore, we consider a set of intermediate cases in which only a part of the contributions is pooled at the European level. Specifically, we assume that the union-wide labor tax finances the fraction λ of total benefits paid out in both countries. The remaining benefits are financed by region-specific labor taxes $\tau_{L,t}$ and $\tau^*_{L,t}$. The parameter $\lambda \in [0, 1]$ hence measures the degree of internationalization of the unemployment insurance system. The polar cases yield the baseline EMU scenario ($\lambda = 0$) and the fully international EUBS ($\lambda = 1$), see (15) and (16). In between, we obtain

$$\lambda \left(\text{Ben}_t + \frac{\text{Ben}^*_t}{n} \right) = \tau_{EU,t} \text{TaxBase}_t + \tau^*_{EU,t} \frac{\text{TaxBase}^*_t}{n}$$
$$(1 - \lambda) \text{Ben}_t = \tau_{L,t} \text{TaxBase}_t,$$

with a corresponding expression for Foreign. We again rule out steady-state transfers by adjusting the parameter c in $\tau^*_{EU,t} = c\, \tau_{EU,t}$.
Fiscal policy in each region is characterized by a standard feedback rule for government spending

$$\ln G_t = (1 - \rho_G) \ln G + \rho_G \ln G_{t-1} + \phi_Y \ln Y_{t-1} + \varepsilon_{G,t}, \tag{17}$$

where $\varepsilon_{G,t}$ denotes a government-spending shock and G refers to government spending in steady state. We assume that government spending reacts to lagged output (determined by the coefficient ϕ_Y) due to lags in decision and implementation processes, as discussed by Blanchard and Perotti (2002). The government raises lump-sum taxes to balance its budget in every period, i.e., $G_t = T_t$.
Since Core and Periphery countries form a monetary union, interest rates are set at the union

level. The central bank reacts to inflation and economic activity according to

$$\ln R_t = \rho_R \ln R_{t-1} + (1-\rho_R)E_t\left[\varpi + \varphi_\Pi \ln\left(\sqrt{\Pi_{t,t-4}\Pi^*_{t,t-4}}\right) + \varphi_Y \ln\left(\sqrt{\widetilde{Y}_t\widetilde{Y}^*_t}\right)\right] + \varepsilon_{R,t}, \quad (18)$$

where $\varepsilon_{R,t}$ denotes a monetary-policy shock, $\Pi_{t,t-4}$ refers to year-over-year inflation of final goods and $\widetilde{Y}_t$ measures the output gap, which is defined as the deviation of current output Y_t from its long-run trend, i.e., the steady-state value. The coefficients φ_Π and φ_Y determine the response of the interest rate to inflation and the output gap. Both feedback rules for monetary policy and government spending are estimated independently of the model, see Section 4.1 for details.

3.6 Equilibrium and aggregation

In equilibrium, markets clear at the level of intermediate goods in each sector. Households maximize utility and firms maximize profits subject to their constraints, government policies, and intital conditions. Following Galí and Monacelli (2005), we define an index for aggregate output in each sector $Y_{A,t} \equiv \left(\int_0^1 Y_{A,t}(j)^{-\varepsilon}dj\right)^{\frac{1}{\varepsilon}}$ and $Y_{N,t} \equiv \left(\int_0^1 Y_{N,t}(j)^{-\varepsilon}dj\right)^{\frac{1}{\varepsilon}}$. Aggregate factor inputs used in the intermediate goods sectors, labor $L_{k,t}$ and capital $K_{k,t}$, are given by

$$L_{k,t} = \int_0^1 L_{k,t}(j)dj \quad \text{and} \quad K_{k,t} = \int_0^1 K_{k,t}(j)dj. \quad (19)$$

Aggregate production in each sector is

$$\zeta_{k,t}Y_{k,t} = Z_{k,t}K^{\theta}_{k,t}L^{1-\theta}_{k,t}, \quad (20)$$

where $\zeta_{k,t} \equiv \int_0^1 \left(\frac{P_{k,t}(j)}{P_{k,t}}\right)^{-\epsilon} dj$ measures price dispersion at the level of intermediate goods. We define exports and imports as $A^*_t \equiv \left(\int_0^1 A^*_t(j)^{-\varepsilon}dj\right)^{\frac{1}{\varepsilon}}$ and $B_t \equiv \left(\int_0^1 B_t(j)^{-\varepsilon}dj\right)^{\frac{1}{\varepsilon}}$, respectively. Real GDP is given by

$$Y_t \equiv C_t + X_t + G_t + \chi V_t + \frac{P^*_{A,t}}{nP_{F,t}}A^*_t - \frac{P_{B,t}}{P_{F,t}}B_t. \quad (21)$$

The real exchange rate and the trade balance are defined as

$$RX_t \equiv \frac{P^*_{F,t}}{P_{F,t}} \quad \text{and} \quad NX_t \equiv \frac{P^*_{A,t}A^*_t - nP_{B,t}B_t}{nP_{F,t}Y_t}. \quad (22)$$

3.7 Efficiency and risk sharing

Finally, we derive measures for efficiency in the quantitative model. Following the discussion in Section 2.1, we define the sector-specific labor wedges for Core and the risk-sharing wedge as follows

Core@Core (non-tradeable): $\frac{-\mathcal{U}_{H,t}}{MP_{N,t}} - \mathcal{U}_{C,t}C_{N,t}$

Core@Core (tradeable): $\frac{-\mathcal{U}_{H,t}}{MP_{A,t}} - \mathcal{U}_{C,t}C_{A,t}$

Core@Periphery (tradeable): $\frac{-\mathcal{U}_{H,t}}{MP_{A,t}} - \mathcal{U}^*_{C,t}C^*_{A,t}$

Overall Core (tradeable): $\frac{-\mathcal{U}_{H,t}}{MP_{A,t}} - \left[\frac{A_t}{Y_{A,t}}\mathcal{U}^{\sigma}_{C,t}C^{\sigma}_{A,t} + \frac{A^*_t}{nY_{A,t}}\mathcal{U}^{*\sigma}_{C,t}C^{*\sigma}_{A,t}\right]^{\frac{1}{\sigma}}$

Risk sharing: $\frac{\mathcal{U}_{C,t}}{\mathcal{U}^*_{C,t}} - \iota\frac{P_t}{P^*_t},$

where $-\mathcal{U}_{H,t}$ denotes marginal disutility of labor,$C_{k,t}$ the partial derivative of the final good (3.2) with respect to good k, and $MP_{k,t}$ the marginal product of labor in sector k, determined by the production function (12). The parameter ι is related to initial wealth differences and, due to the asymmetric calibration, takes a non-unitary value. Specifically, it ensures that the risk-sharing condition is zero in steady state. We define corresponding labor wedges for Periphery.

4 Simulation

We solve the model based on a first-order approximation of the equilibrium conditions around the deterministic steady state to analyze different scenarios. In the following subsections, we discuss the calibration of the model parameters and report the empirical performance of the model.

4.1 Calibration

The two-country model is carefully calibrated to account for key characteristics of a euro area *Core* aggregate (Austria, Belgium, Germany, Finland, France, Netherlands) and a *Periphery* aggregate (Greece, Ireland, Italy, Portugal, Spain).[17] This strategy allows us to compare the effects of a common unemployment insurance on two heterogeneous sets of countries that have been characterized by fundamental asymmetries over the last years. One period in the model corresponds to one quarter. We use data from 1999, the starting date of the EMU, through 2017 for the calibration and estimation of shock processes. In the following, we discuss two sets of parameters: First, structural parameters which define household preferences, the production side of the model, and the labor market. Second, parameters determining the evolution of exogenous variables and the policy rules.

[17]See Appendix B for details on the aggregation.

Table 1: Structural parameters

Symmetric parameters		Value		Calibration target/source	Value	
Risk aversion	γ	1.00		Balanced growth		
Inverse Frisch elasticity	μ	2.00		Domeij and Flodén (2006)		
Utility weight of work	ϑ	36.3		Hours worked steady state	0.30	
Depreciation rate	δ	.017		I/Y	0.21	
Capital share	θ	0.37		Labor share	0.63	
Investment adjustment cost	κ	1.50		Enders et al. (2013)		
Price elasticity	ϵ	6.00		Rotemberg and Woodford (1993)		
Trade price elasticity	σ	1.50		Chari et al. (2002)		
Non-traded price elasticity	η	0.44		Stockman and Tesar (1995)		
Relative regional size	n	1.69		GDP Core/Periphery		
Separation rate	f	.045		Jung and Kuhn (2014)		
Bargaining parameter	Ω	0.50		Mortensen and Pissarides (1994)		
Matching elasticity	Ψ	0.50		Petrongolo and Pissarides (2001)		
Asymmetric parameters		**Core**	**Periph.**	**Calibration target/source**	**Core**	**Periph.**
Replacement rate	$\widetilde{b}$	0.65	0.66	Unemployment/Output volatility	Table 3	
Vacancy posting	χ	0.09	0.02	Unemployment steady state	0.076	0.115
Matching constant	s	0.55	0.35	Normalization V/U	1.000	1.000
Government share	G/Y	0.24	0.19	Government spending share	0.24	0.19
Weight traded goods	υ	0.33	0.34	Production manuf./services	0.485	0.508
Weight domestic goods	ω	0.89	0.76	Import & export share Core	0.037	0.046
Elast. of discount factor	ψ	.013	.012	K/Y	12.1	12.1
Price rigidity tradeables	ξ_T	0.76	0.81	Price duration indust. goods	4.146	5.387
Price rigidity non-tradeables	ξ_N	0.84	0.86	Price duration services	6.270	6.890

Notes: Variables without time subscript refer to steady-state values. Parameters remain unchanged across simulations. See Appendix B for description of the data used for the target values.

Preferences, production, and the labor market: Table 1 shows the first set of parameter values. We distinguish parameters which are symmetric and asymmetric across countries. The table also reports the sources or calibration targets used to determine the parameters.[18]

We set the coefficient of relative risk aversion $\gamma = 1$, which is consistent with balanced growth. Following Domeij and Flodén (2006), the Frisch wage elasticity of labor supply is 0.5, which implies $\mu = 2$. We target steady-state hours worked at 0.3 in both countries and set the disutility-of-work parameter ϑ accordingly. The depreciation rate δ is consistent with the empirical steady-state investment-to-output ratio of 0.21.[19] The capital share θ reflects the empirical labor share in production, the investment adjustment costs are in line with Enders et al. (2013). The price elasticity of intermediate goods of the same type is set to match a markup of 20% (Rotemberg and Woodford, 1993), and the price elasticities in the traded and non-traded goods sectors are taken from Chari et al. (2002) and Stockman and Tesar (1995), respectively. The relative regional size n is set according to the ratio of Core PPP-adjusted GDP relative to that of Periphery. Following Jung and Kuhn (2014), the separation rate is $f = 0.045$. The bargaining parameter Ω and the matching elasticity Ψ are set to 0.5, which is in

[18] Calibration targets are typically determined by several parameters in a general equilibrium model. We hence list the parameter which is most closely linked to the respective target.

[19] We use averages over Core and Periphery countries for symmetric parameters that are calibrated to the data, weighted by PPP-adjusted GDP (i.e., the same weights as for the aggregation of time series below).

line with Mortensen and Pissarides (1994) and Petrongolo and Pissarides (2001), respectively. This implies that the Hosios condition holds in our model, such that the resulting dynamics are not driven by congestion effects.

In order to account for important heterogeneities across regions, we allow for a comprehensive set of asymmetric parameters. These are mainly related to the functioning of the labor market and to the severity of the nominal frictions, as we are interested in the effects of an international unemployment insurance on risk sharing and efficiency. We target an average of relative unemployment and output volatilities, reported in Table 3 below, to pin down the replacement rate of unemployment benefits $\widetilde{b}$. Vacancy posting costs χ are determined by targeting the average unemployment rate, which amounts to 7.6% for Core and 11.5% for Periphery.[20] The number of posted vacancies is normalized to determine the matching constant s.

Government spending for Core and Periphery is, on average, 24% and 19% of GDP, respectively. We hence set the steady-state shares of government spending accordingly. The weight of traded goods in the final good υ is set to match the average ratio of output in the manufacturing sector relative to output in services. For a given weight of traded goods υ, import and export shares in steady state are determined by ω. We set ω such that Core steady-state imports from Periphery amount to 3.7 percent of GDP, while Core exports to Periphery are 4.6 percent of GDP.

We target a steady-state capital-to-output ratio of 12.1, corresponding to the empirical average, to determine the elasticity of the endogenous discount factor ψ. The Calvo parameters ξ_T and ξ_N are chosen to be in line with average price durations for the considered countries, as reported in Dhyne et al. (2006).[21] Price rigidity is higher in Periphery, while prices of non-traded goods are in general more rigid than prices of traded goods.

Technology: Technology in intermediate goods production, approximated by Solow residuals, follows the autoregressive process specific to each region and sector specified in equation (13). Results of the estimation are reported in the top panel of Table 2. We find important differences across countries and sectors. Technology in Periphery is more persistent than in Core, while Core technology is more volatile. Moreover, technology in the tradeable goods sector is slightly less persistent but more volatile than in the non-tradeable goods sector.

Financial frictions: The reduced-form interest rate spread Δ_t in the Euler equation for bonds follows the process given by equation (11). We estimate region-specific processes on data for the quarterly spread between loan and deposit rates in each country aggregate. The estimates are reported in the second panel of Table 2. The spread is found to be more persistent and volatile in Periphery. The size of the innovations, as measured by the variances, is generally quite small.

[20]We use the average over the considered countries in both groups for the asymmetric parameters that are calibrated to the data, weighted by PPP-adjusted GDP.

[21]We follow Baharad and Eden (2004) for the aggregation of price durations across countries.

Table 2: Estimated processes for exogenous variables

Technology		**Core**	**Periphery**
Persistence			
Tradeables	ρ_T	0.88	0.91
Non-tradeables	ρ_N	0.86	0.91
Variance of innovations (10^{-4})			
Tradeables		2.31	1.38
Non-tradeables		0.18	0.13
Financial frictions			
Persistence	ρ_Δ	0.88	0.93
Variance of innovations (10^{-8})		4.47	8.50
Government spending			
Smoothing	ρ_G	0.92	0.90
Output	ϕ_Y	0.03	0.11
Variance of innovations (10^{-4})		0.15	0.24
Monetary policy			
Smoothing	ρ_R	0.97	
Inflation	φ_Π	1.31	
Output gap	φ_Y	0.38	
Variance of innovations (10^{-6})		1.28	

Notes: See Appendix B for description of the data.

Policy rules: Fiscal and monetary policy is governed by the feedback rules specified in equations (17) and (18). We estimate region-specific fiscal policy rules for Core and Periphery.[22] The results are summarized in the third panel of Table 2. The persistence of government spending is found to be slightly higher in Core. In both country aggregates, fiscal policy is generally not reacting strongly to changes in output, where Periphery government spending is more procyclical.

Second, since Core and Periphery are assumed to form a monetary union, we estimate a common monetary policy rule for both regions. As in the model equation (18), the short-term interest rate (shadow rate from 2004Q4 onwards) depends on year-on-year CPI inflation and the output gap (both union-wide, where the output gap is based on linearly detrended data). Following Clarida et al. (1998), we use an instrumental variable approach with year-on-year CPI inflation, the output gap, the short-term interest rate, and commodity prices as instruments in the first stage. The estimates are reported in the bottom panel of Table 2. We find strong interest-rate smoothing and a considerable response of the interest rate to the economic cycle.

[22]OLS estimation with linear trend.

Table 3: Model performance

Core	Data	Model EMU
Std(Y) $\cdot$ 100	1.29	0.93
Std(C)/Std(Y)	0.38	0.90
Std(X)/Std(Y)	2.12	2.68
Std(G)/Std(Y)	0.47	0.55
Std(U)/Std(Y)	4.67	5.30
Std(π)/Std(Y)	0.25	0.36
Periphery		
Std(Y^*) $\cdot$ 100	1.31	0.96
Std(C^*)/Std(Y^*)	0.95	0.81
Std(X^*)/Std(Y^*)	2.42	2.89
Std(G^*)/Std(Y^*)	0.72	0.77
Std(U^*)/Std(Y^*)	5.60	6.13
Std(π^*)/Std(Y^*)	0.41	0.23
Trade		
Std(RX)/Std(Y)	0.32	0.44
Std(NX)/Std(Y)	0.11	0.06
Cross-regional		
Corr(Y, Y^*)	0.81	0.46
Corr(C, C^*)	0.64	0.63
Corr(X, X^*)	0.70	0.33
Corr(G, G^*)	0.60	0.03
Corr(U, U^*)	0.50	0.42
Corr(π, π^*)	0.73	0.83

Notes: See Appendix B for description of the data and the aggregation method. Statistics are based on HP-filtered empirical and theoretical time series.

4.2 Model performance

Table 3 shows the ability of the model to replicate the data. Specifically, we compare the predictions for standard deviations and correlations generated by the baseline model—which captures the EMU with national unemployment benefit schemes—with characteristics of the data. The first three panels of the table show that the model is successful in predicting volatilities of key variables. In particular, the model does not suffer from a lack of volatility of unemployment (Shimer, 2005) because we introduce some degree of effective wage rigidity, see Hagedorn and Manovskii (2008) and Hall and Milgrom (2008) for details. Other key facts are also replicated, such as the ordering of unemployment, investment, output, consumption, and inflation in terms of relative volatilities, where consumption volatility in Core is overpredicted.

The third panel of Table 3 displays the empirical and theoretical standard deviations of the real exchange rate and net exports, divided by the volatility of output in Core. The model is quite successful in capturing the volatilities of these variables. The bottom panel summarizes the cross-regional correlations in the data and the corresponding model predictions. All correlations are positive in the data and in theory. For output, investment, and government spending the model underpredicts the magnitudes, while the correlations of the remaining variables, including unemployment, are close to their empirical counterparts.

Based on the comparison of the 20 empirical and theoretical moments listed in Table 3, we deem the model performance good enough to conduct counterfactual experiments regarding the introduction of a European unemployment benefit scheme in the next section.

5 Effects of a European unemployment benefit scheme

In this section, we evaluate the effects of the introduction of a EUBS. In particular, we identify the implications for volatilities and cross-regional correlations, for the transmission of shocks, as well as for production efficiency and risk sharing.

5.1 Volatilities and correlations

In the following, we document the effects of the introduction of a EUBS on unconditional volatilities of key variables and cross-regional correlations. For this purpose, we implement two different EUBS regimes. The EMU scenario ($\lambda = 0$) serves as the baseline case. The corresponding volatilities and correlations are displayed in the first column of Table 4.

The first counterfactual scenario is a EUBS regime in the second column, as described in Section 3 for $\lambda = 1$. We find that the EUBS lowers the volatility of output and consumption in Core and Periphery, relative to the EMU case. The volatility of the risk-sharing wedge falls considerably, primarily driven by a large increase in the cross-regional correlation of consumption (additional to higher correlations of output and unemployment). Yet, the volatilities of the labor wedges increase in both regions. This is in line with the intuition from our analytical results in Section 2. For most shocks, a EUBS is unable to achieve consumption risk sharing and production efficiency at the same time (see propositions 2, 6, and 7). There is, however, another positive side to the EUBS: the volatilities of the labor taxes are reduced because, in a downturn, national unemployment insurance schemes do not have to raise all required funds domestically.

Finally, in the third column of Table 4, we compare the EUBS scenario to a setting with complete markets, but otherwise the same frictions as in the incomplete-markets case.[23] The volatility of the risk-sharing wedge is zero by construction in this case. This is achieved by implementing implicit transfers in reaction to the specific shocks such that Core volatilities generally decrease, relative to the EMU or EUBS scenarios. At the same time, however, Periphery's volatilities increase with this mechanism. That is, especially the higher technology-shock volatility of Core is 'exported' to Periphery, raising cross-regional correlations substantially.

[23] Labor taxes are set in the same way as in the EMU scenario with national unemployment insurance schemes.

Table 4: Theoretical volatilities and correlations

Core	EMU	EUBS	Complete Markets
Std(Y)	0.93	0.90	0.87
Std(C)	0.84	0.80	0.76
Std(U)	4.94	4.80	4.48
Std(L)	1.32	1.31	1.28
Std(π)	0.34	0.34	0.33
Std(τ)	0.33	0.30	0.30
Std(Labor wedge)	4.73	4.74	4.70
Periphery			
Std(Y^*)	0.96	0.92	0.95
Std(C^*)	0.77	0.74	0.78
Std(U^*)	5.88	6.05	5.84
Std(L^*)	1.45	1.47	1.51
Std(π^*)	0.22	0.23	0.24
Std(τ^*)	0.60	0.48	0.60
Std(Labor wedge*)	4.24	4.31	4.44
Trade			
Std(RX)	0.41	0.46	0.38
Std(NX)	0.05	0.06	0.04
Std(Risk sharing wedge)	0.75	0.59	0.00
Cross-regional			
Corr(Y,Y^*)	0.46	0.57	0.61
Corr(C,C^*)	0.63	0.79	0.87
Corr(U,U^*)	0.42	0.44	0.63
Corr(L,L^*)	0.61	0.60	0.64
Corr(π,π^*)	0.83	0.75	0.81

Notes: Statistics are based on HP-filtered theoretical moments. Standard deviations are multiplied with 100.

5.2 Shock transmission

We now investigate changes in shock transmission that are induced by an introduction of a EUBS. Figures 4-7 plot responses of important variables to shocks in Periphery that have a negative impact on Periphery consumption. As for the supply side, we consider a negative technology shock in the non-tradeable sector (figures 4-5). On the demand side, we analyze the effects of a contractionary financial-friction shock (Figure 7) and an expansionary government-spending shock (Figure 8). Lastly, we investigate the transmission of a contractionary common monetary-policy shock (Figure 9). In all plots, the blue bold line shows the response for the EMU case with national unemployment insurance schemes and a monetary union ($\lambda = 0$). The red bold line plots the counterfactual scenario of a European unemployment benefit scheme within a monetary union (full pooling, $\lambda = 1$). The lines in between, slowly changing colors from blue to red, represent increasing values of λ, from 0 to 1. Finally, the dotted black line represents the complete-markets case, with the same nominal rigidities as in the incomplete-markets case. The shocks sizes are set to one standard deviation of the calibrated shock

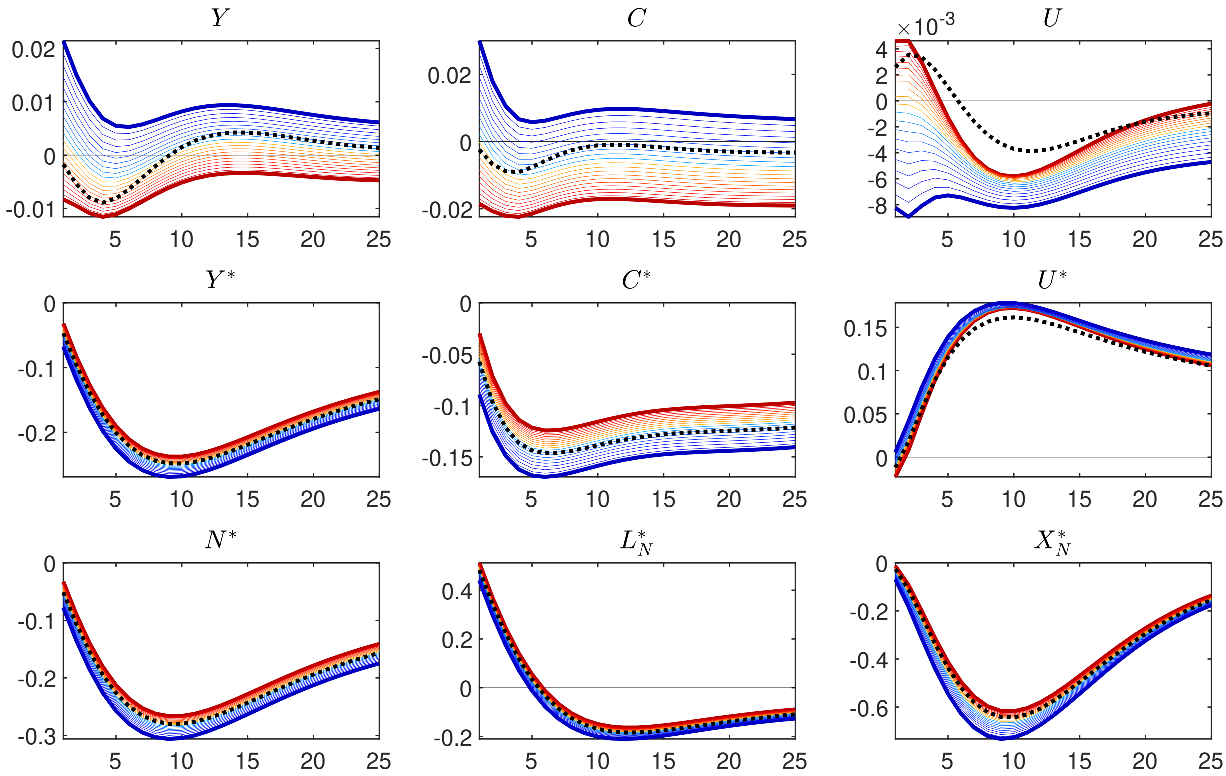

Figure 4: Responses to contractionary technology shock in Periphery non-traded goods sector under EMU (blue), EUBS (red), and complete markets (black dotted) scenarios
Notes: Shock size is one standard deviation of calibrated shock process. Figures show deviations from steady state in percent, except for labor tax rate, unemployment rate, and wedges, which are measured in deviations from steady state, multiplied by 100. Transfers are in percent of Core steady-state GDP.

processes. In all figures, responses are multiplied by 100 to obtain deviations from steady state in percent. Exceptions are those of the labor tax rate, the unemployment rate, and the wedges, which are measured in deviations from steady state. For better readability, they are also multiplied by 100. The transfer is expressed in percent of Core steady-state GDP.

Technology shocks in the non-tradeable sector: The impulse-response functions display spillovers that switch signs following the introduction of a EUBS. Specifically, Figure 4 shows that output and consumption in the Core increase after a negative technology shock in Periphery under the EMU scenario, while unemployment falls. This results from a shift towards Core traded and non-traded goods, as the Foreign traded good, and hence the Core tradeable bundle in general, becomes more expensive. Because of sticky prices, hours worked in Periphery non-tradeable sector increase following the negative technology shock. As a result, labor costs surge, rendering the tradeable sector less competitive. Periphery unemployment nevertheless rises due to the higher labor supply (except for the first periods in case of a EUBS, as initial labor demand rises strongly in the non-tradeable sector, see below).
In the case of a full EUBS with a corresponding transfer towards Periphery, however, the transmission turns positive, see also Section 2.2. Output, consumption, and even unemployment now co-move to some extent across regions. Compared to the EMU case, unemployment in

Periphery is somewhat lower. The increased risk sharing is also visible in the muted responses of these variables in Periphery (note the distinct scales, which let the differences in the Periphery reaction appear smaller in comparison). The change in the shock transmission after the regime shift is in line with the increase in cross-regional correlations documented in Table 4.[24]

With the sign of the spillover flipped, the risk-sharing wedge now 'overshoots': without a EUBS, consumption (and/or prices) in Periphery is too low, seen from a risk-sharing perspective (Figure 5). Implementing a transfer towards Periphery fosters Periphery consumption; the risk-sharing wedge turns positive. This is detrimental for production efficiency, since Periphery prices would now be even more elevated under flexible prices, reinforcing the conclusion that Periphery consumption is inefficiently high. The sum of Core and Periphery output ($Y + Y^*$) is pushed upwards by Periphery consumption if a full EUBS is present. In other words, the pie is a bit larger, but it gets baked inefficiently. This is visible especially in the reactions of variables in the Periphery non-tradeable sector (Figure 4). Since this sector experiences a negative technology shock, sectoral output N_t^* falls. With the EUBS, the transfer embodied in the cross-border insurance payments is spent to a large degree on non-tradeables in Periphery, lifting output N_t^*, labor input $L_{N,t}^*$, and investment $X_{N,t}^*$, relative to the case without a EUBS. That is, more of the inefficiently produced good is demanded. The labor wedges in the tradeable (not shown) and non-tradeable sectors of Periphery are hence larger on impact with a EUBS (Figure 5).[25]

In the top panel of Figure 6 we illustrate the above findings by plotting the volatilities of overall labor wedges for Core (left) and Periphery (middle), as well as the volatility of the risk-sharing wedge (right) for different values of λ (on the x-axis). We consider the cases in which all shocks are turned on, or only technology shocks (in the tradeable or non-tradeable sectors, always in both countries), only government-spending shocks, only monetary-policy shocks, only financial-friction shocks, or all but technology shocks. For each scenario, we normalize volatilities in the no-EUBS case ($\lambda = 0$) to zero by subtracting the corresponding value for $\lambda = 0$ and trace the changes relative to this starting point for rising values of λ. As visible, higher levels of centralization of the unemployment insurance lead to higher volatilities of the labor wedges (yellow lines for shocks in the non-tradeable sector, red lines for the tradeable sector), while the volatility of the risk-sharing wedge falls. An exception is visible for shocks in the non-tradeable sector: the risk-sharing wedge first becomes more stable, but its volatility increases again if λ has surpassed an intermediate value. The corresponding plot in Figure 5, and its discussion

[24]This is similar to the results of the introduction of a common currency. As discussed in detail in Enders et al. (2013), abolishing the nominal exchange-rate also makes foreign technology shocks more and domestic technology shocks less important for domestic business cycles. Since both the monetary union and the introduction of a EUBS shift, in this particular dimension, the dynamics in the same direction, the EUBS is very far from being a perfect substitute for flexible exchange rates: flexible exchange rates reduce the adverse effects of foreign shocks, while a EUBS increases them.

[25]The non-tradeable labor wedge in the Core is positive after the contractionary technology shock in Periphery without a EUBS because of the reduced marginal utility of consumption. With a EUBS, consumption (also of non-tradeables) and the labor wedge falls. This effect, however, is fairly small in comparison to the movement of the labor wedges in Periphery (again, note the differences in scales). We also observe that the overall labor wedges are very similar to those in the non-tradeable sectors.

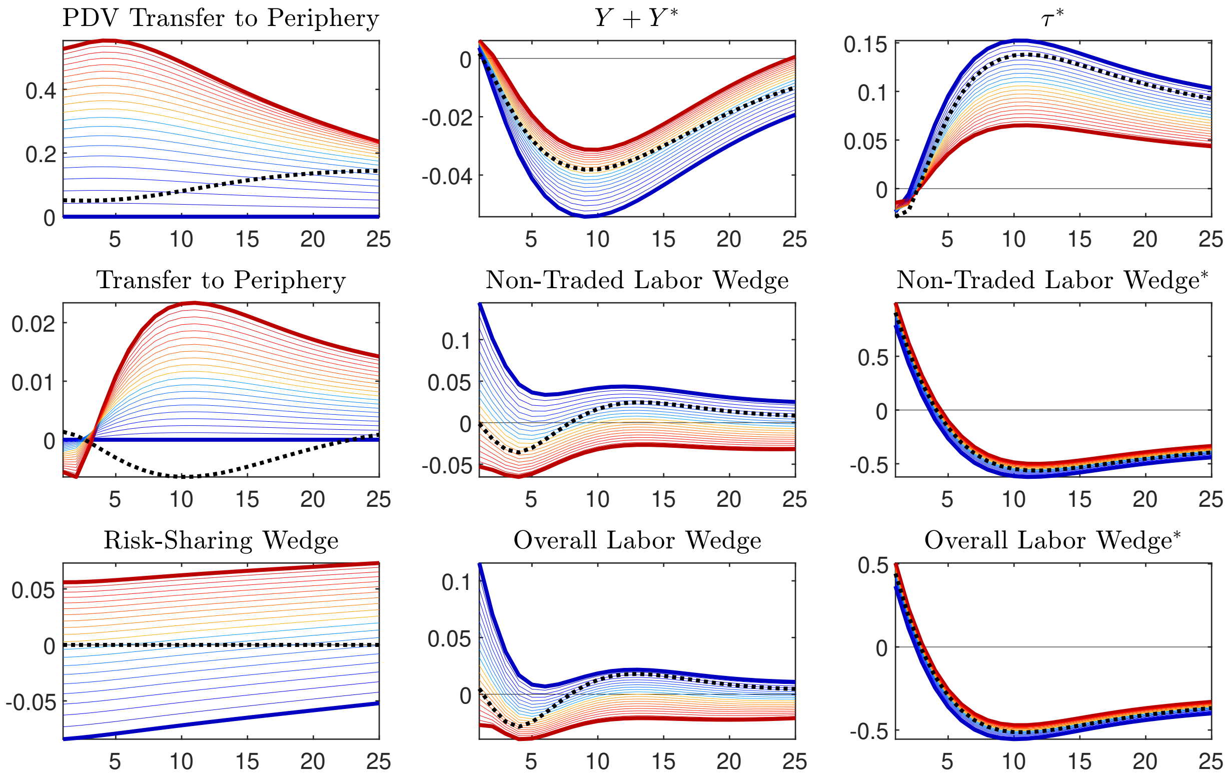

Figure 5: Responses to negative technology shock in Periphery non-traded goods sector under EMU (blue), EUBS (red), and complete markets (black dotted) scenarios
Notes: See Figure 4.

above, give an intuition for this effect.

The described mechanisms render the welfare effect of a EUBS in case of technology shocks negative, as shown in the lower panel of Figure 6. There, we plot welfare gains in percentage of steady-state consumption (of the respective region, on the y-axis) for different values of λ (on the x-axis).[26] We show the welfare gains for the Core (left-hand panel), Periphery (middle panel), and the sum of both, weighted by the relative regional size n (right-hand panel). For each scenario, we again normalize welfare costs in the no-EUBS case ($\lambda = 0$) to zero and trace the gains relative to this starting point for rising values of λ. That is, we subtract the corresponding value for $\lambda = 0$ from all welfare numbers for the same shock. The yellow lines show that joint (and individual) welfare is lower for $\lambda = 1$ than without a EUBS in the case of non-tradeable technology shocks only. Since the transfer, flowing to the recession region, creates negative welfare results, the economies are in the region of high price rigidities and home bias discussed in propositions 3a and 3b.

Note that the welfare effect of shocks in the tradeable sector for increasing λ is different in the two regions and, for the Core, stands in contrast to the effect on the volatility of the overall labor wedge. A EUBS leads to (small) welfare gains in the Core in this case, while it is detrimental for Periphery welfare. The reason lies in the asymmetric calibration. Core's tradeables display the lowest price rigidities and the highest variance of technology of all considered

[26] We insert the theoretical variances and covariances that result from the first-order approximated model in the second-order approximated welfare function.

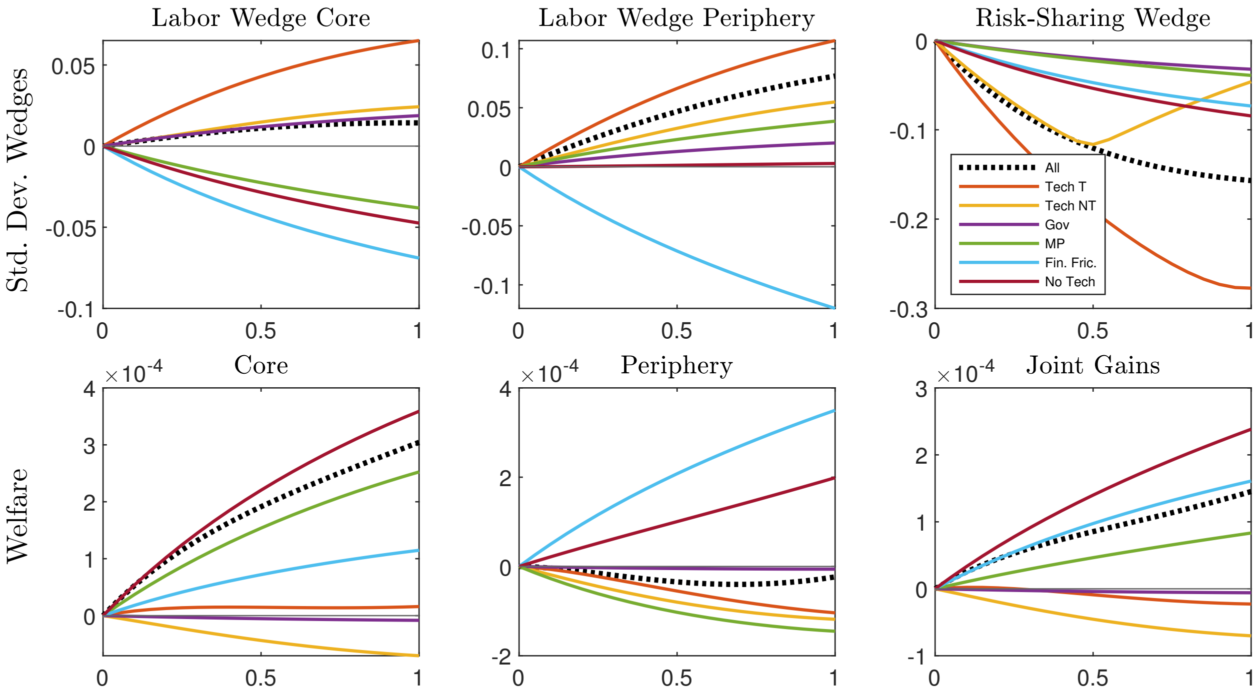

Figure 6: Top row: Standard deviations of overall labor and risk-sharing wedges (times 100) for $\lambda \in [0, 1]$. Bottom row: Welfare gains in percent of steady-state consumption for $\lambda \in [0, 1]$
Notes: 'All', 'Tech', 'Gov', 'MP', 'Fin. Fric.' refer to scenarios, in which all or only technology, government-spending, monetary-policy, financial-friction, or all but technology shocks are turned on. 'No Tech' denotes a scenario in which all but technology shocks are turned on. Numbers are normalized to zero for $\lambda = 0$.

sectors. Taken together, technology fluctuations in this sector lead to large swings of Core consumption (also compared to labor input). In this case, and only in this of all considered cases, the positive insurance effect of a EUBS overturns the negative consequences of opening labor wedges: stabilizing consumption (at the expense of Periphery) raises welfare by slightly more than the reduction via the larger labor wedge. This stabilization is also visible in the strongly declining risk-sharing wedge and will contribute to the conclusion that a EUBS would be beneficial for Core. However, joint welfare in the case of shocks in the tradeable sector would be reduced by the introduction of a EUBS.

Furthermore, there is a positive aspect on the financing side of the EUBS that is not present in the analytical model of Section 2. Absent such a risk-sharing mechanism, labor taxes in the region experiencing a negative technology shock have to increase substantially to finance the unemployment benefits, representing a strong drag on economic activity. In fact, this effect lets the overall labor wedge in the affected region turn negative (i.e., below its steady-state value) after some periods: first, sticky prices lead to an inefficiently high labor input, while rising labor taxes subsequently reduce labor input below its efficient level. With a EUBS, parts of the required funds are obtained from the remaining region, such that labor taxes need to rise by much less. This effect, however, is not strong enough to generate positive welfare effects for Periphery in case of non-tradeable or tradeable technology shocks.

Finally, we note that the complete-markets allocation represents an intermediate case between EMU and a full EUBS. It closes the risk-sharing wedge by construction but opens the overall

Periphery labor wedge further in the initial periods, compared to the EMU case. This result is in accordance with the trade-off between closing labor wedges and the risk-sharing wedge postulated in propositions 2 and 3a. The risk-sharing wedge is closed by a positive present discounted value (PDV) of the transfer that corresponds to that of intermediate values of λ (Figure 5).[27] This increases consumption and hence inefficient production in the Periphery non-tradeable sector. In the times of a negative labor wedge in Periphery (see above) the trade-off is dominated by the effects of a reduction of Periphery labor taxes, which tends to reduce the labor wedge.

Financial-friction shocks: We now turn to demand shocks. Figure 7 shows the responses to a contractionary financial-friction shock in Periphery. As discussed in Section 3, this shock essentially reduces consumption demand for given fundamentals. Periphery consumption and output fall, while unemployment rises. Lower demand in Periphery lets the union-wide inflation rate fall (not shown), triggering an expansionary monetary-policy response. This pushes Core output and consumption upwards. Since consumption in Periphery is too low, seen from an efficiency perspective given current productivity, its overall labor wedge turns negative. Similarly, the risk-sharing wedge is negatively affected by the dampened consumption in Periphery. The Core labor wedge, on the other hand, is positive due to higher domestic demand.

In line with Proposition 5, a EUBS transfer towards Periphery, resulting from the unemployment differential, is able to reduce all wedges, including the Core labor wedge. This includes the risk-sharing wedge, also visible in its volatility (blue line in the upper panel of Figure 6). Thus, the welfare costs of fluctuations triggered by the financial-friction shock are reduced by a EUBS for both regions (lower panel of Figure 6). However, the transfer is not sufficient to close the labor wedge of the region experiencing the shock completely. In a sense, this result is embodied in the transfer mechanism. If the transfer is effective in reducing unemployment differentials, which is mostly the case, it is automatically reduced. These differentials can therefore not be reduced to zero, as no transfer would then take place.

Comparing the EUBS outcome with that of complete markets reveals that the responses of Core consumption and output flip signs in the latter case. This reaction is needed to close the risk-sharing wedge. The allocation is implemented by an implicit transfer that is close to zero. The crucial difference to the EMU scenario is that under complete markets Periphery households cannot not use the riskless bond to save as much, following the contractionary financial-friction shock. Analogously, Core households do not dissave. The reduction in Core consumption is in line with efficient risk sharing but renders Core's labor wedge negative ('too little' is consumed from an efficiency point of view). In a sense, the financial-friction shock is 'exported' to Core in the case of complete markets.

[27] The present discounted value is positive despite the negative values of the transfer, i.e., transfers away from Periphery, in the medium-run, since they are overturned by subsequently positive transfers. By implementing this time path of the transfer, the complete-markets solution achieves relatively higher consumption levels in Periphery in the longer run, such that the risk-sharing wedge remains closed throughout.

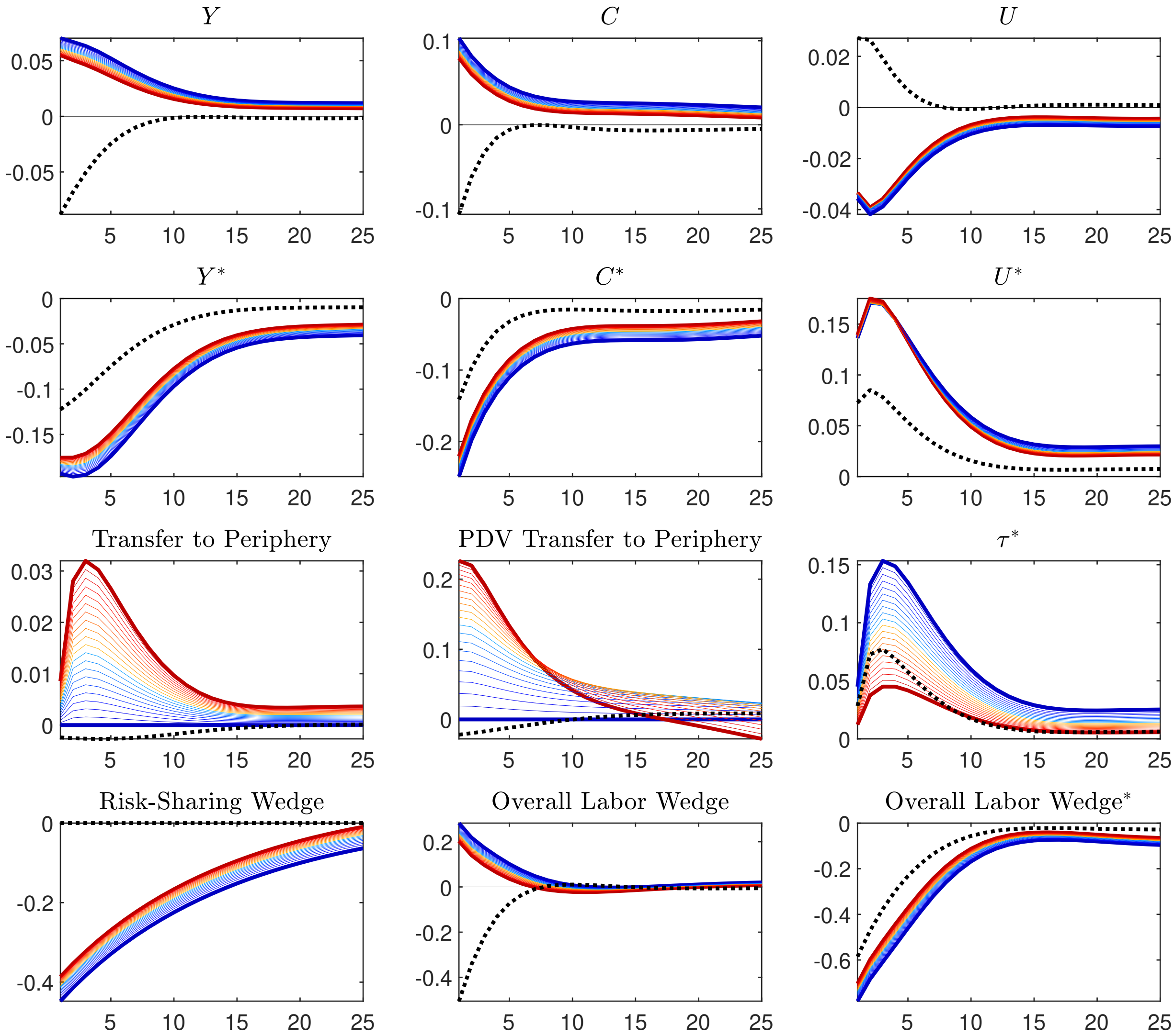

Figure 7: Responses to contractionary financial-friction shock in Periphery under EMU (blue), EUBS (red), and complete markets (black dotted) scenarios
Notes: See Figure 4.

Government-spending shocks: A positive shock to government spending in Periphery leads to a negative wealth effect, falling consumption, and rising output due to higher overall demand in this region, see Figure 8. Hence, net exports from Core to Periphery increase (not shown). At the same time, however, Core consumption (and investment) falls because of the subsequently reduced import demand of Periphery in the medium run. Core GDP is therefore negatively affected. GDP in Periphery falls below the steady-state level after a couple of periods, when the negative wealth effect starts to dominate higher government demand. Thus, unemployment rises above the steady-state level in Periphery after around five periods and displays a stronger positive reaction than in Core, despite the initial opposite output differential.

Implementing a EUBS increases these spillovers further. Because of the mentioned sign-flip in the cross-regional difference in unemployment, the transfer also changes direction over time. Specifically, it flows towards Periphery after around one and a half years. That is, the present discounted value of the transfer is actually positive for Periphery, despite the initial outflow.

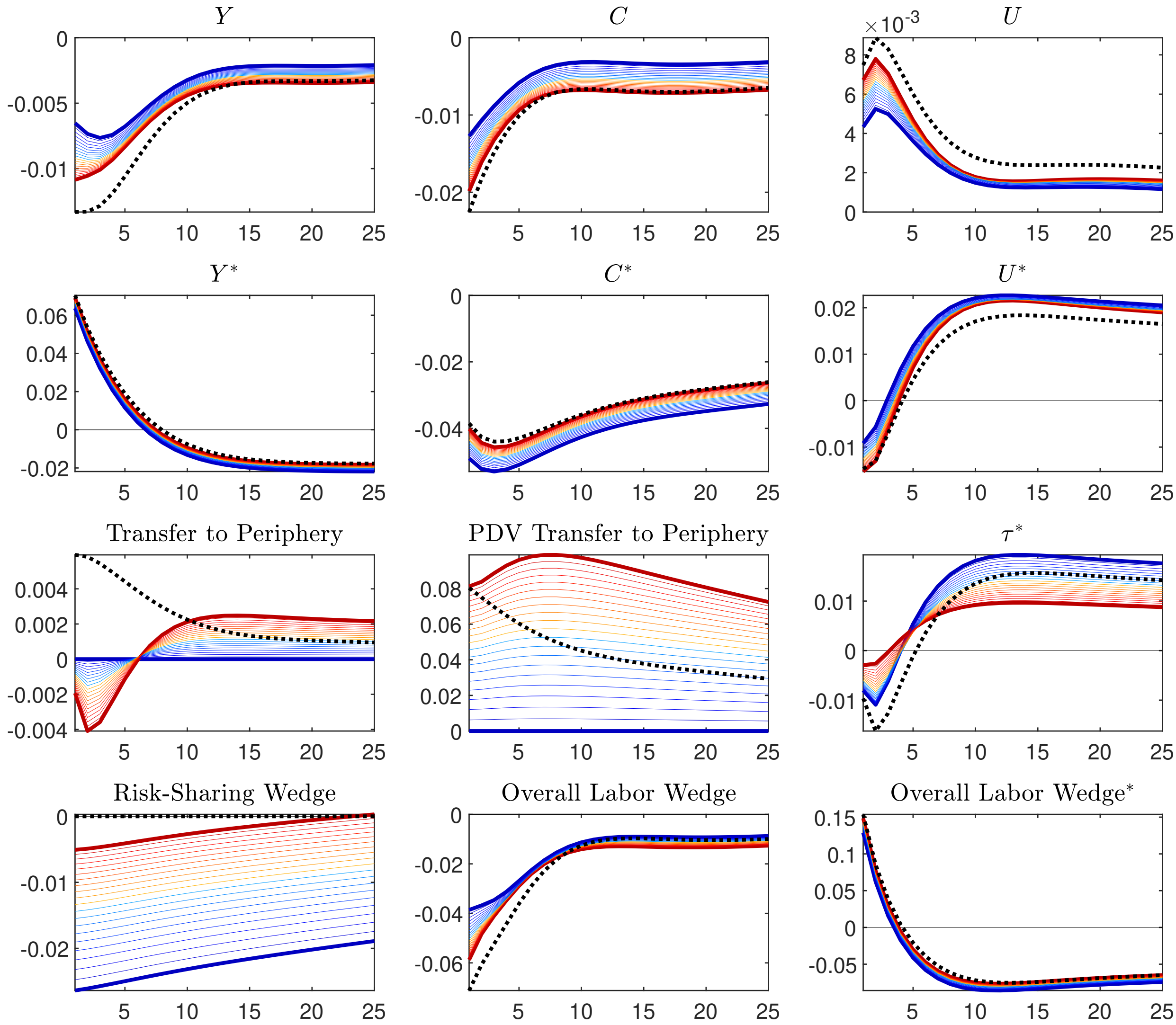

Figure 8: Responses to expansionary government-spending shock in Periphery under EMU (blue), EUBS (red), and complete markets (black dotted) scenarios
Notes: See Figure 4.

This dampens the negative Periphery consumption response and reduces Core consumption. It also reduces unemployment in Periphery. The reduction in export demand, combined with sticky prices, leads to a negative labor wedge in Core, which is aggravated by a EUBS transfer. The transfer-induced increased demand in Periphery falls mainly on Periphery tradeable or non-tradeable goods, pushing the positive labor wedge even further upwards. As in the case of technology shocks, it falls below its steady-state value after some periods because of the increase in the labor tax rate, needed to finance the rising unemployment benefits.

However, the effects of introducing a EUBS on the volatilities of the labor wedges and particularly on welfare are negligible (see the purple lines in Figure 6) because of a relatively low standard deviation of government-spending shocks and the mentioned sign-flip, resulting in a low present discounted value of the transfer. The region-specific and joint welfare effects of the transfer are therefore small, but negative. This is in line with Proposition 6: the welfare effect is negative since the transfer (in terms of its net present value) flows towards the region experiencing a positive government-spending shock and the economies display relatively high price rigidities (see above). Corresponding to the predictions of the proposition, risk sharing is therefore improved by a EUBS, visible in the reduction in the risk-sharing wedge, while efficiency is reduced. Thus, a full EUBS in the large model has detrimental welfare effects for technology *and* government-spending shocks.

Looking at the complete-markets allocation demonstrates the trade-off between risk sharing and efficiency following government-spending shocks postulated in Proposition 6 once more: the risk-sharing wedge is closed completely, while the labor wedges are initially opened up further.

Monetary-policy shocks: A union-wide contractionary monetary-policy shock represents an almost perfectly symmetric shock, see Figure 9. Here, a one-standard-deviation shock corresponds to an increase in the policy rate of 0.46 percentage points (annualized). The qualitative responses are identical across regions and mirror the predictions of Proposition 7 (except for the risk-sharing wedge, which is non-zero due to the asymmetric calibration). In particular, the contractionary shock decreases output and consumption in both regions. It also raises unemployment in the whole currency union. Both labor wedges are negative following the contractionary shock, as nominal rigidities prevent prices from falling further and hence 'too few' hours are worked, relative to the utility gain from consumption.

Due to different economic structures in Core and Periphery, some quantitatively asymmetric effects are observable. Specifically, steady-state profits of labor market firms are higher in Core. Hence, less jobs are destroyed in a downturn and unemployment rises by less, such that the transfer embodied in the EUBS initially flows towards Periphery. Since unemployment in both regions increases, however, the transfer under a EUBS is relatively small, compared to the effect of the shock on, e.g., output. As a result, the effects of the shock are almost unchanged by the introduction of a EUBS. Generally, the union-wide reduction in economic activity is detrimental for Core, which is a net exporter in steady state, such that the consumption drop is somewhat higher than in Periphery. The lower prices in Core then generate a positive risk-sharing wedge. Core borrows from abroad to smooth the impact on consumption. The resulting interest payments reduce demand in the future, which raises Core unemployment slightly above that of Periphery. This differential triggers a series of (small) transfers towards Core. Overall, the present discounted value of the transfer is therefore negative, i.e., Core benefits from a EUBS. This mechanism represents a form of insurance for Core following monetary-policy shocks.

The small EUBS effect on the responses compared to their size makes it difficult to spot the differences. However, since the monetary-policy shock has a relatively high standard deviation, these differences nevertheless impact on welfare. Specifically, the described insurance value of the EUBS for Core brings about welfare gains of a EUBS for Core (and joint welfare) in the case of monetary-policy shocks (see the green lines in the lower panel of Figure 6). For Periphery, however, the welfare effect is negative.

The complete-market solution is again in line with Proposition 7. Given that the risk-sharing wedge opens up due to the asymmetric calibration, an implicit transfer that reduces it also reduces one labor wedge, while increasing the other (also visible, for the incomplete-markets case, in the upper panel of Figure 6).

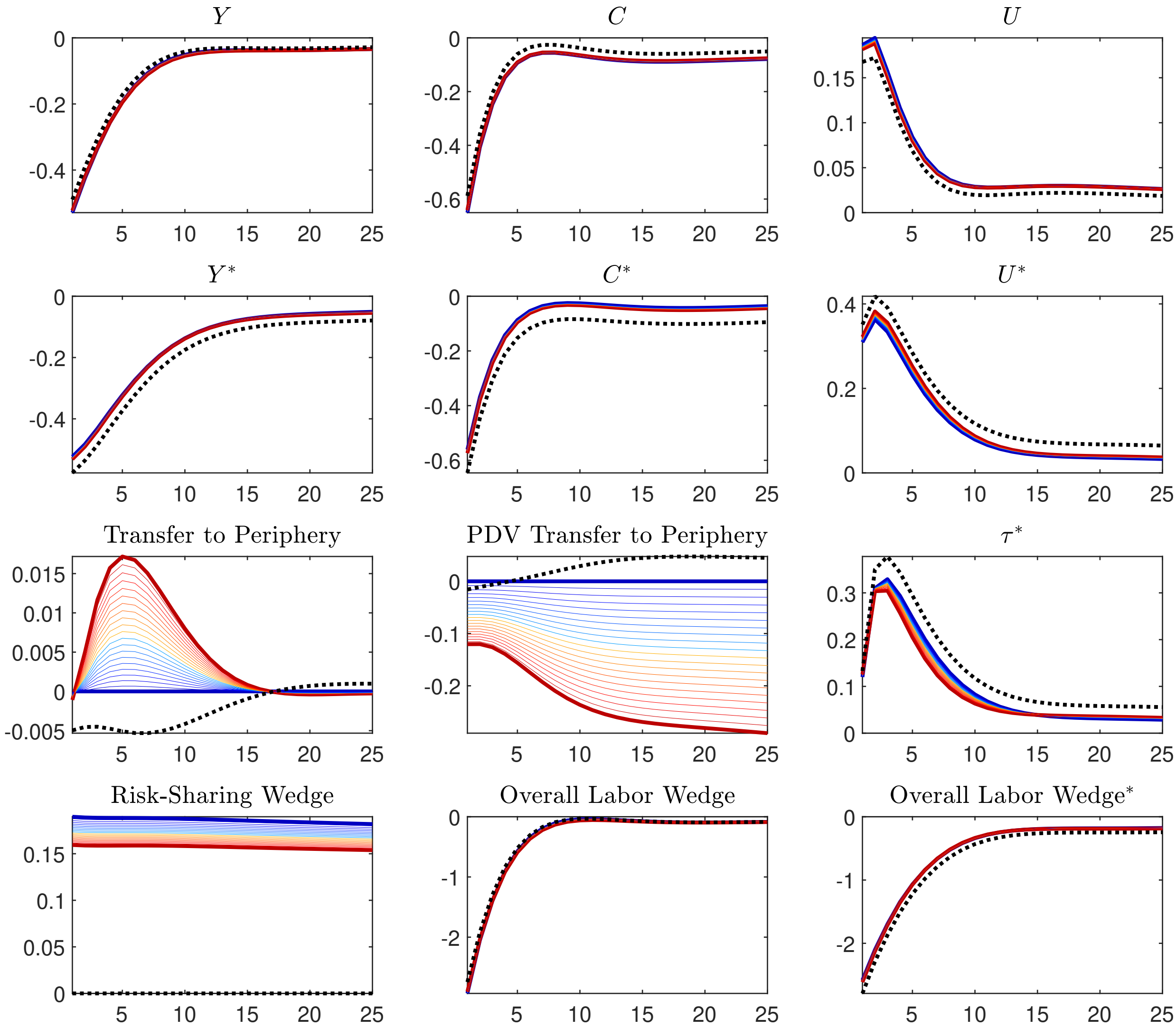

Figure 9: Responses to contractionary monetary-policy shock under EMU (blue), EUBS (red), and complete markets (black dotted) scenarios
Notes: See Figure 4.

6 Policy implications

The introduction of an international unemployment insurance scheme increases the co-movement of consumption, output, and unemployment across European regions, enhancing consumption risk sharing. However, at the same time it can lead to a misallocation of demand and factor inputs, particularly in response to technology shocks. Specifically, sticky prices give rise to a trade-off between consumption insurance and production efficiency, which becomes worse in the presence of consumption home bias, see Section 2. As shown analytically in that section and for the large model in Section 5, a transfer that flows towards the country hit by a negative technology shock, which is what a EUBS would implement, deteriorates production efficiency. In a sense, it leads to a 'zombification' of the now inefficient sector, as spending falls overproportionally on domestic goods. Structural reforms of this sector are therefore in order. Yet, there are also beneficial aspects of a EUBS. First, even in the case of technology shocks, a transfer to the recession region reduces the increase in tax rates that is required to finance

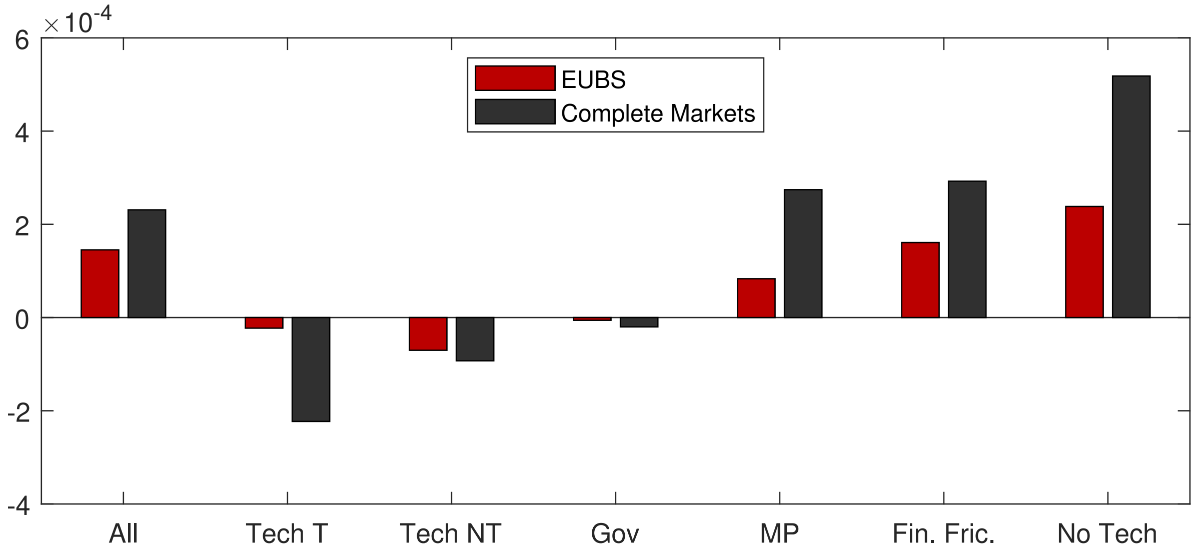

Figure 10: Welfare gains (in percent of steady-state consumption) for different shocks, relative to $\lambda = 0$
Notes: 'EUBS' refers to $\lambda = 1$. For different scenarios, see Figure 6.

the unemployment benefits, which counteracts the efficiency loss. Second, following financial-friction shocks a EUBS is beneficial as it directly offsets the negative demand impulse. Although this is not the case for government-spending shocks, which trigger a transfer in the 'wrong' direction from a efficiency point of view, the impact of a EUBS on the welfare effects of government-spending shocks is negligible. Third, for the calibration of the (asymmetric) large model, a EUBS has positive overall welfare effects in case of monetary-policy shocks, since it acts as an implicit insurance mechanism for the larger Core.

Summing up the positive and negative effects for the European calibration leads to the conclusion that the union of both regions would benefit from the implementation of a EUBS when all considered shocks are active (see black dotted line in Figure 6). Periphery, however, would experience a (very small) decline in welfare. Alternatively, if feasible, a EUBS that is not triggered following technology and government-spending shocks would perform much better in terms of welfare gains, see also Proposition 8. If, in the large model, a full EUBS is active following all shocks less technology shocks, joint welfare gains would already be higher (see dark-red line in Figure 6). That is, a EUBS is most useful after 'pure' demand shocks, where 'pure' excludes government-spending shocks as those shocks change the availability of resources for a given input of production factors. Although discussed in policy circles, the option of triggering a EUBS only after certain shocks might be technically difficult to implement.

The shock dependence is also visible in the comparison between a EUBS transfer scheme and the complete-markets allocation, depicted in Figure 10. Here, we plot the welfare effects of a full EUBS ($\lambda = 1$) and of the complete-markets allocation for the same scenarios as in Figure 6, relative to the EMU ($\lambda = 0$) baseline. If all shocks are active, the complete-markets solution gives the highest welfare. This is due to two facts. First, the implicit transfer of the complete-markets allocation is not tied to one particular variable, as it is the case for the EUBS-transfers. It is therefore able to achieve a complete stabilization of the risk-sharing wedge following all shocks. This is beneficial for welfare because, second, there is no general trade-off between efficiency and risk sharing after financial-friction and monetary-policy shocks. Thus, the complete-markets allocation raises welfare more than the EUBS, which is not able to close the risk-sharing wedge completely after these shocks.

Yet, as discussed previously, closing the risk-sharing wedge is harmful in terms of efficiency after technology and government-spending shocks (see propositions 2 and 6). Here, the objective of the complete-markets allocation to close this wedge renders its welfare effect negative. The EUBS arrangement does better, in particular following technology shocks. We again conclude that a system that could react differently to the different shocks would raise welfare unambiguously.

7 Conclusion

A well-known result from the theory of optimum currency areas states that one option to compensate for the missing adjustment via flexible exchange rates are state-contingent transfers. More recently, politicians in different countries of the euro area have taken up this argument and have pled for the introduction of a European unemployment benefit scheme. In this paper, we evaluate the macroeconomic effects of such a scheme in the specific context of the euro area and assess the impact on allocative efficiency.

We find that a EUBS has indeed the potential to stabilize consumption and reduce unemployment in the negatively-affected region after a shock. Yet, whether a EUBS is welfare enhancing (or decreasing) depends crucially on the reason for existing unemployment differentials. A EUBS can raise welfare in case of certain demand shocks, as the transfer embodied in the unemployment benefit payments counteracts demand shifts across countries. In the case of technology shocks, however, a EUBS increases factor misallocation across countries and sectors. Given that a large part of the transfer that is embodied in the international benefit payments is spent on inefficiently produced goods, a 'zombification' of the adversely affected sectors might result. This calls for accompanying structural reforms in addition to the transfer.

Without such reforms, a EUBS that is only active after certain shocks would maximize joint welfare. Specifically, technology and government-spending shocks drag down the welfare effects of a EUBS. Identifying such shocks in real time, however, poses a major obstacle to such a 'selective' EUBS. Nevertheless, we find (small) positive effects of EUBS on joint welfare even without this conditionality.

Appendix

A Analytical solution of simple model

This appendix presents the simple model of Section 2 and its solution. We first state the linearized equations for the sum of Foreign and Home variables, denoted by the superscript w: $x_t^w = x_t + x_t^*$, where lower-case letters denote percentage deviations from steady state. The variable a_t^w is defined as $a_t^w = a_t + b_t^*$, while $b_t^w = a_t^* + b_t$. The sum of country-specific prices is $p_t^w = p_{a,t} + p_{b,t}^* = p_t + p_t^*$, where $p_{a,t}$ is the price of good A. We directly set $z_t = g_t = \hat{\Delta}_t = 0$, that is, we focus on Foreign shocks. We also make use of the fact that variables are expected to remain in a steady state from the period following the shock onwards, as we assume temporary shocks only and all prices can be adjusted until then. For simplicity, government spending is assumed to be zero in steady state.

The sums of Foreign and Home variables, resulting from the first-order conditions and constraints, are as follows.

$$\begin{aligned}
y_t^w &= h_t^w + z_t^* && \text{Production functions}\\
w_t^w &= p_t^w + h_t^w + c_t^w && \text{Labor supply}\\
p_t^w &= \xi w_t^w - \xi z_t^* && \text{Price setting}\\
0 &= c_t^w + 2r_t + \hat{\Delta}_t^* && \text{Euler equations}\\
y_t^w &= c_t^w + g_t^* && \text{Global demand}\\
a_t^w &= c_t^w + g_t^*/\omega && \text{Demand domestic goods}\\
b_t^w &= c_t^w && \text{Demand imported goods}
\end{aligned}$$

Next, we state the same variables in cross-country differences, denoted by the superscript d, i.e., $x_t^d = x_t - x_t^*$. The variable a_t^d is defined as $a_t - b_t^*$, while $b_t^d = a_t^* - b_t$ and $p_{a,t}^d = p_{a,t} - p_{b,t}^*$.

$$\begin{aligned}
y_t^d &= h_t^d - z_t^* && \text{Production functions}\\
w_t^d &= p_t^d + h_t^d + c_t^d && \text{Labor supply}\\
p_{a,t}^d &= \xi w_t^d + \xi z_t^* && \text{Price setting}\\
p_t^d &= (2\omega - 1)p_{a,t}^d && \text{Price index}\\
y_t^w &= (2\omega - 1)c_t^w - g_t^* - \sigma p_{a,t}^d + \sigma(2\omega - 1)p_t^d && \text{Global demand}\\
a_t^d &= c_t^d - g_t^*/\omega - \sigma p_{a,t}^d + \sigma p_t^d && \text{Demand domestic goods}\\
b_t^d &= -c_t^d - \sigma p_{a,t}^d - \sigma p_t^d && \text{Demand imported goods}
\end{aligned}$$

All above equations hold in all periods, i.e., the period of the shock t and the subsequent expected steady state in $t+1$. The following two equations are valid for the period of the shock only, assuming that the economies start at the old steady state with zero bond holdings and allowing for the implementation of a cross-country transfer in period t only.

$$c_t^d - g_t^* = p_{a,t}^d + y_t^d - p_t^d - 2b_t - 2t_t \qquad \text{Budget constraints in period } t$$
$$D_t = c_t^d + p_t^d - \hat{\Delta}_t^* \qquad \text{Euler equations in period } t$$

The variable D_t represents the cross-country difference in expected nominal consumption. We solve for this difference in period $t+1$. The period $t+1$ represents the new steady state, as expected in period t. The parameter $r_s > 1$ is the real interest rate in the old and new steady state.

$$c_{t+1}^d = p_{a,t+1}^d + y_{t+1}^d + 2b_{t+1}r_s - p_{t+1}^d \qquad \text{Budget constraints periods} > t$$
$$D_t = c_{t+1}^d + p_{t+1}^d \qquad \text{Differences nominal consumption periods} > t$$

We solve the system of linear equations for the cross-country sums and differences. Country-specific variables can then be calculated from this solution. For propositions 1-4, we set $g_t^* = \hat{\Delta}_t^* = 0$. The linearized wedges are derived as follows.

$$rs_t = -c_t^d - p_t^d \qquad \text{Risk-sharing wedge}$$
$$lw_t^w = 2(y_t^w - z_t^*) \qquad \text{Sum overall labor wedges}$$
$$lw_t^d = \frac{1+\sigma}{\sigma} y_t^d - \frac{1-\sigma}{\sigma}(2\omega - 1)c_t^d + 2z_t^* \qquad \text{Difference overall labor wedges}$$
$$lw_t = \frac{lw_t^w + lw_t^d}{2} \qquad \text{Overall labor wedge Home}$$
$$lw_t^* = \frac{lw_t^w - lw_t^d}{2} \qquad \text{Overall labor wedge Foreign}$$

The overall labor wedge at Home results as

$$lw_t = \frac{2\xi(\Xi'-1)[\Xi' r_s + (\Xi+1)(r_s+1)]}{\Gamma} z_t^* + \frac{(\Xi'-1)[2\Xi'\xi(\omega-1)+\xi-2\omega+1]}{\Gamma(\omega-1)} r_s t_t - 2r_t,$$

with

$$\Xi = 2\omega(\sigma-1) \geq 0$$
$$\Xi' = \Xi(\omega-1) \leq 0$$
$$\Gamma = (1+r_s)(1-\Xi')[\xi(2\Xi+1)+1] + \Xi\omega(1-\xi) > 0,$$

while the overall Foreign labor wedge reads as

$$lw_t^* = 2\frac{(\Xi'\xi-1)[\Xi+1-r_s(\Xi'-1)] + r_s(\Xi'-1)\Xi\xi}{\Gamma} z_t^* - \frac{(\Xi'-1)[2\Xi'\xi(\omega-1)+\xi-2\omega+1]}{\Gamma(\omega-1)} r_s t_t - 2r_t.$$

The risk-sharing wedge is

$$rs_t = -\frac{(\Xi'-1)[\xi(2\Xi'\xi-1)-1]}{(\omega-1)\Gamma} r_s t_t - \frac{2\Xi\xi(\Xi'-1)}{\Gamma} r_s z_t^*.$$

For $\sigma=1$, the wedges reduce to the expressions in Section 2. Having solved for the wedges, the proofs of the lemma and propositions are straightforward.

Proof of Lemma 1. The output difference for the general case is

$$\begin{aligned} y_t - y_t^* = & \frac{(\Xi+1)[\xi(2\Xi'-1)+2\omega-1]}{\Gamma} \hat{\Delta}_t^* - \frac{r_s(1-\Xi')(\xi\Xi+1)+\Xi+1}{\Gamma} g_t^* \\ & -2\xi \frac{\Xi(r_s+2)(1-\omega-\Xi')+(r_s+1)(\Xi+1)}{\Gamma} z_t^*. \end{aligned}$$

The derivatives with respect to g_t^* and z_t^* are both negative, while the sign of the derivative with respect to $\hat{\Delta}_t^*$ depends on parameter values. ■

Proof of Proposition 1. The wedges for the case of $\xi=1$ and $g_t^*=\hat{\Delta}_t^*=0$ are

$$\begin{aligned} lw_t &= -\left[1+\frac{\Xi'}{\Xi+1}\frac{r_s}{r_s+1}\right] z_t^* - \frac{\Xi'-1}{\Xi+1}\frac{r_s}{r_s+1} t_t - 2r_t \\ lw_t^* &= -\left[1-\frac{\Xi'}{\Xi+1}\frac{r_s}{r_s+1}\right] z_t^* + \frac{\Xi'-1}{\Xi+1}\frac{r_s}{r_s+1} t_t - 2r_t \\ rs_t &= \frac{\Xi}{\Xi+1}\frac{r_s}{r_s+1} z_t^* + \frac{\Xi'-1}{\Xi'+\omega-1}\frac{r_s}{r_s+1} t_t. \end{aligned}$$

Setting t_t and r_t such that $lw_t = lw_t^* = 0$ yields

$$\begin{aligned} \check{r}_t &= -\frac{z_t^*}{2} \\ \check{t}_t &= \frac{\Xi'}{1-\Xi'} z_t^* \\ rs_t &= 0. \end{aligned}$$

■

Proof of Proposition 2. Setting t_t and r_t such that $lw_t = lw_t^* = 0$ in the general case with $g_t^* = \hat{\Delta}_t^* = 0$ yields

$$\check{r}_t = -\frac{z_t^*}{2}$$

$$\check{t}_t = \frac{(\omega-1)[(\xi-1)(\Xi+1)-r_s(\Xi'-1)(2\Xi'\xi+\xi-1)]}{r_s(\Xi'-1)(2\Xi'\xi(\omega-1)+\xi-2\omega+1)} z_t^*$$
$$rs_t = \frac{\xi-1}{2\Xi'(\omega-1)\xi+\xi-2\omega+1} z_t^*.$$

■

Proof of Proposition 3a. See the proof for Proposition 2 for the value of the transfer $\check{t}_t$ that closes both labor wedges with $g_t^*=\hat{\Delta}_t^*=0$. It is positive (flows to Foreign) whenever

$$\frac{1}{2[\Xi'(\omega-1)\xi-\omega]+1+\xi} z_t^* < 0.$$

Hence, for negative Foreign technology shocks ($z_t^*<0$) it is positive if

$$\xi > \frac{2\omega-1}{1-2\Xi'(1-\omega)}.$$

This is fulfilled for $\xi=1$, i.e., flexible prices. For $\xi=0$, on the other hand, it is not: the transfer reverses its direction. Furthermore, if $\omega\to0.5$, the transfer flows to Foreign, while for $\omega\to1$, it flows to Home, as long as $0<\xi<1$. ■

Proof of Proposition 3b. To derive the optimal transfer, we employ a second-order approximation of the equally weighted sum of country-specific welfare functions. This approximation is then maximized over t_t subject to the solution of the system of equations at the beginning of this section, i.e., the expressions for c_t, c_t^*, c_{t+1}, c_{t+1}^*, h_t, h_t^*, h_{t+1}, and h_{t+1}^* in dependence of t_t and z_t^*, where $g_t^*=\hat{\Delta}_t^*=0$. Expected transfers are assumed to be zero from period $t+1$ onwards, as the economies are expected to reach the new steady state then and we rule out steady-state transfers. For fully flexible prices ($\xi=1$), the optimal transfer $\hat{t}_t$ results as

$$\hat{t}_t = \frac{\mathcal{M}[1-(2\omega+\Xi)^2]}{\mathcal{M}(1+2\omega+\Xi)^2+(1+\Xi)^2} z_t^*.$$

This expression is positive if $z_t^*<0$, i.e., the transfer flows towards Foreign, the country that has experienced a negative technology shock. In contrast, the optimal transfer in case of fully rigid prices ($\xi=0$) is

$$\check{t}_t = \frac{(1-\omega)(2\omega-1)(1-\Xi')[\Xi+1+r_s(1-\Xi')]}{\mathcal{M}[r_s(1-\Xi')^2+(\omega-1)^2(\Xi+2\omega+1)^2]+r_s(1-2\omega)^2(1-\Xi')^2+(\omega-1)^2(\Xi+1)^2} z_t^*.$$

This expression is negative for $z_t^*<0$, i.e., the transfer flows away from Foreign, the country that has experienced a negative technology shock. ■

Proof of Proposition 4. The Foreign@Foreign wedge for $g_t^*=\hat{\Delta}_t^*=0$ is

$$FaF=\frac{(1-\xi)(1-\Xi')}{\Gamma}\frac{\omega}{1-\omega}r_s t_t+2\frac{(\Xi+1)(\Xi'\xi-1)+r_s(\Xi'-1)(\Xi\xi+1)}{\Gamma}z_t^*-2r_t.$$

The denominators of the derivatives of this expression with respect to z_t^* and t_t, i.e., Γ and $(1-\omega)\Gamma$, are positive. Hence, the derivative of the Foreign@Foreign wedge with respect to z_t^* is negative, while the derivative with respect to the transfer is positive for $\xi<1$ (and zero for $\xi=1$). ■

Proof of Proposition 5. For $g_t^*=z_t^*=0$, the wedges result as

$$\begin{aligned}
lw_t=&-\frac{2(\Xi+1)[\Xi'\xi(\omega-2)+\xi-\omega+1]-r_s(\Xi'-1)[\xi(2\Xi+1)+1]}{\Gamma}\hat{\Delta}_t^*\\
&+\frac{(\Xi'-1)[2\Xi'\xi(\omega-1)+\xi-2\omega+1]}{(\omega-1)\Gamma}r_s t_t-2r_t\\
lw_t^*=&\frac{2\omega(\Xi+1)(\xi\Xi'-1)+r_s(\Xi'-1)[\xi(2\Xi+1)+1]}{\Gamma}\hat{\Delta}_t^*\\
&-\frac{(\Xi'-1)[2\Xi'\xi(\omega-1)+\xi-2\omega+1]}{(\omega-1)\Gamma}r_s t_t-2r_t\\
rs_t=&\frac{(\Xi+1)[\xi(2\Xi'-1)-1]}{\Gamma}\hat{\Delta}_t^*+\frac{(\Xi'-1)[\xi(2\Xi'-1)-1]}{(1-\omega)\Gamma}r_s t_t.
\end{aligned}$$

Setting

$$\begin{aligned}
\check{r}_t=&-\frac{\hat{\Delta}_t^*}{2}\\
\check{t}_t=&\frac{(1-\omega)(\Xi+1)}{r_s(1-\Xi')}\hat{\Delta}_t^*
\end{aligned}$$

closes all wedges. The derivative of $\check{t}_t$ with respect to $\hat{\Delta}_t^*$ is positive. ■

Proof of Proposition 6. For $\hat{\Delta}_t^*=z_t^*=0$, the wedges result as

$$\begin{aligned}
lw_t=&-\frac{(\Xi+1)\{2\xi[\Xi'(2\sigma-1)-1]-(3\xi+1)(\sigma-1)\}+r_s(\Xi'-1)\{2\xi[\Xi(2\sigma-1)+\Xi'\sigma+1]+(3\xi+1)(\sigma-1)\}}{2\sigma\Gamma}g_t^*\\
&+\frac{(\Xi'-1)[2\Xi'\xi(\omega-1)-2\omega+\xi+1]}{\Gamma(\omega-1)}r_s t_t-2r_t\\
lw_t^*=&\frac{(\Xi+1)[-2\Xi'\xi(2\sigma+1)+(3+\xi)\sigma+1+\xi]-r_s(\Xi'-1)\{2\xi[\Xi(2\sigma+1)-\Xi'\sigma]+(3+\xi)\sigma+1+\xi\}}{2\sigma\Gamma}g_t^*\\
&-\frac{(\Xi'-1)[2\Xi'\xi(\omega-1)-2\omega+\xi+1]}{\Gamma(\omega-1)}r_s t_t-2r_t\\
rs_t=&-\frac{\Xi\xi(1-\Xi')}{\Gamma}r_s g_t^*+\frac{(\Xi'-1)(2\Xi'\xi-\xi-1)}{(1-\omega)\Gamma}r_s t_t.
\end{aligned}$$

Setting again t_t and r_t such that $lw_t = lw_t^* = 0$ yields

$$\begin{aligned}
\check{r}_t &= \frac{g_t^*}{2} \\
\check{t}_t &= \frac{r_s(\Xi'-1)[2\xi(\Xi'\sigma-\Xi)+\xi(\sigma-1)-\sigma-1]-(\Xi+1)[\xi(\sigma-1)+2\xi\Xi'-\sigma-1]}{2r_s\sigma(\Xi'-1)[2\xi\Xi'(\omega-1)+\xi-2\omega+1]}(\omega-1)g_t^* \\
rs_t &= \frac{\sigma+1-2\xi\Xi'-\xi(\sigma-1)}{2\sigma[2\Xi'\xi(\omega-1)+\xi-2\omega+1]}g_t^*,
\end{aligned}$$

where $\sigma+1-2\xi\Xi'-\xi(\sigma-1)\neq 0$. The transfer is positive for $g_t^*>0$ if

$$\xi > \frac{2\omega-1}{1-2\Xi'(1-\omega-1)}.$$

■

Proof of Proposition 7. For $\hat{\Delta}_t^* = z_t^* = g_t^* = 0$, the wedges result as

$$\begin{aligned}
lw_t &= \frac{(\Xi'-1)[2\Xi'\xi(\omega-1)+\xi-2\omega+1]}{(\omega-1)\Gamma}r_s t_t - 2r_t \\
lw_t^* &= -\frac{(\Xi'-1)[2\Xi'\xi(\omega-1)+\xi-2\omega+1]}{(\omega-1)\Gamma}r_s t_t - 2r_t \\
rs_t &= -\frac{(\Xi'-1)[\xi(2\Xi'-1)-1]}{(\omega-1)\Gamma}r_s t_t.
\end{aligned}$$

■

Proof of Proposition 8. Propositions 3a, 5, 6, 7 show that for low (high) price rigidities, a transfer that reduces both labor wedges, in combination with a suitable monetary-policy response, flows to Foreign if $z^*<(>)0$, $g_t^*>(<)0$ or $\hat{\Delta}_t^*>0$. Low (high) price rigidities are present if $\xi>(2\omega-1)/[1-2\Xi'(1-\omega)]$. The direction of such a transfer in response to $z_t^*<0$, $g_t^*>0$, and $\hat{\Delta}_t^*>0$ for low (high) price rigidities can hence be summarized by $\{+,+,+\}$ ($\{-,-,+\}$). The responses of relative variables are given in Lemma 1 and below (for $t_t=0$, i.e., pre-transfer).

$$\begin{aligned}
\bar{y}_t - \bar{y}_t^* =& -\frac{(\xi-1)[r_s(\Xi'-1)-\Xi-1][r_s(\Xi'-1)+2\Xi'-1]}{(\Xi+1)[\xi(2\Xi'-1)-1]+r_s(\Xi'-1)[\xi(2\Xi+1)+1]}\frac{1}{(r_s+1)(\Xi'-1)}z_t^* \\
&+\left[\frac{1}{\xi(2\Xi'-1)-1}\left(1-\frac{\Xi\xi r_s(\Xi'-1)[\xi(2\Xi'-1)+2\omega-1]}{(\Xi+1)[\xi(2\Xi'-1)-1]+r_s(\Xi'-1)[\xi(2\Xi+1)+1]}\right)-\frac{1}{2(\Xi'-1)}\left(1-\frac{r_s\Xi'}{r_s+1}\right)\right]g_t^* \\
&+\frac{(\xi-1)\omega(\Xi+1)[r_s(\Xi'-1)+2\Xi'-1]}{(\Xi+1)(\Xi'-1)[\xi(2\Xi'-1)-1]+r_s(1-\Xi')^2[\xi(2\Xi+1)+1]}\frac{1}{1+r_s}\hat{\Delta}_t^* \\
c_t - c_t^* =& -2\xi\frac{r_s\{\omega[2-\Xi(\Xi-2(\sigma-\omega)-1)]-1\}+(2\omega-1)(\Xi+1)}{\Gamma}z_t^* \\
&-\xi\frac{r_s(\Xi+2\omega-1)(\Xi'-1)-(2\omega-1)(\Xi+1)}{\Gamma}g_t^* - \frac{(\Xi+1)\{\xi[2\Xi'+2\omega(2\omega-1)-1]-1\}}{\Gamma}\hat{\Delta}_t^*
\end{aligned}$$

$$h_t - h_t^* = \frac{(\Xi+1)[\xi(2\Xi'-1)+1]+(\xi-1)r_s(\Xi'-1)}{\Gamma} z_t^* - \frac{r_s(1-\Xi')(\xi\Xi+1)+\Xi+1}{\Gamma} g_t^* + \frac{(\Xi+1)[\xi(2\Xi'-1)+2\omega-1]}{\Gamma}\hat{\Delta}_t^*.$$

The derivative of the hours-worked differential $n_t - n_t^*$ w.r.t. $\hat{\Delta}_t^*$ is positive (negative) if $\xi < (>)(2\omega-1)/(1-2\Xi')$. The derivative of the hours-worked differential $n_t - n_t^*$ w.r.t. z_t^* is positive (negative) if

$$\xi < (>) \frac{1+r_s(1-\Xi')+\Xi}{1+r_s(1-\Xi')+\Xi-2\Xi'(\Xi+1)}, \tag{23}$$

where the derivative of the right-hand side of this inequality w.r.t. σ is negative. The sign of the derivative of the output-gap differential w.r.t. g_t^* can be best derived by taking the derivative of the output differential reaction to g_t^* w.r.t. ξ:

$$\frac{\partial \frac{\partial y_t - y_t^*}{\partial g_t^*}}{\partial \xi} = \frac{r_s(1-\Xi')\Xi}{\Gamma} - \frac{[r_s(1-\Xi')(\xi\Xi+1)+\Xi+1][(1+r_s)(1-\Xi')(2\Xi+1)-\Xi\omega]}{\Gamma^2} < 0.$$

That is, the direction of the transfer induced by the reaction of $y_t - y_t^*$ to $z_t^* < 0$, $g_t^* > 0$, and $\hat{\Delta}_t^* > 0$ for low (high) price rigidities can be summarized by $\{+,-,-\}$ ($\{+,-,+\}$), the reaction of $\bar{y}_t - \bar{y}_t^*$ by $\{-,-,+\}$, and the reaction of $c_t - c_t^*$ by $\{+,+,+\}$. The reaction of $h_t - h_t^*$ can be summarized by $\{+,-,-\}$ if $\xi > [1+r_s(1-\Xi')+\Xi]/[1+r_s(1-\Xi')+\Xi-2\Xi'(\Xi+1)]$ (high trade-price elasticity and low price rigidities, by $\{-,-,-\}$ if

$$\frac{1+r_s(1-\Xi')+\Xi}{1+r_s(1-\Xi')+\Xi-2\Xi'(\Xi+1)} > \xi > \frac{2\omega-1}{1-2\Xi'}$$

(low trade-price elasticity and low price rigidities) and $\{-,-,+\}$ if $\xi < (2\omega-1)/(1-2\Xi')$ (low trade-price elasticity and high price rigidities). Comparing these reaction with the transfer direction needed for closing both labor wedges completes the proof. ■

B Data

B.1 Data series and sources

Our main data source for all considered countries is the OECD Economic Outlook, but we also take data from the OECD Main Economic Indicators, the OECD Quarterly National Accounts, the IMF Direction of Trade Statistics, the OECD STAN Database, the AMECO Database of the European Commission, national central banks, the European Central Bank, and updates of the data in Wu and Xia (2016). Table B-1 lists the exact names of the data series and the corresponding sources.

Table B-1: Data

OECD Economic Outlook 103, 1999Q1–2017Q4 (quarterly frequency)
GDP, volume, market prices Private final consumption expenditure, volume Gross fixed capital formation, volume Government final consumption expenditure, volume Government gross fixed capital formation, volume Unemployment rate GDP, volume, at 2010 PPP USD Exchange rate, national currency per USD Euro-area consumer price index, harmonised Euro-area core inflation index, harmonised
OECD Main Economic Indicators 2018/7, 1999Q1–2017Q4 (quarterly frequency)
Consumer price index, all items Employment services Employment industry
OECD Quarterly National Accounts 2018/1, 1999Q1–2017Q4 (quarterly frequency)
Industry Services
IMF Direction of Trade Statistics 12/2017, 1999Q1–2017Q4 (quarterly frequency)
Imports, Million USD Exports, Million USD
OECD STAN (ISIC Rev. 4 , SNA08), 1999–2017 (annual frequency)
Manufacturing output (D10T33) Total Services output (D45T99)
AMECO Edition May 2018, 1999–2017 (annual frequency)
Wage share (ALCD2) Capital-output ratio (AKNDV)
National Central Banks, 2000–2017 (quarterly frequency)
Loan rate Deposit rate
European Central Bank, 1999Q1–2017Q4 (quarterly frequency)
EONIA
Wu and Xia (2016), 2004Q4–2017Q4 (quarterly frequency)
Shadow rate euro area

B.2 Country aggregates and parameter values

We construct the parameter and target values for the aggregates *Core* (Austria, Belgium, Germany, Finland, France, Netherlands) and *Periphery* (Greece, Ireland, Italy, Portugal, Spain) using average PPP-adjusted GDP weights. In order to avoid national basis effects, we construct aggregate series by first calculating quarterly growth rates and then aggregating the weighted series. The aggregated growth rates are then cumulated from the normalized base year in order to transform the series into levels. Net exports are calculated based on data on bilateral trade between countries in Core and Periphery, while the real exchange rate equals the ratio of the aggregated region-specific price indices. Commodity prices are based on the difference between the HCPI and Core CPI. Due to (quarterly) data availability, Solow residuals are estimated based on data for production and employment in industry and services.

B.3 Filtering

We generally apply the HP-filter with a smoothing parameter of 1600 to the time series data, before computing statistics of interest. Data used in the estimation of the Taylor rule is not filtered.

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