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ORIGINAL PAPER

Sectoral allocation and macroeconomic imbalances in EMU

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Abstract

The study documents how, over 1996–2008, large capital inflows in Southern Europe coincided with broad-based growth of the nontradable sector, extending beyond the construction and real estate sectors. The authors present a tractable two-sector, two-region ('North' and 'South') model of a monetary union, in which they show how the sharp, permanent, fall in Southern real interest rates that occurred in the run-up to EMU can explain the Southern consumption boom, wage growth, growth of the nontradable sector, and deteriorating external position. Upward pressure on the EMU-wide interest rate induces an opposite process in North. Consequently, both real exchange rates and external positions of the two regions diverge. Including a third country with a flexible exchange rate vis-à-vis the euro amplifies the effects of monetary integration in South, while dampening them in North. The study confirms the key model predictions using a panel-BVAR for the euro area and investigates various policy reforms to facilitate the ongoing rebalancing process in the eurozone.

Keywords EMU · Monetary integration · Current account imbalances · Sectoral allocation

JEL Classification F32 · F34 · F36 · F45

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1 Introduction

In the run-up to the introduction of the euro, both real and nominal interest rates in the Southern members of the Economic and Monetary Union (EMU) decreased markedly. This induced major capital flows from the North to the South, which were initially considered to be largely benign.[1] In retrospect however, the inflow of capital mainly fueled a boom of domestic lending and construction, contributing little to productivity growth or business cycle convergence.[2] As the discrepancy between the external debt level and the capacity to repay kept growing, eventually the solvency of the recipient regions came under pressure (see Giavazzi and Spaventa 2010). Whereas there exists a fairly broad consensus regarding this narrative (see e.g. Baldwin and Giavazzi 2015), less is known about how the sectoral allocation of capital came about. It is therefore also unclear whether the developments in the first decade of EMU were an unfortunate one-off or something that could have been foreseen and possibly prevented.

In this paper, based on a detailed breakdown of the share of production that is absorbed domestically, we document how the growth of the nontradable sector in Southern Europe was a broad-based phenomenon extending beyond the construction- and real estate sectors. We then proceed by constructing a tractable two-sector two-region ('North' and 'South') general equilibrium model of a monetary union. We simulate the non-linear transition path following the permanent drop in the real interest rate experienced by Southern Europe in the run-up to the introduction of the euro. The fall in the interest rate induces a regional demand boom, which increases demand for both tradable and nontradable goods. Whereas the nontradable sector is able to increase prices and output, the tradable sector faces foreign competition and thus has less room to increase prices. Therefore, in real terms, capital and labor are cheaper in the nontradable sector and are (re)allocated to this sector. In North, Southern demand for tradables and upward pressure on the EMU-wide interest rate induce wage moderation and a shift of resources to the tradable sector. As such, cost competitiveness positions in North and South diverge, while Southern external debt accumulates. Absent a debt-elastic interest rate or a debt limit, there is nothing to stop this process. When we extend the model to include a third region—the 'Rest of the World'—the effects of monetary integration in the Southern part of the union are amplified, while spillovers to North are more muted, in part due to an appreciation of the union's exchange rate that limits the growth of the Northern tradable sector.

We empirically validate key model predictions using a reduced-form panel-BVAR for 9 euro area countries. We show most predictions to hold up well: countries which experienced negative interest rate shocks relative to the euro area average, saw a

[1] See for instance Feldstein (2012) who describes the large intra-EMU capital flows and the seminal paper of Blanchard and Giavazzi (2002) for a—at the time—common interpretation of these capital flows.

[2] Comunale and Hessel (2014) describe how the surge in domestic demand was the root cause behind the emergence of current account deficits. Fagan and Gaspar (2007) show that capital inflows fueled a consumption boom while Eichengreen (2010) and Holinski et al. (2012) show that the Southern countries became relatively less productive after monetary integration.

rising price level (relative to the union average), a deteriorating current account balance, and faster growth of the nontradable sector. In contrast, tradable sector growth was not significantly affected by downward shocks to the interest rate.

Our paper contributes to an emerging body of research that studies the allocation of incoming capital flows in Southern Europe, both across and within sectors, and the effects thereof on the external position and productivity.[3] Most related, Benigno and Fornaro (2014), Kalantzis (2015) and Piton (2019), show that in a small open economy (SOE) framework an exogenous fall in the interest rate leads to (relative) growth of the nontradable sector. Piton (2019) focuses on the drivers of rising unit labor costs, while Benigno and Fornaro (2014) show how—in a setting where only the tradable sector experiences productivity growth—the reallocation of labor to the nontradable sector contributes to stagnating productivity growth. Kalantzis (2015) emphasizes how the interest rate drop results in both growth of the nontradable sector as well as increasing leverage, which together make balance-of-payments crises more likely.

Our contribution to the literature is threefold. First, by moving to a multi-country setting with an endogenous interest rate, we document the feedback effects that occur within a monetary union.[4] Our model suggests that wage moderation, tradable sector growth and a current account surplus in Northern Europe do not (only) reflect prudent policies, but also the consequences of unification. In this way, we complement not only the SOE literature, but also studies by Gadatsch et al. (2016) and Bettendorf and León-Ledesma (2015), who focus on the extent to which German economic policies have driven euro area imbalances. Second, our modeling approach takes into account that the interest rate shock hitting Southern Europe was large and long-lasting and allows for monopolistic competition and differing levels of productivity between regions and sectors. We can thereby show that the reallocation of capital and labor towards the nontradable sector induced by a falling interest rate is not hindered by the nontradable sector being the less competitive or productive one. This offers a structural explanation for the empirical findings of Borio et al. (2016) and Cette et al. (2016), who show that credit booms are associated with a productivity slowdown driven by a reallocation of resources towards less productive sectors.[5]

[3] Reis (2013) focuses on financial frictions to show why relatively unproductive firms in the nontradable sector grow at the expense of the tradable sector. Gopinath et al. (2017) and Cecchetti and Kharroubi (2015) show that financial frictions can contribute to the misallocation of capital within sectors, as capital is allocated to firms that have higher net worth but are not necessarily more productive. Sy (2016) emphasizes how the interaction of a common monetary policy and heterogeneous inflation rates implies real rates that are lower in the South than in the North, contributing to growth of the Southern nontrable sector. To rationalize the boom-bust cycle experienced by much of the eurozone, Ozhan (2017) shows how bank balance sheets can amplify fluctuations that are driven by news on the valuation of non-traded sector capital. Coimbra (2010) presents a small open economy model in which falling interest rates lead to an increase in the collateral value of housing, inducing growth of the housing sector and a deterioration of the trade balance.

[4] Over 1999–2007, the former high interest rate countries' represented 32–36% of euro area GDP and 40–41% of the euro area population, rendering the assumption that these countries can be represented as small open economies within the euro area counterfactual. See also Fagan and Gaspar (2007).

[5] Relatedly, Teimouri and Zietz (2018) document that in middle-income countries, capital surges contribute to deindustrialization.

Third, as our model covers both Southern and Northern EMU-countries, we can test the model predictions using a panel-BVAR. To this end, we compute tradable and nontradable sectoral growth rates based on a detailed decomposition of the share of sectoral production that is absorbed domestically.

The results in this paper raise important policy issues, as to correcting external imbalances and preventing new ones. For one, the model suggests that growth of the Southern nontradable sector, deteriorating competitiveness, and current account deficits are relatively straightforward consequences of the economic boom induced by the sharp, permanent decline in real interest rates. A sufficiently strong reaction of Southern interest rates to the accumulating debt, or possibly macroprudential measures, could have helped to moderate these developments, preventing the need for a sharp rebalancing process later on. However, in the absence of these timely stabilizing measures, investors 'waking up' and demanding a higher interest rate premium induces a sharp rebalancing process during which Southern GDP falls.

We investigate various policy options that can accommodate a less disruptive rebalancing process, focusing on product market reforms that have the potential to both boost growth and facilitate the rebalancing process. Firstly, we analyze the effects of a liberalization of the Southern nontradable sector, i.e., allowing for more domestic competition. Perhaps counter-intuitively, but in line with Cavelaars (2006), this does not improve the region's external position. As markups in the nontradable sector come down, demand for nontradable goods increases and the sector expands. Total output in South grows, while the external position marginally deteriorates. Spillovers from liberalizing the Northern nontradable sector are limited. Secondly, we simulate a decrease in the markup on tradable goods (interpreted as a deepening of the European internal market). This induces a shift of productive resources towards the tradable sector and boosts growth, though in the short run it does come at the expense of a deterioration of the external position of the union as whole.

2 Stylized facts

In anticipation of the introduction of the euro, nominal interest rates in Southern Europe fell sharply. As, in a number of countries, this partly reflected falling inflation expectations, the drop of economically more relevant real interest rates was somewhat less extreme. Nevertheless, it was substantial: in the 3 years prior to the introduction of the euro, real 1-year yields—the nominal 1-year yield on government debt minus 1-year ahead Consensus inflation expectations—in Italy, Ireland, Portugal and Spain (the 'IIPS', with data for Greece being unavailable before 1998) fell by on average *four* percentage points, see Fig. 1a. Over the same period, real rates in the rest of the euro area (REA) remained roughly constant.

In the first years of EMU, interest rates in the entire euro area increased. In the North, where interest rates had not fallen in the run-up to EMU, they reached the highest level in years. Following the collapse of the dotcom bubble, union-wide interest rates came down again. However, inflation expectations and realized inflation in the GIIPS remained persistently above those in the REA. Consequently, real rates in the GIIPS remained below those in the REA up to the onset of the crisis.

Low and falling interest rates induced a domestic demand boom in the GIIPS (Fig. 1b). Over 1999–2007, domestic demand in the GIIPS grew by on average 3% a year. In the REA, domestic demand increased by 1.7% a year. The demand boom in the GIIPS contributed to a surge in imports, but was not matched by a similar increase in exports. Export performance even somewhat lagged behind the REA (Fig. 1c). As a result, the current account of the GIIPS which was balanced at the onset of EMU, deteriorated sharply in the years thereafter. The GIIPS' current account deficit was matched by an increasing current account surplus in the REA (Fig. 1d).[6] Accordingly, the euro area's external position remained close to balance.

To shed more light on the sectoral composition of growth, Fig. 2 displays the dynamics of nontradable value added relative to total value added. To this end, we use data from the World Input Ouput Database (Timmer et al. 2015) and estimate for each sector in each country the share of production that is absorbed domestically. We aggregate these results for all euro area countries, weighing each member by its share in total euro area output. Subsequently, we construct the nontradable sector by selecting those sectors that depend most heavily on domestic demand. Figure 12 in "Appendix 1" shows for the year 1999 per sector the share of production that is absorbed domestically. In Fig. 2a, c, we construct the nontradable sector by aggregating the 8 sectors that depend most heavily on domestic demand and which jointly produce 33% of total euro area output. In Fig. 2b, d, we construct the nontradable sector by aggregating the 14 sectors that depend most heavily on domestic demand and which jointly produce 50% of total output.

Irrespective of the threshold used, the share of nontradable value added in total value added in the GIIPS grew significantly during EMU's first decade: from 45% in 1999 to 48.5% in 2008 when using the more restrictive definition of the nontradable sector (Fig. 2a), and from 63 to 67% when using the less restrictive definition. By contrast, in the REA, nontradable value added as share of total value added increased by one percentage point only (when using the more restrictive definition) or stayed flat (using the broader definition).

Numerous country or sector specific reasons can be identified to explain the allocation of capital inflows. One popular explanation focuses on excessive growth in the real estate sector. Housing bubbles have certainly been an important factor driving current account imbalances in countries such as Spain and Ireland. However, the nontradable boom was not limited to real estate and construction. Figure 2b, d show the share of value added created in the nontradable sector as a share of total value added when *excluding* the construction and real estate sector from both nominator and denominator. This somewhat mutes the growth of the nontradable sector in both the GIIPS and the REA, but the overall pattern remains the same: in the GIIPS, the share of the nontradable sector grows by 2% (in the restrictive definition) and almost 4% (using the wider definition). In the REA, the share of the nontradable sector now stays flat, no matter which definition is used (see Fig. 2c, d). Overall,

[6] Consistent with this pattern, Berger and Nitsch (2014) provide evidence of a significant widening of bilateral intra-euro area trade imbalances.

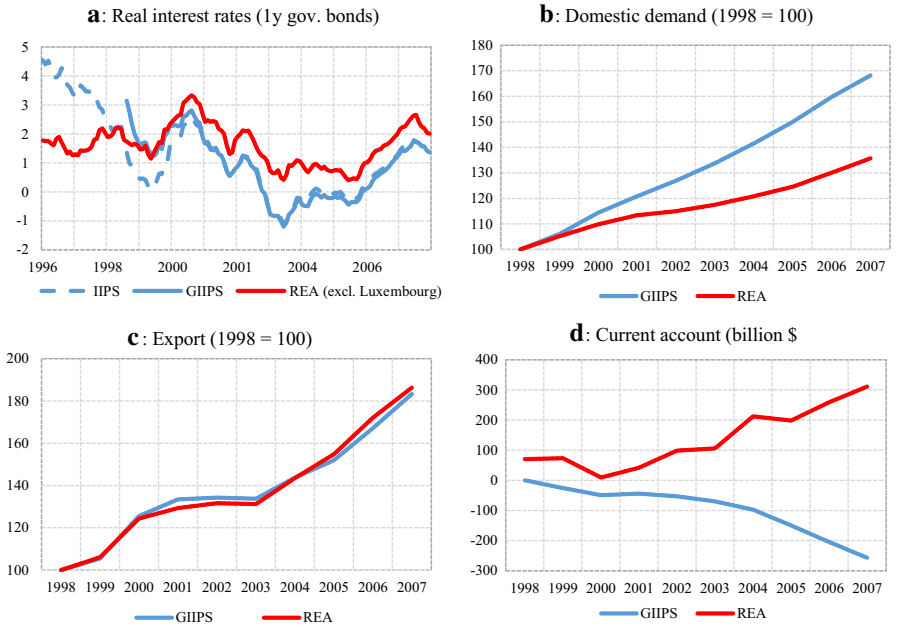

Fig. 1 Interest rates and macroeconomic imbalances. The IIPS include Ireland, Italy, Portugal and Spain, the GIIPS also includes Greece. The REA includes the other EMU-12 countries: Austria, Belgium, Finland, France, Germany, Luxembourg and the Netherlands. **a** The real 1 year interest rate, calculated as the 1 year yield on government bonds minus inflation expectations over the same 1 year period (calculated using Consensus data). **b**, **d** Based on data from the IMF WEO database October 2015, **c** uses AMECO data

the rapid growth of the nontradable sector in the GIIPS appears to have been more broad-based than is sometimes suggested.[7]

3 Model description

The model builds on the two-region two-sector framework introduced by Stockman and Tesar (1995) and Obstfeld and Rogoff (1995). The regions are labeled 'North' and 'South'. Following monetary integration, both regions become part of a single monetary union. Both regions exist of a large number of identical households, a large number of firms and a government which all have perfect foresight.

Households consume, supply labor, accumulate financial assets (one-period risk free bonds), and own the firms. Firms invest in capital subject to diminishing returns to scale, and hire labor from households. In each region there are two types of firms, producing nontradable goods (N) and tradable goods (T) respectively. The tradable

[7] The financial sector, another sector typically mentioned as a fast growing (closed) 'services' sector, is too open to be part of our nontradable sector and thus not driving the growth thereof.

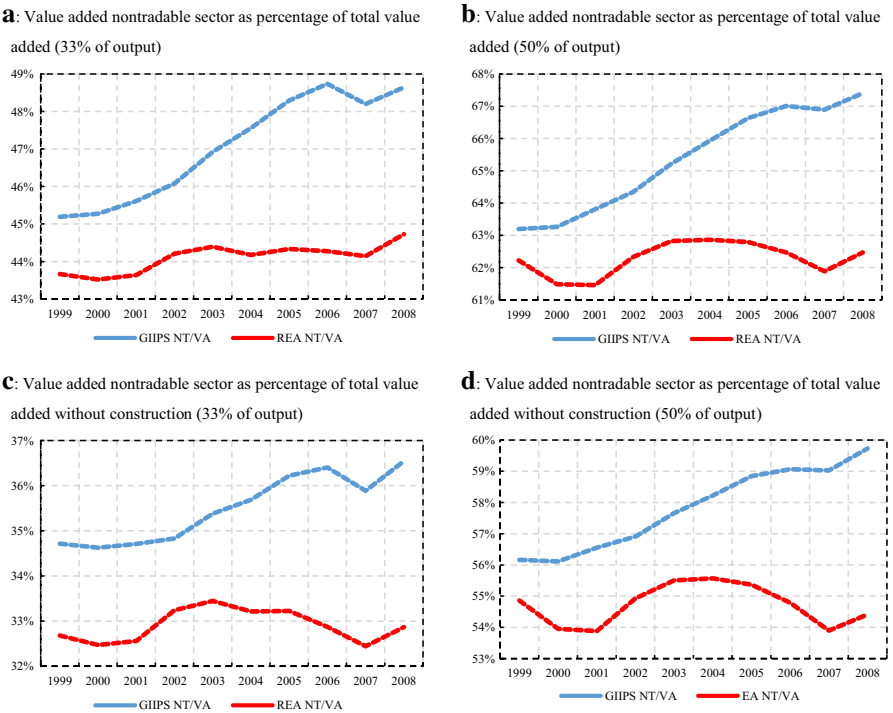

Fig. 2 Nontradable sector growth and as percentage of GDP. The GIIPS include Greece, Ireland, Italy, Portugal and Spain. The REA includes the other EMU-12 countries excluding Luxembourg: Austria, Belgium, Finland, France, Germany and the Netherlands. *Source*: Own calculations based on WIOD, release 2013 (Timmer et al. 2015), see "Appendix 1.1"

good is used either as consumption good or as investment in the tradable and nontradable capital stock. The nontradable good can only be consumed.

The monetary union as a whole is a closed economy, a simplifying assumption which we relax in Sect. 5.3. Within the union labor is mobile across sectors, but not between regions. Exchange rates are fixed, i.e., pegged in the immediate run-up to EMU, and irrevocably fixed thereafter. In the run-up to EMU, regional interest rates are higher in South than in North by an exogenous premium, which can be thought of as reflecting e.g. exchange rate or inflation risk (for a similar approach, see Kollmann et al. 2015). Following the introduction of a single currency, this premium disappears and interest rates converge.

3.1 Households

Households living in region $j \in \{n, s\}$, where n = North and s = South, maximize lifetime utility by choosing consumption and labor supply:

$$U^j = \sum_{v=0}^{\infty} (\beta^j)^v \left[\log C_t^j - \frac{\theta (L_t^j)^{1+\sigma_l}}{1+\sigma_l} \right], \quad \theta, \sigma_l > 0 \quad \text{and} \quad 0 < \beta^j < 1, \tag{1}$$

where C_t^j denotes consumption in region j at time t and L_t^j denotes labor supply. The parameters $\beta^j = 1/(1+\rho^j)$, θ and σ_l denote, respectively, the discount rate, the weight of labor in the utility function and the inverse of the elasticity of work effort.

The consumption good is a composite of a nontradable $C_t^{j,N}$ and a tradable good $C_t^{j,T}$ which are transformed into the final consumption good via a standard aggregator function: $C_t^j = \left(C_t^{j,N}\right)^{\eta} \left(C_t^{j,T}\right)^{1-\eta}$ where $0 < \eta < 1$ denotes the share of nontradables. Note that the tradable good is either produced in the home region j or in the foreign region denoted by j', i.e. consumption of the tradable good in region j is denoted as $C_t^{j,T} = C_t^{jj,T} + C_t^{jj',T}$. The nontradable good is only produced domestically. The consumer price index is a composite of the price of the nontradable good $P_t^{j,N}$ and the price of the tradable good $P_t^{j,T}$ and is obtained by minimizing the expenditure necessary to obtain one unit of the composite good C_t^j:[8]

$$P_t^j = \frac{\left(P_t^{j,N}\right)^{\eta} \left(P_t^{j,T}\right)^{1-\eta}}{(\eta)^{\eta}(1-\eta)^{1-\eta}}. \tag{2}$$

For the tradable good the law of one price holds, as there are no trade restrictions any price difference is arbitraged away: $P_t^{n,T} = P_t^{s,T}$. Throughout the remainder of this paper, the price of the tradable good will serve as the numeraire and will be set to one

Households can borrow or lend via single period bonds issued in both North and South. We assume that, prior to EMU, there is an exogenous wedge between Southern and Northern risk-free interest rates:

$$r_t^{f,n} + \omega = r_t^{f,s}, \tag{3}$$

where $r_t^{f,j}$ is the endogenously determined risk free interest rate on bonds issued by region j and ω is an exogenous premium that disappears after monetary integration. The uncovered interest rate parity condition ensures that after integration the nominal interest rate is the same in both regions: $r_t^{f,n} = r_t^{f,s} \equiv r_t^{f,e}$, where $r_t^{f,e}$ is the union interest rate.

It is a characteristic of international business cycle models with incomplete financial markets that there is no unique deterministic steady state (see e.g. Schmitt-Grohé and Uribe 2003; Boileau and Normandin 2008). In particular, whereas the interest rate pins down both regions' net lending, their external asset holdings are indeterminate. To pin down the equilibria, and prevent any one region from

[8] I.e. minimizing $P_t^j C_t^j = \sum_{j'}^{j} \{P_t^{j',T} C_t^{jj',T}\} + C_t^{j,N} P_t^{j,N}$ subject to the constraint $C_t^j = (C_t^{j,N})^{\eta} (C_t^{j,T})^{1-\eta}$.

endlessly accumulating debt, we introduce a debt-elastic interest rate premium x_t^j. The interest rate premium increases in the regions' external debt level:

$$x_t^j = \xi(e^{-N_t^j} - 1), \tag{4}$$

where ξ denotes how strongly the interest rate premium responds to debt accumulation and $N_t^j \equiv \frac{NFA_t^j}{Y_t^{j,T} + P_t^{j,N} Y_t^{j,N}}$ denotes the net foreign asset position as percentage of GDP, NFA_t^j denotes the net financial assets of region j and $Y_t^{j,T}$ and $P_t^{j,N} Y_t^{j,N}$ denote (nominal) GDP in the tradable and nontradable sector respectively. As such, a region's borrowing rate is given by $r_t^j = r_t^{f,j} + x_t^j$. This implies that the rate paid by the borrower is higher than the one received by the lender. The difference can be thought of, and micro-founded as, the cost of financial intermediation (Boileau and Normandin 2008). Alternatively, it can be interpreted as a premium on default risk that is absorbed by the intermediary bearing the risk.[9]

The household budget constraints are represented by:[10]

$$\sum^{j'} B_t^{j'j} + C_t^{j,T} + P_t^{j,N} C_t^{j,N} = \sum^{j'} \left(1 + r_{t-1}^j\right) B_{t-1}^{j'j} + \pi_t^{j,N} + \pi_t^{j,T} + L_t^j W_t^j, \tag{5}$$

where $L_t^j W_t^j$ denotes nominal labor income, $B_t^{j'j}$ denotes net bonds issued in country j and held by households in country in j', $\pi_t^{j,N}$ and $\pi_t^{j,T}$ are firm profits (hence households are the true owners of the firms). Households maximize utility by choosing consumption, labor supply and bond holdings, subject to the budget constrained and a no-Ponzi condition. Labor is perfectly mobile within regions, but does not move across the two regions. As a consequence, the wage rate is equal across sectors but may differ between regions.

3.2 Firms

In both regions the economy is occupied by two types of intermediate firms producing wholesale tradables (T) and wholesale nontradables (N), respectively. For brevity we define $Z \in (T, N)$. Intermediate firms in both sectors hire labor from the household sector, invest in capital subject to diminishing returns to scale, and sell their wholesale goods to retailers. Retailers use the wholesale goods to produce the final goods. The retailers are introduced only to realize monopolistic competition in a tractable manner.

The aggregate production technologies of the nontradable and tradable intermediate firms are specified by a Cobb–Douglas form:

[9] During the first decade of EMU risk premia were mostly absent while they suddenly spiked when the solvency of the Southern states became questionable. Section 5.4 describes the consequences of such a sudden increase in the interest rate premium.

[10] We assume that, within regions, actuarially fair priced state-contingent securities exist that insure each household against idiosyncratic variations in labor and dividend income. Consequently, at the regional level, individual household income will correspond to aggregate household income.

$$y_t^{j,Z}(i) = A_t^{j,Z}\left(K_{t-1}^{j,Z}(i)\right)^{1-\alpha^Z}\left(L_t^{j,Z}(i)\right)^{\alpha^Z}, \tag{6}$$

where $A_t^{j,Z}$ denotes the productivity level in region j and sector Z, $K_t^{j,Z}$ denotes the physical capital stock, total labor demand is given by $L_t^j = L_t^{j,N} + L_t^{j,T}$ and α^Z denotes the share of labor in production. Both types of firms accumulate capital according to the following accumulation identities:

$$K_t^{j,Z} = (1-\delta)K_{t-1}^{j,Z} + I_t^{j,Z}, \tag{7}$$

where $I_t^{j,Z}$ denotes investment in the physical capital stock and δ is the depreciation rate. For reasons of tractability we assume that firms fund their investments through domestic households. Consequently, the return to capital equals the domestic borrowing rate r_t^j. The nontradable and tradable capital production function is subject to diminishing returns to scale. For each unit of investment $I_t^{j,Z}$ only $I_t^{j,Z} - \frac{\phi}{2}\left(\frac{I_t^{j,Z}}{K_{t-1}^{j,Z}} - \delta\right)^2 K_{t-1}^{j,Z}$ of new capital is produced. Intermediate firms maximise the discounted value of future cash flows subject to their production constraint and the capital accumulation identity, see "Appendix 1.3".

We model monopolistic competition by introducing a retail sector that aggregates the intermediate goods produced by the nontradable and tradable firms respectively, into two (tradable and nontradable) final goods. Retailers buy the products of the intermediate firms and use the following CES production functions to produce the final goods (Dixit and Stiglitz 1977):

$$Y_t^{j,Z} = \left[\int_0^1 y_t^{j,Z}(i)^{1-1/\mu^{j,Z}} di\right]^{1/(1-1/\mu^{j,Z})}, \tag{8}$$

where $y_t^{j,Z}(i)$ denotes nontradable or tradable output produced by intermediate nontradable or tradable firm i, $Y_t^{j,Z}$ is the final goods and $\mu^{j,Z}$ denotes the degree of substitutability between the intermediate products and determines the amount of market power of the nontradable and tradable firms. In the limit ($\mu^{j,Z} \to \infty$), pricing is perfectly competitive.

Retailers minimize the cost of buying output from intermediate firms $\int_0^1 P_t^{j,Z}(i)Y_t^{j,Z}(i)di$ subject to the CES production function (8). The retail sector is perfectly competitive. Therefore both type of retail firms maximize their profit function by setting prices equal to their marginal costs $mc_t(i)$. The aggregate nontradable and tradable price can be expressed as the weighted sum of the intermediate good prices:

$$P_t^{j,Z} = \left[\int_0^1 p_t^{j,Z}(i)^{1-\mu^{j,Z}} di\right]^{1/1-\mu^{j,Z}}, \tag{9}$$

where $p_t^{j,Z}(i)$ is the price set by intermediate firm i for intermediate input $y_t^{j,Z}(i)$.

3.3 Market equilibrium conditions

The goods market equilibrium in the market for nontradables requires that production of nontradable goods in each region is equal to consumption of nontradable goods:

$$Y_t^{j,N} = C_t^{j,N}. \tag{10}$$

The market for tradables and investment is fully internationally integrated. Hence, equilibrium requires that in the Union as a whole production equals consumption and investment:

$$\sum_j Y_t^{j,T} = \sum_j \left[C_t^{j,T} + I_t^{j,T} + I_t^{j,N} + AC_t^j + IC_{t-1}^j \right]. \tag{11}$$

Here, $AC_t^j = \sum_Z \left[\frac{\phi}{2} \left(\frac{I_t^{j,Z}}{K_{t-1}^{j,Z}} - \delta \right)^2 K_{t-1}^{j,Z} \right]$ denotes the combined capital adjustment costs in the tradable- and the nontradable sector (which, like the investment good itself, is expressed in terms of tradables) and IC_{t-1}^j denotes the cost of financial intermediation ($-x_{t-1}^j NFA_{t-1}^j$).[11] While the current account of the union as a whole thus needs to be balanced, individual regions are allowed to run deficits or surpluses. As borrowing and lending is only possible through one-period bonds, a region's net financial asset position (NFA) is denoted by:

$$NFA_t^j = \left(1 + r_{t-1}^j\right) NFA_{t-1}^j + Y_t^{j,T} - C_t^{j,T} - I_t^{j,T} - I_t^{j,N} - AC_t^j. \tag{12}$$

Here, the cost of intermediation is included in the overall (risk-adjusted) interest rate. The current account balance is defined as the first difference of a country's NFA. Equilibrium in the market for financial assets requires:

$$NFA_t^n + NFA_t^s = 0. \tag{13}$$

4 Calibration

We calibrate the model to broadly match the evolution of the Northern and Southern parts of the euro area following monetary integration, and to simulate the effect of various policy measures. Time is quarterly and both regions are equal in size. We will run two calibrations. The first, highly stylized, one limits differences between both sectors and region to an absolute minimum, and serves to illustrate the basic mechanism at work following the shock to Southern interest rates. Thereafter, we

[11] In the pre-integration steady state the cost of intermediation theoretically also contains $-\omega * NFA_{t-1}^s$. As however ω is calibrated to achieve net foreign asset positions of zero, this term always equals zero.

introduce more heterogeneity between regions and sectors, and discuss how this affects the results.

In both cases, we will analyze the effects of a large and highly persistent (arguably permanent) shock that can lead to large and long-lasting deviations from the initial steady state. In this situation, log-linearizing the model around the steady state can lead to misleading results. We therefore instead carry out a numerical simulation of the full nonlinear model, using Dynare's deterministic setting (see Adjemian et al. 2011). This assumes that (i) the shock to interest rates is unexpected and (ii) agents are certain that no future shocks will occur ('perfect foresight'). The key advantage of this approach is that it provides us with the exact transition path of the endogenous variables following the shock to the Southern interest rate, whereas any log-linearized solution would become less accurate the further the variables move away from their initial steady state.

4.1 Simplified model

In our stylized baseline simulations, we assume perfect competition ($\mu^{j,Z} \to \infty$) in all sectors and regions. Productivity is constant and equal across sectors regions. Other parameters are set in line with other multi-region general equilibrium models for the euro area, specifically (Smets and Wouters 2003), the ECB's EAGLE model (Gomes et al. 2012), and the European Commission's QUEST III model for the euro area in the two-sector version described by Vogel (2014).

Both sectors are equally labor intensive, with the labor share set to 0.67 [in between Gomes et al. (2012) and Vogel (2014)]. In line with Vogel (2014), the share of nontradable goods in production is set to 0.65. The inverse of the elasticity of labor supply is set to 2, in line with the EAGLE model and the prior used by Smets and Wouters (2003). The depreciation rate is set 2.5% per quarter, or 10% per year, as in both Smets and Wouters (2003) and the EAGLE model. We introduce some persistence through capital adjustment costs. As this is essentially the only rigidity in the model, we set ϕ equal to a (fairly low) value of 2, in line with the broader RBC literature.

To reconcile that, prior to monetary integration, current accounts in both the Northern and the Southern parts of EMU were close to balance while interest rates were higher in South, we assume that the discount factor in North is higher than in South. As such, following monetary integration and the resulting convergence of interest rates, South borrows from North.

Finally, we calibrate the size of the country specific debt-elastic risk premium such that South's external debt stabilizes at 70% of GDP, in line with the average external debt of the GIIPS in 2007. Parameter values are presented in Table 1.

4.2 Extended model

In the more elaborate version of the model, we aim to capture some of the key differences between North and South, and between tradable and nontradable sectors.

Firstly, we assume that $\alpha^N > \alpha^T$, i.e., the nontradable sector is more labor intensive than the tradable sector. Secondly, we introduce monopolistic competition, and assume hat $\mu^{n,N} > \mu^{s,N}$, i.e., the nontradable sector in the Southern part of Europe is less competitive than the nontradable sector in the Northern part of Europe. The tradable sector on the other hand is equally competitive in both parts of the union (due to the existence of a single market) and more competitive than the nontradable sector (that is, $\mu^{j,T} > \mu^{j,T} \forall j$). Thirdly, we calibrate the productivity levels in the tradable and nontradable sector in both regions using the database constructed by Mano and Castillo (2015). Productivity is calculated as total value added per sector and country divided by total hours worked in each sector and country. Mano and Castillo (2015) classify a sector as tradable if more than 10% of the sector is exported. We aggregate productivity at the region level by taking the weighted average based on the countries share in total EMU valued added. The resulting productivity levels, where we normalize tradable productivity in the North to 1 are: $\bar{A}^{n,N} = 0.76$, $\bar{A}^{n,T} = 1$, $\bar{A}^{s,N} = 0.79$, $\bar{A}^{s,T} = 0.92$.

Finally, we recalibrate the size of the country specific debt-elastic risk premium such that also in this version of the model the South's external debt stabilizes around 70% of GDP. Parameter values are presented in Table 2.

5 Model simulations

5.1 Simplified two-region model

After monetary integration, the interest premium paid by South disappears and interest rates in North and South converge, see Fig. 3a. Consequently, South experiences a demand boom: households reduce saving and increase consumption (Fig. 3b), while firms increase investment. Capital starts to flow from North to South.

Southern demand for both tradable and nontradable goods increases. However, whereas tradable goods can be imported, nontradable goods need to be produced at home. In the absence of foreign competition, firms in the nontradable sector have more space to increase prices when their production costs increase without slackening demand. Competition with the North implies that Southern firms active in the tradable sector have less room to increase their prices as production costs increase. The rising relative price of nontradables implies that, in real terms, capital and labor are cheaper inputs in the nontradable sector. The effect is a reallocation of capital and labor towards the nontradable sector (Fig. 3f).

In North, an opposite effect occurs: Southern demand for capital increases the union-wide interest rate. Southern demand for tradables grows, while domestic demand in the North falls. As a result, the nontradable sector shrinks and both wages and the relative price of nontradables fall. Capital and labor are reallocated to the growing tradable sector.

The Southern boom in consumption and investment, as well as the shift of productive resources to the nontradable sector cause the external position of South to deteriorate (Fig. 3h). The rising debt causes the risk premium to increase until the net foreign asset position stabilizes. The rising interest rate also facilitates a shift of

Table 1 Calibrated parameters—simplified model

Parameters	Description	Value
β^n	Discount factor households, North	0.990
β^s	Discount factor households, South	0.980
σ_l	Inverse of the elasticity of work effort	2.000
θ	Weight of leisure	1.000
η	Share of nontradables in consumption	0.600
α^T	Share of labor in the tradable production function	0.670
α^N	Share of labor in the nontradable production function	0.670
δ	Depreciation rate of physical capital	0.025
$\mu^{n,N}$	Market power nontradable sector, North	9999
$\mu^{s,N}$	Market power nontradable sector, South	9999
$\mu^{j,T}$	Market power tradable sector, region j	9999
ξ	Credit premium reaction	0.007
$\bar{A}^{j,Z}$	Productivity region j, sector Z	1.000
h	Relative share of North in union	0.500
ϕ	Capital adjustment costs	2.000

resources back to the tradable sector to produce the goods necessary to re-balance imports and exports.

5.2 Extended model

In the extended version of our model, our calibration better matches some key stylized facts: in both regions, the nontradable sector is more labor intensive, less productive, and less competitive than the tradable sector. Productivity levels and the degree of competition also differ across sectors and regions. Qualitatively, these changes do not affect the results: the basic mechanism described earlier continues to apply.

There are however subtle differences, partly driven by the different labor intensity of the tradable and nontradable sector. As wages in South increase following monetary integration (Fig. 4c), the more labor intensive nontradable sector experiences a relative cost increase compared to the tradable sector. The relative price of the nontradable good thus increases. As a result, demand for nontradable products increases by less than the demand for tradable products ('demand effect'). In North, the opposite occurs, with falling wages benefiting the nontradable sector. This offers a sleight counterweight to the mechanism described in Sect. 5.1.

The differing levels of productivity across sectors and regions do not inhibit the sectoral reallocation that follows the interest rate drop. However, mechanically, the fact that resources migrate to the less productive sector implies that total output falls. This is in line with the empirical findings documented by Borio et al. (2016) who show that credit booms like those experienced by Southern Europe after the

Table 2 Calibrated parameters—changes relative to simplified model

Parameters	Description	Value
α^T	Share of labor in the tradable production function	0.640
α^N	Share of labor in the nontradable production function	0.700
$\mu^{n,N}$	Market power nontradable sector, North	5.000
$\mu^{s,N}$	Market power nontradable sector, South	3.500
$\mu^{j,T}$	Market power tradable sector, region j	10.000
ξ	Credit premium reaction	0.0065
$\bar{A}^{n,N}$	Productivity region n, sector N	0.760
$\bar{A}^{s,N}$	Productivity region s, sector N	0.790
$\bar{A}^{n,T}$	Productivity region n, sector T	1.000
$\bar{A}^{s,T}$	Productivity region s, sector T	0.920

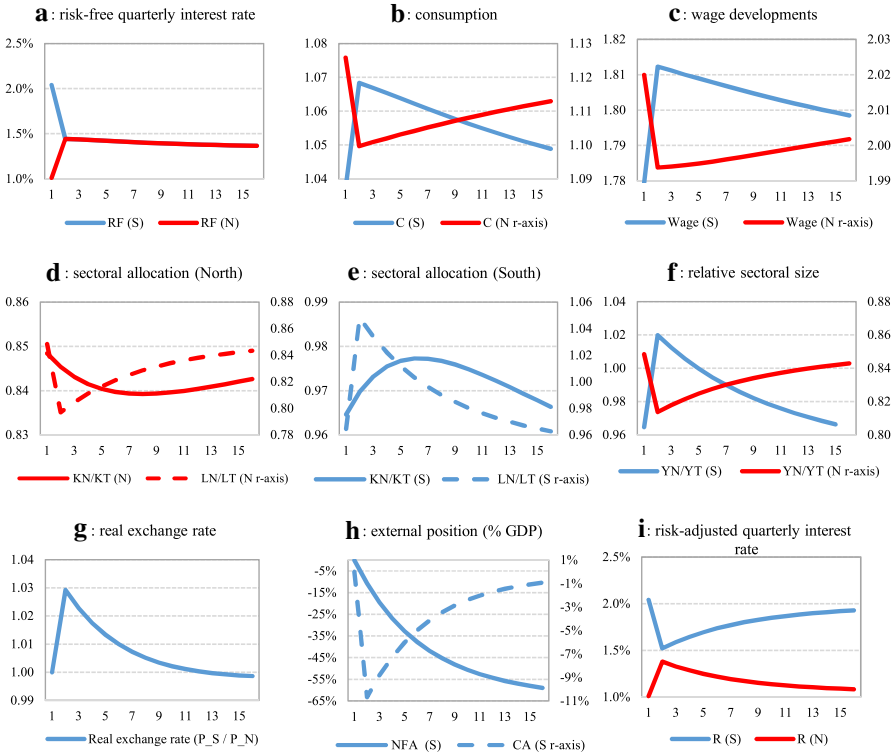

Fig. 3 Consequences of monetary integration—simple model. This figure shows the effects of the permanent elimination of the wedge ω between Southern and Northern risk-free interest rates in (3). The x-axis displays the number of quarters following the shock

introduction of the EMU are associated with a productivity slowdown driven by a reallocation of resources towards less productive sectors. In addition, relative to the

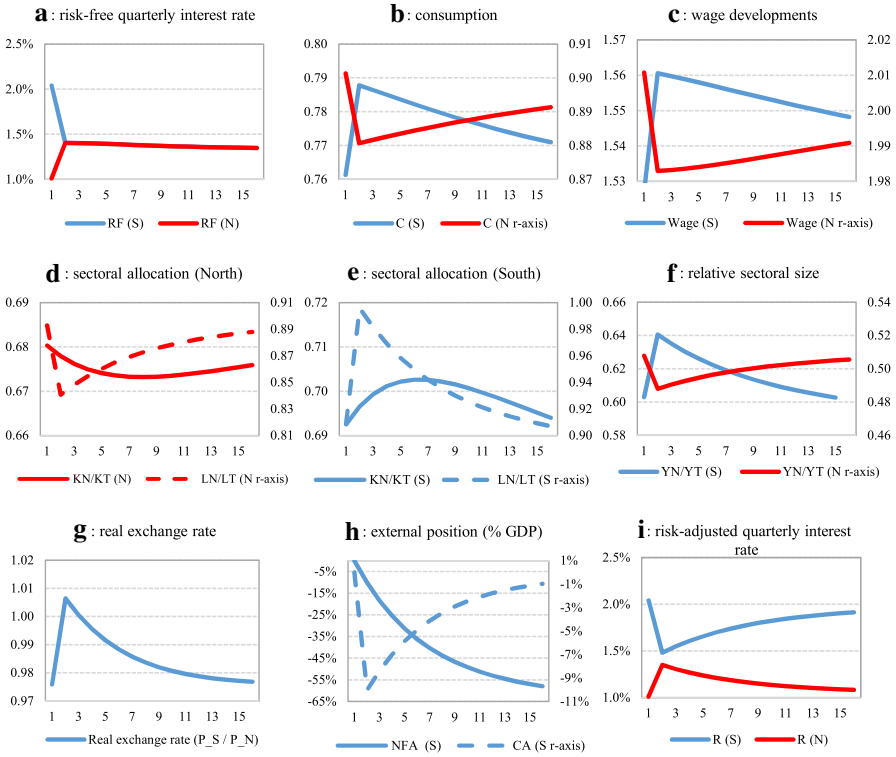

Fig. 4 Consequences of monetary integration—full model. This figure shows the effects of the permanent elimination of the wedge ω between Southern and Northern risk-free interest rates in (3). The x-axis displays the number of quarters following the shock

simple model, the fact that the nontradable sector is less productive implies that the ratio of nontradable to tradable *output* increases somewhat less steeply than in the simple model.

Overall however, the effect of the different assumptions regarding productivity and labor intensity is relatively modest. In South, the ratio of nontradable to tradable output (Fig. 4f) in period 1 increases by 6%, rather than the 7% of the more simple model. On impact, also the Southern current account deficit increases somewhat less steeply in the full version of the model.

Finally, while the steady state *size* of the nontradable sector clearly depends on the height of mark-ups, the reallocation of resources towards the nontradable sector following monetary integration is not hindered by the nontradable sector being the less competitive one. As illustrated by Fig. 13 in "Appendix 1", the degree of reallocation is basically independent from the degree of competition.[12]

[12] If one were to look two digits behind the comma, the growth rate of the nontradable sector would be very slightly larger when the degree of competition is low.

5.3 Including the RoW

So far, we assumed a closed economy for the monetary union as a whole. In this section, this simplifying assumption is relaxed by including a third country labeled 'Rest of the World' (RoW). In line with the ECB's EAGLE model, we assume RoW to form 77% of the world economy, with the euro area making up the remaining 23%. RoW has a flexible exchange rate with the monetary union, is connected to (initially, the Northern part of) the monetary union via an UIP and the Law of One Price and in terms of parameters mimics the Northern part of the monetary union. See "Appendix 1.4" for the technical details.

As before, we simulate an interest rate shock in South (Fig. 5). The addition of a third region somewhat amplifies the effects of this shock in South, while it attenuates the effects in North. Firstly, relative to RoW, the union's economic boom induces an appreciation of the real exchange rate. To remain competitive, the relative price of tradables must fall. In South, this results in an even sharper increase in the relative price of the nontradable good, contributing to a faster reallocation of resources towards the nontradable sector. In North, the fall in the relative price of the nontradable good is mitigated, dampening the reallocation towards the tradable sector. Secondly, and somewhat trivially, the addition of a third region increases the size of the total economy. As a result, the impact of the Southern boom on interest rates in North is attenuated. Interest rates do rise, and North continues to realize a current account surplus, but compared to the two-region case this is significantly smaller. In contrast, the attenuated response of risk-free interest rates implies South enjoys a boom and current account deficit even larger than in the two-region case.

5.4 Crash

Our model is primarily constructed, and calibrated, to show how monetary integration can lead to the emergence of a sizeable current account deficit and relative growth of the nontradable sector in Southern Europe. Due to the presence of a debt-elastic interest rate, the model is stable. Yet, even in this setting, it is fairly straightforward to see how a crisis could occur. As in e.g. Eggertsson and Krugman (2012), the crisis can be modeled as a 'Minsky moment' in which risk aversion suddenly increases.

In our case, this is most naturally simulated through an unexpected, permanent increase in the elasticity of the interest rate premium to a region's debt level. This simultaneously increases interest rates in the debtor region, while lowering them in the surplus region, in line with the capital 'flight to safety' observed during the euro crisis (see e.g. Brunnermeier and Reis 2019).

In our model, the propagation of a shock to the elasticity of the interest rate premium is very similar to that of the shock to the exogenous wedge between Northern and Southern interest rates discussed earlier. As such, the effects of this 'crisis scenario' are mostly intuitive and the opposite of the ones presented in Sect. 5.1: external borrowing and investment in South collapse, consumption falls, and resources temporarily reallocate to the tradable sector. As a peculiarity of our fairly stylized

model, (perfectly flexible) wages fall, so that employment actually rises. Eventually a new steady state, with a lower external debt level and a stable current account, is reached. "Appendix 1" presents the results in more detail. With the collapse mirroring the dynamics of the built-up phase, it follows naturally that a more muted boom—for instance due to a sharper reaction of interest rates to debt levels—would have contributed to a smaller crash.

As only the future can tell whether the euro crisis has permanently affected the pricing of sovereign risk, we have also simulated the crisis as a *temporary* shock. This initially propagates in the same way. However, once the shock has faded out, Southern domestic consumption and relative sectoral sizes temporarily overshoot upwards, as the external debt re-converges to its steady-state level. Results are available on request.

6 Empirical analysis

6.1 Methodology and data

The design of the model is motived by the sharp decline in real interest rate experienced by Southern Europe in the run-up to the introduction of the euro. However, as shown in the previous section, the predictions of the model are more general and can be summarized as follows: a negative interest rate shock in part of the union, e.g. as experienced by multiple Southern European countries in anticipation of EMU, leads to a reallocation of resources towards the nontradable sector, an increase in the price level relative to the rest of the union, and the emergence of a current account deficit. The opposite holds for a positive interest rate shock, as can be seen from the results for Northern Europe.

A direct translation of the theoretical model to an empirical setting would be to estimate the parameters of the model directly using a structural VAR (see, e.g., Smets and Wouters 2003; Christiano et al. 2005) for two seminal contributions to DSGE estimation). However, in the model we abstained from frictions and rigidities and opted for a conventional parameter setting to keep the model as parsimonious and tractable as possible. The main goal of this approach is to show that the main mechanism—a redistribution of resources to the nontradable sector following a decline in a country's real ex-ante interest rate—does not rely on the presence of frictions and rigidities. Instead, the key feature of the model driving the redistribution of resources is the assumption that some goods cannot be traded. For this reason, we adopt a reduced form estimation approach that tries to test directly whether output is redistributed to the nontradable sector following a decline in real interest rates.

We use a Bayesian approach to estimate the model. Over-parameterization can be an issue for VAR systems of fairly modest size and a Bayesian estimation approach could in this case lead to better performance (Litterman 1986). A Bayesian estimation approach is, in particular, suitable to handle large dynamic systems and can be used to extend the information set to include disaggregated and sectorial indicators

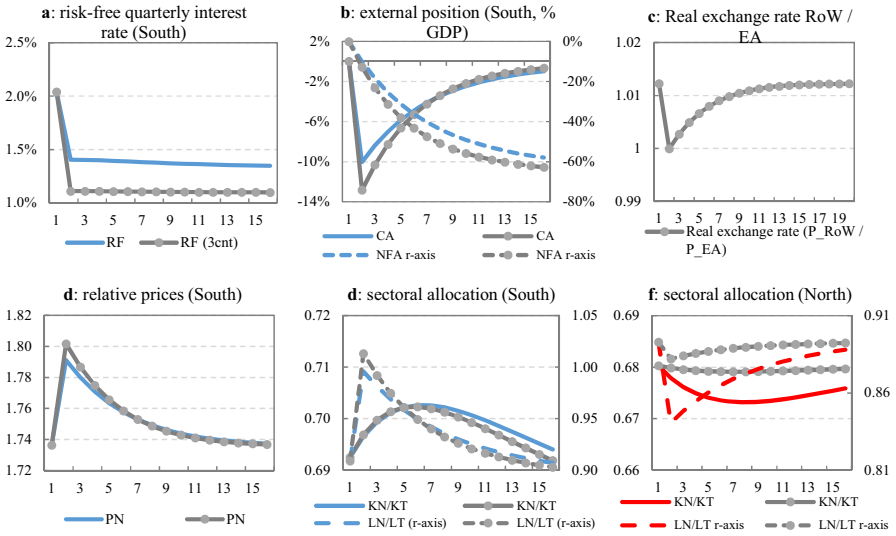

Fig. 5 Consequences of monetary integration: effects of including the RoW. This figure shows the effects of the permanent elimination of the wedge ω between Southern and Northern risk-free interest rates in (3) in a closed (2-region)- and open (3-region marked lines) version of the model

(Bańbura et al. 2010).[13] We estimate a standard macroeconomic framework with output growth, inflation and a short-term interest rate which is often used to identify interest rate shocks (see, e.g., Christiano et al. 1999), but allow for three deviations to fit the estimation more closely to the theoretical model. First, output growth is split into a tradable and a nontradable component, so as to examine the effect of an interest rate shock on the growth rates of both sectors separately. Second, ex-ante real interest rates are used as expected rather than realized real rates are arguably more important for investment decisions.[14]Third, current account flows are added as an additional variable to the VAR, thereby opening up the model, as we are interested in the effect of interest rate shocks on cross-border capital flows.

We estimate the following reduced form panel-BVAR equation:

$$X_t = \alpha_0 + \Phi(L)X_{t-1} + \varepsilon_t, \tag{14}$$

where $\Phi(L) \equiv \Phi_0 + \Phi_1 L^1 + \cdots + \Phi_p L^p$ is a lag polynomial and X_t is a vector containing the observed variables as discussed:

[13] We attempted to estimate the model using a simple panel-VAR approach. While the estimation results are qualitatively similar, the impulse response functions are less precise and show oscillating behavior, suggesting over-parameterization. The main efficiency gain of the Bayesian approach, despite an agnostic prior, comes from the assumptions that all parameters are drawn from the same distribution and that the impact of the lags is decaying with each further lag.

[14] We also estimated the model using nominal interest rates, optionally including inflation expectations as a separate variable. The results, which are available upon request, are qualitatively the same.

$$X_t = \left[(y^N_{t,i} - \bar{y}^N_t), (y^T_{t,i} - \bar{y}^T_t), (\pi_{t,i} - \bar{\pi}_t), \left(\frac{CA_{t,i}}{Y_{t,i}} - \frac{\bar{CA}_t}{\bar{Y}_t} \right), (i^r_{t,i} - \bar{i}^r_t) \right]', \quad (15)$$

where $y^N_{t,i}$ denotes the year-on-year growth rate of the nontradable sector at time t in country i, $y^T_{t,i}$ denotes the year-on-year growth rate of the tradable sector, $\pi_{t,i}$ denotes the year-on-year inflation rate, $\frac{CA_{t,i}}{Y_{t,i}}$ denotes a country's current account balance as percentage of GDP and $i^r_{t,i}$ is the ex-ante expected real interest rate. All variables with a bar denote euro area averages, which we subtract from our variables to control for any euro area wide trend.[15] Finally, ε_t is a vector of stacked reduced form residuals.

To identify the shocks we assume orthogonality and use a Cholesky decomposition of which the ordering is specified in Eq. (15). As is common when identifying interest rate shocks, we assume that the real interest rate adjusts contemporaneously to innovations in output growth, in our case nontradable and tradable growth shocks, and to innovations in the inflation rate. However, the growth rate of the nontradable and tradable sector is affected by real interest rate or inflation shocks only with a lag (see Christiano et al. 1999).[16] The model is estimated using a (pooled) Bayesian estimation procedure. The data is observed at a quarterly frequency and therefore we include four lags.[17] To let the data speak as much as possible, we impose an (agnostic) Minnesota prior: all lagged coefficients take a prior value of 0.8. The hyperparameters are set at standard values, i.e., the overall tightness parameter is set equal to 0.1 and the lag decay parameter is set equal to 1.[18]

The growth rates for both the nontradable and tradable sector are calculated using Eurostat data for countries for which disaggregated output time series are available: Austria, Belgium, Germany, Finland, France, Ireland, Italy, the Netherlands, Spain and Portugal. Due to extremely volatile growth rates, we exclude Ireland from our regression analysis.[19] So far, in our stylized facts, we have used a detailed breakdown of GDP aggregates by industry. However, this detailed breakdown is only

[15] Our preferred specification is a VAR using demeaned growth rates. First, demeaning the variables ensures that the impulse responses are not overly affected by the large fluctuation around the financial and euro area crisis. Second, growth rates ensure stationarity of our macro-economic variables [confirmed by the Levin et al. (2002) panel unit root test]. However, as (non)tradable output and the price level appear to be integrated of order 1, we also estimated the model in demeaned log-levels (Sims et al. 1990). In Fig. 15 in "Appendix 1" we show that both approaches give rise to broadly similar results.

[16] To verify the robustness of the identification strategy, the model is also estimated using different identification schemes, for instance, by assuming that nontradable and tradable growth can respond contemporaneously to innovations in the interest rate. The main results presented in the paper are robust to these different identification schemes.

[17] The various information criteria available suggest different lag lengths. Results are qualitatively robust to including one up to six lags.

[18] We have tested the sensitivity of our results to a range of hyperparameter values: a prior coefficient value in the range of 0.5–1, an overall tightness parameter in the range of 0.05–0.2 and a lag decay parameter in the range of 0.5–4. Results are qualitatively unaffected.

[19] To check whether our results are driven by individual countries, we re-estimated all regressions while excluding one country at the time and found similar results. Ireland was the only exception, likely due to tradable growth rates that varied from − 20 to 58%.

available on an annual basis. Identifying interest rates shocks using a Cholesky decomposition and annual data is arguably a stretch, as it assumes that output does not respond to shocks in the other variables for up to a year. We therefore resort to a more basic breakdown that is available on a quarterly basis. To construct quarterly series of nontradable and tradable growth, we use a similar methodology as in Sect. 2.[20] We label a sector in our quarterly data series (non)tradable when it contains mostly (non)tradable industries as classified in Fig. 12. We group and aggregate these series to obtain tradable and nontradable data series on an aggregate level, see Table 6 in"Appendix 1".[21]

We use nominal interest rates on 1-year government bonds as a proxy for the country-wide nominal interest rate and the consensus forecast inflation expectations 1 year ahead to transform the nominal interest rates into ex-ante real interest rates. For inflation we use Eurostat HICP data. Finally, we use data from the World Economic Outlook database and the Statistical Data Warehouse database to collect data on current account balances.

The quarterly time series cover the period 1996Q3–2017Q3. As in general no data is available for Luxembourg, this country is dropped from the sample. For Greece we lack data on nominal interest rates on 1-year governments bonds before 1999Q1. As the inflation expectations measure covers inflation expectations over a 1-year period, the only consistent way to create ex-ante real interest rates is to use 1-year interest rates. Table 5 in "Appendix 1" summarizes the descriptive statistics.[22]

6.2 Empirical results

The panel-BVAR is estimated over the period 1996Q3–2017Q3.[23],[24] Figure 6 shows the impulse response functions following a positive interest rate shock for the entire sample period. In line with the model predictions, a country that is hit by a positive interest rate shock of one standard deviation experiences a decline in the growth

[20] The Eurostat classification is slightly different from the WIOD classification used in Fig. 2. Specifically, the WIOD contains more detailed information about the openness of sectors, but data is only available until 2011. We therefore match the WIOD classification with the Eurostat classification to categorize the Eurostat sectors in a tradable and nontradable sector, see Table 3 in "Appendix 1".

[21] For some sectors this classification is rather arbitrary as the sector contains both tradable and nontradable industries. We re-estimated our BVAR while switching our classifying and find qualitatively similar results.

[22] For robustness we experiment with 10-year government bond yields as those are also available for Greece before 1999. The nominal rates are transformed in ex-ante expected real rates using the 1-year inflation expectations. This assumes that inflation expectations remain constant over the 10-year period. Results, which are not presented here, are similar to the results presented below.

[23] Dynamics may differ between the build-up phase and the period following the sudden bust. In a related analysis, Bobeica et al. (2016) for instance finds a negative relation between domestic demand pressure and exports during busts, but not during booms. We therefore estimated our model over the subperiod 1996Q3–2008Q3. However, in this case, both the response of the tradable and nontradable sector following an interest rate shock is insignificant at the 90% credibility level, most likely due to the reduction in sample size.

[24] The panel-BVAR is estimated using the ECB BEAR-toolbox developed by Dieppe et al. (2016), which builds on the methodology surveyed by Canova and Ciccarelli (2013).

rate of the nontradable sector, a persistent decline in the inflation rate, and a sharply improving current account balance. Figure 6 also shows that, on impact, there is no effect of the interest rate shock on the growth of the tradable sector. After a few years, there is a small positive effect.

These results are largely in line with the model which actually predicts, counter-intuitively, a small increase in the growth rate of the tradable sector following a positive interest rate shock. They also help to explain part of the strong growth of Northern Europe's tradable sector.

As the model is symmetric we can also interpret negative interest rate shocks, as experienced in Southern Europe. In the theoretical model we reduce the risk premia in South by 4% resulting in a 3% drop in nontradable output in the South. The same shock results in a 0.5% increase in tradable output in the North. These theoretical impulse response are plotted in Fig. 7 alongside the corresponding empirical impulse response functions following a comparable shock. More specifically, a back-of-the-envelope calculation shows that a 4% decrease in interest rates (see Fig. 1), causes, according to the cumulative impulse response functions, a relative increase in the nontradable of about 2%, largely in line with the theoretical model. For the tradable sector the theoretical prediction lies within the credibility interval of the empirical impulse response, suggesting that the cumulative impact is indistinguishable from zero. The relative difference between nontradable and tradable output growth is about 2%. This comes on top of the overall trend of increasing nontradable sector growth observed in all European countries. Hence, it appears that the magnitudes of the empirical results are broadly in line with the predictions of the theoretical model and that interest rate shocks can explain a large fraction of the higher growth rates of the Southern European nontradable sector described in Fig. 2.[25]

In Sect. 5.3 we showed that when the model is extended to include a third region—the 'Rest of the World'—the effects of monetary integration in the Southern part of the union are amplified, while spillovers to North are more muted. We test this prediction of the model empirically by estimating the model separately for 'North' and 'South' defined as in Sect. 2. The results are presented in Fig. 8 in which the interest rate shock is normalized to 1% in both regions. The point estimates indeed suggest that the drop in nontradable growth is somewhat stronger and more persistent (assessed at the 68% credibility interval) for 'peripheral' countries (Italy, Spain and Portugal) than it is for 'core' countries (Belgium, Germany, France, Finland, Austria, the Netherlands). The pattern reverses for the tradable sector. In line with the predictions of the model, tradable growth increases significantly in North after a negative interest rate shock, but the corresponding estimate for South

[25] In the paper, to test our theoretical predictions, we focus on the response to interest rate shocks. The full set of responses—which do stretch our identification assumptions—can be found in the Online Appendix. Most impulse response functions have the expected sign. A sudden increase in inflation, for instance, is followed by a deterioration of tradable output, while nontradable output increases. A shock to a country's current account is associated with a decline in its inflation rate—making the country's export goods more attractive—and an increase in its tradable output and a decrease in its nontradable output. Vice versa, positive innovations in tradable (nontradable) output are associated with an increase (decrease) in inflation and an improvement (worsening) of current account positions.

is much smaller and less persistent. It appears that a negative interest rate shocks, as experienced in South, causes, in particular, growth of the Southern nontradable sector and a deterioration of the region's current account, while a positive interest rate shocks, as experienced by North, causes growth in the Northern tradable sector and a decrease in the region's inflation rate.

7 Policy options and discussion

The results presented highlight major challenges in terms of correcting existing imbalances and preventing new ones. Macroprudential policy, through limiting private sector borrowing, could play an important role in preventing the developments stressed in this paper from reoccurring (see e.g. Quint and Rabanal 2013; Bielecki et al. 2017). Currently, however, the first challenge for EMU is to reduce existing imbalances in a way that does not unduly harm GDP growth. In Sect. 5.4 we showed how a sudden increase in the Southern interest rate premium induces a 'sudden stop' like rebalancing process in which external borrowing and investment collapse, consumption falls, and resources reallocate to the tradable sector. In this section, various policy options that can accommodate a less disruptive rebalancing process are examined.

7.1 Increasing competition in the nontradable sector

Figure 9 shows the effects of a liberalization of the nontradable sector in South, i.e., a decrease in the markup on nontradable products. A liberalization of the nontradable sector causes nontradable prices to fall, increasing relative demand for nontradables. Real income also increases, contributing to increased demand for both tradable and nontradable products. As nontradable products need to be produced at home, this leads to an expansion of the nontradable sector. The effect on the external position is limited; initially the falling price level does lead to a slight increase in the external debt as percentage of (nominal) GDP.

Spillovers from a liberalization of the Northern nontradable sector are limited. North grows and from a Southern perspective both external demand and the interest rate increase. GDP and the sectoral allocation of resources in the South are largely unaffected, while the external position slightly improves. Figure 10 displays the results in more detail.

7.2 Deepening the internal market

The introduction of the euro was intended in part to deepen the internal market, thereby increasing competition in the market for tradables. Evidence on whether the euro achieved this is mixed. Deepening the internal market is however still seen as a policy priority (see e.g. European Commission 2015). We simulate the effects of a deepening of the internal market through a decrease in the markup on tradables in both regions of the EA. As shown in Fig. 11, this induces a fall in the relative price

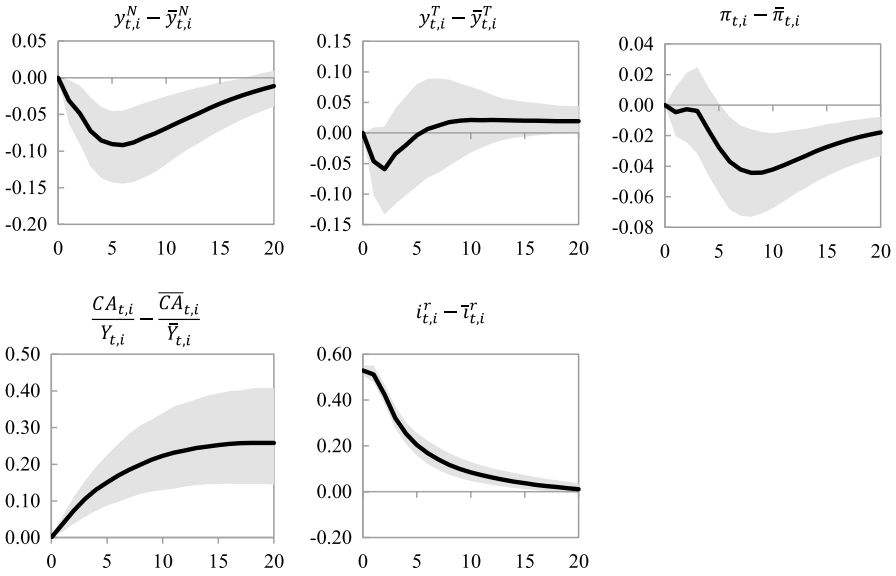

Fig. 6 Impulse response functions following a shock in the real interest rate in EMU countries. The black lines represent the median response to a real interest rate shock estimated over the time period 1996Q3–2017Q3 using a Bayesian panel-VAR with 4 lags and a Cholesky decomposition (ordering as in Eq. 15). Shaded areas denote 90% credibility intervals which are generated by drawing 50,000 draws from the posterior distribution of which 40,000 draws are discarded as burn-in iterations. Horizontal axes specify quarters. Vertical axes denote percent point deviations from average euro area growth, ratio or rate

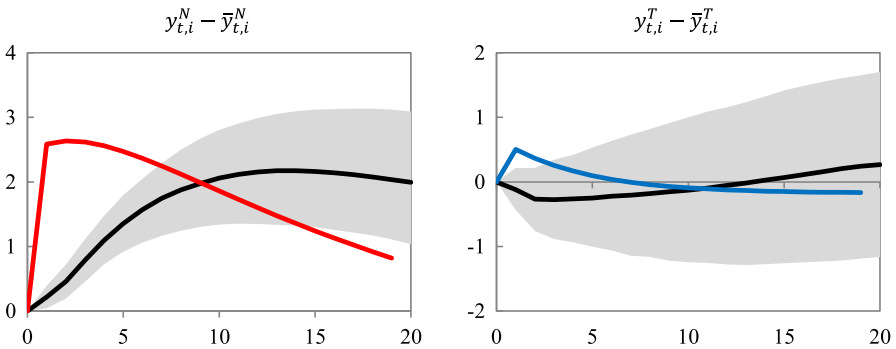

Fig. 7 Theoretical and empirical cumulative impulse response functions for nontradable and tradable output after a 4% shock in the real interest rate. The black lines represent the median cumulative response to a 4% real interest rate decline (LHS) and increase (RHS) estimated over the time period 1996Q3–2017Q3 using a Bayesian panel-VAR with 4 lags and a Cholesky decomposition (ordering as in 15). Shaded areas denote 90% credibility intervals which are generated by drawing 50,000 draws from the posterior distribution of which 40,000 draws are discarded as burn-in iterations. Horizontal axes specify quarters. Vertical axes denote percent point deviations from average euro area growth, ratio or rate. The two additional lines show the percentage change in the nontradable sector in the South and the percentage change in the tradable sector in the North following a 4% real interest rate decline generated by the theoretical model

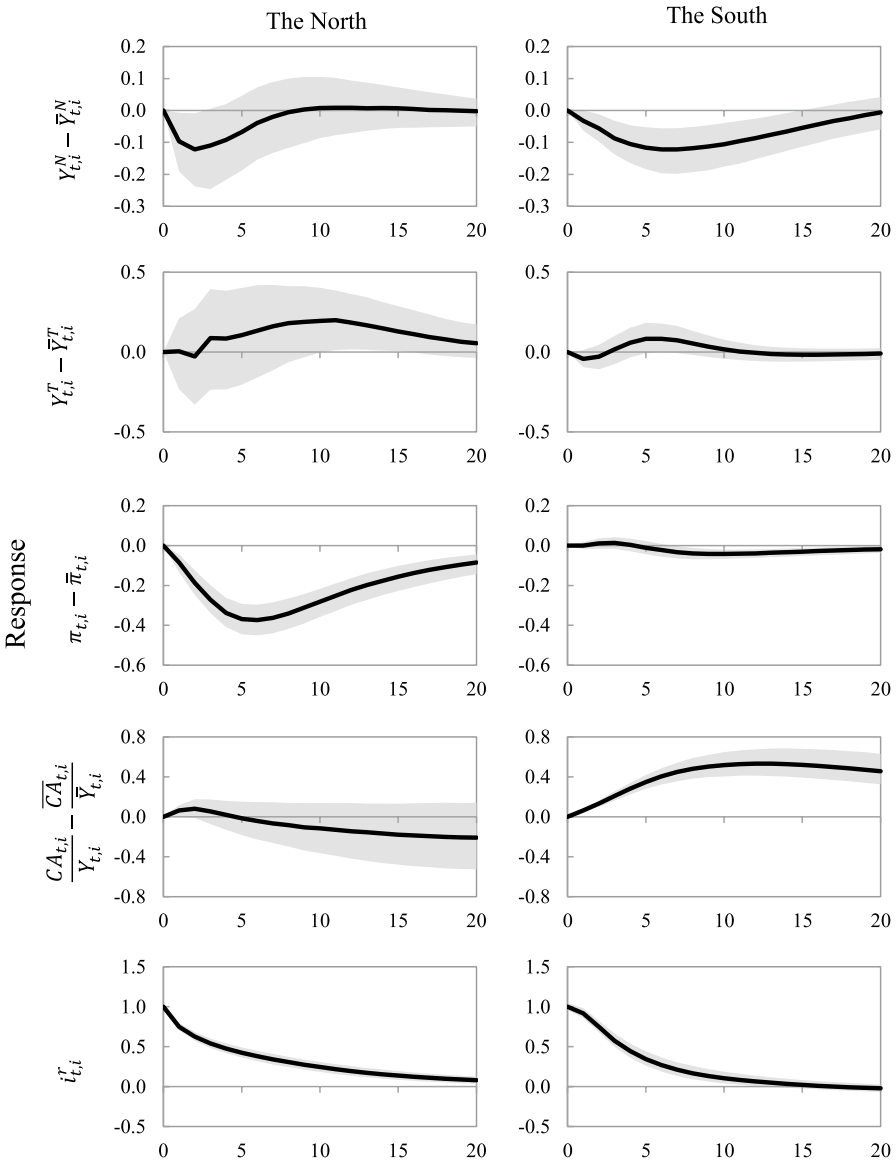

Fig. 8 Nontradable and tradable impulse responses following a negative real interest rate shock in Northern (left column) and Southern (right column) EMU countries. The black lines represent the median response to a real interest rate shock (normalised to 1%) estimated separately for the North: in Austria, Belgium, Finland, France, Germany and the Netherlands (left column) and the South: Italy, Portugal and Spain (right column) over the full time period 1996Q3–2017Q3. We use a Bayesian panel-VAR with 4 lags and a Cholesky decomposition (ordering as in Eq. 15). Shaded areas denote 68% credibility intervals which are generated by drawing 50,000 draws from the posterior distribution of which 40,000 draws are discarded as burn-in iterations. Horizontal axes specify quarters. Vertical axes denote percent point deviations from the euro area average

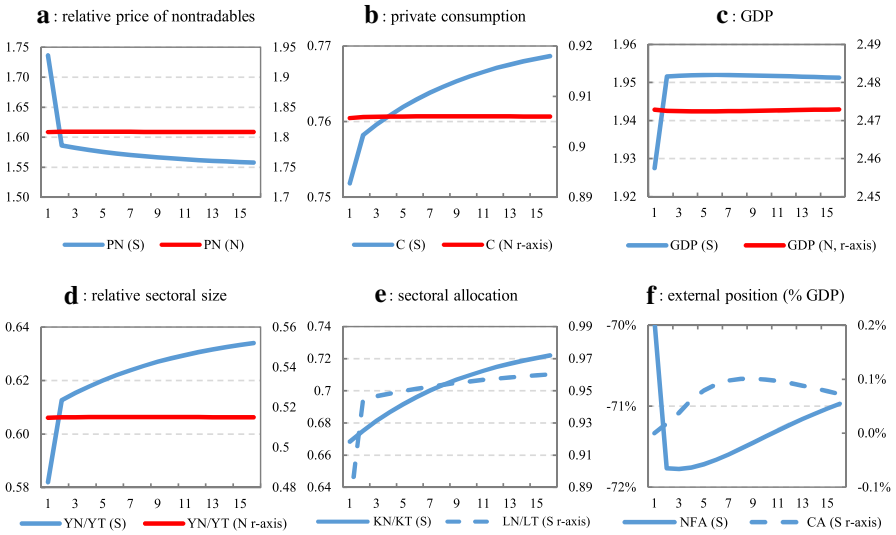

Fig. 9 Product market reform in South, transition path. This figure shows the effects of a permanent reduction of markups in the Southern nontradable sector. The simulation starts from the post-monetary integration steady state and is conducted using the extended 2-region version of the model; results using the 3-region version are highly similar and available upon request

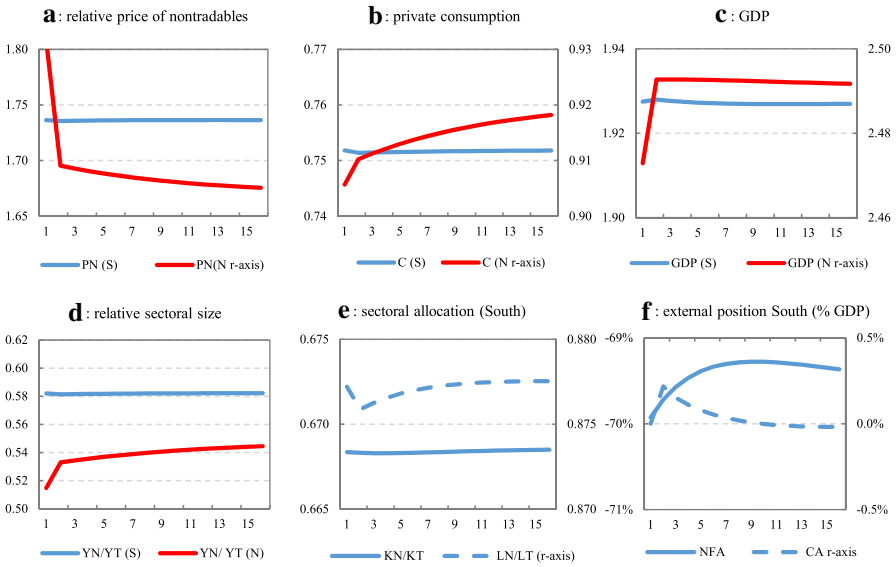

Fig. 10 Product market reform in North, transition path. This figure shows the effects of a permanent reduction of markups in the Northern NT sector. The simulation starts from the post-monetary integration steady state and is conducted using the extended 2-region version of the model; results using the 3-region version are highly similar and available upon request

of tradables and thereby speeds up the desired shift of resources towards the tradable sector. It boosts investment and GDP growth. As demand for tradable goods increases faster than supply, the EA initially develops a trade deficit with the RoW. This is accommodated by a real appreciation of the euro. The rise in the relative price of tradable goods in the RoW dampens local demand. In the long run, the tradable sector in the RoW shrinks marginally, whereas the tradable sector in both regions of the EA grows significantly.

8 Conclusion

In this paper, we documented empirically the broad-based growth of the Southern European nontradable sector. We then showed in a two-region two-sector general equilibrium model that many of the key characteristics of the first decade of EMU can be explained by the fall in interest rates the Southern European countries experienced when joining EMU. This fall can be shown to explain both the divergence of current account positions and wage rates between Northern and Southern Europe, as well as the allocation of capital and labor towards the nontradable sector in South. The allocation of incoming capital to the nontradable sector occurs irrespective of any differences in competitiveness or productivity across sectors or regions.

Clearly, the largely symmetric (but opposite) response of Northern and Southern Europe to monetary integration is an oversimplification of reality. In part this is the straightforward consequence of the assumption that 'North' and the 'South' are of equal size. Less straightforward, we show that relaxing the closed economy assumption, through including the rest of the world in the model, also attenuates the Northern response, while it amplifies the Southern one. We then proceed by confirming the main model predictions using a panel-BVAR for 9 euro area countries over the period 1996–2017.

Our results highlight several challenges for policy makers. When foreign borrowing is not matched by an increased export capacity, a point made forcefully by Giavazzi and Spaventa (2010), solvability problems can emerge. Macroprudential policy might have offered a tool to prevent excessive private borrowing. In a quest for a way to reduce existing imbalances, we investigated two options for product market reform. Improving the European internal market for tradables, i.e., further strengthening competition in this sector, appears to be the most promising option, facilitating a further rebalancing towards tradables while simultaneously boosting growth.

Our findings suggest various directions for further research. Throughout the analysis, we have assumed that goods are either tradable or nontradable. From a policy perspective, it is a highly relevant question to what extent improving the European internal market for services can contribute to increasing the share of traded 'goods', and what effects this would have. Additionally, our study focuses on the sectoral allocation of capital inflows in a nearly frictionless environment. Others have focused on the allocation of capital within sectors, highlighting the role of financial frictions. Combining both perspectives seems a fruitful avenue for further research. In this regard, also the potential effects of the banking union and the Capital Markets Union on cross-county firm ownership, risk sharing, and interest rate spreads

merits attention. Finally, our study points to the need of explicitly monitoring, and potentially curtailing, foreign borrowing within a monetary union, which since 2011 is done via the Macroeconomic Imbalances Procedure (MIP). To enforce the MIP, instruments are needed to curtail excessive borrowing. Macroprudential policy offers promise in this respect, but still faces major challenges that need further investigation.

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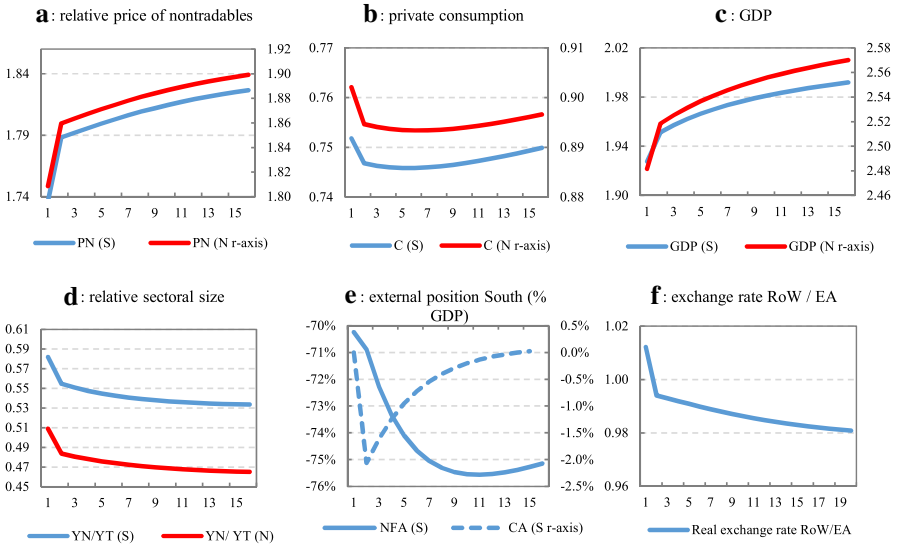

Fig. 11 Deepening the EA internal market, transition path. This figure shows the effects of a permanent reduction of markups in the Northern and Southern tradable sector. The simulation starts from the post-monetary integration steady state and is conducted using the 3-region version of the model in order to shed light on exchange rate dynamics

Appendix 1

1.1. Sectoral dependence on domestic demand

See Fig. 12 and Table 3.

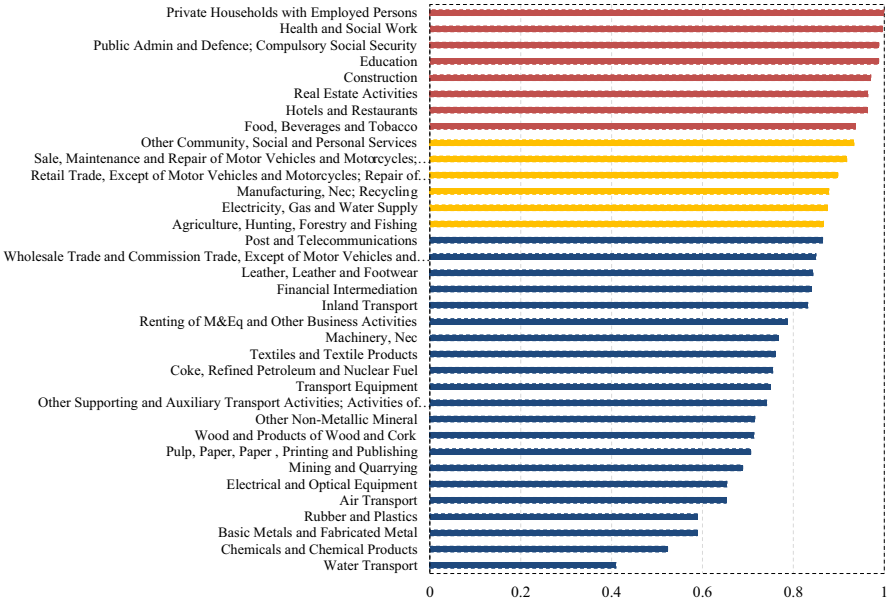

Fig. 12 Share of value added from domestic demand in the euro area. The upper 8 sectors sum to a nontradable sector that produces 33% of total euro area output and the upper 14 sectors sum to a nontradable sector that produces 50% of total euro area output. Source: own calculations using WIOD, release 2013 (Timmer et al. 2015)

1.2. Households problem

Household maximization problem:

$$\max \sum_{v=0}^{\infty} (\beta^j)^v \left[\log (C_t^{j,N})^{\eta} (C_t^{j,T})^{1-\eta} - \frac{\theta (L_t^j)^{1+\sigma_l}}{1+\sigma_l} \right] \quad \text{s.t.}$$
$$\sum_{j}^{j'} B_t^j + C_t^{j,T} + P_t^{j,N} C_t^{j,N} = \sum_{j}^{j'} (1 + r_{t-1}^j) B_{t-1}^j + \pi_t^{j,N} + \pi_t^{j,T} + L_t^j W_t^j. \tag{16}$$

Households maximize their utility by choosing both consumption goods, labor supply, money holding and bond holdings, subject to the budget constraint and a no-Ponzi condition. The FOCs are:

$$\frac{1-\eta}{C_t^{j,T}} = \lambda_t^h, \tag{17}$$

$$\frac{\eta}{C_t^{j,N}} = P_t^{j,N} \lambda_t^h, \tag{18}$$

Table 3 WIOD, EUROSTAT and KLEMS classification and mapping

WIOD classification	VA Dom-esti-cally (%)	Total output	Cumulative share (%)	EUROSTAT and KLEMS
Private households with employed persons	100.0	26,194	0.2	T
Health and social work	99.8	574,381	4.7	Q
Education	99.7	378,891	7.7	P
Real estate activities	99.7	890,490	14.6	L
Public admin and defence; compulsory social security	99.5	603,584	19.4	O
Sale, maintenance and repair of motor vehicles and motorcycles	99.0	223,209	21.1	G45 - G46 - G47
Construction	98.6	913,288	28.3	F
Hotels and restaurants	98.5	359,423	31.1	I
Retail trade, except of motor vehicles and motorcycles; repair of household goods	98.1	485,831	34.9	G47
Other community, social and personal serv.	97.2	429,865	38.2	R + S + U
Electricity, gas and water supply	97.0	271,372	40.4	D
Post and telecommunications	94.2	255,341	42.4	J - J62 - 63 + H53
Wholesale trade and commission trade, except of motor vehicles and motorcycles	92.6	643,040	47.4	G46
Financial intermediation	92.4	614,538	52.2	K
Inland transport	90.6	292,791	54.5	H-H53
Renting of M&Eq and other business activities	90.4	1,144,176	63.5	M + N + J 62 - 63
Other supporting and auxiliary transport activities; activities of travel agencies	85.5	238,207	65.3	H - H53
Agriculture, hunting, forestry and fishing	84.0	315,989	67.8	A
Mining and quarrying	83.2	76,820	68.4	B
Wood and products of wood and cork	79.8	80,283	69.0	C
Food, beverages and tobacco	77.1	568,989	73.5	C
Other non-metallic mineral	76.5	151,818	74.7	C
Pulp, paper, printing and publishing	74.4	285,858	76.9	C
Coke, refined petroleum and nuclear fuel	73.6	127,712	77.9	C
Basic metals and fabricated metal	68.7	475,078	81.6	C

Table 3 (continued)

WIOD classification	VA Dom-esti-cally (%)	Total output	Cumulative share (%)	EUROSTAT and KLEMS
Manufacturing, Nec; recycling	66.3	138,993	82.7	C
Rubber and plastics	62.9	152,780	83.9	C
Air transport	60.5	74,950	84.5	H - H53
Textiles and textile products	54.3	183,217	85.9	C
Leather, leather and footwear	52.7	46,897	86.3	C
Machinery, Nec	46.9	366,348	89.2	C
Electrical and optical equipment	44.5	416,984	92.4	C
Transport equipment	42.7	533,056	96.6	C
Chemicals and chemical products	40.8	391,655	99.7	C
Water transport	26.7	40,050	100.0	H - H53

Table describes how the sectoral classification in WIOD can be mapped into the Eurostat and KLEMS classification. The sectors are ranked from high to low based on the share of value added absorbed domestically. Total output denotes a sector's total output at the euro area level (original EMU-12) in 1999 in millions of dollars. The horizontal lines describe the two thresholds we use to split output into a nontradeable and a tradeable component, i.e., 33% and 50%

$$\lambda_t^h = \lambda_{t+1}^h (1 + r_t^j)\beta^j, \tag{19}$$

$$\theta (L_t^j)^{\sigma_l} = W_t^j \lambda_t^h, \tag{20}$$

where λ_t^h denotes the households' Lagrangian multiplier. Using the FOC for the tradable consumption good (17), $C_t^{j,T}$, to substitute the Lagrangian multiplier out gives:

$$C_t^{j,T} = \frac{C_{t+1}^{j,T}}{(1 + r_t^j)\beta^j}, \tag{21}$$

$$\frac{1-\eta}{C_t^{j,T}} = \frac{\eta}{C_t^{j,N} P_t^{j,N}}, \tag{22}$$

$$C_t^{j,T} = \frac{1-\eta}{\theta} \frac{W_t^j}{(L_t^j)^{\sigma_l}}. \tag{23}$$

1.3. Firms

Retailers are perfectly competitive. We therefore consider a representative retailer which buys input $y_t^{j,Z}(i)$ from intermediate firm i and produces output $Y_t^{j,Z}$ according the following aggregator function:

$$Y_t^{j,Z} = \left[\int_0^1 y_t^{j,Z}(i)^{(\mu^{j,Z}-1)/\mu^{j,Z}} di \right]^{\mu^{j,Z}/(\mu^{j,Z}-1)}. \tag{24}$$

The retailer has a budget constraint which is denoted by: $P_t^{j,Z} Y_t^{j,Z} = \int_0^1 p_t^{j,Z}(i) y_t^{j,Z}(i) di$. Retailers minimize their cost subject to their production function:

$$\mathcal{L}_t^j = \int_0^1 p_t^{j,Z}(i) y_t^{j,Z}(i) di - \lambda_t^r \left(Y_t^{j,Z} - \left[\int_0^1 y_t^{j,Z}(i)^{(\mu^{j,Z}-1)/\mu^{j,Z}} di \right]^{\mu^{j,Z}/(\mu^{j,Z}-1)} \right), \tag{25}$$

where λ_t^r is the retailer's marginal cost of producing an extra unit of final output. Dividing the FOC w.r.t. to production input $y_t^{j,Z}(i)$ of firm i and production input $y_t^{j,Z}(i')$ of firm i' gives the relative pricing equation:

$$y_t^{j,Z}(i) = y_t^{j,Z}(i') \left(\frac{p_t^{j,Z}(i)}{p_t^{j,Z}(i')} \right)^{-\mu^{j,Z}}. \tag{26}$$

If we combine the budget identity $P_t^{j,Z} Y_t^{j,Z} = \int_0^1 p_t^{j,Z}(i) y_t^{j,Z}(i) di$ and aggregator function (24) and substitute subsequently the relative pricing equation (26) to solve for $P_t^{j,Z}$, we obtain:

$$P_t^{j,Z} = \left[\int_0^1 p_t^{j,Z}(i)^{1-\mu^{j,Z}} di \right]^{1/1-\mu^{j,Z}}. \tag{27}$$

We can substitute (27), together with the relative pricing equation (26) for $y_t^{j,Z}(i)$, back in the budget identity to obtain the retailer's demand for intermediate product $y_t^{j,Z}(i)$:

$$y_t^{j,Z}(i) = \left[\frac{P_t^{j,Z}}{p_t^{j,Z}(i)} \right]^{\mu^{j,Z}} Y_t^{j,Z}. \tag{28}$$

Intermediary firms maximize the discounted value of future cash flows:

$$\max_{I_t(i),K_t(i),L_t(i)} V_0^{j,Z}(i) = E_0 \sum_{t=0}^{\infty} \left(\frac{1}{1+r_t} \right) \left(y_t^{j,Z}(i) - W_t^j L_t^{j,Z}(i) - I_t(i) - \frac{\phi}{2} \left(\frac{I_t^{j,Z}(i)}{K_{t-1}^{j,Z}(i)} - \delta \right)^2 K_{t-1}^{j,Z}(i) \right) \tag{29}$$

subject to the capital accumulation identity:

$$K_t^{j,Z}(i) = I_t^{j,Z}(i) + (1-\delta) K_{t-1}^{j,Z}(i) \tag{30}$$

and subject to the production function:

$$y_t^{j,Z}(i) = A_t^{j,Z} (K_{t-1}^{j,Z}(i))^{1-\alpha^j} (L_t^{j,Z}(i))^{\alpha^j} \tag{31}$$

We denote the Lagrangian multipliers by $q_t^{j,Z}$ for the capital accumulation identity and $\lambda_t^{j,Z}$ for the production function, respectively. The FOC w.r.t. $L_t^{j,Z}(i)$ is represented by:

$$W_t^j = \lambda_t^{j,Z} \frac{\alpha^j y_t^{j,Z}(i)}{L_t^{j,Z}(i)}, \tag{32}$$

The FOC w.r.t. investment $I_t^{j,Z}(i)$ is represented by:

$$q_t^{j,Z} = 1 + \phi \left(\frac{I_t^{j,Z}(i)}{K_{t-1}^{j,Z}(i)} - \delta \right), \tag{33}$$

where $\lambda_t^{j,Z}$ is the Lagrangian multiplier representing the intermediate firms' marginal costs of producing an additional unit of output. The FOC w.r.t. $K_t^{j,Z}(i)$ is represented by:

$$q_t = E_t\left(\frac{1}{1+r_{t+1}}\right)\left(\lambda_{t+1}^{j,Z}\frac{(1-\alpha^j)y_{t+1}^{j,Z}(i)}{K_t^{j,Z}(i)} + (1-\delta)q_{t+1}\right), \tag{34}$$

where $q_t^{j,Z}$ is the Lagrangian multiplier of intermediate firms with respect to accumulating an additional unit of capital.[26] Using the FOCs in the production function gives the expression for marginal costs, $\lambda_t^{j,Z}$, which is the same for all intermediate firms:

$$\lambda_t^{j,Z} = \frac{1}{A_t^{j,Z}}\left(\frac{(1+r_t^j)q_t^{j,Z} + (1-\delta)q_{t-1}^{j,Z}}{(1-\alpha^j)}\right)^{(1-\alpha^j)}\left(\frac{W_t^j}{\alpha^j}\right)^{\alpha^j}. \tag{35}$$

As retailers face imperfect substitutability between intermediate inputs, intermediate firms have some market power and can set their prices as a markup over their marginal costs $\lambda_t^{j,Z}$. Intermediary firms maximize their profits w.r.t. prices:

$$\pi_t^{j,Z}(i) = [p_t^{j,Z}(i) - \lambda_t^{j,Z}(i)]y_t^{j,Z}(i). \tag{36}$$

The FOCs w.r.t. $p_t^{j,Z}(i)$ after we have substituted demand for $y_t^{j,Z}(i)$ (28) and solving for $p_t^{j,Z}(i)$ gives:

$$p_t^{j,Z}(i) = \left(\frac{\mu^{j,Z}}{\mu^{j,Z}-1}\right)\lambda_t^{j,Z}. \tag{37}$$

Hence, intermediate firms set prices as a markup over their marginal costs. We can subsequently use (24) and (27) to aggregate over all firms and rewrite (6), (32) and (34) in terms of aggregate output $Y_t^{j,Z}$ and aggregate prices $P_t^{j,Z}$.

1.4. Including the rest of the world

The RoW economy is set up the same way as the Northern and Southern region, but has its own (floating) exchange rate. As before, the various regions are denoted by superscript j, with $j \in \{n, s, r\}$.

Prior to monetary integration, we assume the Rest of the World to be connected to the Northern part of the euro area via an UIP:

$$1 + r_{f,t}^n = (1 + r_{f,t}^r)\frac{E_{t+1}^{r,n}}{E_t^{r,n}}, \tag{38}$$

where $E_t^{r,n}$ is the nominal exchange rate between the rest of the world and the Northern part of the euro area (expressed as the price of one unit of RoW currency in

[26] The FOC w.r.t. $K_t^{j,Z}(i)$ also contains the second order term $-\frac{\phi}{2}\left(\frac{I_{t+1}^{j,Z}(i)}{K_t^{j,Z}(i)} - \delta\right)^2 + \phi\left(\frac{I_{t+1}^{j,Z}(i)}{K_t^{j,Z}(i)} - \delta\right)\frac{I_{t+1}^{j,Z}(i)}{K_t^{j,Z}(i)}$ which we omit to keep the model tractable.

Table 4 Calibrated parameters—RoW

Parameters	Description	Value
β^r	Discount factor households	0.990
θ^r	Weight of leisure	0.009
η^r	Share of nontradables in consumption	0.600
μ^r	Market power nontradable sector	5.000
ξ^r	Credit premium reaction	0.009
$\bar{A}^{N,r}$	Productivity	0.760
$\bar{A}^{T,r}$	Productivity	1.000

In line with the ECB's EAGLE model, we assume the RoW to form 77% of the world economy, with the euro area making up the remaining 23%. We assume that the RoW has the same parameters as the Northern part of the monetary union and a flexible exchange rate with the monetary union via an UIP and the Law of One Price

units of region n currency). As in the 2-region version of the model, Northern and Southern currencies are pegged, with the UIP between North and South given by:

$$r^n_{f,t} + \omega = r^s_{f,t}. \tag{39}$$

As such, in the above setup Southern Europe pays a risk premium vis-à-vis both the Northern part of Europe and the rest of the world that can be easiest thought of as an exchange rate risk premium. Following monetary integration, as the peg is exchanged for a more-difficult-to-reverse common currency, this premium disappears.

The Law of One Price is assumed to hold both within Europe, as between Europe and the rest of the world:

$$p^n_t = E^{r,n}_t p^r_t. \tag{40}$$

World equilibrium in the market for financial assets is now given by:

$$NFA^n_t + NFA^s_t + E^{r,n}_t NFA^r_t = 0, \tag{41}$$

where NFA^j_t represents the net financial assets held by region j denominated in domestic currency.

We set the weight of leisure in RoW to 0.009, implying that the union is responsible for 23% of global output, and RoW for 77%, in line with Gomes et al. (2012). In terms of other parameters, such as the degree of competition in the nontradable sector, the Rest of the World mimics the Northern part of Europe (see Table 4).

1.5. Sensitivity to degree of competition in southern NT sector

See Fig. 13.

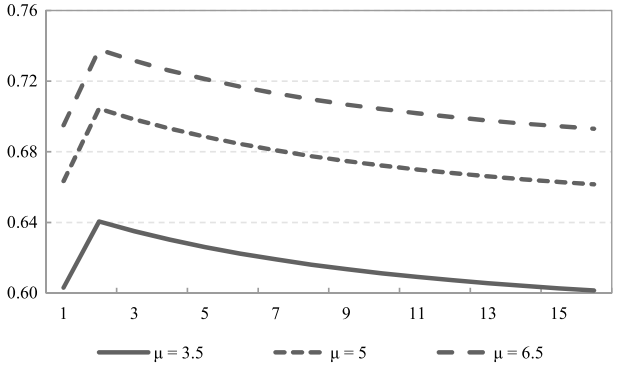

Fig. 13 Impact of monetary integration on relative sectoral sizes in South, for different values of the NT markup in South. This figure illustrates the effects of monetary integration on the relative sectoral size in South, $\frac{Y_t^{s,N}}{Y_t^{s,T}}$, for different values of $\mu^{s,N}$, in the 2-region version of the model. See Sect. 5.1

1.6. Reaction to a sudden increase in the elasticity of interest rates to debt levels

See Fig. 14.

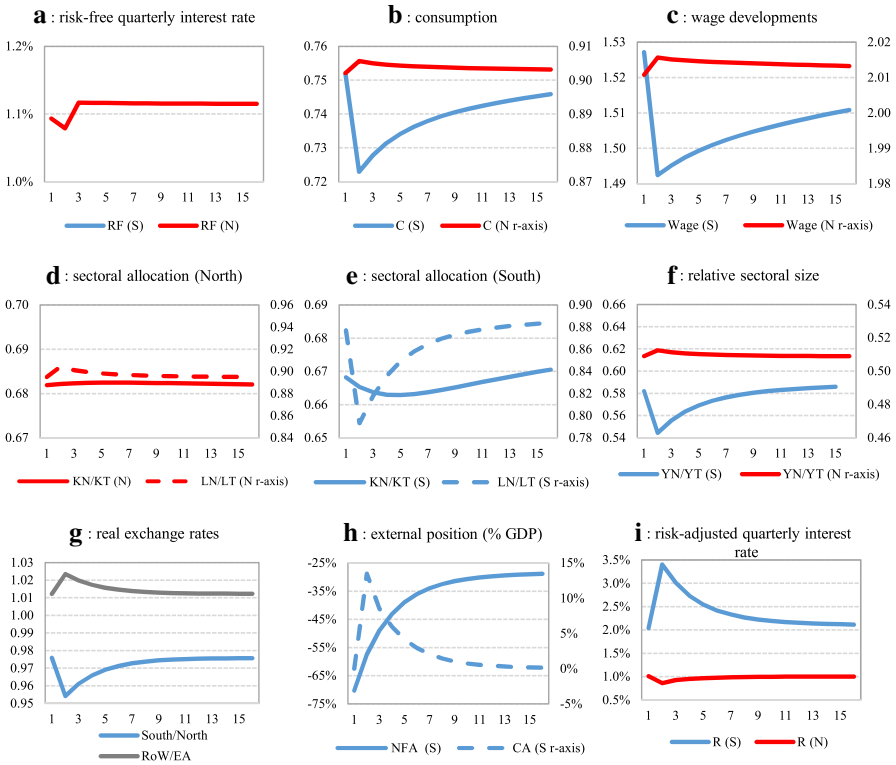

Fig. 14 Reaction to a sudden increase in the elasticity of interest rates to debt levels. Figure illustrates the effects of a permanent increase in the debt-elasticity of interest rates in the 3-region version of the model. Starting point of the simulations is the post-monetary integration steady state

1.7. Empirics

See Tables 5, 6 and Figs. 15, 16.

Table 5 Descriptive statistics

	$y^N_{t,i} - \bar{y}^N_t$	$y^T_{t,i} - \bar{y}^T_t$	$\frac{B_{t,i}}{Y_{t,i}} - \frac{\bar{B}_t}{\bar{Y}_t}$	$i^r_{t,i} - \bar{i}^r_t$	$y^N_{t,i}$	$y^T_{t,i}$	$\frac{B_{t,i}}{Y_{t,i}}$	$i^r_{t,i}$
Mean	0.17	0.12	− 0.20	0.49	0.48	0.54	− 0.10	1.04
Median	0.10	− 0.01	0.07	− 0.03	0.50	0.44	0.17	0.67
SD	1.31	3.14	5.01	6.51	2.77	1.03	5.04	6.58
Observations	946	946	946	946	946	946	946	946

The first four columns denote the descriptive statistics of the average deviation of all countries' sectoral output growth rate, current account and interest rate from the euro area average. The last four columns denote the same descriptive statistics, without subtracting the euro area average

Table 6 Quarterly data tradable and nontradable definition

Sector	T or NT
Agriculture, forestry and fishing	T
Industry (except construction)	T
Manufacturing (already included in Industry)	T
Construction	NT
Wholesale and retail trade, transport, accommodation and food service activities	T
Information and communication	T(/NT)
Financial and insurance activities	T(/NT)
Real estate activities	NT
Professional, scientific and technical activities; administrative and support service activities	NT
Public administration, defence, education, human health and social work activities	NT
Arts, entertainment and recreation; other service activities; activities of household and extra-territorial organizations and bodies	NT

The Eurostat classification is slightly different from the WIOD classification used in Fig. 2. Specifically, the WIOD contains more detailed information about the openness of industries, but data is only available until 2011. We therefore match the WIOD classification with the Eurostat classification to categorize the Eurostat industries in a tradable and nontradable sector. However, the less granular classification at the quarterly level complicates a clean separation between tradable and nontradable industries. Eurostat sectors that contain both tradable and nontradable industries according to Table 3 are denoted as T(/NT). Here T denotes the classification in the benchmark results and (NT) the classification that we used in the robustness tests

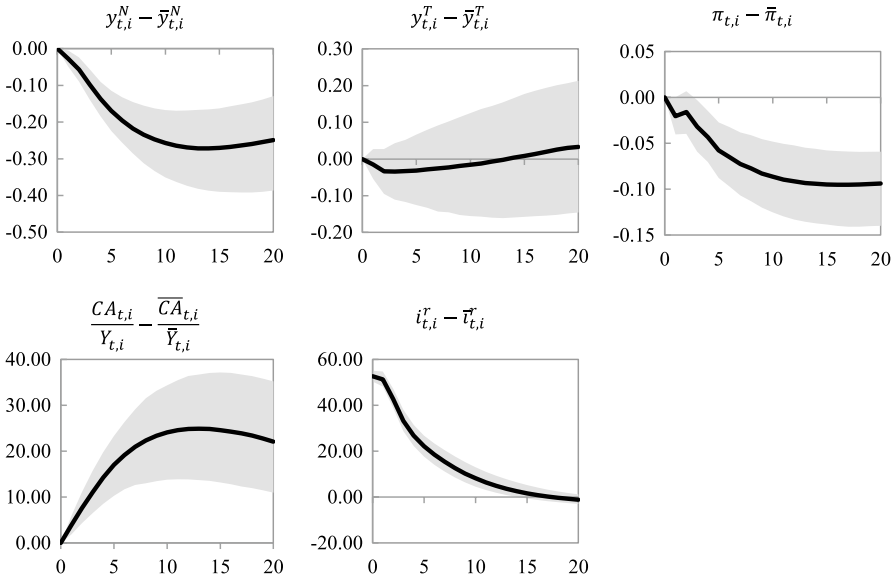

Fig. 15 Log-level impulse response functions following a shock in the real interest rate in EMU countries. The black lines represent the median response to a real interest rate shock estimated in log-levels over the time period 1996Q3–2017Q3 using a Bayesian panel-VAR with 4 lags and a Cholesky decomposition (ordering as in Eq. 15). Shaded areas denote 90% credibility intervals which are generated by drawing 50,000 draws from the posterior distribution of which 40,000 draws are discarded as burn-in iterations. Horizontal axes specify quarters. Vertical axes denote percent point deviations from average euro area growth, ratio or rate

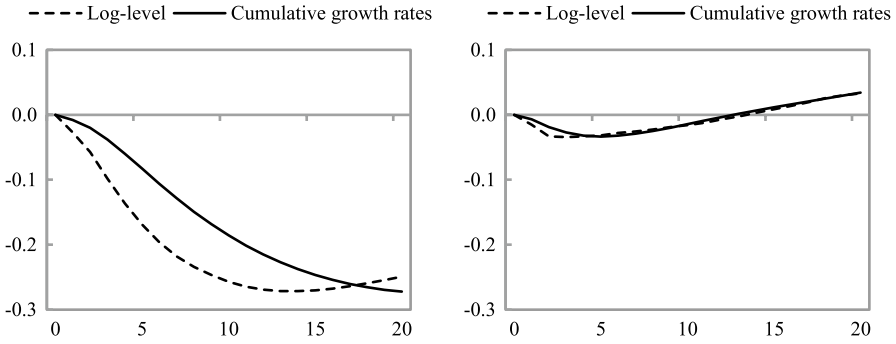

Fig. 16 Log-level and cumulative growth rate impulse response functions following a shock in the real interest rate. The black (dotted) lines represent the median cumulative (log-level) response to a real interest rate shock estimated over the time period 1996Q3–2017Q3 using a Bayesian panel-VAR with 4 lags and a Cholesky decomposition (ordering as in Eq. 15). Horizontal axes specify quarters. Vertical axes denote percent point deviations from average euro area growth, ratio or rate

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